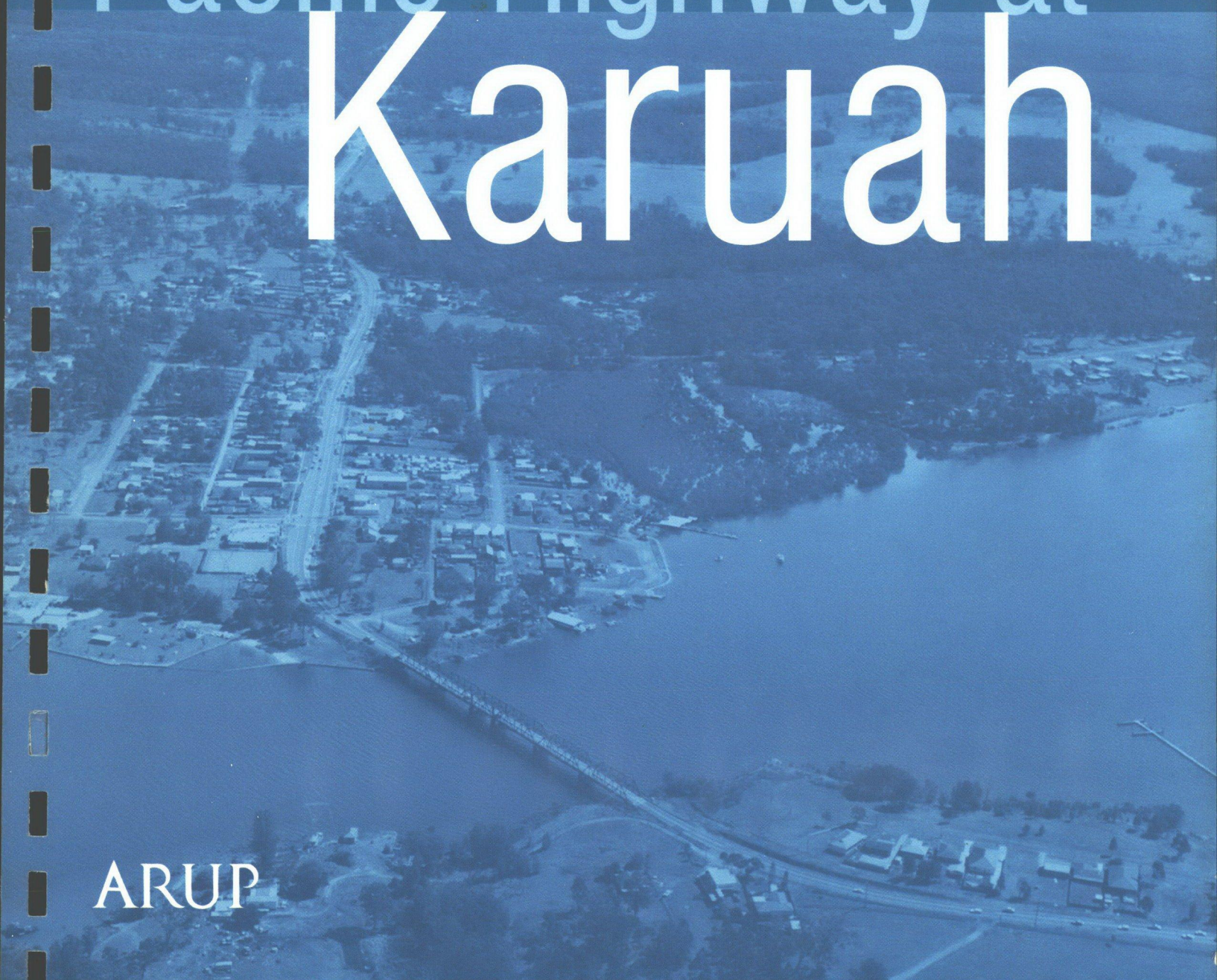
RTA
Roads and Traffic Authority
www.rta.nsw.gov

Upgrading the Pacific Highway

COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL SERVICES

Proposed Upgrade of the

Pacific Highway at Karuah



ARUP

Species Impact Statement

Pacific Highway Upgrade at Karuah

Species Impact Statement

October 1999

Gunninah Environmental Consultants

Pacific Highway Upgrade at Karuah

Species Impact Statement

October 1999

Project Team:

F. Dominic Fanning
Jayne Tipping
Amelia Hurren
Matthew Chambers
Anne Carey
Steven Chamberlain
Claire deLacey
Samantha Lloyd
Felicity Hargraves
Erwin Budde
Alex Cowdery
Tom Celebrezze
Lindy Brincat

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

PACIFIC HIGHWAY UPGRADE at KARUAH

SPECIES IMPACT STATEMENT

October 1999

Declaration

This Species Impact Statement has been prepared in accordance with Sections 109, 110 and 111 of the *NSW Threatened Species Conservation Act 1995,* after consultation with the Director-General of the NSW National Parks & Wildlife Service, as required.

For Gunninah Environmental Consultants

. . . . . .

F Dominic Fanning Bsc (Hons 1) MEIA MAIBiol MESA MECA
Director and Principal

For the Roads & Traffic Authority

. . . . . .

Graham Kinnear
Project Manager

Pacific Highway Upgrade at Karuah

Species Impact Statement

October 1999

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Pacific Highway Upgrade at Karuah

Species Impact Statement

October 1999

1 INTRODUCTION and BACKGROUND

1.1 Introduction

The Roads & Traffic Authority (RTA) is proposing to upgrade the Pacific Highway at Karuah[1], on the mid-north coast of NSW (Figure 1.1). After a detailed route selection process, a route which bypasses the town of Karuah (the 'Horse Island' route) was selected as the 'preferred option' in preference to other options including the upgrade of the existing route through Karuah (Figure 1.2). The proposed Bypass diverges to the north from the existing Highway approximately 5km west of the town of Karuah and will pass approximately 3km to the north of the town, crossing the Karuah River at Horse Island, via a new bridge. The crossing at Horse Island was selected in part to reduce the required span of the proposed bridge.

The proposed upgrade of this section of the Highway is part of the overall Pacific Highway Upgrading Program, which is a joint NSW State/Commonwealth Government initiative. The Program has committed some $2.2 billion over ten years for upgrading of the Pacific Highway between Hexham and the Queensland border.

The proposal[2] includes the construction of a dual carriageway four-lane road to the north of the town of Karuah, interchanges between the existing Highway (which will be retained for local access) and the new Highway, a major bridge over the Karuah River, and the associated stormwater management features. With respect to flora and fauna matters, the proposed roadworks will include an array of features designed to facilitate fauna movements and to minimise adverse impacts upon the natural environment, as well as compensatory habitat measures to offset the adverse impacts which will be imposed by the project.

As required under Part 5 of the *NSW Environmental Planning & Assessment Act 1979* (EP&A Act), the proposal has been the subject of an Environmental Impact Statement (EIS), which has been prepared by Ove Arup & Partners on behalf of the RTA. Consideration of the proposal with respect to the EP&A Act requires an assessment pursuant to Section 5A (s.5A) of the EP&A Act to determine *"whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats"*.

The s.5A Assessment of Significance[3] prepared for the proposed Pacific Highway Bypass of Karuah has indicated that there may be "*a significant effect*" imposed on several threatened species and their habitats (Gunninah 1999b). As a consequence, it was concluded that a Species Impact Statement (SIS) for the project should be prepared.

This SIS addresses the matters contained in Sections 109, 110 and 111 of the *NSW Threatened Species Conservation Act 1995* (TSC Act) and the matters contained in the Director-General's requirements (D-G's Requirements) of the National Parks & Wildlife Service (NP&WS), pursuant to Section 111 of the TSC Act.

---

1 The project is entitled either the Pacific Highway Bypass at Karuah or the Pacific Highway Upgrade at Karuah, interchangeably.

2 Details of the proposed activity are provided in Appendix L.

3 The full Section 5A Assessment of Significance is provided as Appendix 7 to the Flora & Fauna Assessment report (Gunninah 1999b), which is included as Working Paper 8 of the EIS.



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Kilometres

Figure 1.1 General location of the Proposed Karuah Bypass (Horse Island Route) of the Pacific Highway.

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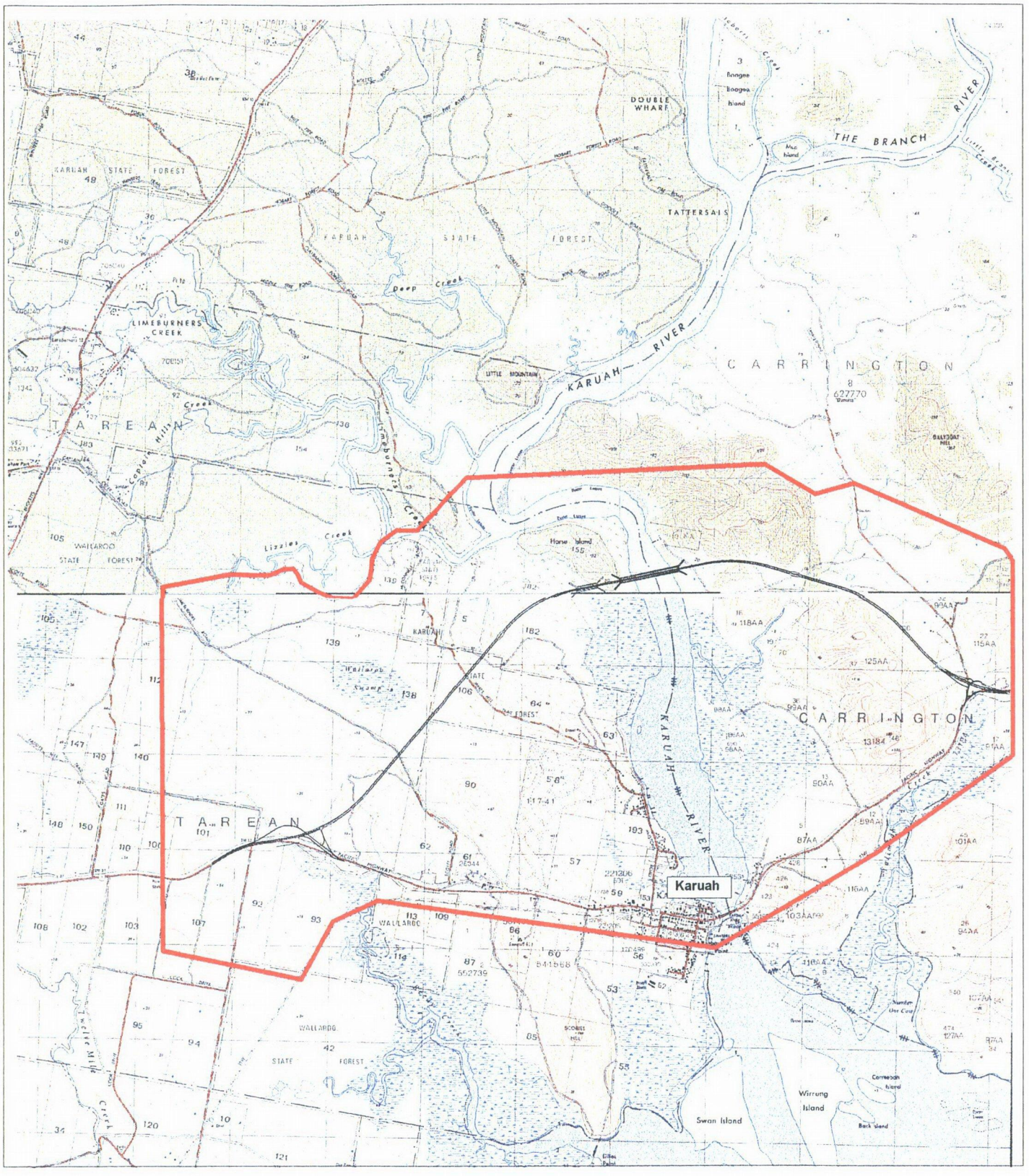

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Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Figure 1.2 Topographic map of Karuah outlining the Proposed Karuah Bypass (Horse Island Route) and study area.

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1.2 Context

The initial route selection process for the Karuah Bypass (Gunninah 1997a) involved consideration of the options for the Bypass within a relatively small study area to the north of the existing Pacific Highway (Figure 1.2). However, a range of social factors required that the proposed Bypass be located further from the town of Karuah, given that upgrading the existing Highway through the town was regarded as an unacceptable option. A supplementary investigation of a Horse Island Route was conducted (Gunninah 1997a; 1999b) to determine the biological constraints of a more northerly alignment and to contribute to the selection of the least environmentally damaging northern route. Notwithstanding the higher potential impacts of this northern alignment on native biota in general and on threatened species and their habitats in particular, other constraints (both social and engineering) determined the selection of the Horse Island route as the preferred alignment for the Karuah Bypass (Figure 1.3).

The study area for the Karuah Upgrade Project supports a range of land uses and vegetation types and has been subjected to varying degrees of disturbance. The study area is bisected by the Karuah River, which flows in a north-south direction and supports a range of estuarine vegetation communities, including saltmarsh and mangroves. Extensive saline wetlands in the study area have been classified as gazetted Coastal Wetlands pursuant to *State Environmental Planning Policy No 14* (SEPP 14) - *Coastal Wetlands* (Figure 1.4).

The majority of the western portion of the study area is forested, and includes Wallaroo State Forest (SF), a portion of the newly gazetted Karuah Nature Reserve (NR) and privately owned forest. The eastern portion of the study area includes cleared grazing land and steep forested land (Figure 1.3).

The proposed Bypass has been specifically aligned to minimise adverse impacts upon the natural environment wherever possible. The route east of the Karuah River, in particular, has been aligned through cleared agricultural lands to the greatest extent possible to avoid areas of potentially significant native vegetation.

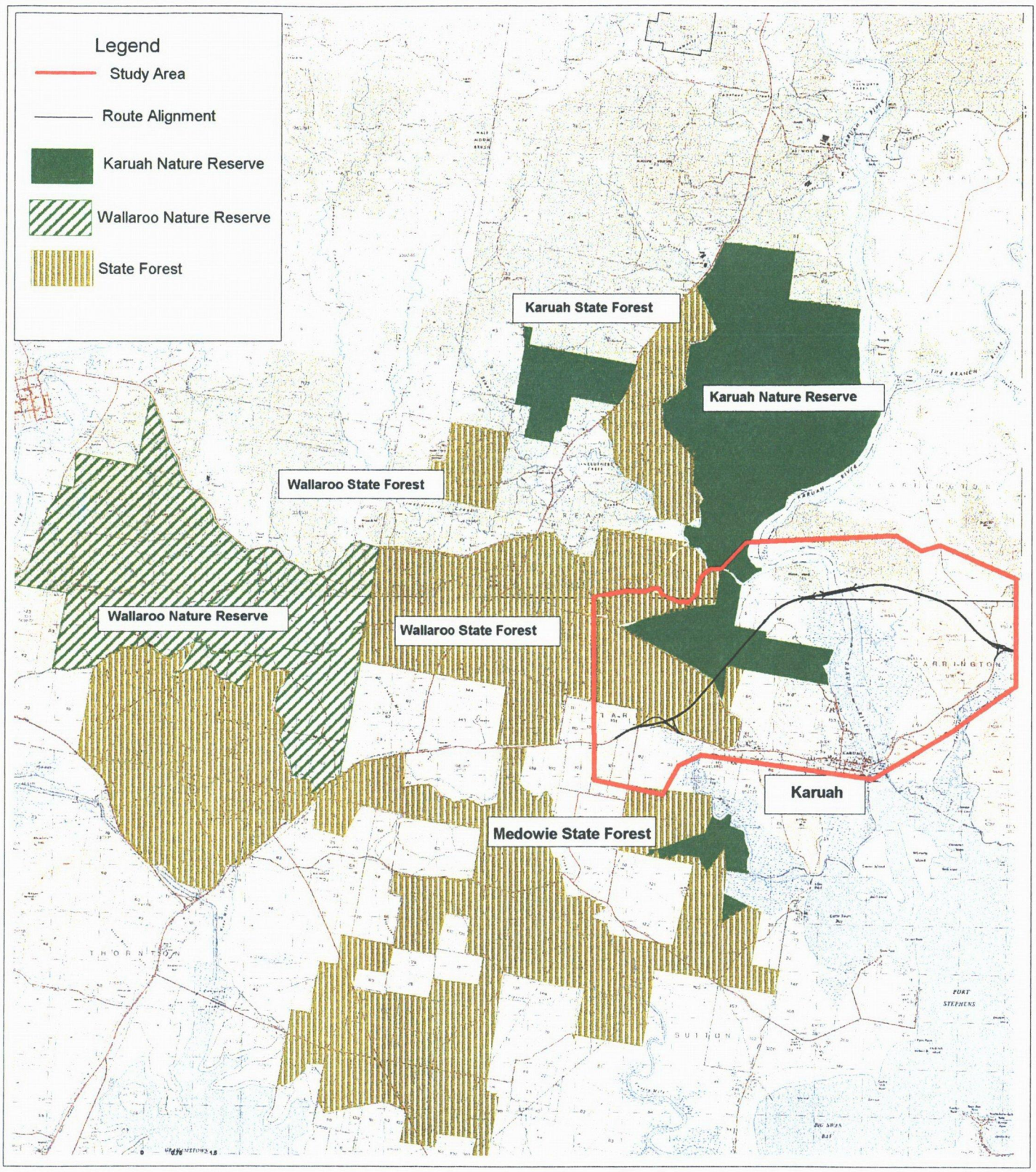
To the west of the Karuah River, there are significant topographic limitations (*eg* Wallaroo Swamp) to the location of the proposed Karuah Bypass, and the alignment cannot avoid traversing areas of native vegetation. Whilst some cleared and modified land to the south of Horse Island has been utilised for the alignment, the southwestern portion of the road will unavoidably traverse part of Wallaroo SF and the newly gazetted Karuah NR. It should be noted that the portion of the Karuah NR, which is to be affected by the proposed Bypass, was gazetted six months after the selection of the Horse Island route as the preferred route option. Whilst native vegetation cannot be avoided in the portion of the alignment west of the River, the location and design of the proposed road has involved consideration of the natural environment as a significant constraint. The road has been located (in part) to minimise the requirements for cut and fill, and specific measures are included in the design to facilitate the continued safe movement of native fauna through the general locality (Chapter 12).

1.3 Legislative Background

This SIS has been prepared to satisfy the requirements of Sections 109, 110 and 111 of the TSC Act.

The TSC Act requires that the planning and development approval process for developments and activities have regard to the potential for adverse impacts to be imposed upon threatened fauna and flora, and their habitats. For developments or activities which require approval under Parts 4 or 5 of the EP&A Act, the TSC Act requires that a determining or consent authority assess "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats.*" This assessment is conducted on the basis of eight factors, which are included in Section 5A (s.5A) of the EP&A Act.

If it is determined on the basis of s.5A of the EP&A Act that the proposed development or activity is "*on land that is, or is part of, critical habitat or is likely to significantly affect*



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Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 1.3 **Location of study area of the Proposed Karuah Bypass (Horse Island Route) and surrounding land uses.**

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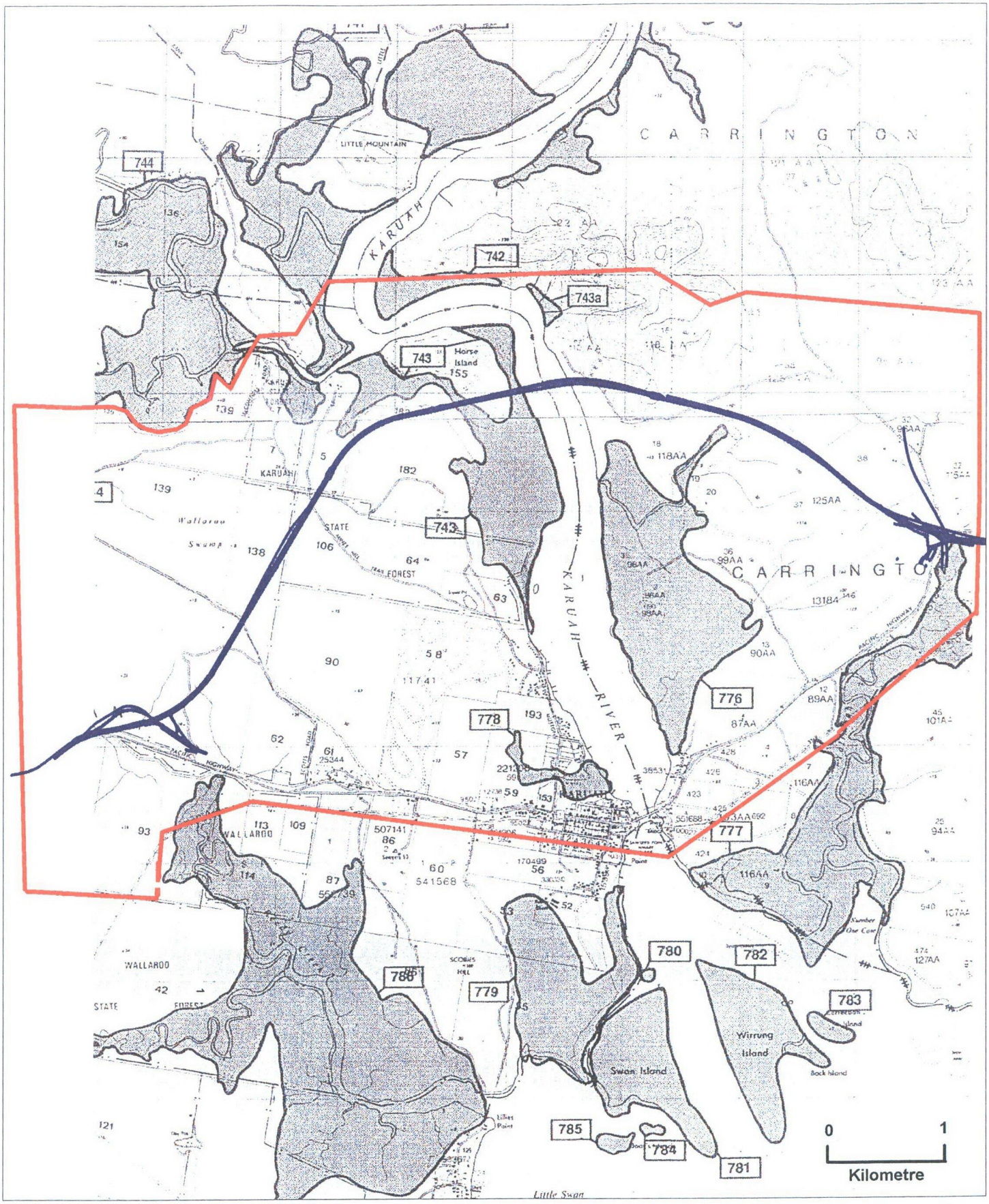

Karuah SIS

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Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 1.4 SEPP 14 Wetlands within the vicinity of the Proposed Karuah Bypass (Horse Island Route).

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threatened species, populations or ecological communities, or their habitats", then an SIS is required. The SIS accompanies, or is part of, an EIS, Development Application or other impact assessment documents prepared for a proposed development.

Where "*a significant effect on threatened species, populations or ecological communities, or their habitats*" is likely to arise from a proposed development, and an SIS is required, the proponent must obtain specific requirements for the preparation of the SIS from the Director-General of the NSW NP&WS (pursuant to s.111 of the TSC Act), in addition to fulfilling the requirements of Sections 109 and 110 of the TSC Act. Furthermore, the Director-General of the NP&WS must concur with, or the Minister for the Environment must be consulted, regarding any development consent for the proposed activity, where such "*a significant effect*" is likely to arise and an SIS has been prepared.

The TSC Act and the D-G's Requirements of the NP&WS contain an array of definitions which are relevant to the SIS. A glossary of relevant terms used throughout the SIS is also provided (see Glossary).

1.4 Report Structure and Compliance

This SIS has been prepared in accordance with the requirements of Sections 109, 110 and 111 of the TSC Act. Details of the compliance of the SIS with the relevant subsections of the Act and with the D-G's Requirements of the NSW NP&WS (Appendix A) are provided below, and are also detailed in Appendix B.

As required under Section 109(1) of the TSC Act, this SIS is in writing.

As required under Section 109(2) of the TSC Act, the SIS has been signed by the principal author (F Dominic Fanning of Gunninah Environmental Consultants) and by "*the proponent of the activity proposed to be carried out*" (the RTA - see Declaration at the front of this document).

The SIS has been structured according to Section 109 and 110 of the TSC Act, and by reference to the D-G's Requirements, which were obtained for its preparation, as required under Section 111(1) of the TSC Act (Appendix A). The D-G's Requirements state that "*the SIS must be formatted to follow the sections and subsections provided in Sections 109 and 110 of the TSC Act, and the DGRs*[4]".

The following chapters in this document contain the information required under Sections 110 and 111 of the TSC Act:

- Chapter 2 — provides a description of the proposed development - Section 110(1) (Appendix L);
- Chapter 3 — presents details of the survey methods applied during the fauna and flora investigations on which the SIS is based - as required in the D-G's Requirements under Section 111(1) of the TSC Act;
- Chapter 4 — provides an "*initial habitat assessment*" of the study area - as required in the D-G's Requirements (Appendix A);
- Chapter 5 — provides a "*general description of the threatened species or populations known or likely to be present in the area*" - Section 110(2)(a);
- Chapter 6 — indicates the threatened species considered of relevance to the proposed development - Section 110(2)(b);
- Chapter 7 — provides details of the conservation status and habitat requirements of threatened species of relevance - Section 110(2)(c);
- Chapter 8 — provides information regarding the abundance of threatened species relevant to the proposed development - Section 110(2)(d);

4 DGR's - Director General's Requirements

- Chapter 9 deals with the types and distributions of the relevant habitats for threatened species - Section 110(2)(f);
- Chapter 10 provides an assessment of the likely effects of the proposed development on relevant threatened species - Section 110(2)(g), as modified by the D-G's Requirements;
- Chapter 11 provides information regarding alternatives to the proposal - Section 110(2)(h);
- Chapter 12 provides information regarding proposed impact amelioration measures - Section 110(2)(i);
- Chapter 13 details additional information regarding other approvals and licensing that is required - Section 110(2)(j); and
- Chapter 14 details the "*qualifications and experience*" of the principal author of this SIS, and other relevant persons - Section 110(4).

1.5 Matters which have been Limited or Modified

Section 110(2)(e) of the TSC Act is identical to Section 110(2)(a), and is consequently not addressed separately, having been listed as a matter which "*need not be addressed*" by the Director-General of NP&WS (Appendix A).

Section 110(3) of the TSC Act relates to information required relating to "*ecological communities*". There are no "*endangered ecological communities*" of relevance to the proposed development, and Section 110(3) has consequently not been addressed. Similarly, there are no "*endangered populations*" of relevance, and the requirements of the Director-General indicate that "*the TSC Act does not currently list any endangered populations or ecological communities within the locality*", and that consequently "*all reference to endangered populations and endangered ecological communities*" need not be addressed.

The D-G's Requirements note that "*there is currently no declared critical habitat in NSW*". Consequently, there is no requirement to address "*critical habitat*".

As noted in the D-G's Requirements for this SIS, "*Draft Recovery Plans*" have been prepared for a number of threatened species. Where available, relevant Draft Recovery Plans for threatened species have been consulted in the preparation of this SIS.

2 DESCRIPTION of the PROPOSED DEVELOPMENT

The TSC Act requires, under Section 110(1) that a SIS includes:

> "*a full description of the action proposed, including its nature, extent, location, timing and layout and, to the fullest extent reasonably practicable, the information referred to in this section*" (*ie* Section 110).

The NP&WS Director-General also requires this SIS is to provide a range of specific information regarding the proposed development (as detailed in Item 1 of Appendix A), including:

> "*1.1 The nature of the action proposed must be detailed. This must include the timetable for the carrying out of the proposed development, the number of hectares affected, the number of hectares of each vegetation type within the study area, details of the location of any auxiliary infrastructure and all components of the proposed development*";
>
> "*1.3 An aerial photograph (or reproduction of such a photograph), preferably colour, of the locality must be provided, separate to the vegetation map This aerial photograph should clearly show the study area and the scale of the photograph, and [be] include an outline of the proposed corridor* "; and
>
> "*1.4 A topographic map of the locality at an appropriate scale must be provided. This map will detail the location of the proposal, major land tenure units such as National Parks, Nature Reserves, and State Forests, boundaries of the study area and areas of high human activity such as townships, regional centres and major roads*".

This Chapter of the SIS provides a general description of the 'proposal'; relevant chapters from the EIS detailing both 'Project Description' and 'Construction Issues' are contained in Appendix L of this SIS. A full description of the project is provided in the EIS for the project (Ove Arup and Partners 1999).

The specific D-G's Requirements regarding maps, plans and other information are also included within the SIS, as detailed in the Compliance report (Appendix B).

2.1 Overview of the Proposal

The preferred route for the proposal, which is the subject of this SIS, was selected following extensive investigation of a broad study area and analysis of numerous route options (Figure 2.1 & 2.2). The proposal involves the upgrading of the Pacific Highway, from 48.3km north of Newcastle to 57.9km further north where it rejoins the Highway north of Karuah. The proposal includes the construction and operation of a new dual carriageway bypassing the town of Karuah. The Bypass will deviate from the existing Highway alignment east of Swan Bay Road and rejoin again east of The Branch Lane. The project also includes the construction of four new bridges over a minor creek, Mosquito Creek and two bridges on either side of Horse Island. The total length of the proposal is 9.8km, and the existing Highway facility will be retained as a local road.

The proposed Bypass will be designed to comply with all relevant RTA design requirements. The Bypass cross section consists of two carriageways, each with two 3.5m wide traffic lanes and a 2.5m wide left shoulder, separated by an 11m wide median without a central barrier.

The proposed upgrade of this section of the Highway is part of the Pacific Highway Upgrading Program, which is a joint NSW State/Commonwealth Government initiative. The program has committed some $2.2 billion over ten years for the upgrading of the Pacific Highway between Hexham and the Queensland border.

2.1.1 From the Current Highway to Horse Island

The proposed Bypass starts west of Karuah, where a right-turn bay will provide for access to and from Karuah for north and south bound traffic (the western interchange). Traffic leaving Karuah will have an acceleration lane enabling safe entry onto the dual

carriageway. Immediately north-east of the western interchange the proposed Bypass is located in a cutting 5m deep, and follows in a north-east direction through sections of Wallaroo SF. North of the Scotts Road overpass, the proposed Bypass moves onto an embankment 2.5 - 4.0m above the surrounding land in the vicinity of Wallaroo Swamp. The proposed Bypass then moves close to the north-west corner of the cleared site for the approved Karuah sewerage treatment works, and traverses Karuah NR for approximately 800m. Northeast of the Nature Reserve, the proposed Bypass traverses privately-owned land in a series of 5m cuttings and embankments through partially forested terrain before reaching SEPP 14 Wetland No 773 on the western side of Horse Island. A 212m long bridge crosses this section of wetland to Horse Island with a clearance of 11m above the wetland.

2.1.2 Horse Island and the Karuah River

The proposed Bypass traverses the southern section of Horse Island for approximately 250m, with this section of the road providing part of the support structure for the two bridges on either side of Horse Island. Drainage on this section of the road will flow from Horse Island westwards away from the River, and will be treated in sedimentation and water quality treatment basins located in cleared areas. The 612m bridge across the Karuah River is the most significant structure on the proposed Bypass, and maintains a minimum 10m clearance above the navigable eastern part of the River.

2.1.3 East of Karuah River to Branch Lane

East of the Karuah River, the proposed Bypass traverses a cleared area on a section of fill which is up to 7m deep. Immediately east of this section of fill, the proposed Bypass will cross a minor creek on a 15m high bridge, and crosses Mosquito Creek on a 20m high bridge. East of Mosquito Creek, the Bypass traverses cleared land and gradually reverts to an 11m wide median. The Bypass joins the proposed duplication of the Pacific Highway from this point northwards to Bulahdelah.

2.2 Construction Issues

The method of construction for a project such as the Karuah Bypass would generally involve a specific sequence of activities, although variations are likely to arise as a consequence of particulars and issues determined during the final design and contractual phases of the project.

The general sequence of construction activities would generally involve:

- site establishment - safety fencing of site, and establishment of site compounds and access;
- installation of temporary erosion, sediment and water quality controls including diversion drainage;
- clearing of vegetation and mulching of plant material for reuse;
- stripping, stockpiling and management of topsoil;
- bulk earthworks;
- installation of drainage lines, fauna underpasses and local access;
- bridge construction;
- foundation works and pavement construction;
- topsoil rehabilitation and revegetation of batters and berms;
- landscaping;
- installation of off-site noise mitigation measures;
- line marking and signposting;
- interchange lighting; and
- finishing works (including general site clean up and removal of site compounds).



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Gunninah Environmental Consultants

Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 2.1 Aerial map of Karuah, including the study area of the Proposed Karuah Bypass (Horse Island Route).

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Figure 2.2 Topographic map of Karuah, including the study area of the Proposed Karuah Bypass (Horse Island Route).

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3 METHODS

The D-G's Requirements for this SIS (Appendix A) include the need to conduct and to fully document a "*threatened species survey*" (Item 1), including:

> "*1.12 A fauna and flora survey is to be conducted in the study area. Targeted surveys must be conducted for all subject species. As a minimum, survey methods must follow those detailed in Appendix 3, unless justification for variation from these methods can be provided to the satisfaction of NPWS. Field survey and identification of species and habitat must be undertaken by suitably qualified and experienced persons. Species of taxonomic uncertainty must be confirmed by a recognised authority such as the Australian Museum or NSW National Herbarium*";
>
> "*1.13 A full description of the methods used in the fauna and flora surveys and habitat assessment must be provided, including survey techniques employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and prevailing weather conditions. Where appropriate this information must be provided in map format at the same scale as previous maps. Surveys must be undertaken during seasons in which the subject species are most likely to be detected and, where possible, in appropriate climatic conditions. A table must be provided indicating compliance with survey methods provided in Appendix 3*"; and
>
> "*1.14 The impact of the season, prevailing weather conditions, and limitations of survey techniques employed must be considered and discussed with respect to the results of the survey*".

The Director-General has provided detailed survey techniques and documentation requirements for individual species (in Appendices 3 and 4 of the D-G's Requirements), as included in Appendix A of this SIS. These survey requirements are considered by the Director-General to be the "*minimum standard for survey for the subject area*".

3.1 Survey Activities

3.1.1 General

A number of investigations for flora and fauna have been conducted previously in the Bypass study area at Karuah and in the vicinity, contributing to a substantial database of information on native biota and their habitats in lands along and/or adjacent to the alignment. Documentation of the previous surveys and assessments conducted, and information collected through the general Karuah area, was reviewed for data regarding biota of relevance to the Karuah Bypass project.

Investigations of the Karuah area, including (in part) the study area, have been conducted by Ecotone (1995), Gunninah Environmental Consultants (Gunninah 1997a, b, c, d; 1999a, b) and ERM Mitchell McCotter (1999), amongst others. These investigations provide information pertaining to vegetation, fauna habitats and plant and animal assemblages of the area, with particular emphasis on threatened species and endangered populations. Details of these investigations conducted in the vicinity, including specific survey activities, are described below.

General and targeted surveys for flora and fauna have been conducted in the study area specifically for the Karuah Bypass project by Gunninah from 1997 (for the initial route selection phase) to 1999 (Gunninah 1997a; 1999b, c). The investigations specifically for the Karuah Bypass project are described briefly below (Table 3.1, 3.2), with "*a full description of the methods used in the fauna and flora surveys and habitat assessment*" provided in Appendix C of this SIS. Information regarding "*survey techniques employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and prevailing weather conditions*" is provided in Appendix C and D as required.

3.1.2 Flora

Several flora surveys have been conducted in the study area and in the locality (Ecotone 1995; Gunninah 1997a, b, c, d; 1999b, c), providing a substantial information base on the flora and vegetation communities along the alignment and in the vicinity.

- *Ecotone 1995 - Karuah Hardrock Quarry*

The initial flora investigation at the Karuah Quarry site involved a half day random meander survey (Cropper 1993) in the vicinity of the existing hardrock quarry, which is located adjacent to the Pacific Highway, immediately to the north of the eastern end of the proposed Karuah Bypass project. The survey involved the identification of vegetation communities, searches for species of conservation significance and the preparation of an inventory of flora species.

The Ecotone investigation identified an open forest community dominated by Smooth-barked Apple, Red Bloodwood and Tallow-wood, as well as a range of sclerophyllous understorey shrubs and groundcover plants. The threatened species *Tetratheca juncea* was located during the investigation, in the vicinity of the existing Karuah Red Quarry.

- *Gunninah 1997a - Proposed Pacific Highway Upgrade Karuah Route Selection. Flora & Fauna Constraints*

A flora survey of the Karuah Upgrade Route Selection study area was conducted on the 24th and 25th of April 1997 (Table 3.1; Figure 3.1; Appendix C). The initial route selection study area involved an area approximately 2km to the south of the Horse Island Route, within approximately 1km of the township of Karuah.

The flora investigation involved random meander surveys (Cropper 1993) throughout the study area. Vegetation communities were identified according to structural and floristic characteristics, and an inventory of flora species was prepared. Targeted searches for *Tetratheca juncea* were conducted in areas of suitable habitat, and other threatened or rare plant species known from the locality were also targeted during the surveys.

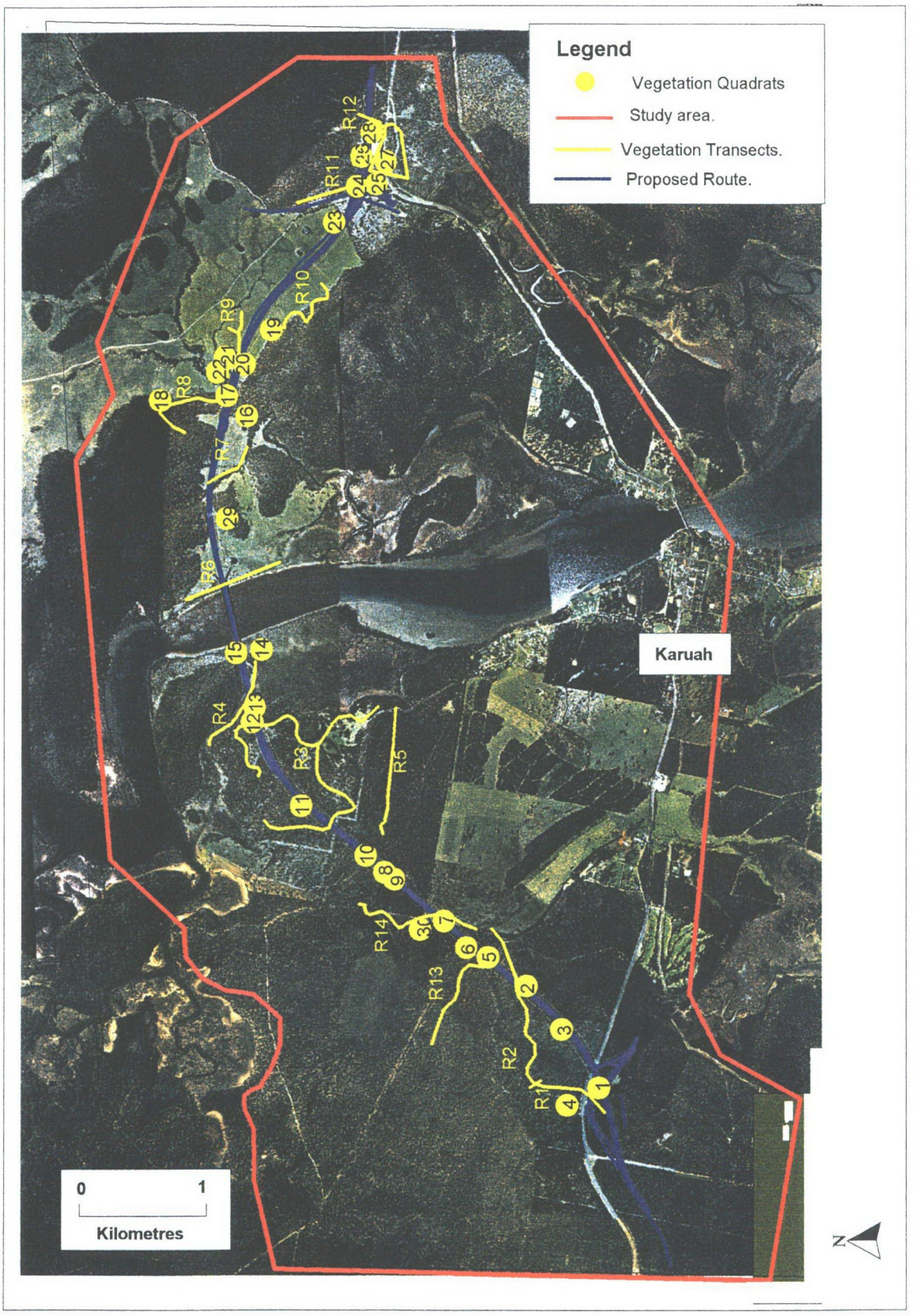
A wide range of vegetation communities and flora species were identified, reflecting the diversity of habitats in the study area. Estuarine and saltmarsh communities supporting a range of salt-tolerant species (including mangroves and Samphires) were recorded along the Karuah River and in the SEPP 14 wetlands to the immediate north of Karuah, and on the eastern bank of the River. Remnant and regenerating open forest communities were well represented in the study area, particularly within the State Forests. Cleared agricultural land also occurred commonly in the study area, and has facilitated the invasion of introduced species into adjacent native vegetation.

Tetratheca juncea was recorded during these investigations, in remnant open forest within Karuah SF on the western side of the Karuah River.

- *Gunninah 1997b - Proposed Pacific Highway Upgrade -Raymond Terrace to Karuah. Fauna & Flora Assessment*

A detailed flora survey of the study area for the proposed Raymond Terrace to Karuah Pacific Highway Upgrade was conducted on the 20th and 21st of March 1997. The study area consisted of a narrow band of vegetation (up to 50m in width) along the existing Pacific Highway. The Raymond Terrace to Karuah upgrade of the Pacific Highway involved the addition generally of a single lane road to the existing carriageway, in mostly disturbed or modified vegetation adjacent to the existing Highway. The area investigated included the western end of the current study area for the Karuah Upgrade project, as far east as the Karuah Golf Course.

Surveys along the Raymond Terrace to Karuah Upgrade involved the identification of vegetation communities and flora species, dedicated searches for threatened plants known from the locality, the preparation of a flora species inventory, and descriptions of the



Gunnimah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 3.1 **Aerial map of Karuah outlining the location of vegetation quadrats and transects used for flora investigations within the study area.**

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structural and floristic characteristics of the communities present. In particular, specific targeted searches for *Tetratheca juncea* were conducted throughout the study area.

The Raymond Terrace to Karuah flora investigation identified a mosaic of vegetation communities, including open forest, riparian forest and cleared agricultural land. No threatened flora species were recorded in the study area for this investigation.

- *Gunninah 1997c - Karuah Hardrock Quarry. Fauna & Flora Assessment*

A flora survey of the site for a proposed quarry to the immediate north of the eastern extremity of the Karuah Upgrade study area was conducted on the 16th and 17th of December, 1997. The study area for this investigation was to the immediate north of the Ecotone (1995) study area and addressed a proposed additional quarry site.

Vegetation communities and flora species were identified within five representative quadrats in the study area, and general random surveys were also conducted. An inventory of flora species was compiled, and the structural and floristic composition of vegetation communities recorded. In addition to quadrat surveys, targeted surveys for *Tetratheca juncea* and other rare or threatened plant species known from the general locality were conducted throughout areas of suitable potential habitat in the study area.

The investigation identified open forest vegetation dominated by Grey Gum, White Mahogany, Small-fruited Grey Gum and Tallow-wood. The understorey and groundcover in this study area varied according to disturbance and aspect. More sheltered areas supported a range of mesic species (such as Cheese Tree and Jackwood), whilst more disturbed areas supported a dense thicket of the introduced species, such as Lantana. Sclerophyllous understorey and groundcover species were present in drier areas.

Tetratheca juncea was located at the southern end of the existing quarry, near the Pacific Highway, as well as on the western slopes to the southwest and northwest of the proposed new quarry.

- *Gunninah 1997d - Proposed Pacific Highway Upgrade -Raymond Terrace to Karuah. Additional Surveys for Tetratheca juncea*

Because the original flora surveys for *Tetratheca juncea* along the proposed Raymond Terrace to Karuah Upgrade alignment were conducted in March (Gunninah 1997b) outside of the main flowering period of this species, supplementary targeted investigations were conducted on the 6th of August 1997. Targeted searches were conducted in areas identified as potentially suitable for this species during the earlier March surveys.

Four sites were surveyed along the Raymond Terrace to Karuah project, including one of approximately 2km in length running from Old Swan Bay Road to Limeburners Road, opposite the Karuah Golf Course. These supplementary surveys failed to locate *Tetratheca juncea*.

- *Gunninah 1999b- Proposed Pacific Highway Upgrade -Karuah Horse Island Route Option. Fauna & Flora Assessment*

Flora surveys for the preliminary flora and fauna assessment for the Horse Island Route Option were conducted between the 10th and the 13th of November 1998, inclusive, and on the 10th of December 1998 (Table 3.1, 3.2; Figure 3.1; Appendix C).

Flora surveys consisted of a combination of walked transects or 'random meander' surveys (Cropper 1993) and quadrat surveys. A total of 30 quadrats and 14 random transects throughout the study area were investigated (Figure 3.1). The vegetation quadrats were standard 20m x 20m (*ie* 400m^2), and were intensively surveyed, with all plant species present recorded. Information on vegetation communities and flora species present were recorded during both survey techniques. Information on disturbance (such as fire and clearing) and land use was also recorded.

Additionally, opportunistic information was obtained throughout the study area and survey period, including when driving to and from survey sites.

Targeted searches were conducted in potential habitat for *Tetratheca juncea* and other flora species of conservation significance known to occur in the general locality. *Tetratheca juncea* stands were recorded within Wallaroo SF.

The vegetation community studies and detailed vegetation quadrats documented during the December 1997 investigation form the basis of the vegetation descriptions provided in Chapter 4 of this SIS.

- *Gunninah 1999c - Proposed Pacific Highway Upgrade -Karuah. Horse Island Route. Species Impact Statement*

The flora surveys for this SIS were based on the surveys completed for the Horse Island Route Option Flora and Fauna Assessment report (Gunninah 1999b). These surveys complied with the requirements of the NP&WS Director-General (Appendix A).

Given that detailed surveys of the vegetation communities present in the study area were conducted during the route selection investigations (Gunninah 1997a), the supplementary surveys for the SIS primarily involved the preparation of species inventories, and detailed searches for "*subject species*" (*eg Tetratheca juncea*) as defined by the NP&WS Director-General. The quality and extent of suitable habitat for "*subject species*" was also noted, as was the extent and degree of disturbance.

3.1.3 Fauna

Several fauna surveys have been conducted previously in the "*study area*" or general vicinity (Ecotone 1995; Gunninah 1997a, b, c, d, 1999b, c, ERM Mitchell McCotter 1999). Field investigations for native fauna have been conducted between 1997 and 1999 for the current proposal, including for the route selection studies, preliminary investigations, supplementary investigations and the current EIS and SIS study. Other investigations include those conducted for the Karuah Quarry, the Raymond Terrace to Karuah Upgrade of the Pacific Highway, and the Karuah to Bulahdelah Upgrade.

- *Ecotone 1995 - Karuah Hardrock Quarry*

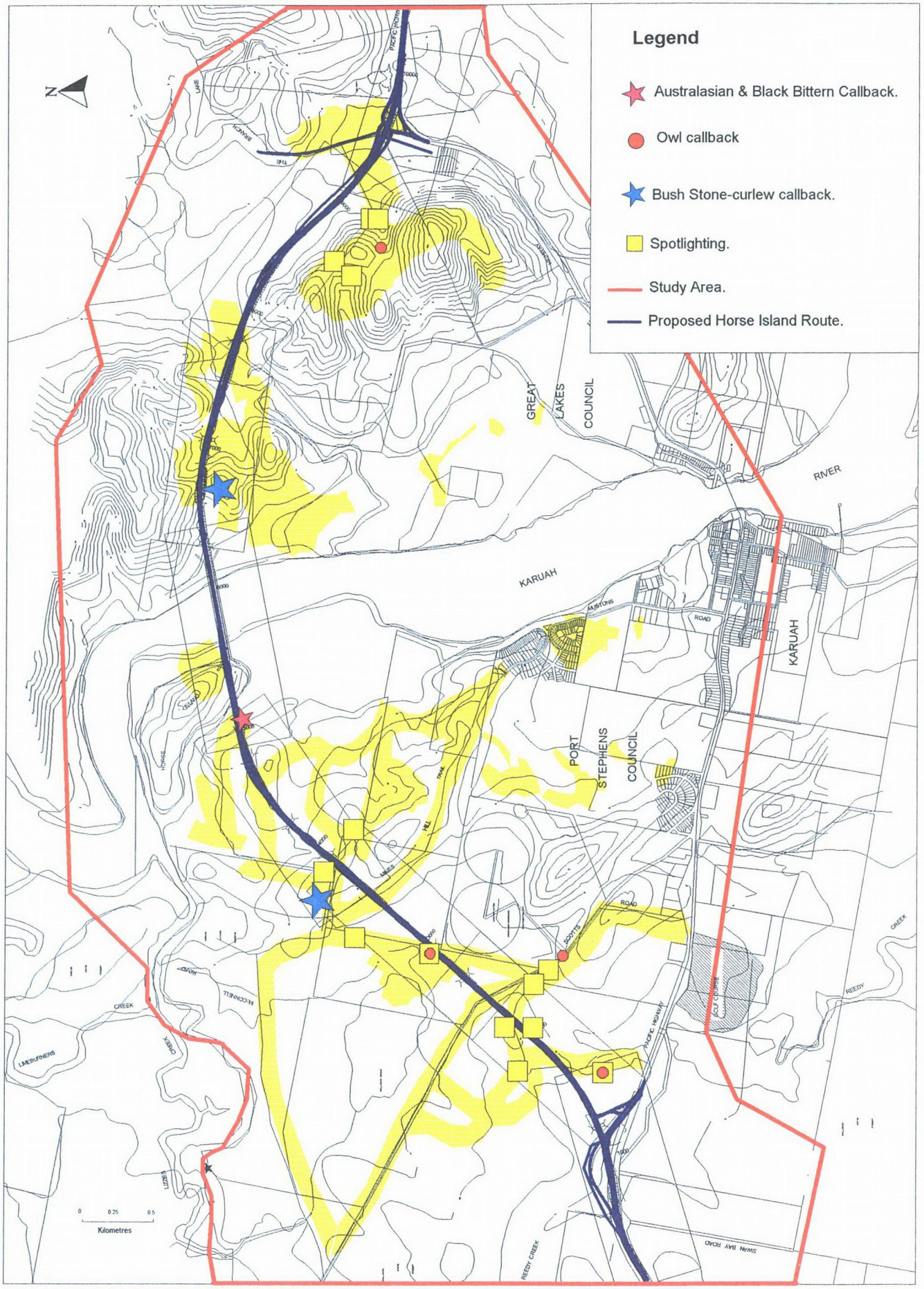
Ecotone conducted a fauna investigation in the vicinity of the Karuah hardrock quarry, to the immediate east of the proposed Karuah Upgrade alignment (on the 24th of May 1995). The investigation involved opportunistic diurnal surveys for fauna and fauna habitats, and two person-hours of spotlighting during which hand-held Anabat II echolocation recorders were also deployed to record the presence of microchiropteran bats. In addition, threatened owls and the Yellow-bellied Glider were targeted using call playback surveys.

- *Gunninah 1997a - Proposed Pacific Highway Upgrade -Karuah Route Selection. Flora & Fauna Constraints*

Gunninah conducted fauna surveys for the route selection of the Karuah Upgrade project from the 21st to the 26th of April, 1997. The field surveys investigated a study area approximately 2km to the south of the Horse Island Route, in the vicinity of the township of Karuah.

A range of methods were employed during the field surveys, including detailed trapping surveys and targeted searches for threatened fauna species known from the locality. Surveys involved (Table 3.1; Figure 3.2a, 3.2 b; Appendix C):

- diurnal surveys, including avifauna surveys, active searches for herpetofauna, habitat assessment and investigations for indirect evidence of the presence of fauna species (such as scats, bones, diggings, tracks *etc*);
- opportunistic fauna surveys throughout the study area;



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Gunninah Environmental Consultants
Phone (02) 9906 5436 Fax (02) 9906 7770

Figure 3.2a **Fauna survey locations of spotlighting and call playback within the study area.**

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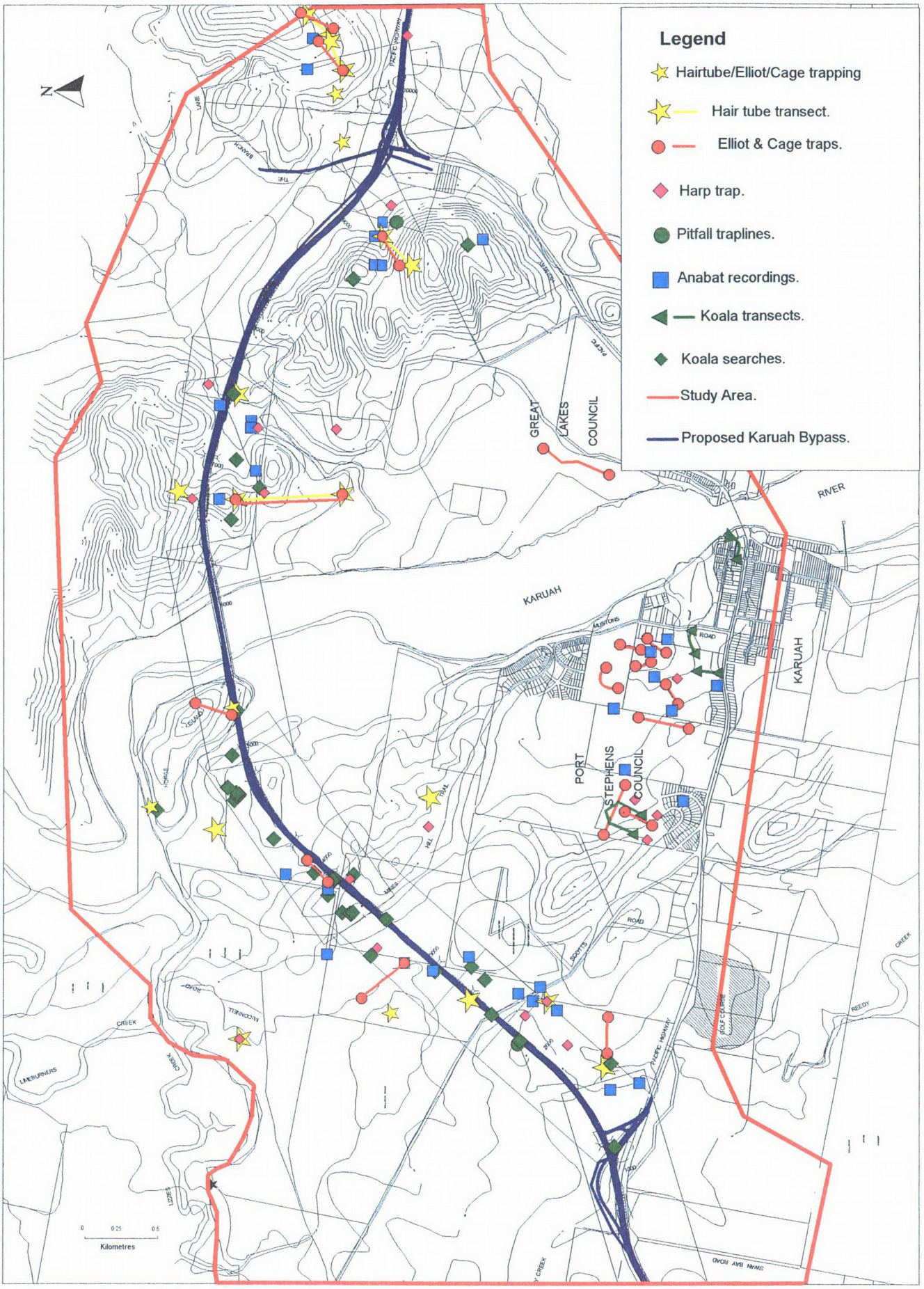

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Project No. 98071

Gunninah Environmental Consulants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 3.2b **Fauna survey locations of Elliot, pitfall, cage and harp trapping, hair tube transects, Koala surveys and Anabat recordings within the study area.**

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- trapping for terrestrial and arboreal mammals along seven representative transects consisting of:
    - 468 trap-nights with ground-based Elliott traps for small terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
    - 83 trap-nights with tree-mounted Elliott traps for arboreal mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
    - 24 trap-nights with cage traps for medium-sized terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species; and
    - 119 trap-nights with hair tubes to detect a range of mammal species. Hair tubes were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species;
- microchiropteran bat surveys involving:
    - 25 hours of Anabat II echolocation recordings at eight locations over four nights; and
    - 8 trap-nights with Harp traps for the direct capture and identification of bats;
- 13 person-hours of spotlighting throughout the study area, involving both walked and driven surveys. Spotlighting targeted arboreal mammals, nocturnal birds and herpetofauna; and
- detailed Koala surveys along four survey transects involving:
    - examination of seventy-four trees (preferred food tree species with a DBH > 30cm were targeted, where possible) for evidence of Koalas, such as scats and scratches, or the presence of individuals.

- *Gunninah 1997b - Proposed Pacific Highway Upgrade -Raymond Terrace to Karuah. Flora & Fauna Assessment*

Gunninah conducted fauna surveys for the proposed upgrade of the Pacific Highway between Raymond Terrace and Karuah, to the immediate southwest of the Karuah Upgrade study area. The survey area included a portion of the existing Pacific Highway that overlaps with the Karuah Upgrade study area.

The fauna surveys were conducted from the 20th to the 25th of March, 1997 (inclusive), and involved:

- trapping for terrestrial and arboreal mammals along eleven representative transects, consisting of:
    - 660 trap-nights with ground-based Elliott traps for small terrestrial mammals. Traps were baited with a mixture of peanut butter/honey/rolled oats;
    - 140 trap-nights with tree-mounted Elliott traps for arboreal mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
    - 132 trap-nights with cage traps for medium-sized terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species; and

- 132 trap-nights with hair tubes to detect a range of mammal species. Hair tubes were baited with a mixture of peanut butter/honey/rolled oats or chicken, depending on the target species;

- microchiropteran bat surveys involving:
  - 25 hours of Anabat II echolocation recordings at ten locations over four nights; and
  - 10 trap-nights with harp traps at two locations for the direct capture and identification of bats;
- detailed Koala surveys at fifty-five survey locations, involving:
  - examination of up to twenty trees at each survey location (targeting preferred food tree species with a DBH > 30cm, where possible) for evidence of Koalas, such as scats and scratches, or the presence of individuals;
- diurnal surveys at sixteen survey locations, involving:
  - 20 minute avifauna surveys at fifteen survey locations;
  - active diurnal reptile searches in potential habitat at nine locations and at each of the Koala survey locations; and
  - habitat assessment and investigations for indirect evidence of the presence of fauna species (such as scats, bones, diggings, tracks *etc*);
- opportunistic fauna surveys throughout the study area; and
- nocturnal spotlighting surveys, involving:
  - a total of 50 person-hours of walked and driven surveys targeting arboreal mammals and nocturnal birds;
  - call playback for threatened owl species (Powerful, Masked, Sooty and Barking Owl) at six locations; and
  - nocturnal stream-side surveys for herpetofauna at seven locations.

- *Gunninah 1997c - Karuah Hardrock Quarry. Flora & Fauna Assessment*

Gunninah conducted fauna surveys for a proposed quarry located to the immediate north of the eastern extremity of the proposed Horse Island route between the 15th and 16th and the 23rd and 24th of January 1997 and on the 8th of February 1997.

The fauna surveys at the Karuah Quarry site involved:

- diurnal surveys, involving:
  - 14 person-hours of dedicated avifauna surveys throughout all habitats;
  - 22 person-hours of dedicated diurnal reptile searches in potential habitat; and
  - habitat assessment and investigation for indirect evidence of the presence of fauna species (such as scats, bones, diggings, tracks);
- specific amphibian surveys at three locations within potentially suitable habitat, including dams and soaks;
- nocturnal spotlighting surveys, involving:
  - a total of 14.75 person-hours targeting arboreal mammals and nocturnal birds;

- call playback for threatened owl species (Powerful, Masked, Sooty and Barking Owl); and
- 2 person-hours of reptile searches;

- specific Koala surveys, involving eight person-hours of investigation of preferred food tree species for evidence of the presence of Koalas, such as scats, scratches or individuals; and
- microchiropteran bat surveys involving:
  - 14 hours of harp trapping over three nights;
  - 7.5 hours of mist netting over three nights; and
  - 3 hours of Anabat II echolocation recordings over three nights.

- *Gunninah 1999b - Proposed Pacific Highway Upgrade -Horse Island Route Option. Fauna & Flora Assessment*

Field investigations for native fauna were conducted in the Horse Island study area between the 26th of February and the 6th of March 1998, involving ten person-days (Table 3.1, 3.2; Figure 3.2a, 3.2 b; Appendix C). These surveys were conducted in the same study area as the surveys for the SIS and involved:

- diurnal surveys, including avifauna surveys, active searches for herpetofauna, habitat assessment and investigations for indirect evidence of the presence of fauna species, such as scats, bones, diggings, tracks etc;
- opportunistic fauna surveys throughout the study area;
- trapping for terrestrial and arboreal mammals along five representative transects consisting of:
  - 372 trap-nights with ground-based Elliott traps for small terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
  - 8 trap-nights with tree-mounted Elliott traps for arboreal mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
  - 54 trap-nights with cage traps for medium-sized terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species; and
  - 650 trap-nights with hair tubes to detect a range of mammal species. Hair tubes were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species;
- microchiropteran bat surveys involving:
  - Anabat II echolocation recordings at seven locations over four nights; and
  - 12 trap-nights with harp traps at five locations for the direct capture and identification of bats;
- 17 person-hours of spotlighting throughout the study area, involving both walked and driven surveys. Spotlighting targeted arboreal mammals, nocturnal birds and herpetofauna;
- playback of Masked, Powerful, Barking and Sooty Owl calls at two locations along the route;
- detailed Koala surveys along 16 surveys transects, involving examination of 193 trees (>30cm DBH where possible) for individuals, scratches and scats; and

- detailed habitat searches to detect the presence or absence of tree-hollows and tree-hollow sizes along the proposed alignment and in the surrounding area.

- *Gunninah 1999c - Proposed Pacific Highway Upgrade- Karuah. Horse Island Route. Species Impact Statement*

Detailed field surveys specifically for this SIS were conducted along the preferred road corridor between the 24th and 29th of November 1998 (inclusive), the 1st, 5th and 16th of December 1998, the 12th and 28th of January, and the 7th to the 11th of August 1999. The latter surveys were somewhat fragmented as a result of unsuitable weather conditions. Details regarding the fauna survey methods employed during investigations specifically for this SIS are provided in Appendix C (Table 3.1, 3.2; Figure 3.2a, 3.2b).

The field surveys for fauna along the Karuah Upgrade route involved targeted surveys for "*subject species*", consisting of:

- diurnal surveys, including avifauna surveys, active searches for herpetofauna and habitat assessment;
- trapping for terrestrial and arboreal mammals along eight representative transects consisting of:
    - 800 trap-nights with ground-based Elliott traps for small terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
    - 320 trap-nights with tree-mounted Elliott traps for arboreal mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats;
    - 32 trap-nights with cage traps for medium-sized terrestrial mammals. Traps were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species;
    - 1222 trap-nights with hair tubes to detect a range of mammal species. Hair tubes were baited with a standard mixture of peanut butter/honey/rolled oats or chicken, depending on the target species; and
    - 80 trap-nights with pitfall traps to detect a range of small terrestrial mammals and reptiles.
- microchiropteran bat surveys involving:
    - 11 nights of Anabat II echolocation recordings at 11 transect sites, and 0.5 hours of Anabat II echolocation recordings at each of a further 7 transect sites; and
    - 27 trap-nights with harp traps for the direct capture and identification of bats;
- 43.5 person-hours of spotlighting throughout the study area, involving both walked and driven surveys. Spotlighting targeted arboreal mammals, nocturnal birds and herpetofauna;
- detailed Koala surveys along sixteen survey transects (as conducted for the Horse Island Route Option Preliminary Flora and Fauna Assessment) involving:
    - examination of sixty-eight potential Koala habitat trees for the presence of Koalas;
    - surveys of identified potential Koala food trees and trees with a diameter at breast height >30cm for Koala presence, scats and scratches;
    - opportunistic diurnal scat identification surveys; and

- nocturnal spotlighting with respect to the Koala;
- owl call playback surveys conducted over six nights in seven separate locations to the east of the river. The Powerful, Masked, Barking and Sooty owls were targeted during these investigations;
- call playback surveys for the Bush-stone Curlew conducted over two nights in two locations, and for the Australasian and Black Bittern over two nights in one location; and
- scat collection (both mammal and bird species) and analysis.

Habitat assessment was conducted during all surveys, involving assessment of the value of the features in the study area as habitat for native fauna. This is considered an important survey method, particularly in enabling predictions to be made regarding the species likely or unlikely to occur in the study area, and in determining the optimal sites for dedicated searches and surveys (*eg* trapping, call playback *etc*).

Habitat assessment is conducted by initially interpreting aerial photography to locate features of potential value for native fauna, such as areas of vegetation and creeklines. Areas of potentially suitable habitat are then traversed during field surveys. During habitat assessments, particular attention is paid to the presence of specific features and resources, including:

- mature hollow-bearing trees and stags, which provide nesting and shelter resources for many species;
- the structure of vegetation communities, including the presence or absence of a canopy, shrublayer, groundcover *etc*;
- the diversity and density of flora species and the presence of flowering plants;
- the structure and composition of the groundcover, including the presence of dense vegetation, hollow logs, leaf litter and rock outcrops;
- the presence of natural and artificial waterbodies and creeklines; and
- the presence of artificial features, such as bridges, buildings and debris which can provide habitat for some species.

Specific records were obtained only for particular habitat resources or features, notably hollow-bearing trees (Appendix J) and Koala activity in relation to food trees (Chapter 5). The Karuah Bypass alignment does not support habitat features or elements of restricted distribution or particularly high significance for any of the threatened or "*affected*" species recorded or likely to occur.

3.2 Prevailing Weather Conditions

The Director-General requires, in Item 1.14, that "*the impact of the season, prevailing weather conditions, and limitations of survey techniques employed must be considered and discussed with respect to the results of the survey*".

Details of the "*prevailing weather conditions*" during the field investigations are outlined below and detailed in Appendix D. The conditions during the surveys in the study area (Gunninah 1999b, 1999c) were generally warm to hot and humid, with rain falling over 3 days during the February 1998 surveys and heavy rain falling over two days in the December 1998 surveys. Consequently, the conditions during the surveys were generally suitable for the detection of most fauna species, with several days of light to heavy rainfall providing particularly favourable conditions for amphibian surveys.

Given the considerable array of field investigations which have been previously conducted in the area, the period over which they have been conducted (1995 to 1999), and that the Gunninah investigations were conducted in a variety of weather conditions (Appendix D), it is considered that the study area has been adequately surveyed through a representative range of climatic and seasonal conditions, and over a considerable period.

Immediately prior to and during some of the fauna surveys, there were extended periods of rain, including some periods of extremely heavy rainfall (probably exceeding 25mm in 24 hours). These circumstances provided above average conditions for amphibian searches. Across the landscape, water tables were high, with extensive ponding and pooling of water over several months. Farm dams were full through much of the study period, creeklines were flowing through the study area, and the previously dry Wallaroo Swamp slowly filled. The wet climate and subsequent environmental conditions were highly favourable for the detection of the threatened amphibians known from the region, particularly including the Green-thighed Frog. The wet conditions were sufficient on occasions to hamper some survey efforts that required dry conditions, and limited 4 wheel-drive access at times across some of the study area, due to impassable roads.

Seasonal considerations and "*prevailing weather conditions*" are of potential significance with respect to the detection of many fauna and flora species. The observation and identification of a range of native biota can be influenced by seasonal and climatic factors, potentially affecting the value or validity of information obtained from the field investigations. Species or guilds of native fauna and flora, which may be particularly affected by seasonal and climatic conditions, include:

- ground orchids, many of which are not present above ground during parts of the year and may therefore not be detectable at all if surveyed in inappropriate seasons;
- many reptile and amphibian species, which hibernate during the winter or may aestivate during extended dry hot periods;
- migratory or nomadic bird species, which include latitudinal migrants (species which migrate in a north - south direction on a seasonal basis), altitudinal migrants (species which migrate from coastal habitats to sites at higher elevation on a seasonal basis) and nomadic species (which move in response to the availability of food resources or other relevant habitat features). Species of relevance in this regard include the Regent and Painted Honeyeaters, Turquoise and Swift Parrots, the Glossy Black Cockatoo, Black Flying Fox and a range of other nectarivorous and frugivorous species; and
- microchiropteran bats, many of which either migrate to warmer climes during the winter or enter a state of torpor.

Whilst there is some potential for climatic and seasonal conditions to affect the value and validity of information obtained during field investigations, it should be noted that the substantial information contained in previous reports and investigations from the study area (Section 3.1) have been incorporated, providing a comprehensive series of field investigations over a representative range of climatic and seasonal conditions. Despite the extensive and comprehensive field investigations, which have been conducted for this proposal, seasonal factors and "*prevailing weather conditions*" will doubtless have been of some limited impact "*with respect to the results of the survey*". Conversely, inclusion of information from previous investigations in the locality is regarded as adequately compensating for any limitations which might otherwise have prevailed.

3.3 Efficacy of Survey Techniques

The surveys in the study area included a range of techniques, aimed at locating and identifying as many species as possible. The combination of survey techniques, as outlined by the Director-General, is considered more than adequate to record most of the species which would occur in the study area.

The combination of ground trapping (pitfall traps, cage traps and Elliott traps) and hair tubes is considered appropriate to detect the presence of terrestrial fauna species, as is the combination of tree-mounted Elliott traps and tree-mounted hair tubes to detect arboreal mammals. Spotlighting surveys further complement these trapping activities.

Microchiropteran bat surveys were conducted using three methods: mist nets, harp traps and Anabat II echolocation recorders. Given that different species fly at different heights, the use of these three techniques is considered appropriate to record the majority of the

species likely to occur in the study area. Some very high-flying species, such as the Yellow-bellied Sheathtail Bat, may not have been recorded, given that such species are difficult to record with any survey method. In such instances, habitat assessment is a valid way to determine the possible presence of the species.

Table 3.1 Total effort (transects & trap-nights/hours) and dates of the flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah for the *Route Selection-Flora & Fauna Constraints* report (Gunninah 1997a); *Proposed Horse Island Route-Flora & Fauna Assessment* report (Gunninah 1999b), and *Species Impact Statement* (1999c).

Survey Method	Effort		Months
	Transects*	Trap-nights/Hours	
FLORA	44	69	April 1997; Nov & Dec 1998
FAUNA			
Trapping			
Elliott: Ground-based	19 (410)	1640	April 1997; March, Nov & Dec 1998
Elliott: Tree-based	18 (123)	483	April 1997; March, Nov & Dec 1998
Cage	19 (19)	86	April 1997; March, Nov & Dec 1998
Hair Tubes: Ground-based	24 (147)	1685	April 1997; March, Nov & Dec 1998
Hair Tubes: Tree-based	8 (24)	306	April 1997; March, Nov & Dec 1998
Pitfall	2 (20)	110	Nov 1998 & Aug 1999
Microchiropteran Bat Surveys			
Anabat	33	24 nights & 9.75 hours	April 1997; March, Nov & Dec 1998
Harp Traps	22	47 nights	April 1997; Jan, Nov & Dec 1998; Jan 1999
Spotlighting	NA	74 hours	April 1997; Nov & Dec 1998; Jan & Aug 1999
Herpetological Searches	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999
Call Playback: Green Thighed Frog	1	1	Aug 1999
Bird Surveys			
General	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999
Call Playback: Owl	8	9.5 hours	Nov & Dec 1998; Aug 1999
Bitterns	2	1.5 hours	Dec 1998 & Jan 1999
Bush-stone Curlew	1	1.5 hours	Aug 1999
Koala Surveys	339 trees	NA	April 1997; March 1998; August 1999
Stag Watch	4	6 hours	August 1999
General Habitat Searches	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999

* the number in brackets indicates the total number of traps

Table 3.2 Survey methods applied in the study area for "*subject species*" and other relevant threatened species in the locality.

Subject Species	Survey Methods
Amphibians	
Green & Golden Bell Frog	habitat assessment; active diurnal and spotlight searches
Green-thighed Frog	habitat assessment; active diurnal and spotlight searches; call playback
Wallum Tree Frog	habitat assessment; active diurnal and spotlight searches
Wallum Froglet	habitat assessment; active diurnal and spotlight searches
Stuttering Barred Frog	habitat assessment; active diurnal and spotlight searches
Gold-eyed Barred Frog	habitat assessment; active diurnal and spotlight searches
Silver Blue-eyed Barred Frog	habitat assessment; active diurnal and spotlight searches
Great Barred Frog	habitat assessment; active diurnal and spotlight searches
Reptiles	
Pale-headed Snake	Specific diurnal and nocturnal foot-based searches during spotlighting
Stephens Banded Snake	Specific diurnal and nocturnal foot-based searches during spotlighting
Three-toed Snake-toothed Skink	no suitable habitat present or outside of known distribution
White-Crowned Snake	no suitable habitat present or outside of known distribution
Mammals	
Brush-tailed Phascogale	habitat assessment; searches for scats, scratches and nests; spotlighting; hairtubes; Elliott Traps
Common Planigale	habitat assessment; pitfall traps
Koala	habitat assessment; targeted tree inspection and searches for scats and scratches; spotlighting
Squirrel Glider	habitat assessment; spotlighting; surveys for evidence of foraging (*ie* chew marks); tree-mounted Elliott traps; tree-mounted hair-tubes
Yellow-bellied Glider	habitat assessment; spotlighting; surveys for evidence of foraging (*ie* chew marks);
Tiger (Spotted-tailed) Quoll	habitat assessment; searches for scats; cage trapping; hair tubes; spotlighting
Long-nosed Potoroo	habitat assessment; searches for scats; spotlighting; cage trapping; hair tubes
Parma Wallaby	habitat assessment; searches for scats; spotlighting
Black-striped Wallaby	habitat assessment; searches for scats; spotlighting
Red-legged Pademelon	habitat assessment; searches for scats; spotlighting
Rufous Bettong	habitat assessment; searches for scats; spotlighting
Eastern Chestnut Mouse	habitat assessment; hair tubes; Elliott traps
Common Wombat	habitat assessment; searches for scats and burrows; spotlighting
New Holland Mouse	habitat assessment; hair tubes; Elliott traps
Black Flying Fox	no suitable habitat present
Common Bent-wing Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Little Bent-wing Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Large Pied Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Eastern Free-tail Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Beccarii's Freetail Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Large-footed Myotis	Anabat II echolocation recordings; Harp trapping; habitat assessment
Golden-tipped Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Greater Broad-nosed Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Hoary Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Eastern Cave Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Northern Long-eared Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Queensland Blossom Bat	Anabat II echolocation recordings; Mist nets; habitat assessment
Yellow-bellied Sheathtail Bat	Anabat II echolocation recordings; Harp trapping; habitat assessment
Birds	
Australasian Bittern	habitat assessment; specific field surveys and observations; call playback
Black Bittern	habitat assessment; specific field surveys and observations; call playback
Barred Cuckoo Shrike	habitat assessment; specific field surveys and observations; call playback
Black-breasted Button Quail	no suitable habitat present or outside of current distribution
Black-necked Stork	habitat assessment; specific field surveys and observations
Brolga	habitat assessment; specific field surveys and observations

Table 3.2 contd Survey methods applied in the study area for "*subject species*" and other relevant threatened species in the locality.

Subject Species	Survey Methods
Birds contd	
Bush Hen	no suitable habitat present or outside of current distribution
Bush Stone Curlew (Thick-knee)	habitat assessment; specific field surveys and observations; call playback
Chestnut-rumped Heathwren	habitat assessment; specific field surveys and observations
Comb-crested Jacana	habitat assessment; specific field surveys and observations
Glossy Black-Cockatoo	habitat assessment; specific field surveys and observations
Lesser Sand Plover	habitat assessment; specific field surveys and observations
Little Tern	habitat assessment; specific field surveys and observations
Masked Owl	habitat assessment; specific field surveys and observations; call playback
Powerful Owl	habitat assessment; specific field surveys and observations; call playback
Sooty Owl	habitat assessment; specific field surveys and observations; call playback
Barking Owl	habitat assessment; specific field surveys and observations; call playback
Eastern Grass Owl	no suitable habitat present or outside of known distribution
Osprey	habitat assessment; specific field surveys and observations
Pied Oystercatcher	habitat assessment; specific field surveys and observations
Sooty Oystercatcher	habitat assessment; specific field surveys and observations
Red Goshawk	habitat assessment; specific field surveys and observations
Regent Honeyeater	habitat assessment; specific field surveys and observations
Square-tailed Kite	habitat assessment; specific field surveys and observations
Rose-crowned Fruit-Dove	habitat assessment; specific field surveys and observations
Superb Fruit Dove	habitat assessment; specific field surveys and observations
Wompoo Fruit Dove	habitat assessment; specific field surveys and observations
Doubled-eyed Fig Parrot	habitat assessment; specific field surveys and observations
Swift Parrot	habitat assessment; specific field surveys and observations
Coxen's Fig Parrot	habitat assessment; specific field surveys and observations
Ground Parrot	no suitable habitat present or outside of current distribution
Turquoise Parrot	habitat assessment; specific field surveys and observations
White-eared Monarch	habitat assessment; specific field surveys and observations
Plants	
Blandfordia grandiflora	habitat assessment; active searches; targeted quadrat surveys
Eucalyptus fergussoni	habitat assessment; active searches; targeted quadrat surveys
Eucalyptus robusta	habitat assessment; active searches; targeted quadrat surveys
Gonocarpus salsoloides	habitat assessment; active searches; targeted quadrat surveys
Grevillea guthrieana (obtusiflora)	habitat assessment; active searches; targeted quadrat surveys
Hakea bakeriana	habitat assessment; active searches; targeted quadrat surveys
Syzygium paniculatum	habitat assessment; active searches; targeted quadrat surveys
Tetratheca juncea	habitat assessment; active searches; targeted quadrat surveys

3.4 Compliance of Survey Activities

The Director-General's (D-G's) Requirements for the Karuah Bypass SIS include the application of an array of dedicated survey methods for threatened fauna and flora species (as documented in Appendix 3 of the D-G's Requirements) (Table 3.5).

The field investigations for flora and fauna, which have been conducted for the Karuah Bypass project (including the initial route selection investigations, the Horse Island Route Flora & Fauna Assessment study, and the supplementary detailed investigations for this SIS), provide a comprehensive and extensive database of native flora and fauna in the study area for assessing the potential impacts of the proposed road on native flora and fauna, and particularly on threatened species. The array of investigations which have been conducted, including relevant elements of the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999), the Raymond Terrace to Karuah EIS (Gunninah 1997b), and the Karuah Quarry flora and fauna investigations (Gunninah 1997c) essentially comply with the methods outlined

in the D-G's Requirements. There are, however, a few instances where minor variations or non-compliance with the strict methods provided in the D-G's Requirements has been applied (Tables 3.3, 3.4, 3.5). Conversely, a range of complementary or alternative survey methods has been utilised throughout the investigations to provide a satisfactory level of investigation for all threatened biota regarded as likely to occur within the study area (Tables 3.1, 3.2).

A number of the threatened fauna species listed in the D-G's Requirements (the "*subject species*" listed in Item 1.11, and additional species discussed in Appendix 3 of the D-G's Requirements - *survey methods*) were not subjected to specific or dedicated surveys, either because there is no suitable habitat for them along the proposed alignment or within the road corridor (*eg* the Yellow-bellied Glider and Eastern Grass Owl), or because the study area is well outside their known or likely distributional ranges (*eg* the Three-toed Snake-toothed Skink and Black-breasted Button Quail). Whilst no dedicated or targeted investigations were conducted for these species (Table 3.3), the intensive and comprehensive field investigations conducted throughout the study area for native biota in general and threatened biota in particular include an array of survey methods appropriate for detecting these species, if present.

As discussed above, the D-G's Requirements (Appendix A of this SIS) include (in Appendix 3 of the Requirements) details regarding the survey methods and effort required to satisfy the "*minimum standard for survey for the subject area*", as determined by the NP&WS. A full description of the methods used ("*including survey techniques employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and prevailing weather conditions*") has been provided (Appendices C and D of this SIS), as required (Item 1.12 of the D-G's Requirements). A Compliance report for the methods detailed in the D-G's Requirements is included in Appendix B of this SIS.

The D-G's Requirements indicate that "*NPWS predicted distribution maps*" are available for some of the threatened fauna known from the locality. Relevant available maps were provided by NP&WS, and were used to assess the presence of potential habitat for "*subject species*", and to address the likelihood of occurrence of such species (Appendix K).

3.5 Non-Compliance of Methods

Some of the methods detailed in Appendix 3 of the D-G's Requirements have not been strictly complied with in the investigations conducted for the Karuah Bypass project. Several of the species included in Appendix 3 of the D-G's Requirements, and some "*subject species*" were not addressed by targeted surveys (Table 3.3). Species in this category include those for which the study area provides no suitable habitat or resources (in particular rainforest-dependent species), or for which the study area is substantially outside of their currently known distributions.

Conversely, fauna and flora investigations have been conducted within the study area over an extensive period (from 1995 to August 1999), and the combined survey effort for threatened biota constitutes a comprehensive database over a number of years and through a full range of climatic conditions and seasons. The broad array and comprehensive nature of the investigations conducted in the study area are regarded as having included suitable techniques to locate these species, if present.

Doubtless, the use of areas of land by native fauna will vary between seasons and climatic circumstances, with many species being nomadic or migratory, or utilising areas only under particular circumstances. Furthermore, the variations over time in the nature and condition of vegetation communities and habitats (in response to historical land use activities or a history of fire) will result in alterations to the use of portions of the landscape by native fauna, including threatened species. Similarly, the presence of native plants, particularly of threatened species, will be dependent (to some extent at least) on prevailing and previous climatic and land use circumstances. In this regard, for example, the threatened plant *Tetratheca juncea* appears highly susceptible to fire, and an inappropriate (too frequent) burning regime can eliminate the species from areas of forest or woodland, which might otherwise be of value as habitat.

Notwithstanding the above observations regarding variability in use of areas of native vegetation by flora and fauna, the array of investigations which have been conducted within the study area, either for the Karuah Bypass project itself or for other projects in the vicinity, provides a comprehensive (albeit not exhaustive) investigation of the flora and fauna assemblage in the locality. Whilst a few of the methods detailed in Appendix 3 of the D-G's Requirements have not been strictly complied with, the substantial array of investigations includes suitable and appropriate methods for surveying native (particularly threatened) biota within the study area.

One circumstance which had affected the suitability of portions of the study area for a number of threatened fauna species, and for the threatened plant *Tetratheca juncea*, involved a major bush fire within Karuah SF between the investigations conducted for the Horse Island - Flora & Fauna Assessment report (Gunninah 1999b) and the conduct of supplementary investigations for the SIS, pursuant to the requirements of the Director-General of NP&WS. As a consequence of the fire through Karuah SF, no additional information was able to be obtained regarding the distribution of *Tetratheca juncea* in this area, and much of the forest and woodland had been rendered unsuitable for a number of threatened fauna species (such as the Tiger Quoll, Long-nosed Potoroo and Bush Stone-curlew). Nevertheless, previous investigations in the study area and in the vicinity provide suitable information regarding the distribution of these species and of relevant or potential habitat for them.

Table 3.3 Justification for a lack of targeted surveys for some "*subject* species" and other species included in Appendix 3 of the D-G's Requirements.

Species	Justification
Black-flying Fox	Occurs across northern Australia, including the far northeast coast of NSW. The study area is outside of the known distribution of this species.
Eastern Tube-nosed Bat	This species does not occur in the area.
Eastern Grass Owl	The study area does not support suitable habitat for this species.
Bush Hen	This species occurs from approximately Ballina to Cape York. The study area is outside of its known distribution.
Black-breasted Button Quail	This species has a very restricted distribution from the extreme northeast corner of NSW to southeastern Queensland. The study area is outside of its known distribution.
Ground Parrot	The study area does not support suitable habitat for this species.
White-crowned Snake	Restricted to the northeastern corner of NSW, where it inhabits subtropical rainforest and wet sclerophyll forest. The study area is outside of the known distribution of this species, and does not support habitat of relevance.
Three-toed Snake-toothed Skink	This species has an extremely restricted distribution in the far northeastern corner of NSW and southeastern corner of Queensland, where it inhabits rainforest. The study area is outside of its distribution, and does not support habitat of known relevance.

3.5.1 Call Playback

Call playback for several relevant species (the Powerful, Sooty, Barking and Masked Owls, the Australasian and Black Bittern, the Bush Stone-curlew the Green-thighed Frog) was conducted at a number of potentially "*suitable habitat*" sites through the study area

(Appendix C; Figure 3.2a & b), whilst several other species were not surveyed using this technique (as detailed below).

The Masked Owl could occur widely in the locality, given its use of open forest and woodland vegetation, and the Powerful Owl could also occur throughout the study area (although probably at lower frequencies and in fewer sites). The Green-thighed Frog could potentially occur throughout the study area, but suitable breeding sites are uncommon, and all potentially suitable sites located were surveyed (using call playback, habitat searches, spotlighting and call identification). The Bush Stone-curlew could occur widely in the woodland habitats present in the study area, and has been recorded (ERM Mitchell McCotter 1999) in the vicinity of Karuah township. The call playback sites for these species (Appendix C; Figure 3.2a, 3.2b) provide a thorough coverage of 'suitable habitat' in the study area.

Call playback was not used to census several "*subject species*" or other threatened species discussed in Appendix 3 of the D-G's Requirements (*survey methods*), because:

- the species had already been recorded along the road corridor or in the vicinity by other survey methods;
- no additional useful or relevant information was anticipated as a result of the call playback technique; and/or
- there was no relevant habitat or resources present, and no other survey methods indicated the presence of any of these species (Table 3.4).

Table 3.4 Justification for not using call playback to survey for several species along the Karuah Bypass.

Species	Justification
Koala	Recorded at several locations through the study area by scats and sightings; no additional relevant data anticipated; other survey techniques considered appropriate and sufficient.
Squirrel Glider	Recorded at several locations through the study area by sightings; no additional relevant data anticipated; other survey techniques considered appropriate and sufficient.
Yellow-bellied Glider	No suitable habitat; no previous records in the locality from any study; no responses to Powerful Owl calls (this species often responds to Powerful Owl call playback); no evidence for presence (sap-feeding sites, spotlighting).
Wompoo, Superb & Rose-crowned Fruit Dove	The study area does not support suitable habitat for these species. The only habitat of potential value is to the North-east of Karuah Quarry, which has been surveyed in detail (Gunninah 1997c).
Ground Parrot & Eastern Grass Owl	The study area does not support suitable habitat for these species.
Green & Golden Bell Frog	The study area does not support suitable habitat for this species. All potential habitat (of which there is very little) was searched.
Wallum Froglet; Wallum Sedgefrog; Stuttering Frog; Great Barred Frog & *Mixophyes fleayi*	There was no relevant habitat or resources present, and no other survey methods indicated the presence of any of these species.

3.5.2 Hairtubes

There is considerable difficulty in the interpretation of "*all potential habitat*" (Appendix 3 of the D-G's Requirements) for the Tiger (Spotted-tailed) Quoll and the Brush-tailed Phascogale. The former species prefers moister forest communities, but can also utilise open forest and woodland vegetation. The Phascogale prefers drier more open forest and

woodland vegetation, which is widespread in the locality. The occurrence of both species, particularly west of the Karuah River, may have been affected by the bushfire, which occurred in Karuah SF between the original surveys for the project and those conducted specifically for the SIS.

Theoretically, there could be more than 10000ha of "*potential habitat*" for the Tiger Quoll and Brush-tailed Phascogale "*up to 5km from the route*". On the basis of the NP&WS requirements, particularly that "*survey effort should comprise a minimum of one transect per 50 hectares of habitat*", a minimum of 200 hairtube transects would be required in that instance.

However, habitat values are not homogeneous along the corridor, and those areas which were surveyed for the Tiger Quoll and Brush-tailed Phascogale were selected on the basis of their apparent potential habitat value for these species (based on previous experience in the locality and on previous records). The area of 'suitable' or 'likely' habitat for these species is considerably less than the total area of "*all potential habitat*", and a significant portion of the study area west of the Karuah River had been severely burnt shortly prior to the supplementary investigations conducted for the SIS in late 1998/early 1999.

A total of 1991 hair tube-nights (Table 3.1) have been conducted within the Karuah Bypass study area for this project, in addition to 232 hair tube-nights in adjacent areas (the Raymond terrace to Karuah Upgrade and the Karuah Quarry projects). This survey intensity is considered appropriate for these species (particularly in conjunction with trapping and spotlighting surveys), given the "*objectives for fauna surveys for the Pacific Highway upgrade*" (NP&WS D-G's Requirements), and the nature and condition of the habitats present.

Hair tubes were utilised through several of the field studies in the study area, involving a range of weather conditions. Despite the wet conditions during some of the field investigations, sufficient periods of dry weather occurred to allow for effective survey using the hair tubes.

3.5.3 Trapping

Tree-mounted Traps
Ten tree-mounted Elliott traps were deployed at each of the survey sites for the SIS, rather than the twenty noted by the NP&WS. The overall survey intensity for the relevant species (the Squirrel Glider and the Brush-tailed Phascogale) is regarded as appropriate, however, including the tree-mounted traps (483 trap-nights), tree-mounted hair tubes (306 trap-nights), ground-based Elliott traps (Brush-tailed Phascogales have been collected in ground-based Elliott traps) and spotlighting along the Karuah Bypass project, as well as the survey effort applied along the Raymond Terrace to Karuah Upgrade project and on the Karuah Quarry site. Given the combined array of survey methods employed, a doubling of tree-mounted Elliott traps is not regarded as likely to have provided any additional relevant information.

The Elliott traps used were 'A' size (approximately 10cm x 8cm x 30cm), not the larger 'B' size traps. However, we have successfully trapped Squirrel Gliders in 'A' size Elliott traps in the past (*eg* at Tomago (Gunninah 1995)), and the Brush-tailed Phascogale has frequently been collected in this size Elliott trap (M Chambers *pers comm*).

No additional threatened fauna species are regarded as likely to have been detected using 'B' size Elliott traps, given the array of other survey methods employed along the Karuah Bypass project and in the vicinity. The use of cage traps, hairtubes, 'A' size Elliott traps, spotlighting and dedicated habitat searches is considered sufficient to have detected those threatened fauna species occupying the road corridor, and satisfies the requirements for detailed surveys for "*subject species*" within the study area.

Cage Traps
Only one cage trap was deployed per trapping transect (not the 10 cage traps noted by the NP&WS). However, areas of habitat regarded as particularly suitable for the target species (the Tiger Quoll and Long-nosed Potoroo) along the alignment are relatively few, and the groundcover was generally relatively sparse, particularly following the bushfire west of the

Karuah River. Additionally, the extensive spotlighting and hair tube surveys provide appropriate supplementary survey techniques for these species throughout the study area.

3.5.4 Ultrasonic Call Recording

The use of Anabat II ultrasonic receivers has varied through the study area, with sites surveyed between one and three times, using a combination of walked, driven and stationary recordings of microchiropteran bat activities (Appendix C).

To achieve the desired replication of survey effort (Appendix 3 of the D-G's Requirements), supplementary surveys had to be conducted in August 1999. However, it should be noted that the total survey effort for microchiropteran bats during the investigations conducted specifically for the Karuah Bypass project (with respect solely to ultrasonic recordings) has included a total of twenty-four nights and 9.75 hours of Anabat recordings (Appendix C; Table 3.1), involving:

- twenty-four nights with Anabat receivers deployed at fixed locations all night;
- two nights of 3 and 3.75 hours of Anabat recordings; and
- six nights of 30 minute recordings using walked transects to supplement the previous surveys.

In addition, there have been nineteen nights of Anabat surveys associated with the Karuah Quarry project (Ecotone 1995; Gunninah 1997c) and in the vicinity of the Karuah Bypass project, including the Raymond Terrace to Karuah Upgrade project (Gunninah 1997b) and the Karuah to Bulahdelah project (ERM Mitchell McCotter 1999). General habitat searches to identify potential roost sites within the study area included a hollow-bearing tree survey along and within 200m of the alignment and stag watch in four locations over four days (Appendix C).

3.5.5 Common (Queensland) Blossom Bat

Mist nets were not used to target the Common Blossom Bat, because there is no particularly relevant or suitable habitat for this species along the alignment or in the vicinity. Furthermore, this species has not been recorded in previous investigations in the vicinity, and is not likely to be present (D Fanning and M Chambers *pers obs*).

3.5.6 Frog Surveys

No tadpoles were located or collected along the alignment during the various investigations for amphibians, including those undertaken for the SIS. Conditions were ideal on several occasions for the surveying of amphibians (raining and warm), and many species were recorded calling. However, no tadpoles were located in the few water bodies present along the alignment.

Given the excellent amphibian survey conditions experienced during the surveys for the Karuah Bypass (Appendix C), it is not regarded as likely that species would have been missed in the investigations, or that additional species would have been identified, by the presence of tadpoles.

Table 3.5 Survey requirements for threatened fauna as described in Table 1 of Appendix 3, in the NP&WS D-G's Requirements (Appendix A).

Species Name	Spot Light	Call Play Back	Hair Tubes	Scats	Mist Net	Harp Trap	Bat Calls	Species Specific	Elliott Trap	Pitfall
Amphibians										
Crinia tinnula	√	X						√		
Litoria aurea	√	X						√		
Litoria brevipalmata	√	√						√		
Litoria olongburensis	√	X						√		
Mixophyes iteratus	√	X						√		
Reptiles										
White-crowned Snake *Cacophis harriettae*	X							X		
Three-toed Snake-toothed Skink *Coeranoscincus reticulatus*								X		
Pale-headed Snake *Hoplocephalus bitorquatus*	√							√		
Stephen's Banded Snake *Hoplocephalus stephensii*	√							√		
Flying Mammals										
Black Flying Fox *Pteropus alecto*	X									
Common Bent-wing Bat *Miniopterus schreibersii*						√	√			
Eastern Little Mastiff Bat *Mormopterus norfolkensis*							√			
Golden-tipped Bat *Kerivoula papuensis*						√		√		
Greater Broad-nosed Bat *Scoteanax rueppellii*						√	√			
Hoary Bat *Chalinolobus nigrogriseus*						√	√			
Large Pied Bat *Chalinolobus dwyeri*						√	√			
Large-footed Myotis *Myotis adversus*						√	*	√		
Little Bent-wing Bat *Miniopterus australis*						√	√			
Beccarii's Freetail Bat *Mormopterus beccarii*						*	√			
Eastern Tube-nosed Bat *Nyctimine robinsoni*	√									
Northern Long-eared Bat *Nyctophilus bifax*						√	*			
Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*					X	√	√			
Queensland Blossom Bat *Syconycteris australis*	√				X	√				
Eastern Cave Bat *Vespadelus troughtoni*						√				
Non-flying Mammals										
Brush-tailed Phascogale *Phascogale tapoatafa*	√		√	*					√	
Common Planigale *Planigale maculata*										√
Koala *Phascolarctos cinereus*	√			√				√		

Table 3.5 contd Survey requirements for threatened fauna as described in Table 1 of Appendix 3, in the NP&WS D-G's Requirements (Appendix A).

Species Name	Spot Light	Call Play Back	Hair Tubes	Scats	Mist Net	Harp Trap	Bat Calls	Species Specific	Elliott Trap	Pitfall
Non-flying Mammals contd										
Long-nosed Potoroo *Potorous tridactylus*	√		√	√				√		
Rufous Bettong *Aepyprymnus rufescens*	√		√	√				√		
Squirrel Glider *Petaurus norfolcensis*	√	X						√	*	
Tiger Quoll *Dasyurus maculatus*	√		√							
Yellow-bellied Glider *Petaurus australis*	√	X						√		
Birds										
Australasian Bittern *Botaurus poiciloptilus*								√		
Barred Cuckoo Shrike *Coracina lineata*								√		
Black Bittern *Ixobrychus flavicollis*								√		
Black-breasted Button Quail *Turnix melanogaster*								X		
Black-necked Stork *Ephippiorhynchus asiaticus*								√		
Brolga *Grus rubicunda*								√		
Bush Hen *Amaurornis olivaceus*								X		
Bush Stone-curlew *Burhinus grallarius*		√						√		
Comb-crested Jacana *Irediparra gallinacea*								√		
Double-eyed Fig-parrot *Cyclopsitta diophthalma coxeni*								√		
Grass Owl *Tyto capensis*	X	X		X						
Glossy Black cockatoo *Calyptorhynchus lathami*								√		
Masked Owl *Tyto novaehollandiae*	√	√		√						
Osprey *Pandion haliaetus*								√		
Powerful Owl *Ninox strenua*	√	√		√						
Red Goshawk *Erythrotriorchis radiatus*								√		
Rose-crowned Fruit Dove *Ptilinopus regina*								√		
Sooty Owl *Tyto tenebricosa*	√	√		√						
Square-tailed Kite *Lophoictinia isura*								√		
Superb Fruit Dove *Ptilinopus superbus*								√		
White-eared Monarch *Monarcha leucotis*								√		
Wompoo Fruit Dove *Ptilinopus magnificus*								√		

√ - Compliance with the NP&WS D-G's Requirements.
X - Non-compliance with the NP&WS D-G's Requirements (Section 3.5; Table 3.3).
* - Additional field surveys completed by Gunninah.

4 GENERAL DESCRIPTION of the STUDY AREA

The NP&WS D-G's Requirements include a general discussion of the characteristics of the study area. In this regard, the specific requirements for this SIS involves:

> "*1.6 In describing the study area, consideration must be give to the previous land uses and the effect of these land uses on the study area. Relevant historical events may include sand mining, fire history, clearing, logging, recreational use and agricultural activities*";

4.1 Physical Characteristics of the Study Area

The Karuah Upgrade study area is located to the north of the existing Pacific Highway, and is approximately 3 to 4km north of the town of Karuah at its furthest point. The study area generally supports a mosaic of largely cleared agricultural land, remnant and regenerating forest and freshwater and estuarine wetlands. The Karuah River flows in a north-south direction and divides the study area into eastern and western sections. Horse Island, directly north of Karuah town, is an important feature of the study area. Other than scattered houses, the study area does not support residential development, most of which is concentrated to the south, in and around the township of Karuah.

The study area ranges from relatively flat in the western portion to very steep in the east. In the western portion of the study area, the topography is undulating, sloping downward to the River. Horse Island is relatively steep over some sections. To the east of the Karuah River the topography is initially flat, becoming steep to very steep away from the River.

The geology of the Karuah area is diverse and ranges in origin from the Carboniferous period to the Permian, with some recent depositions occurring adjacent to the Karuah River. The area to the east of the Karuah River, in the vicinity of the existing Karuah Quarry, was historically volcanically active, and the geology of this area features volcanic deposits dating back to the Carboniferous. The western side of the River consists of sandstones and conglomerates deposited in the Permian. During this period, uplifting occurred, resulting in folds, faults and the steep landform which exists today.

4.2 Previous Land Uses

The majority of the western portion of the Karuah Upgrade study area traverses forest and woodland, much of which was previously included in Wallaroo and Karuah SFs. As a result of the recent forestry decision, most of Karuah SF has been transferred to the Estate of the NSW NP&WS as part of the Karuah NR. Wallaroo SF has been reserved as an Interim Forestry Deferred Area.

Outside of the Karuah NR, the land on the western side of the Karuah River primarily consists of State Forest, privately owned forest and agricultural land. As a result of their management by State Forests, much of the forest and woodland to the west of the Karuah River has been subjected to selective logging practices. This is evidenced by stands of trees of a similar age class with few over-mature or senescent trees present. However, some areas support a more intact and diverse range of flora species and age classes, in particular on Horse Island. The western side of the Karuah River also supports occasional patches of cleared land on which virtually all native vegetation has been removed for the purposes of grazing.

The Karuah River supports fringing salt marshes and mangroves, which are classified under *State Environmental Planning Policy No 14 - Coastal Wetlands* (SEPP 14) (Figure 1.4). The River is used for recreational boating and fishing, as well as for commercial fishing and oyster farming. There appears to be stock access to some areas of the wetlands, particularly on the eastern side of the River, which has resulted in some trampling and weed invasion, although these wetland areas are generally in good condition. SEPP 14 wetlands also occur to the south of the proposed alignment on both sides of the river, in the vicinity of the township of Karuah, as well as associated with Reedy and Yalimbah Creeks, to the south of the existing Highway (Figure 1.4).

The eastern side of the Karuah River supports a mosaic of privately owned forest and agricultural land. Whilst the eastern bank of the River at the proposed bridge crossing supports a band of native trees, the immediately adjacent land has been cleared for grazing. Beyond this cleared land to the east, the landform consists of steep to very steep topography, much of which is unsuitable for agriculture, other than in the valley where clearing has also occurred to support cattle grazing.

Other land uses and disturbance, which are evident in the study area, include extractive industry, fire and public recreation. Karuah Quarry is located to the immediate north of the eastern end of the proposed Highway, where it joins the existing Highway. Fire is currently the most obvious form of disturbance in the study area, with land on the western side of the River exhibiting the effects from a wildfire in approximately November 1997. This area appears to be burnt regularly and as a result supports reduced structural and floristic diversity.

4.3 Biological Features

4.3.1 Vegetation

With respect of vegetation communities in the study area, the NP&WS D-G's Requirements include:

> "*1.2 A vegetation map of the study area must be provided. This map will show the location and type of the vegetation communities present within the study area and the scale of the map. The map must be presented in colour. The vegetation units mapped should follow a standard classification system such as Walker and Hopkins (1990), and include dominant species in each vegetation unit*".

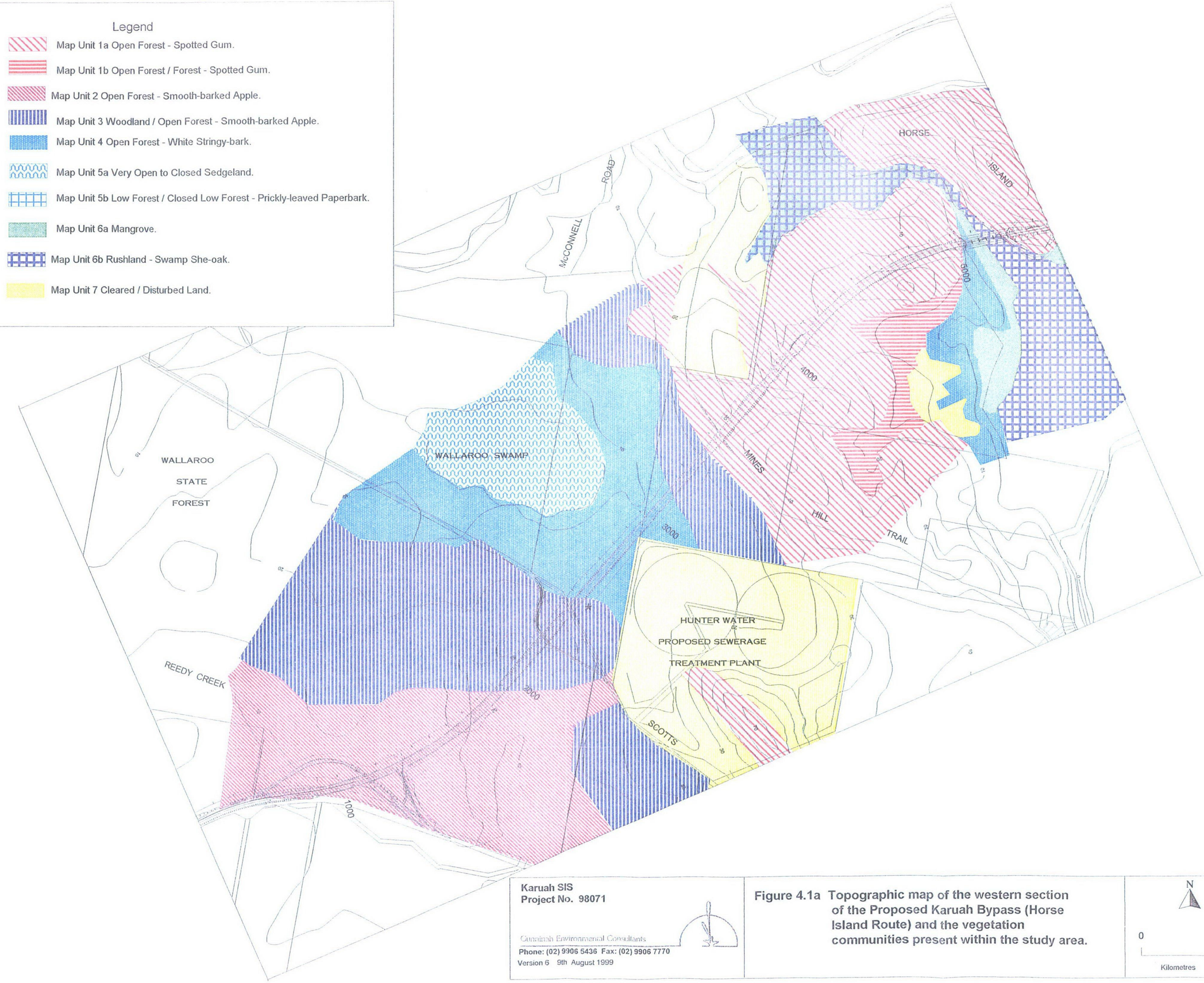
Figure 4.1a and 4.1b provides "*a vegetation map of the study area*". The vegetation communities present in the study area are considered below, with reference to the "*dominant species in each vegetation unit*". The Flora & Fauna Assessment report (Gunninah 1999b) provides details of the different vegetation communities in the study area. A summary of that information is provided here, and the reader is referred to the Flora & Fauna Assessment report for detailed information on floristics and structure of the communities present.

The vegetation communities present in the study area are diverse, and include woodland and open forest, freshwater wetland and sedgelands, estuarine saltmarsh and mangrove, and cleared pasture. Seven separate community types were defined within the study area, three of which were broken into two sub-communities. Many of the communities are structurally similar, but are defined by floristic differences:

Community 1a	Open Forest dominated by Spotted Gum *Corymbia maculata*
Community 1b	Open Forest/Forest dominated by Spotted Gum *Corymbia maculata*
Community 2	Open-Forest dominated by Smooth-barked Apple *Angophora costata* and Sydney Peppermint *Eucalyptus piperita*
Community 3	Woodland/Open-Forest dominated by Smooth-barked Apple *Angophora costata*, Brown Stringybark *Eucalyptus capitellata* and Bastard Mahogany *E umbra.*
Community 4	Open-Forest dominated by Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *E globoidea* and Rough-barked Apple *Angophora floribunda.*
Community 5a	Freshwater Wetlands: Sedgeland
Community 5b	Low-Forest/Closed Low-Forest
Community 6a	Estuarine communities - Mangrove Open Scrub

Legend

- Map Unit 1a Open Forest - Spotted Gum.
- Map Unit 1b Open Forest / Forest - Spotted Gum.
- Map Unit 2 Open Forest - Smooth-barked Apple.
- Map Unit 3 Woodland / Open Forest - Smooth-barked Apple.
- Map Unit 4 Open Forest - White Stringy-bark.
- Map Unit 5a Very Open to Closed Sedgeland.
- Map Unit 5b Low Forest / Closed Low Forest - Prickly-leaved Paperbark.
- Map Unit 6a Mangrove.
- Map Unit 6b Rushland - Swamp She-oak.
- Map Unit 7 Cleared / Disturbed Land.



Karuah SIS
Project No. 98071

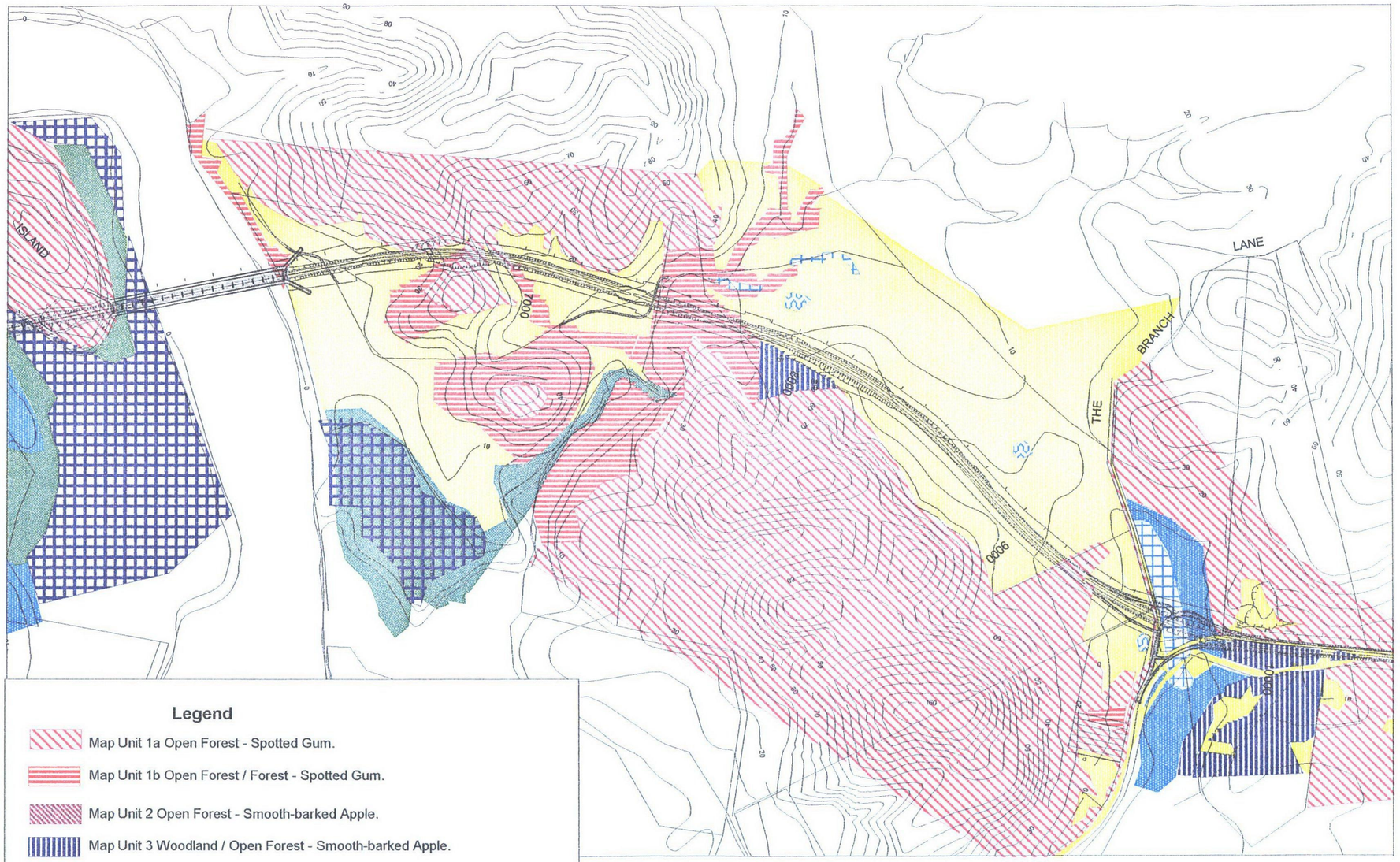
Cunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770
Version 6 9th August 1999

Figure 4.1a Topographic map of the western section of the Proposed Karuah Bypass (Horse Island Route) and the vegetation communities present within the study area.

N

0 0.5

Kilometres



Legend

- Map Unit 1a Open Forest - Spotted Gum.
- Map Unit 1b Open Forest / Forest - Spotted Gum.
- Map Unit 2 Open Forest - Smooth-barked Apple.
- Map Unit 3 Woodland / Open Forest - Smooth-barked Apple.
- Map Unit 4 Open Forest - White Stringy-bark.
- Map Unit 5a Very Open to Closed Sedgeland.
- Map Unit 5b Low Forest / Closed Low Forest - Prickly-leaved Paperbark.
- Map Unit 6a Mangrove.
- Map Unit 6b Rushland - Swamp She-Oak.
- Map Unit 7 Cleared Disturbed Land.

Karuah SIS
Project No. 99071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 4.1b **Topographic map of the eastern section of the Proposed Karuah Bypass (Horse Island Route) and the vegetation communities present within the study area.**

N

0 0.5

Kilometres

Community 6b Estuarine Wetlands: Saltmarsh

Community 7 Cleared Pasture/Highly Modified Lands with remnant and/or regenerating native species

Community 1a *Open Forest dominated by Spotted Gum Corymbia maculata.*

Characteristics

- Open-Forest reaching 15-20m in height, Foliage Projective Cover (FPC) 20-40%;
- dominant species include Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Gum *E punctata*, Northern Grey Ironbark *E siderophloia*, White Stringybark *E globoidea*, Tallow-wood *E microcorys*;
- conservation significant species include Grey Gum *Eucalyptus propinqua*, Grey Gum *E punctata* and Tallow-wood *E microcorys* (SEPP 44 - *Koala Habitat Protection*).

Distribution

This community occurs widely in the study area, generally within the northeastern parts of Wallaroo SF, Karuah SF, on Horse Island and on the higher slopes and ridges to the east of the Karuah River.

Structure

The trees are generally 15-18m high, single trunked, and exhibit some coppice growth (a response to disturbance). The majority of upper canopy species are juvenile, semi-mature and regenerating forms, with mature specimens constituting a very small proportion of the canopy. A discontinuous mid-canopy occurs to 4.5m in height, being slightly taller in damper areas. The understorey is limited in diversity, and generally occurs to 1.5m in height. The groundcover appears well represented and moderately diverse. Exotic species are generally limited to the forest edge and highly modified areas.

Floristics

Upper canopy

The upper canopy is dominated by *Corymbia maculata*, *Eucalyptus siderophloia*, *E propinqua*, *E globoidea* and occasional specimens of *E microcorys*. Occasional specimens of *E fibrosa* ssp *fibrosa* occur in some areas.

Mid-storey

The mid-canopy is dominated by *Allocasuarina littoralis* and *Exocarpos cupressiformis*, with occasional specimens of *A torulosa* and *Glochidion ferdinandi* ssp *ferdinandi* occurring in moister sites.

Shrub layer

Common species include *Breynia oblongifolia*, *Bursaria spinosa* var *spinosa*, *Pultenaea villosa*, *Leucopogon juniperinus*, *Pimelia linifolia* ssp *linifolia*, *Acacia myrtifolia*, *Daviesia ulicifolia*, *Ozothamnus diosmifolius* and *Ac ulicifolia*.

Groundcover

Common species include *Themeda australis*, *Senecio diaschides*, *Entolasia marginata*, *Dichondra repens*, *Dianella longifolia* var *longifolia*, *Lomandra longifolia*, *Lomandra obliqua*, *Oplismenus aemulus*, *Brunoniella australis*, *Opercularia varia*, *Epaltes australis*, *Xanthosia pilosa*, *Entolasia stricta*, *Aristida ramosa*, *Eragrostis brownii*, *Cymbopogon refractus*, *Hypericum gramineum*, *Hardenbergia violacea* and *Eustrephus latifolius*.

Exotic species

Common exotic species include *Verbena rigida*, *Chloris gayana*, *Sporobolus capensis*, *Hypochaeris radicata*, *Sonchus oleraceus*, *Bidens pilosa*, *Sida rhombifolia* and *Senecio madagascariensis*. *Lantana camara* occurs along the edges of this community where it is adjacent to highly disturbed sites, whilst *Ligustrum* spp occur along some of the minor drainage lines adjacent to residential or pastoral sites.

Community 1b *Open Forest/Forest dominated by Spotted Gum Corymbia maculata*

Characteristics

- Open-Forest/Forest reaching 18-25m in height, FPC 20-55%;
- dominant species include Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Ironbark *E paniculata*, Northern Grey Ironbark *E siderophloia*, Turpentine *E siderophloia*, *Syncarpia glomulifera*, Tallow-wood *E microcorys*;
- conservation significant species include Grey Gum *Eucalyptus propinqua*, Grey Ironbark *E paniculata* and Tallow-wood *E microcorys* (SEPP 44).

Distribution

Some remnants occur on the eastern side of Karuah River, predominantly on lower slopes, sheltered sites and gullies. Some small, isolated patches occur on the western side of the river on private property, although these remnants have been heavily modified. More intact examples of this community occur on private land to the south of the proposed Bypass route at its eastern end. Present and prior disturbance events include logging, grazing by cattle and altered fire regimes.

Structure

Trees are between 18 and 22m high, mainly single trunked, with some coppice growth (a response to disturbance). The majority of upper canopy species consist of juvenile, semi-mature and regenerating forms, with mature specimens constituting a small proportion of the canopy. A discontinuous secondary canopy occurs to 4.5 to 6m high, with some taller specimens in damper sites. The understorey exhibits limited diversity and generally occurs to 2.5m high. The groundcover layer appears well represented and moderately diverse. The occurrence of exotic species is limited to forest edges and heavily modified sites.

Floristics

Upper Canopy

Characteristic upper canopy species are *Corymbia maculata*, *Eucalyptus siderophloia*, *E propinqua*, *Syncarpia glomulufera*, *E paniculata* and *E microcorys*, with occasional specimens of *E pilularis*.

Mid-canopy

The mid-canopy commonly consists of *Allocasuarina torulosa* and *Acacia implexa*, with *Glochidion ferdinandi* ssp *ferdinandi*, *Acmena smithii* and *Ceratopetalum gummiferum* in moister, sheltered sites.

Shrub Layer

Commonly occurring shrub species include *Breynia oblongifolia*, *Bursaria spinosa* var *spinosa*, *Zieria pilosa* and *Daviesia ulicifolia*.

Groundcover

The herb layer commonly comprises *Themeda australis*, *Senecio diaschides*, *Entolasia marginata*, *Dichondra repens*, *Dianella longifolia* var *longifolia*, *Lomandra longifolia*, *Oplismenus aemulus*, *Microlaena stipodes*, *Opercularia varia*, *Pratia purpurascens*, *Cymbopogon refractus*, *Pteridium esculentum*, *Calochlaena dubia*, *Blechnum cartilagineum* and *Viola hederacea*. Common climbing and trailing species are *Eustrephus latifolius*, *Geitonoplesium cymosum*, *Parsonsia straminea* and *Marsdenia rostrata*.

Exotic species

Commonly occurring species include *Verbena rigida*, *Chloris gayana*, *Sporobolus indicus* var *capensis*, *Hypochaeris radicata*, *Sonchus oleraceus*, *Bidens pilosa*, *Sida rhombifolia* and *Senecio madagascariensis*. *Lantana camara* occurs along edges of this community adjacent to highly disturbed sites, while *Ligustrum* spp occur in some minor drainage lines adjacent to residential or pastoral sites.

Community 2 *Open-Forest dominated by Smooth-barked Apple Angophora costata and Sydney Peppermint Eucalyptus piperita.*

Characteristics

- Open-Forest reaching 15-20m in height, FPC 20-40%;
- dominant species include Smooth-barked Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Sydney Peppermint *Eucalyptus piperita* and White Stringybark *E globoidea*, and occasionally with Broad-leaved Ironbark *E fibrosa*, Bastard Mahogany *E umbra* and Red Mahogany *E resinifera* ssp *resinifera*;
- regionally significant species include *Hakea bakeriana* (Benson 1996).

Distribution
This community is located in Wallaroo SF primarily adjacent to Reedy Creek, and merges with Community 4 adjacent to Wallaroo Swamp, both communities sharing some common species.

Structure
The trees within this community are generally 15-18m in height, reaching a maximum of 20m. They have broad, spreading canopies and straight trunks. A discontinuous mid-canopy occurs in damper areas, to 4.5m in height. The shrub layer is typically dense and varied, generally 2-3m in height. Damper areas support relatively dense stands of sedges and rushes. The groundcover is relatively diverse, supporting a variety of native herb, sedge and grass species. Climbing and trailing species are less common, appearing beneath the dense mid-canopy and shrubs at moister sites.

Disturbance and weed-invasion appear limited to roadside verges and the interfaces between this community and cleared land.

Floristics
Upper-canopy
Dominant species include *Angophora costata* and *Eucalyptus piperita*, with other characteristic and common species including *E umbra*, *E resinifera* ssp *resinifera*, *E globoidea*, *Corymbia gummifera* and *Syncarpia glomulifera*. Species occurring occasionally where the community merges with Community 1 include *C maculata*, *E siderophloia* and *E propinqua*. Another minor species occurring on drier sites is *E fibrosa* ssp *fibrosa*.

Mid-canopy
The mid-canopy, where present in moister areas, includes *Allocasuarina torulosa*, *A littoralis*, *Acacia irrorata* ssp *irrorata*, *Melaleuca styphelioides*, *M decora* and *Exocarpos cuppressiformis*, with occasional specimens of *Glochidion ferdinandi* ssp *ferdinandi*.

Shrub Layer
The shrub layer is dense and varied, with common species including *Acacia terminalis*, *Ac linifolia*, *Ac longifolia*, *Ac falcata*, *Melaleuca nodosa*, *Bossiaea obcordata*, *Pomaderris lanigera* and *Pultenaea villosa*. Species common to adjacent communities and occurring in ecotones with Community 2 include *Banksia spinulosa* var *collina*, *Lambertia formosa*, *Isospogon anemonifolius*, *Dillwynia retorta*, *Bossiaea heterophylla*, *Gompholobium glabratum*, *Banksia serrata*, *Leucopogon juniperinus*, *Epacris pulchella*, *Pimelea linifolia* ssp *linifolia*, *Persoonia linearis*, *Persoonia levis*, *Mirbelia rubiifolia* and *Lomatia silaifolia*. Common rushes and sedges include *Gahnia melanocarpa*, *Gahnia sieberana*, *Juncus usitatus* and *Lomandra longifolia*.

Groundcover
Typical groundcovers include *Echinopogon caespitosus* var *caespitosus*, *Entolasia stricta*, *Entolasia marginata*, *Gonocarpus teucrioides*, *Goodenia heterophylla* ssp *heterophylla*, *Pratia purpurascens*, *Pomax umbellata*, *Lomandra filiformis* ssp *filiformis*, *Lomandra glauca*, *Pteridium esculentum*, *Cyathochaeta diandra*, *Ptilothrix deusta*, *Dianella caerulea* var *producta*, *Oplismenus imbecillis* and *Billardiera scandens*.

Exotic Species
Exotic species appear limited to sites that have been heavily disturbed, notably roadsides and areas adjacent to pasture. Common species include *Chloris gayana*, *Paspalum dilatatum*, *Lantana camara*, *Verbena rigida*, *Verbena bonariensis* and *Conyza albida*.

Community 3 *Woodland/Open-Forest dominated by Smooth-barked Apple Angophora costata, Brown Stringybark Eucalyptus capitellata and Bastard Mahogany E umbra.*

Characteristics

- Woodland/Open-Forest reaching 12-18m in height, FPC 10-40%;
- dominant species include Smooth-barked Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Brown Stringybark *Eucalyptus capitellata* and Bastard Mahogany *E umbra* and occasionally Broad-leaved Ironbark *E fibrosa* ssp *fibrosa*;
- species of conservation concern include *Tetratheca juncea* (Vulnerable - TSC Act; 3VCa-Briggs & Leigh 1996), *Blandfordia grandiflora* (regionally significant-Benson 1986), and *Hakea bakeriana* (regionally significant-Benson 1986).

Distribution

This community generally occurs on the ridges and gentle slopes of Wallaroo SF along the western end of the proposed alignment, merging with Community 2 near creeklines.

Structure

The trees generally have broad canopies and are present as semi-mature and juvenile forms, rarely mature. A mid-canopy occurs discontinuously to 4-5m in height. The shrub layer is relatively diverse, supporting a wide variety of sclerophyllous species, and is continuous throughout this community, with the occurrence of taller shrubs and mid-canopy species increasing on the lower slopes. Shrubs are generally Fabaceous and Proteaceous species from 1.2-2.5m high. Groundcover species are well represented and form a dense layer throughout the least disturbed sites.

Floristics

Upper-canopy

Dominant species include *Corymbia gummifera, Eucalyptus umbra, Angophora costata* and *E capitellata*, with occasional specimens of *E globoidea* and *E piperita*. On poorer less fertile sites, *E globoidea* is replaced by *E fibrosa* ssp *fibrosa*. Where this community merges with Community 2, such as in the moister gullies, drainage lines and on sites with impeded drainage, *E piperita* is present.

Mid-canopy

Typical species include *Leptospermum trinervium, Persoonia linearis, Persoonia levis, Acacia longifolia, Hakea dactyloides* and *Allocasuarina littoralis.*

Shrub Layer

Common species include *Acacia terminalis, Ac ulicifolia, Ac myrtifolia, Ac longifolia, Ozothamnus diosmifolius, Dodonaea triquetra, Epacris pulchella, Leptospermum polygalifolium* ssp *polygalifolium, Leptospermum juniperinum, Isopogon anemonifolius, Banksia spinulosa* var *collina, Banksia spinulosa* var *spinulosa, Mirbelia rubiifolia* and *Lambertia formosa.* Widespread, although occasional, species include *Ac suaveolens, Ac linifolia, Gompholobium latifolium, Leucopogon attenuatus, Bossiaea obcordata, Oxylobium ilicifolium, Comesperma ericinum, Banksia serrata, Grevillea sericea, Daviesia squarrosa, Boronia polygalifolium, Pultenaea villosa, Platysace linearifolia* and *Pimelia linifolia* ssp *linifolia.*

Groundcover

Common species include *Hardenbergia violacea, Gompholobium minus, Billardiera scandens, Pomax umbellata, Lomandra obliqua, Patersonia glabrata, Cheilanthes sieberi, Cassytha glabella, Bothriochloa decipiens, Entolasia stricta, Themeda australis, Dampiera stricta, Gonocarpus tetragynus, Goodenia hederacea* var *hederacea, Kennedia rubicunda, Thysanotus tuberosus, Danthonia tenuior* and *Dianella caerula* var *producta.* Less common species include *Xanthosia tridentata, Schoenus imberbis, Lindsaea linearis, Lindsaea microphylla, Viola hederacea, Laxmannia gracilis, Hypoxis hygrometrica, Ptilothrix deusta, Hovea linearis, Bossiaea heterophylla, Hibbertia diffusa, Eragrostis brownii, Entolasia marginata, Chionochloa pallida, Stipa pubescens, Schizaea bifida, Dipodium punctatum* and *Calochilus campestris. Imperata cylindrica* var *major* is common along disturbed edges.

Exotic species
Common exotic species include *Cortaderia selloana, Bidens pilosa, Conyza bonariensis, Medicago arabica, Paspalum dilatatum, Senecio madagascariensis* and *Melinis repens.* Species occurring adjacent to cleared areas include *Rubus fruticosus* species aggregate, *Hydrocotyle bonariensis, Ageratina adenophora, Ipomoea indica, Pennisetum clandestinum* and *Sonchus oleraceus.*

Community 4 *Open-Forest dominated by Cabbage Gum Eucalyptus amplifolia, White Stringybark E globoidea, and Rough-barked Apple Angophora floribunda.*

Characteristics

- Open-Forest reaching 16-20m in height, FPC 20-40%;
- dominant species include White Stringybark *Eucalyptus globoidea*, Forest Red Gum *E tereticornis*, Cabbage Gum *E amplifolia* ssp *amplifolia* and Rough-barked Apple *Angophora floribunda*, and occasionally Swamp Mahogany *E robusta*, Smooth-barked Apple *An costata*, Spotted Gum *Corymbia maculata*, Northern Grey Ironbark *E siderophloia*, Grey Box *E moluccana* and Broad-leaved Ironbark *E fibrosa* ssp *fibrosa*;
- species of conservation concern include Swamp Mahogany *Eucalyptus robusta* (regional conservation significance (Benson 1986).

Distribution
This community occurs within Wallaroo SF, surrounding Wallaroo Swamp, and along minor creeklines east of the Karuah River and adjacent to the eastern end of the proposed alignment.

Structure
Trees are predominantly single trunked with broad canopies, and are present as juvenile, semi-mature and regenerating forms. A continuous and occasionally dense mid-canopy occurs to 6.5m in height, particularly adjacent to wetlands and drainage lines. The shrub layer appears to be of limited diversity, particularly where the upper and mid-canopies are well established. The groundcover is generally sparse, with species diversity increasing in open areas. Exotic species are generally restricted to disturbed sites adjacent to cleared areas and open pasture.

Floristics
Upper-canopy
Dominant upper-canopy species include *Eucalyptus globoidea, E tereticornis, Angophora floribunda* and *E amplifolia* ssp *amplifolia.* Occasional specimens of *E robusta, E moluccana, An costata, Corymbia maculata* and *E siderophloia* also occur. *E fibrosa* ssp *fibrosa* has a patchy distribution throughout this and adjacent communities.

Mid-canopy
The mid-canopy generally consists of dense stands of *Melaleuca* spp, dominated by *M styphelioides, M linariifolia, M sieberi* and *M nodosa.* Other species include *Glochidion ferdinandi* ssp *ferdinandi* and *Breynia oblongifolia*, with sclerophyllous species including *Acacia irrorata* ssp *irrorata, Ac longifolia, Ac falcata, Leptospermum polygalifolium* ssp *polygalifolium, Allocasuarina littoralis* and *Exocarpos cupressiformis.* Adjacent to minor creeks on private land near Branch Lane on the eastern side of the Karuah River, shrub and mid-canopy species including *Acmena smithii, Syzygium oleosum, Ceratopetalum gummiferum* and *Callistemon salignus* also occur along with a number of the above-mentioned species.

Shrub Layer
Melaleuca nodosa often forms dense stands, with other common species including *Acacia terminalis, Persoonia levis, Hakea sericea, Pultenaea villosa, Kunzea ambigua, Lambertia formosa, Banksia spinulosa* var *collina, Pimelia linifolia* ssp *linifolia, Ozothamnus diosmifolius, Ac myrtifolia, Bossiaea obcordata* and *Ac ulicifolia.*

Groundcover
Common species include *Adiantum aethiopicum, Cheilanthes sieberi, Pteridium esculentum, Gleichenia dicarpa, Imperata cylindrica* var *major, Bothriochloa decipiens, Themeda australis, Entolasia marginata, Alternanthera denticulata, Dichondra repens,*

Centella asiatica, Pratia purpurascens, Aristida ramosa, Eragrostis brownii, Lepidosperma lineare and *Hardenbergia violacea.* Semi-aquatic species occurring in damper or poorly drained sites include *Gahnia melanocarpa, Juncus usitatus, Phragmites australis, Typha orientalis* and *Schoenoplectus mucronatus.*

Community 5a *Freshwater Wetlands: Sedgeland*

Characteristics

- Very Open Sedgeland to closed sedgeland reaching 1-2m in height, FPC 0-80%;
- dominant species include *Bolboschoenus caldwellii, Baumea articulata, Eleocharis* spp, *Schoenoplectus* spp, *Gahnia* spp and *Cyperus* spp.

Distribution
This community occurs predominantly within the Wallaroo Swamp, with minor occurrences throughout the survey area on poorly drained sites and surrounding several artificially created dams, which occur throughout the easement in disturbed sites. Sedgeland also fringes saltmarsh communities along the intertidal zone of the Karuah River (Community 6b).

Structure
Very open sedgeland to closed sedgeland reaching 1-2m in height, FPC 0-80%. Surrounding adjacent vegetation is dominated by *Melaleuca* spp, often forming dense impenetrable thickets to 6m in height. Other sclerophyllous species may be present where the canopy is more open or undergoing regeneration.

Floristics
Aquatic species
Typical species include *Azolla pinnata, Azolla filiculoides, Potamogeton tricarinatus, Nymphoides geminata* and *Vallisneria gigantea.*

Sedges and Rushes
Common sedge and rush species include *Schoenoplectus mucronatus, Juncus usitatus, Juncus polyanthemus, Juncus prismatocarpus, Baumea articulata, Typha orientalis, Philydrum lanuginosum, Cyperus difformis, Villarsia exalata, Eleocharis acuta* and *Eleocharis sphacelata.* Larger sedge and rush species (eg *Gahnia melanocarpa, Lomandra longifolia* and *Typha orientalis*) often form dense fringing vegetation.

Surrounding canopy
Surrounding vegetation is dominated by a dense fringing band of *Melaleuca styphelioides, M linariifolia, M sieberi* and *M nodosa.* Other common tree species include *Eucalyptus amplifolia* ssp *amplifolia* and *Casuarina glauca.*

Surrounding Shrub Layer
Common shrubs include *Kunzea ambigua, Exocarpos cupressiformis, Acacia longifolia, Ac falcata* and *Glochidion ferdinandi.* Common herbs on drier sites bordering wetlands include *Entolasia marginata, Gonocarpus tetragynus, Lomandra longifolia, Imperata cylindrica* var *major, Bothriochloa decipiens, Dichondra repens, Centella asiatica, Cymbopogon refractus, Pratia purpurascens* and *Hardenbergia violacea.*

Exotic Species
Exotic species are more common along the forest edges, with common species including *Croccosmia* x *croccosmifolia, Verbena* spp, *Sida rhombifolia, Bidens pilosa, Chloris gayana, Ligustrum* spp, *Conyza canadensis, Paspalum dilatatum, Lantana camara* and *Senecio madagascariensis.*

Community 5b *Low-Forest/Closed Low-Forest*

Characteristics

- Low Forest/Closed Low Forest reaching 7m in height, emergent trees to 15m, FPC 35 - 60%;
- dominant species include *Melaleuca linearifolia*, Ball Honeymyrtle *M nodosa*, Sieber's

Paperbark *M sieberi*, Prickly-leaved Paperbark *M styphelioides*; emergent tree species include Cabbage Gum *Eucalyptus ampliolia* ssp *amplifolia* and Swamp She-Oak *Casuarina glauca*.

Distribution
This community occurs along the entire easement and in adjacent areas in poorly drained sites. Most of the Open Forest communities may also have areas of this community occurring along poorly-drained creek flats, but these generally consist of patches too small to be separately mapped.

Structure
Low Forest or Low Closed Forest to 7m high, with some emergent trees up to 15m high. The community generally consists of a dense mid-canopy of *Melaleuca* spp, with a poorly developed shrub layer where the mid-canopy is dense, but with dense regeneration along disturbed edges. The herb layer is characterised by a range of grass and herb species tolerant of poor drainage and/or occasional inundation.

Floristics
Mid-canopy
Mid-canopy species are *Melaleuca styphelioides* and *M linariifolia*, with *M sieberi* and *M nodosa* as common understorey species. Occasional emergent tree species are *Eucalyptus amplifolia* and *E tereticornis*; saline sites may have *Casuarina glauca*, while other sites may have species from adjacent communities such as *E acmenoides*, *E siderophloia*, *E globoidea*, *Angophora floribunda* and *Corymbia maculata*.

Understorey
Understorey species include *Breynia oblongifolia*, *Melaleuca nodosa* and *Bursaria spinosa*.

Groundcover
Groundcover species include *Themeda australis*, *Cynodon dactylon*, *Pratia purpurascens*, *Centella asiatica*, *Dichondra repens*, *Microlaena stipoides*, *entolasia marginata* and *Oplismenus imbecillis*. Occasional climbing and trailing species include *Eustrephus latifolius*, *Parsonsia straminea* and *Geitonoplesium cymosum*. Sedge and rush species occurring in poorly drained sites include *Gahnia sieberiana*, *Carex longebrachiata*, *Cyperus polystachyos*, *Juncus usitatus* and *Juncus continuus*.

Exoric Species
Exotic species are more common where disturbance levels are higher, particularly where cattle grazing is current. Common species are *Hypochaeris radicata*, *Senecio madagascariensis*, *Sida rhombifolia*, *Paspalum dialtatum*, *Verbena rigida*, *Conyza canadensis*, *Sonchus oleraceus*, *Phalaris arundinacea*, *Cirsium vulgare* and *Ranunculus repens*. Shrub species include *Lantana camara* and *Ligustrum sinense*.

Community 6a *Estuarine communities - Mangrove Open Scrub*

Characteristics

- Open-Forest/Forest/Closed-Forest reaching 5-8m in height, FPC 20-80%;
- dominant species include Grey Mangrove *Avicennia marina* var *australasica* and River Mangrove *Aegiceras corniculatum*.

Distribution
This community is present on estuarine mudflats with regular tidal inundation along the Karuah River and around Horse Island.

Structure
Mangroves are multi-branching close to their bases, and with broad canopies. The majority are semi-mature, juvenile or regenerating forms, with few mature specimens. The understorey and herb layer are absent until the transition with saltmarsh (Community 6b).

Floristics
The Mangrove open scrub of the study area is dominated by *Avicennia marina* var *australasica*, with occasional isolated individuals of *Aegiceras corniculatum* occurring

along the less exposed edges of the mudflats and further upstream.

Community 6b *Estuarine Wetlands: Saltmarsh (merging with fringing freshwater communities)*

Characteristics

- Open-Herbland/Herbland reaching 1-2m in height, FPC 20-80%;
- dominant species include *Zoysia macrantha*, *Sarcocornia quinqueflora* and *Suaeda australis*;
- some areas of fringing Rushland/Sedgeland dominated by *Juncus kraussii*;
- some areas of fringing low open Swamp Forest to 15m in height, dominated by *Casuarina glauca* and *Baumea juncea*.

Distribution

Saltmarsh communities occur behind Mangrove open scrub (Community 6a) along the Karuah River, in areas which experience tidal inundation during very high tides or periods of flooding. A fringing band of sedgeland/rushland occurs behind the saltmarsh communities in areas with infrequent tidal inundation. A fringing band of Swamp Forest occurs along the lower lying areas of adjacent slopes and creek flats, which are poorly drained and have some saline influence.

Structure

The majority of the saltmarsh community is dominated by halophytic shrubs and herbs <1m high. This community is generally bordered by rushes and sedges to 2m. The fringing band of low open Swamp Forest behind the sedges and rushes is of varying width and to a height of 15m.

Floristics

Saltmarsh Herbland

Dominant herbs include *Sarcocornia quinqueflora* and *Suaeda australis*, with the encroachment of salt tolerant species from adjacent rushland and sedgeland including *Juncus kraussii*, *Baumea juncea*, *Triglochin striata*, *Cotula coronopifolia* and *Bolboschoenus caldwellii*.

Rushland/Sedgeland

Typical species include *Juncus kraussii*, *Baumea juncea*, *Triglochin striata*, *Cotula coronopifolia*, *Zoysia macrantha*, *Isolepis nodosus*, *Sporobolus virginicus* var *minor* and *Boloboschoenus caldwellii*. Other less frequent species include *Phragmites australis* and *Selliera radicans*.

Low Open Swamp Forest

Dominant upper canopy species include *Eucalyptus amplifolia* ssp *amplifolia* and *Casuarina glauca*, with occasional stands or individuals of *E robusta* and *Angophora floribunda*, and species from adjacent communities including *An costata*. Along some of the lower reaches of Kilaben Creek, *Casuarina glauca* forms dense stands.

Mid-canopy

The mid-canopy is usually dominated by *Melaleuca styphelioides* and *M linariifolia* to 7m in height, with these species often forming dense, impenetrable stands behind *Casuarina glauca* and where the upper-canopy is absent. In these situations, the shrub layer is often dominated by *M nodosa* and *Acacia longifolia*, the former often to 4m.

Groundcover

The groundcover is generally of poor diversity, the most common species including *Cynodon dactylon*, *Imperata cylindrica* var *major*, *Sporobolus virginicus* var *minor* and *Lomandra longifolia*. Other species occurring occasionally include *Juncus kraussii*, *Samolus repens*, *Crinum pedunculatum*, *Gahnia sieberana*, *Isolepis nodosus*, *Zoysia macrantha*, *Baumea juncea* and *Phragmites australis*.

Exotic species

Common exotic species within rushland/sedgeland and in disturbed areas within swamp forest include *Cyperus eragrostis*, *Phalaris aquatica*, *Cakile edulenta*, *Atriplex hastata* and *Hydrocotyle bonariensis*. Common species in disturbed brackish areas or backswamps

include *Conyza bonariensis, Verbena rigida, Lantana camara, Bidens pilosa, Plantago lanceolata* and *Senecio madagascariensis.*

Community 7 *Cleared/Pasture/Highly Modified Land with remnant and/or regenerating native species.*

Characteristics

- primarily cleared pasture comprising introduced grasses and some native species;
- highly disturbed fragmented remnant woodland/open-forest reaching 15-20m in height, FPC 0-30%;
- dominant native species include Forest Red Gum *Eucalyptus tereticornis*, Spotted Gum *Corymbia maculata*, Broad-leaved Ironbark *E fibrosa*, White Stringybark *E siderophloia*, Grey Gum *E punctata*, Bastard Mahogany *E umbra* and Smooth-barked Apple *Angphora costata.*

Distribution
Cleared and disturbed land generally occurs along the eastern portion of the proposed route option, and to the northeast and southeast of the western portion of the proposed alignment. This community type is characteristic of much of the surrounding region.

Structure and Floristics
The vegetation of disturbed areas is dominated by exotic pasture species, with some small and isolated stands of native canopy, shrub and groundcover species occurring. Common canopy species include *Eucalyptus siderophloia, Corymbia maculata, E fibrosa* ssp *fibrosa* and *E umbra.* Along drainage lines, particularly near the western end of Branch Lane, a dense mid-canopy comprised of *Melaleuca decora, M nodosa, Acacia longifolia* and *Ac irrorata* ssp *irrorata* occurs. In this vicinity, remnant and regenerating specimens of *Angophora floribunda, E amplifolia* ssp *amplifolia, E robusta* and *E resinifera* ssp *resinifera* occur in small fragmented stands.

Further to the west, occasional stands of canopy species include *Eucalyptus umbra, Corymbia maculata, Angophora costata, A floribunda* and *E resinifera* ssp *resinifera*, with *Acmena smithii, Glochidion ferdinandi* var *ferdinandi, Melaleuca decora* and *M nodosa* occurring along gullies and creeklines. The understorey is a mixture of exotic species and hardier native groundcover species including *Pratia purpurascens, Pomax umbellata, Dichondra repens, Brachycome angustifolia* var *angustifolia* and *Hardenbergia violacea.* Common grasses and ferns include *Echinopogon caespitosus* var *caespitosus, Imperata cylindrica* var *major, Bothriochloa decipiens, Entolasia marginata, Cynodon dactylon* and *Pteridium esculentum.*

4.3.2 Condition of Habitat

The D-G's Requirements state (in section 1.8) that the "*condition of habitat*" be addressed, including "*the prevalence of introduced species*" (Appendix A).

The level of disturbance and "*condition of habitat*" varies substantially throughout the study area with some areas, such as Horse Island, exhibiting lower levels of disturbance and a more intact and diverse array of habitats for native flora and fauna.

The primary source of disturbance along the proposed route on the eastern side of the Karuah River is clearing for agriculture. Where clearing has occurred, native species are sparse to absent and introduced flora species dominate. Clearing has involved the removal of the understorey vegetation and the majority of the trees, other than scattered individual specimens. Consequently, foraging, shelter and nesting resources for native fauna species are largely absent, and the quality of habitat for native fauna in cleared areas is limited. Clearing on the eastern side of the River has also caused fragmentation of vegetation and has reduced the quality of the habitat provided by the remnant vegetation for some fauna species. Areas of cleared land form a barrier to movement for disturbance-intolerant terrestrial species, and such species are less able to move between areas of suitable habitat.

The eastern side of the Karuah River also provides areas of habitat of value for native fauna, particularly the large area of forest between the existing and the proposed Pacific Highway. This steep, dense forest has experienced limited disturbance, given topographical restrictions, and provides a range of resources of value for native fauna.

Clearing has also occurred on the western side of the River, although to a limited extent. Much of this land is included in Wallaroo SF and Karuah NR (formally Karuah SF). In these areas, the primary source of disturbance is logging, which is evident throughout. In addition, the western side of the River appears to have been burnt regularly, including approximately one year prior to field investigations, and as a result, the "*condition of habitat*" has been reduced for many species, particularly those requiring dense vegetation.

The wetlands and creeklines in the study area have been disturbed to varying degrees, with cattle access the primary source of disturbance. The SEPP 14 wetlands have been subjected to limited disturbance, other than some access by cattle, and weed invasion in these areas is limited.

Tables 4.1 and 4.2 indicate the degree and cause of disturbance at each of the vegetation quadrats and transects surveyed. The presence of exotic species has also been detailed in Section 4.3.1.

Table 4.1 Level and cause of disturbance in each of the vegetation survey quadrats.

Quadrat Number	Community Type	Disturbance
1	2	Burnt November 1997
2	3	Burnt Nov 1997; minimal exotic species infestation
3	3	Burnt Nov 1997; minimal exotic species infestation
4	3	Burnt Nov 1997
5	4	Partially burnt Nov 1997
6	4	Partially burnt Nov 1997; east/south-east unburnt; on fire trail
7	7	Partially burnt Nov 1997; cleared; moderate exotic species infestation
8	3/4	Burnt Nov 1997
9	2	Burnt Nov 1997
10	1	Burnt Nov 1997; minimal exotic species infestation
11	1	Logged; understorey disturbed; minimal exotic species infestation
12	6a	Minor disturbance due to cattle
13	6b	Disturbance generally absent
14	3	Disturbance limited, exotic species absent
15	1	Disturbance limited, exotic species absent
16	4	Grazed, clearing, moderate exotic species infestation
17	4	Grazed
18	1	Grazed, shrub and middle canopy absent; minimal exotic species infestation
19	1	Grazed, poor groundcover, moderate exotic species infestation
20	3	Grazed; herb layer disturbed on rocky sites; moderate exotic species infestation
21	5	Remnant vegetation along freshwater dam in open paddock; high exotic species infestation

Table 4.1 contd Level and cause of disturbance in each of the vegetation survey quadrats.

Quadrat Number	Community Type	Disturbance
22	5	Grazed; drainage line to dam (Q21); trampled by cattle; very high exotic species infestation
23	7	Wholly or partially cleared; limited tree vegetation; high exotic species infestation
24	4	Regrowth area; powerline easement slashed
25	4	Bisected by powerlines; moderate exotic species infestation
26	3	Disturbance limited, exotic species limited
27	4	Regeneration of upper canopy; moderate exotic species infestation
28	2	Moderate exotic species infestation; dense Lantana understorey at eastern end
29	1	Grazed; poor regeneration of understorey; moderate exotic species infestation including Lantana
30	4	Burnt Nov 1997; minimal exotic species infestation

Table 4.2 Level and cause of disturbance in each of the vegetation survey transects.

Transect Number	Community Type	Disturbance
1	2	Burnt Nov 1997; understorey not present
2	3	Burnt before 1997; *T juncea* destroyed by fire
3	1	Disturbance limited, exotic species limited
4	1	Disturbance limited, exotic species limited
5	1	Burnt Nov 1997
6	6a - 1	High exotic species infestation
7	1	Partially cleared; cattle disturbed; moderate exotic species infestation
8	1	Grazed; moderate exotic species infestation
9	7	Almost entirely composed of exotic species / occasional remnant vegetation
10	1	Grazed; poor regeneration of shrub and upper canopy; moderate to high exotic species infestation
11	4	Moderate exotic species infestation; powerline easement
12	2	Minimal exotic species infestation
13	4	Burnt Nov 1997; some areas intact
14	4	Burnt Nov 1997; moderate exotic species infestation

4.3.3 Habitats for Fauna

The Director-General of the NP&WS requires that this SIS provides details of the habitats for native fauna, in particular the "*subject species*". The Director-General requires:

> "*1.8 A description of fauna and flora habitat components such as the frequency and size of tree hollows and stags, density of understorey vegetation, substrate and presence and nature of wetlands, rock outcrops etc must be given. Particular attention must be given to areas which are used in the study area, and for what purposes these areas are used (e.g. roosting, feeding, nesting or breeding, etc). The location of tree-hollows and stags within the study area must be mapped.*
>
> *The condition of the habitat within the study area must be discussed, including the prevalence of introduced species. The importance of the study area for all life-cycle stages of the subject species in the locality shall be identified and discussed*".

The habitat requirements of all of the "*subject species*" are provided in Appendix F. Chapter 7 of this SIS provides details regarding the habitat requirements of threatened species of relevance to this SIS (as defined in Appendix F and Chapter 6 of this SIS). Chapter 9 details the habitats present in the study area for species of relevance.

The general habitat features present in the study area are detailed below, and are discussed in terms of their relevance to the threatened fauna species known from the locality and/or those recorded during the field investigations. The "*condition of habitat within the study area ... including the prevalence of introduced species*" is also described below, as well as above, in section 4.3.2 (Tables 4.1 & 4.2).

Habitat along the Karuah Upgrade alignment includes wetlands, mangroves, swamp forest, open forest communities, creeks and rivers, as well as disturbed habitats (such as pasture). Whilst some portions of the alignment are highly modified (in particular agricultural lands) or are disturbed and degraded as a result of previous activities (*eg* agricultural activities, selective logging, clearing, general access, fire and weed-infestation), other portions of the alignment retain high quality habitats and resources for native fauna species.

Wetland, riparian and estuarine habitats

A range of wetland habitats are present along or located near the proposed road corridor, including saltmarsh, mangrove forest, Casuarina swamp forest and freshwater wetland. These habitats theoretically provide foraging, roosting and nesting resources and other features of particular relevance for the "*subject species*", including amphibians (such as the Green & Golden Bell Frog and Green-thighed Frog), wetland birds (such as the Black and Australasian Bitterns, Comb-crested Jacana, Brolga and Black-necked Stork) and a few mammal species (such as the Large-footed Myotis and other microchiropteran bats).

The Karuah River provides a range of potential habitats and resources for native fauna, including "*subject species*". The saltmarsh communities along the River provide potential resources and habitats for a number of migratory and nomadic wading bird species (such as the Black-necked Stork and Brolga). Furthermore, associated mudflats are likely to provide foraging resources for a number of other, more common waders, such as Spoonbills, Egrets and Herons. Mud and sand flats, particularly surrounding Horse Island, may also potentially provide foraging, roosting and nesting resources for a number of "*subject species*", including Pied and Sooty Oystercatchers and Lesser Sand Plovers.

Mangrove communities, which are extensive along the River and around Horse Island, provide an array of features and resources of particular relevance to certain avifauna in the locality. Furthermore, mangroves provide important habitat for aquatic fauna, and are regarded as significant elements in the maintenance of healthy aquatic ecosystems.

Freshwater creeklines, swamps and wetlands in the general locality (in particular Wallaroo Swamp) provide resources for wetland bird species (including ducks, grebes and herons) and amphibians. These features also provide a source of water and food for a range of terrestrial

and aerial species, such as macropods and microchiropteran bats. Farm dams, despite their artificial nature, may also provide some resources of relevance for these species.

Forest and woodland habitats

An array of different forest and woodland communities are present along the proposed Karuah Upgrade alignment. The dry sclerophyll communities include forest and woodland dominated by Smooth-barked Apple, Sydney Peppermint, Spotted Gum, Brown Stringybark and a variety of other canopy species. These are located widely along the alignment (Figure 4.1a, 4.1b), and potentially or theoretically at least provide specific habitats and resources for a number of "*subject species*" including forest and woodland-dependent birds (such as the Bush Stone-curlew, Glossy Black Cockatoo, Swift Parrot, Regent Honeyeater and Powerful and Masked Owls), arboreal mammals (such as the Koala and Squirrel Glider), terrestrial mammals (such as the Long-nosed Potoroo and Tiger Quoll), microchiropteran bats (such as the Little Bent-wing Bat and Eastern Freetail Bat) and reptiles (such as the Pale-headed Snake).

Resource features and elements present in these forest and woodland communities of relevance for native fauna include hollow-bearing trees and stags (which are not common along the proposed alignment), rock outcrops, hollow logs and other forest litter, the vegetation canopy and understorey plants.

Tree-hollows and Stags

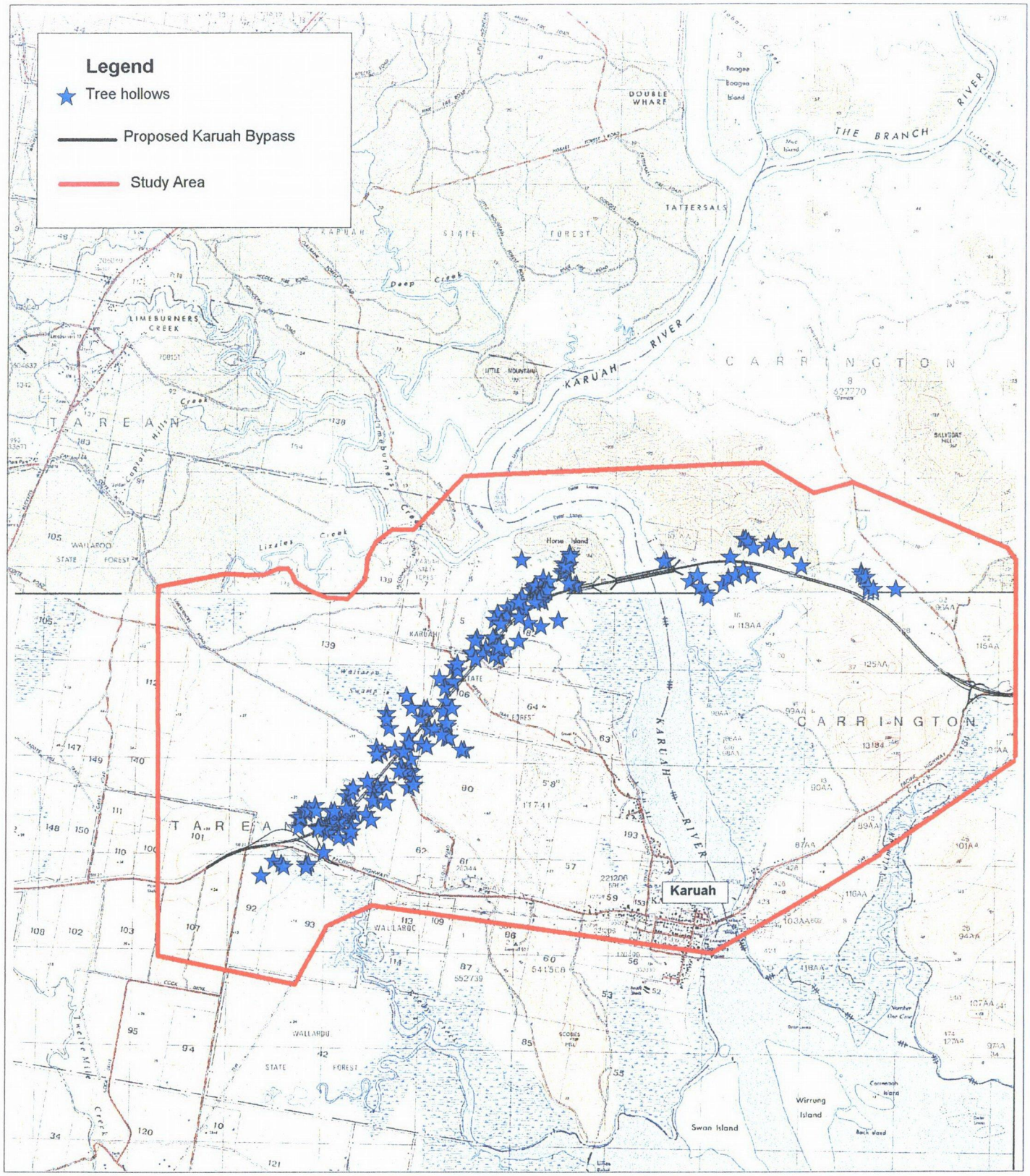
Tree-hollows and stags are an important habitat resource for many species, providing a nesting and shelter resource for mammals (such as the Squirrel Glider and Brush-tailed Phascogale), small passerine birds (such as Pardalotes), non-passerine birds (such as owls, parrots and cockatoos) and some arboreal reptiles. The hollow requirements of different species vary widely, with small passerine birds inhabiting small hollows, gliders and possums preferring small to medium-sized hollows and owls and cockatoos generally requiring very large hollows, particularly species such as the Powerful Owl. Consequently, forest and woodland with abundant hollows of various sizes will generally support a greater diversity of hollow-dependent fauna.

The presence of tree-hollows is dependent upon a range of factors, primarily age of trees, tree species and tree size, and the presence of hollows is dependent to some extent on site history, such as clearing, logging and fire (Williams & Woinarski 1997). The abundance of hollow-bearing trees in the study area is relatively low, and even in the more intact areas such as Horse Island, stags and tree-hollows are not abundant compared with some areas of forested lands in the locality (D Fanning *pers obs*). Furthermore, the tree-hollows which do occur are generally small, and very large tree-hollows are sparse or absent over much of the study area as a result of long-term burning and logging, and the limited numbers of mature and/or senescent trees (Figure 4.2; Appendix J).

Understorey Vegetation

The types of vertebrate species in an area is often a result of the structural and floristic characteristics of the understorey vegetation (Williams & Woinarski 1997). For example, a sparse and open understorey favours species which forage on grass (such as large macropods) and which inhabit areas where sunlight is able to penetrate (in particular reptiles). Conversely, a dense understorey will favour shy species, which require dense shelter such as the Long-nosed Potoroo. The diversity of understorey species will also be reflected in the vertebrate species present, for example nectarivorous species will be abundant where proteaceous species (such as Banksias and Grevilleas) are abundant, and granivores will be more abundant where there is a healthy understorey.

The diversity of species and density of understorey vegetation is highly variable throughout the study area. The understorey in the study area is generally sclerophyllous, and is likely to favour nectarivorous, and foliage gleaning (*eg* Possums) and exudate gleaning (*eg* Gliders) species. The majority of the forest in Karuah NR and adjacent areas supports an understorey of limited diversity and density, particularly following the recent wildfire throughout the area. The understorey in this area is likely to favour generalist species with little requirement for dense shelter. Other areas, such as on Horse Island, in the far western portion of the study area and to the east of the Karuah River support dense and more diverse understorey vegetation, and are likely to support a wider array of vertebrate species.



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Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Figure 4.2 Location of tree hollows and stags along and within 200m of the alignment.

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Groundcover

Groundcover include vegetation, rocks, tree-debris, leaf litter and soil, each of which provide resources for different vertebrate fauna species. Groundcover vegetation, where dense, provides shelter and foraging substrates for small terrestrial species, including reptiles and mammals (such as rodents and dasyurids). Leaf litter also provides shelter for such species, as well as providing a moist environment for amphibians. Tree-debris, in particular fallen hollow logs, provides shelter and nesting resources for mammals (such as the Tiger Quoll) and reptiles, as do crevices and fractures in rock outcrops. Leaf litter and vegetation also support a diversity of invertebrate species, on which insectivorous birds, reptiles, mammals and amphibians forage.

In the study area, groundcover is generally composed of vegetation, leaf litter and soil, with few rock outcrops or log debris present in most areas. Less disturbed areas, such as Horse Island, support a reasonably good groundcover of vegetation and leaf litter, whereas degraded areas, such as Wallaroo SF, support large areas of bare soil, which provide limited resources for ground-dwelling fauna.

Agricultural landscapes

The remainder of the proposed road corridor occupies agricultural lands and other modified landscapes. Pasture and grassland provide resources for some native fauna species, in particular macropods, which use open, cleared land for foraging, and adjacent woodlands and forest for shelter. Furthermore, farm dams often provide resources for fauna, including a source of water for mammals and birds, a concentrated source of invertebrates for insectivorous birds and microchiropteran bats, and aquatic habitats for amphibians and water birds.

However, habitats associated with cleared agricultural landscapes are neither restricted in extent nor considered of particular concern, given the generalist nature of the fauna species which utilise these communities. These agricultural habitats do not provide resources of particular or special value for any "*subject species*", which do or may occur in the study area.

4.4 Corridors

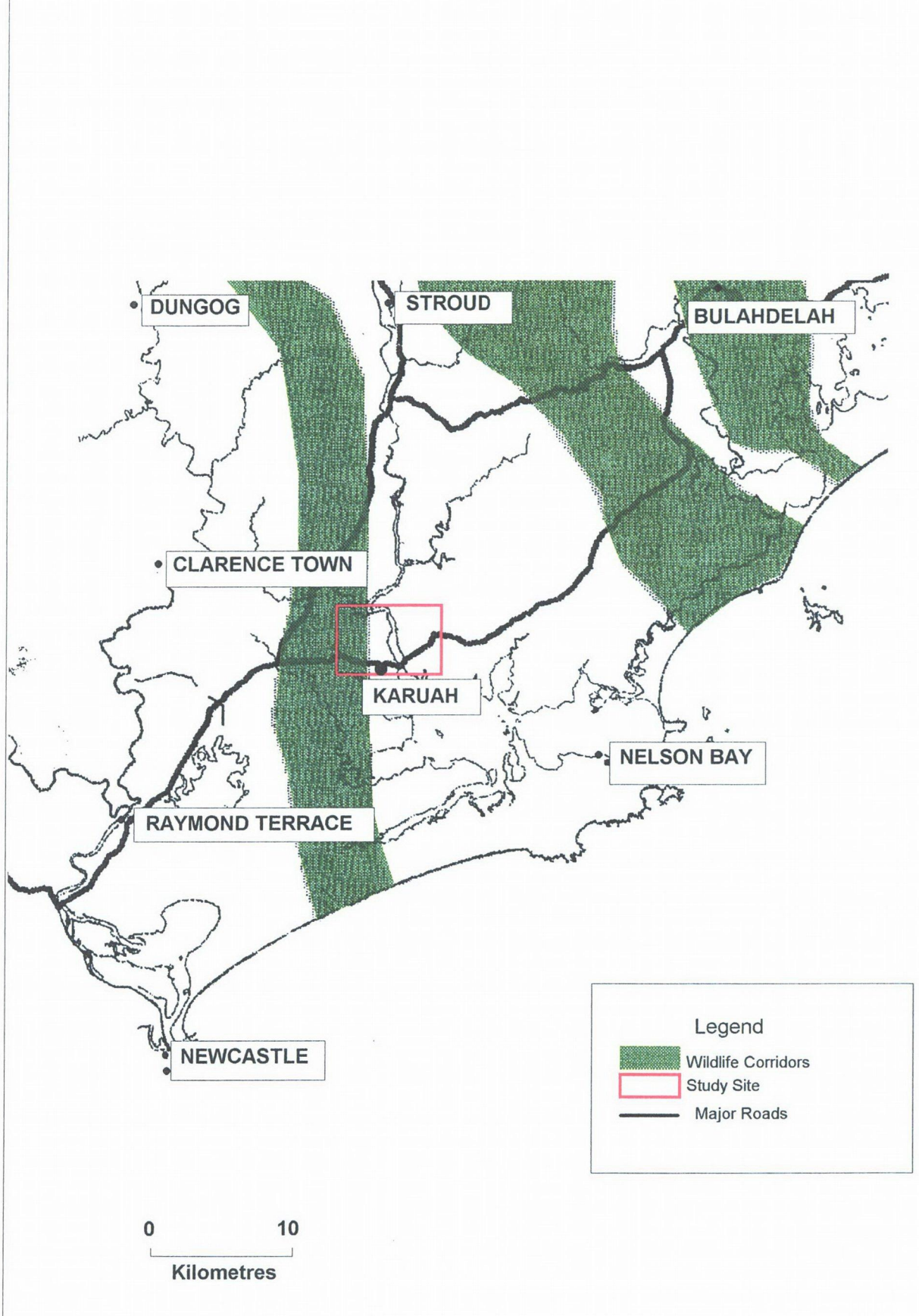
The D-G's Requirements for this SIS (Appendix A) include:

> "*1.15 Any areas which may act as local or regional corridors between the study area and adjacent areas of likely habitat for subject species must be identified and described*".

The NP&WS has identified wildlife corridors in the locality, one of which is of particular relevance to the Karuah Upgrade study area (Figure 4.3). The corridor in question extends for approximately 90km from the centre of Newcastle Bight north to approximately Barrington Tops National Park. It includes the majority of the western portion of the study area, primarily comprising Wallaroo SF and Karuah NR.

This corridor is already fragmented as a result of the existing Pacific Highway and The Bucketts Way, neither of which incorporate structures to facilitate fauna movement through the locality. The proposed Highway upgrade at Karuah will unavoidably increase the fragmentation of the corridor through the study area. However, the impact of the new alignment on the corridor will be minimised through the proposed construction of specific fauna movement structures at appropriate locations along the route.

Another corridor has been identified along Mosquito Creek, which passes through cleared agricultural land (Figure 4.3). The vegetated creekline links the large area of steep, dense forest to the south, with similar forest to the north. A link for more mobile fauna between these two areas is also provided by the vegetated crests between which are cleared saddles. These vegetated crests provide stepping-stones between areas of suitable habitat through inhospitable areas, and are of particular value for more mobile fauna, including Koalas and other terrestrial and arboreal fauna.



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Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 4.3 NP&WS identified wildlife corridors for Karuah to Bulahdelah.

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4.5 Protected Fauna and Flora

The D-G's Requirements for this SIS (Appendix A) include:

> "*1.16 A full list of the protected fauna and native plant species (as defined by the National Parks and Wildlife Act 1974) found during the course of the surveys must be included. Such information is indicative of the habitat quality of the site. This list must indicate whether the species is introduced, significant or threatened and the site or habitat in which each species was recorded*".

All native fauna in NSW are protected under the *NSW National Parks & Wildlife Act 1974* (NP&W Act). Consequently, all of the species recorded in the study area (with the exception of introduced species) are protected. Appendix G lists the native fauna species recorded during investigations in the study area (Gunninah 1997a; 1999b, c), and whether the species is "*introduced, significant or threatened*".

Protected native flora in NSW are those which are included in Schedule 13 of the NP&W Act. Fifteen protected flora species were recorded in the study area for the Karuah Upgrade Project (Table 4.3), during investigations for both the SIS and route selection investigations. An inventory of all of the native and introduced flora species identified during field investigations for the proposal (Gunninah 1997a; 1999b, c) is provided in Appendix H.

Table 4.3 Flora species recorded within the study area that are listed under Schedule 13 of the NP&W Act.

Botanical Name	Common Name	Quadrat/Transect #	Community
Actinotus helianthi	Flannel Flower	*	No record
Blandfordia grandiflora	Christmas Bell	Near Q1	2
Boronia ledifolia	Sydney Boronia	T1,T2	2,3
Boronia pinnata	Pinnate Boronia	T3	1
Boronia polygalifolia	-	T3	1
Caustis pentandra	-	*	No record
Ceratopetalum gummiferum	Christmas Bush	Q17,Q18,T8	4,1,1
Cymbidium suave	Snake Orchid	*	1
Dendrobium aemulum	White Feather Orchid	*	1
Dipodium punctatum	Hyacinth Orchid	*	3
Doryanthes excelsa	Gymea Lily	*	No record
Lomatia silaifolia	Crinkle Bush	T2,T3,T5,T11, T12	3,1,1,4,2
Restio tetraphyllus ssp meiostachyus	Restio	T11	4
Xylomelum pyriforme	Woody Pear	*	No record
Adiantum aethiopicum	Maiden-hair Fern	Q16,Q17,Q29, T7,T11	4,4,1,1,4

* Species found during previous surveys for the Horse Island Route selection assessment (Gunninah 1997a; 1999b, c).

5 GENERAL DESCRIPTION of THREATENED SPECIES or ENDANGERED POPULATIONS

The TSC Act requires, under Section 110(2)(a), that a SIS includes:

> "*a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action*".

No endangered populations of relevance to this project have been declared in NSW to this date, and this element of the TSC Act cannot therefore be addressed.

The D-G's Requirements for this SIS (Appendix A) include:

> "*1.10 A list of subject species must be provided. In determining these species, consideration shall be given to the habitat types present within the study area, records of threatened species in the locality and their known distribution. Criteria to be used to assess the conservation significance of species include those outlined by Sheringham and Westaway (1995)*";
>
> "*1.11 Databases such as the NPWS Atlas of NSW Wildlife and NPWS predictive habitat models should be used to assist in compiling the list*"; and
>
> "*1.18 Where available, threatened species information provided must include species name, date recorded, name of person who made the record, type of record (e.g. scat identification, trapped, sighted), specific use of habitat (e.g. nesting, roosting, foraging), number of individuals recorded*".

The D-G's Requirements provides an extensive list of "*subject species*" (Appendix A) which are to be included.

A "*list of subject species*" has been compiled following consideration of:

- the "*habitat types present within the study area, records of subject species in the locality and their known distribution*"[5];
- relevant databases and reports[6];
- the list of species provided by the Director-General of NP&WS; and
- the "*predictive habitat models*" provided by the NP&WS in the North East Forests Biodiversity Study (NP&WS 1994b).

Tables 5.1 (fauna) and 5.3 (flora) provide a list of threatened and regionally significant species identified as "*subject species*". However, as detailed further throughout this SIS, not all of the "*subject species*" are of relevance to this SIS, and thus a large number are not discussed in detail in this document. The list of subject species includes threatened fauna and flora species, which are not known from the locality and are not likely to be present (given distributions and habitat requirements), species known from the locality (as defined in Chapter 1) but which are not "*likely to be affected by the action*", as well as "*threatened species ... known or likely to be present in the area that is the subject of the action*". Chapter 5 and Appendix F provide details regarding the selection of subject species of relevance to this SIS.

The list of "*subject species*" also includes several species that are not listed as threatened on the TSC Act, but which are regarded as nationally, regionally or locally rare. Whilst these species are not listed as threatened in NSW, pursuant to the TSC Act, their listing in the D-G's Requirements requires their inclusion for consideration in the SIS.

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5 Included in Item 2 of the D-G's Requirements for this SIS.

6 As specified in Item 2 of the D-G's Requirements, the NP&WS Atlas of NSW Wildlife, the Birds Australia database and the NSW Bird Atlassers database were used to compile this list. In addition, a number of studies which address the flora and fauna in the general locality were reviewed (Williams & Harden 1979; Hunter 1992; Parker 1992; Milledge & McKinley 1992; Milledge & Associates 1992, 1993; Mount King Ecological Surveys 1994; Gunninah 1995, 1996; Kinhill 1996).

5.1 Fauna

The threatened fauna species listed below (Table 5.1) include several species "*known or likely to be present in the area that is the subject of the action*", as well as species that may occur in the study area as only transitory or occasional visitors, or which are not likely to occur in the study area (*eg* pelagic and coastal species, or species with restricted distributions).

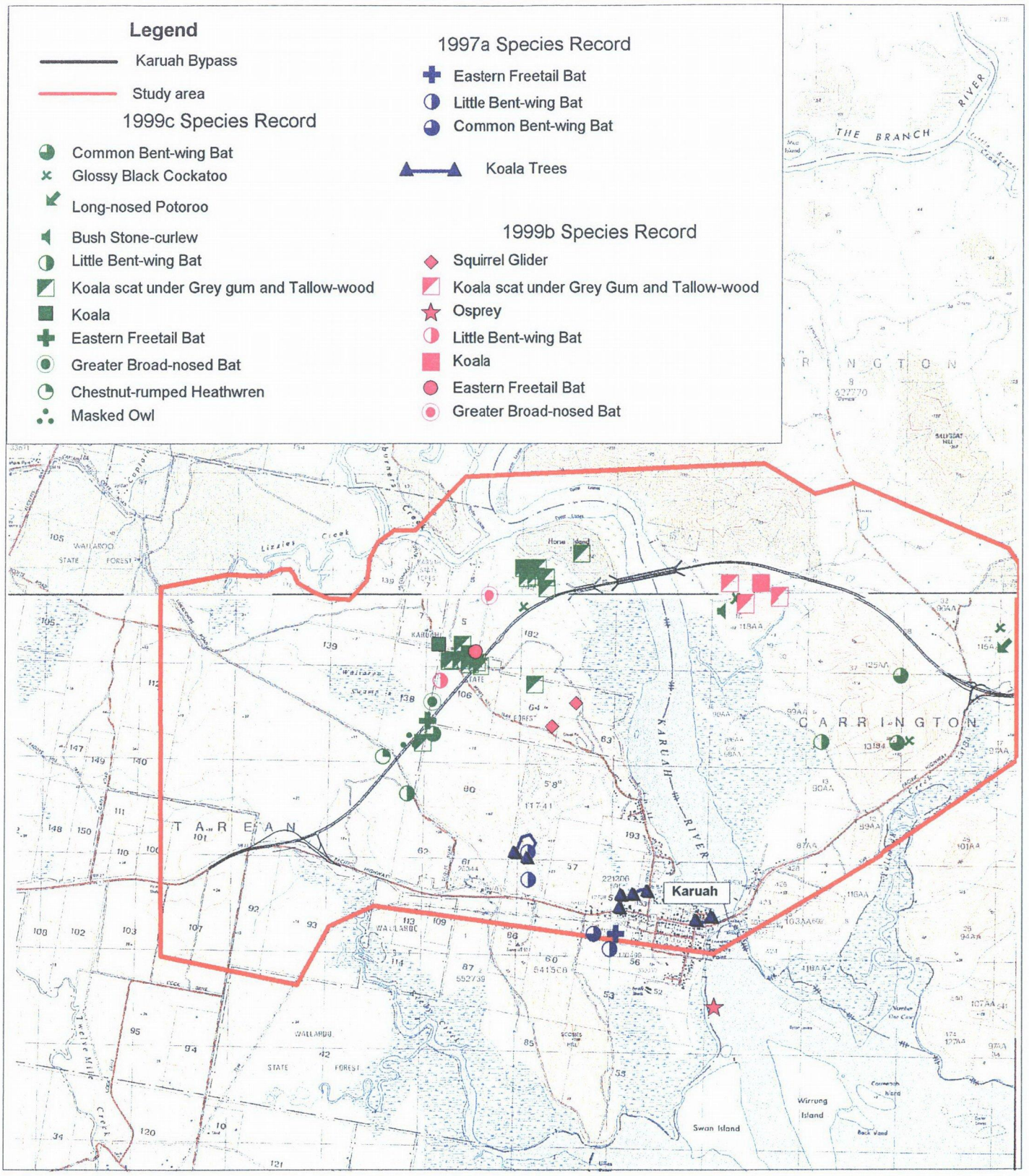
Most of the species included as "*subject species*" are either not likely to occur in the study area, or are not likely to be adversely affected by the proposed development, even if they do occur on occasions (as discussed in detail in Chapter 6 and Appendix F of this SIS). The majority of the threatened fauna species included in Table 5.1 are not considered likely to be present in the areas "*likely to be affected by the action*", other than on a rare or transitory basis, if at all.

5.1.1 Species Recorded in the Study Area

Twelve threatened fauna species were recorded during the field investigations in the study area (as indicated in Table 5.2; Figure 5.1 and Appendix I of this SIS). These species are all considered of relevance to the Karuah Upgrade Project and are discussed in detail throughout the remainder of the SIS.

Table 5.2 provides "*threatened species information*", which includes, as requested in Item 1.18 of the D-G's Requirements, "*species name, date recorded, name of person who made the record, type of record (e.g. scat identification, trapped, sighted), specific use of habitat (e.g. nesting, roosting, foraging), number of individuals recorded*".

All fauna species were recorded by Mr Matthew Chambers, whose qualifications and experience are outlined in the *Curricula Vitae* in Appendix M.



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Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Figure 5.1 **Location of subject fauna species recorded during SIS survey (1999c) and other recent surveys (1999b,1997a) in the study area.**

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Table 5.1 Threatened fauna species recorded in the study area and the general vicinity, and additional species listed on the NSW NP&WS D-G's Requirements for the SIS (Appendix A). Species are grouped according to habitat preferences.

Vegetation Type	
Woodland/Forest	
Square-tailed Kite	*Eastern Freetail Bat (Little Mastiff Bat)
Red Goshawk	*Little Bent-wing Bat
*Bush Stone Curlew (Bush Thick-knee)	*Common Bent-wing Bat
*Glossy Black Cockatoo	Eastern (Northern) Long-eared Bat
Turquoise Parrot	*Greater Broad-nosed Bat
Swift Parrot	Hoary Bat
Regent Honeyeater	Large Pied Bat
Powerful Owl	Yellow-bellied Sheathtail Bat
*Masked Owl	White-crowned Snake
Barking Owl	Tiger Quoll
*Koala	Parma Wallaby
*Long-nosed Potoroo	Black-striped Wallaby
Brush-tailed Phascogale	Rufous Bettong
Common Planigale	Common Wombat
*Squirrel Glider	New Holland Mouse
Yellow-bellied Glider	Bichir's Freetail Bat
Queensland Blossom Bat	Eastern Cave Bat
Rainforest	
Suburb Fruit-dove	Golden-tipped Bat
Rose-crowned Fruit-dove	Stephen's Banded Snake
Wompoo Fruit-dove	Pale-headed Snake
Double-eyed Fig Parrot (Coxen's Fig Parrot)	Red-legged Pademelon
Sooty Owl	Three-toed Snake-toothed Skink
White-eared Monarch	Black-breasted Button-quail
Black Flying-Fox	
Wetland/Swamp	
Black-necked Stork	Large-footed Myotis (Fishing Bat)
Brolga	Green & Golden Bell Frog
Comb-crested Jacana	Wallum Froglet
Bush-hen	Wallum Tree Frog
*Osprey	Green-thighed Frog
Coastal/Pelagic	
Little Tern	
Sooty Oystercatcher	
Pied Oystercatcher	
Lesser Sand Plover	
Riparian	
Black Bittern	
Australasian Bittern	
Gold-eyed (Southern) Barred Frog	
Stuttering Barred Frog	
Blue-eyed Barred Frog (Fleay's Frog)	
Grassland/Heathland	
Eastern Grass Owl	
Ground Parrot	
Eastern Chestnut Mouse	
*Chestnut-rumped Heathwren	

* species recorded in the study area during the investigations for this SIS.

Table 5.2 Details of fauna records of those "*subject species*" which were recorded in the study area during investigations[7] for the proposal (Figure 5.1).

Report/Survey Method	Species	Date	Observation Type	Use of Habitat	Number of Individuals
Fauna & Flora Constraints Report (1997a)					
Anabat recording	Little Bent - wing Bat	22/04/97	Definite	Foraging	-
		23/04/97	Probable	Foraging	-
		24/04/97	Probable	Foraging	-
	Common Bent-wing Bat	23/04/97	Probable	Foraging	-
	Eastern Freetail Bat	24/04/97	Possible	Foraging	-
Koala Search	Koala	21/04/97	Scratchings & scats	Foraging	-
	Koala	22/04/97	Scratchings	Foraging	-
		23/04/97	Scratchings	Foraging	-
		24/04/97	Scratchings	Foraging	-
Fauna & Flora Assessment Report (1999b)					
Spotlight	Squirrel Glider	02/02/98	Observed	Foraging	1
		03/03/98	Observed	Foraging	1
	Koala	05/03/98	Observed	Foraging	1
Opportunistic	Osprey	05/03/98	Observed	Foraging	1
Harp Trap	Little Bent-wing Bat	03/03/98	Observed	Foraging	4
Anabat recordings	Eastern Freetail Bat	02/03/98	Definite	Foraging	-
	Greater Broad-nosed Bat	02/03/98	Probable	Foraging	-
Koala Search	Koala	04/03/98	Scats	Foraging	-
		04/03/98	Scats	Foraging	-
		04/03/98	Scratches & scats	Foraging	-
		04/03/98	Scratches	Foraging	-
Species Impact Statement (1999c)					
Spotlight	Long-nosed Potoroo	24/11/98	Observed	Foraging	1
	Bush-stone Curlew	26/11/98	Heard	Foraging	1
	Glossy Black Cockatoo	26/11/98	Crushed cones	Foraging	-
	Koala	28/01/99	Observed	Foraging	1
	Koala	28/01/99	Scats	Foraging	-
	Masked Owl	07/08/99	Observed	Foraging	1
		07/08/99	Nest tree	Nesting	-

[7] Investigations include those for the route selection and those conducted specifically for the Species Impact Statement.

Table 5.2 contd Details of fauna records collected of those "*subject species*" which were recorded in the study area during investigations for the proposal (Figure 5.1).

Report/Survey Method	Species	Date	Observation Type	Use of Habitat	Number of Individuals
Species Impact Statement (1999c) contd					
Diurnal Bird Survey	Chestnut-rumped Heathwren	07/08/99	Observed	Foraging	1
Anabat recording	Greater Broad-nosed Bat	29/12/98	Possible	Foraging	-
	Little Bent-wing Bat	26/11/98	Definite	Foraging	-
		07/08/99	Definite	Foraging	-
		09/08/99	Definite	Foraging	-
	Common Bent-wing Bat	09/08/99	Probable	Foraging	-
		10/08/99	Probable	Foraging	-
		10/08/99	Possible	Foraging	-
	Eastern Freetail Bat	10/08/99	Definite	Foraging	-
Targeted Search	Glossy Black Cockatoo	28/11/98	Crushed cones	Foraging	-
		17/01/99	Crushed cones	Foraging	-
		08/08/99	Crushed cones	Foraging	-
Koala Search	Koala	06/03/98	Scats	Foraging	-
		06/03/98	Scats	Foraging	-
		08/08/99	Scats	Foraging	2
		08/08/99	Scratchings & scats	Foraging	1
		08/08/99	Scratchings & scats	Foraging	1
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
		08/08/99	Scratchings	Foraging	-
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		09/08/99	Scratchings	Foraging	-
		09/08/99	Scratchings	Foraging	-
		09/08/99	Scats	Foraging	-
		09/08/99	Scats	Foraging	-
		09/08/99	Scats	Foraging	-
		09/08/99	Scats	Foraging	-

5.1.2 Species Known from the Locality

In addition to those species recorded in the study area during investigations for the Karuah Upgrade Project, a number of additional species are known from the locality (Ecotone 1995; Gunninah 1997b; NP&WS Wildlife Atlas 1999). These species are considered potential users of the study area, given the presence of suitable habitat.

The Brush-tailed Phascogale and Masked Owl were both recorded during investigations in the Raymond Terrace to Karuah Pacific Highway Upgrade study area (Gunninah 1997b). The Masked Owl was recorded during spotlighting investigations near Ringwood Road, approximately 11km from the western end of the Karuah Upgrade study area, and the Brush-tailed Phascogale was identified during spotlighting near the Balickera Canal, approximately 10km from the study area. Given that both species are known from the vicinity, and the presence of suitable habitat in the study area, and given the highly mobile and wide-ranging habits of the Masked Owl, both species are considered of relevance to the proposal.

The Tiger Quoll, whilst not recorded during field investigations, is known to occur in the steep, dense forest on the eastern side of the Karuah River, between the existing Highway, the proposed Highway and the SEPP 14 wetland along the Karuah River (R Clark *pers comm*). Similarly, the Green-thighed Frog has not been recorded in the study area, despite extensive investigations during suitable weather conditions, but is known to occur in Nerong SF approximately 20km to the northeast (L Baker NPWS *pers comm*). Given the presence of both species in the area, and the presence of potentially suitable habitat, both the Tiger Quoll and Green-thighed Frog are considered of relevance to the proposal.

5.1.3 Other Species

In addition to those species recorded in the study area, a large number of additional species have been identified as "*subject species*" for the project by the NP&WS (Section 1.11 and Appendix 3 of the D-G's Requirements) or are listed on relevant databases (Table 5.1). Given the absence of records of any of these additional species in the areas "*likely to be affected by the action*" (despite targeted searches in potentially suitable habitat), and the absence of habitat features or resources of particular significance or of restricted distribution, it is considered that there is not a likelihood of "*a significant effect*" being imposed on any of these species. Nevertheless, to satisfy the requirements of the legislation and of the Director-General of the NP&WS, these additional species are discussed briefly below.

The list of "*subject species*", as provided in the NP&WS D-G's Requirements (Section 1.11 and Appendix 3 of the D-G's Requirements), include a number of species whose distributions are well outside of the locality of the study area (Appendix F). The Black-breasted Button Quail, Black-striped Wallaby, Black Flying Fox, Beccari's Freetail Bat, Eastern Long-eared Bat, Bush Hen, White-crowned Snake and Three-toed Snake-tooth Skink all occur in northern NSW (Gilmore & Parnaby 1994; NP&WS 1994b), and are not likely to occur in the study area. On this basis, these species are not considered of relevance to the Karuah Bypass project, and are not discussed further.

A number of coastal and/or pelagic species are known from the locality or are listed by the NP&WS (Table 5.1), including the Little Tern, Sooty and Pied Oystercatchers and Lesser Sand Plover (Table 5.1). These species roost, forage and nest on sandy beaches, rocky shorelines or offshore islands. Whilst the areas "*likely to be affected by the action*" include features which could potentially be used by some of these species, and individuals could occur on a rare or occasional basis, there is no potential for the imposition of "*a significant effect*" on any of these species as a result of the proposed activities.

The list of "*subject species*" also includes a number of forest and woodland dwelling species, including birds, mammals, amphibians and reptiles. Threatened bird species known from the locality which forage and nest in forest and woodland include the Red-tailed Black Cockatoo, Regent and Painted Honeyeaters. Whilst potentially suitable habitat and resources, such as preferred food trees, suitable prey species (for the owls), and tree-hollows and other nesting features, are present in the study area, none of these species have been recorded, despite targeted surveys. Consequently, none of these forest-dwelling avian species are considered of relevance to the proposed activities.

Other forest and woodland-dwelling species include arboreal and terrestrial mammals (such as the Common Planigale) and an array of threatened microchiropteran bats (such as the Yellow-bellied Sheathtail Bat, Hoary Bat and Large Pied Bat). The study area provides suitable habitats and resources for all of these species, such as tree-hollows for roosting and nesting, and a range of foraging resources. However, none were recorded during the field investigations. Whilst microchiropteran bats are likely to occur in the study area on occasions, none of these species are likely to be adversely affected by the proposed activities to any significant extent due to their high mobility, and consequently they are not discussed further in this SIS.

A number of rainforest species have been listed by the NP&WS (Section 1.11 and Appendix 3 of the D-G's Requirements) as potentially occurring in the region, including the Superb, Rose-crowned and Wompoo Fruit-doves, Sooty Owl, Golden-tipped Bat and Stephen's Banded Snake (Table 5.1). However, there is no rainforest habitat along the alignment or in the immediate vicinity. Consequently, none of these rainforest-dwelling species are regarded as of relevance to this SIS.

Species known from the locality which inhabit riparian environments, swamps and wetlands include the Black-necked Stork, Comb-crested Jacana, Black and Australasian Bitterns, Wallum Frog and Gold-eyed Barred Frog (Table 5.1). The study area provides potentially suitable habitats and resources for all of these species, including areas of shallow open water, dense riparian vegetation (such as reeds and sedges) and small creeklines. However, none of these species have been recorded during the field investigations for this project, despite targeted surveys, and these species are not regarded as of relevance to this SIS.

5.2 Flora

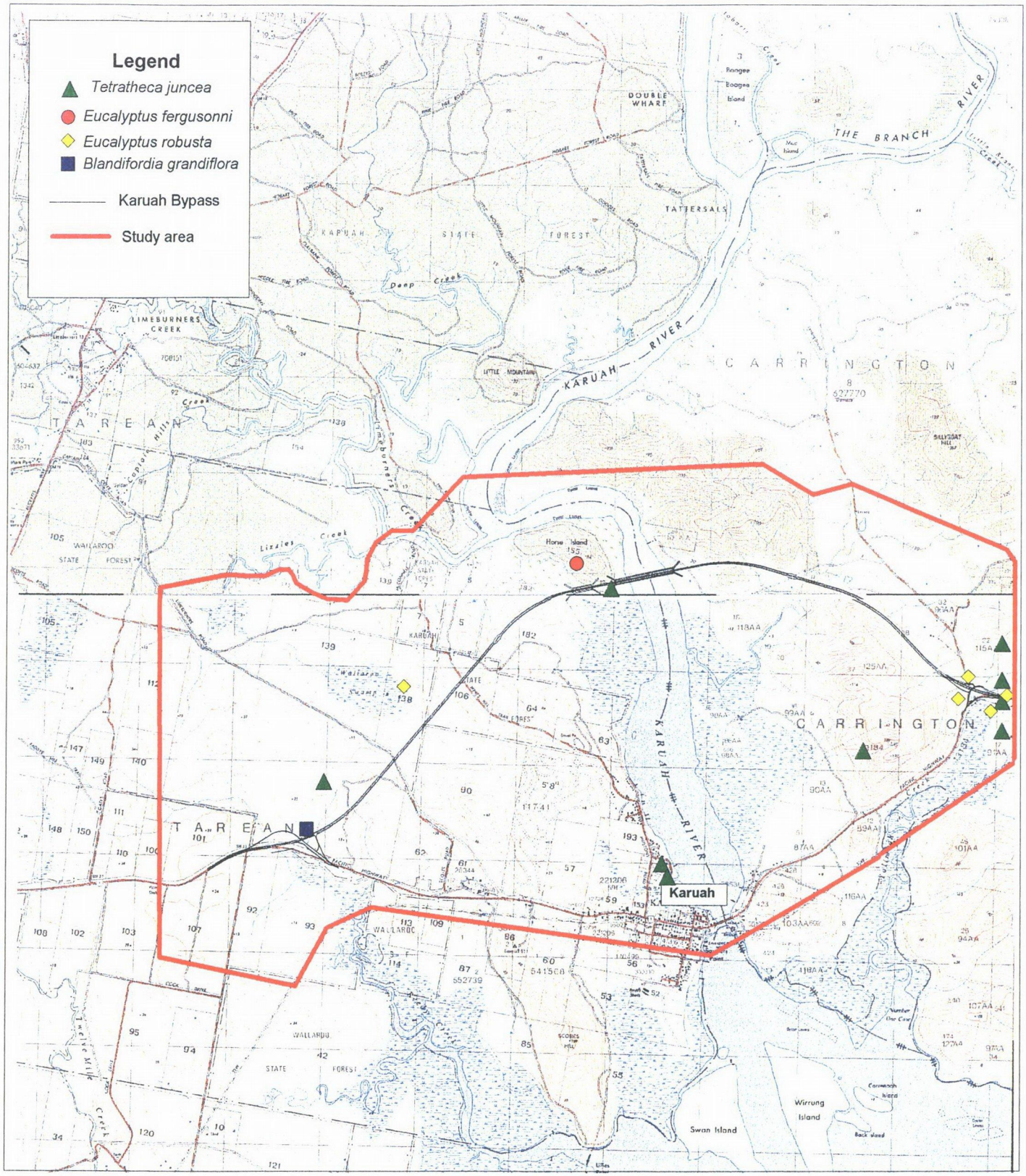
Eight threatened or rare flora species are known or expected to occur in the general locality, and have been specified by the Director-General as "*subject species*" (Appendix A; Table 5.3). Of the species listed in Table 5.3 (Table 5.4), one threatened species and three rare species were recorded during the field investigations in the study area, and potential habitat for a further three rare species was identified (Figure 5.2).

The threatened species recorded (*Tetratheca juncea*) is discussed in detail throughout the SIS. Whilst a further seven species were recorded or could potentially occur, only those species which were identified during flora investigations are discussed in detail.

Table 5.3 Threatened flora species recorded in the study area and the general vicinity, and additional species listed in the NSW NP&WS D-G's Requirements for the SIS (Appendix A).

Species Name	Common Name	Status			SA	GL
		TSC	ROTAP	RARE		
Blandfordia grandiflora	Christmas Bells	-	-	✔	✔	-
Eucalyptus robusta	Swamp Mahogany	-	-	✔	✔	-
Eucalyptus fergusonii	-	-	3KC-	-	✔	-
Gonocarpus salsoloides	-	-	3RCa	-	-	-
Grevillea guthrieana (obtusiflora)	-	-	3V	-	-	-
Hakea bakeriana	-	-	-	✔	✔	-
Syzygium paniculatum	-	-	3VCi	-	-	-
Tetratheca juncea	Black-eyed Susan	✔	3VCa	-	✔	✔

TSC *NSW Threatened Species Conservation Act 1995*
ROTAP Rare Or Threatened Australian Plants (Briggs & Leigh 1996) - see Table 5.4 below.
RARE regionally or locally rare (NSW NP&WS)
SA Recorded in the study area
GL Recorded in the general locality (NP&WS Wildlife Atlas)



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Figure 5.2 **Location of subject flora species recorded during SIS survey (1999c) and other recent surveys (1999b,1997a) in the study area.**

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Table 5.4 National conservation status codes for Rare or Threatened Australian Plants (Briggs & Leigh 1996).

Distribution Category	
1	Known by only one collection only.
2	Species with a geographic range of less than 100 km.
3	Species with a geographic range of greater than 100 km.
Conservation Status	
X	**Presumed extinct**: not collected or otherwise verified over the past 50 years.
E	**Endangered**: taxon in serious risk of disappearing from the wild within 10-20 years if present land use and other threats continue to operate.
V	**Vulnerable**: not currently endangered; at risk of disappearing from the wild state within 20-50 years.
R	**Rare**: but not currently endangered or vulnerable.
K	**Poorly Known**: taxon that is suspected, but not definitely known, to belong to one of the above categories. At present, accurate field distribution information is inadequate.
C	**Reserved**: has at least one population within a National Park, Conservation Reserve, or area dedicated for the protection of flora.
Size-class of all Reserved Populations	
a	1000 plants or more are known to occur within a conservation reserve(s).
i	less than 1000 plants are known to occur within a conserved reserve(s).
-	reserved population size is not accurately known.
t	Total known population reserved;
+	Overseas occurrence (included if the taxon has a natural occurrence overseas).

Tetratheca juncea was recorded in a number of locations in the study area during this and previous investigations for the Karuah Upgrade Project, as detailed on Figure 5.2. Whilst this species was only recorded in two of the thirty quadrats investigated and was not located during any of the fourteen random transects (Figure 5.2; Tables 5.5 & 5.6), potential habitat for this species was identified in approximately five additional quadrats and along one of the transects. Locating *Tetratheca juncea* and the other "*subject species*" was difficult in a number of areas as a result of the wildfire, which passed through much of the western portion of the study area in approximately November 1997. Where species were unable to be directly recorded, the presence of suitable habitat was noted.

All "*subject species*" were identified by Mr Steven Chamberlain, whose qualifications and experience are detailed in Appendix M.

Table 5.5 Location of "*subject species*" recorded during quadrat-based flora surveys (Figure 5.2). Other "*subject species*" not recorded but which could potentially occur on the basis of community type are also noted where relevant.

Quadrat Number	Community	Subject Species Recorded	Potential Subject Species
1	2	*Blandflordia grandiflora* recorded nearby	*Tetratheca juncea*; *Hakea bakeriana*; *Grevillea guthrieana*
2	3	-	*Tetratheca juncea*; *Hakea bakeriana*; *Grevillea guthrieana*; *Blandflordia grandiflora*
3	3	-	*Tetratheca juncea*; *Hakea bakeriana*; *Grevillea guthrieana*; *Blandflordia grandiflora*
4	3	-	*Tetratheca juncea*; *Hakea bakeriana*; *Grevillea guthrieana*; *Blandflordia grandiflora*

Table 5.5 contd Location of "*subject species*" recorded during quadrat-based flora surveys (Figure 5.2). Other "*subject species*" not recorded but which could potentially occur on the basis of community type are also noted where relevant.

Quadrat Number	Community	Subject Species Recorded	Potential Subject Species
5	4	*Eucalyptus robusta* 300m to north of quadrat	-
6	4	-	-
7	7	*Eucalyptus robusta* to north	-
8	-	-	*Eucalyptus fergusonii*
9	2	-	*Eucalyptus fergusonii; Tetratheca juncea; Hakea bakeriana; Grevillea guthrieana; Blandflordia grandiflora*
10	1	-	*Eucalyptus fergusonii*
11	1	*Eucalyptus fergusonii* found nearby	*Eucalyptus fergusonii*
12	6a	-	-
13	6b	-	-
14	3	*Tetratheca juncea*	-
15	1	*Eucalyptus fergusonii*	-
16	4	-	*Syzygium paniculatum*
17	4	-	*Syzygium paniculatum*
18	1	-	*Eucalyptus fergusonii*
19	1	-	*Eucalyptus fergusonii*
20	3	-	*Eucalyptus fergusonii*
21	5	-	-
22	5b	-	*Syzygium paniculatum*
23	7	-	-
24	4	-	*Syzygium paniculatum*
25	4	-	-
26	3	*Tetratheca juncea*	*Grevillea guthrieana; Hakea bakeriana; Blandflordia grandiflora*
27	4	-	-
28	2	-	-
29	1	-	*Eucalyptus fergusonii*
30	4	-	-

Table 5.6 Location of "*subject species*" recorded during transect-based flora surveys (Figure 5.2). Other "*subject species*" not recorded but which could potentially occur on the basis of community type are also noted where relevant.

Transect #	Community	Subject Species Recorded	Potential Subject Species
1	2	-	*Tetratheca juncea; Hakea bakeriana; Blandflordia grandiflora; Grevillea guthrieana*
2	3	-	*Hakea bakeriana; Blandflordia grandiflora; Grevillea guthrieana*
3	1	*Eucalyptus fergusonii*	-
4	1	*Eucalyptus fergusonii*	-
5	1	-	*E fergusonii*
6	6a - 1	-	-
7	1	-	-
8	1	-	-
9	7	-	-
10	1	-	*Eucalyptus fergusonii*
11	4	-	-
12	2	-	*H bakeriana*
13	4	-	-
14	4	-	-

6 RELEVANT THREATENED SPECIES or ENDANGERED POPULATIONS

The TSC Act requires, under Section 110(2)(b), that a SIS includes the following information:

> "*an assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action*".

The NP&WS D-G's Requirements include (Appendix A):

> "*1.10 A list of subject species must be provided. In determining these species, consideration shall be given to the habitat types present within the study area, records of subject species in the locality and the known distribution of threatened species*".

The Director-General, in the detailed requirements for this SIS (Appendix A), has included an extensive list of species which "*shall be considered for inclusion in the list of subject species*". The list of "*subject species*" (provided in Table 5.1 of this SIS) includes all of those listed by the Director-General, as well as additional species known from the locality.

In assessing which of the threatened fauna and flora species known from the study area and the subject site or considered likely to occur in the locality "*are likely to be affected by the action*", and in addressing the issue of "*subject species*", the following matters were considered:

- has the species or population been recorded on the subject site or within the study area?
- are there any records of the species or population from the locality or general vicinity (*ie* from past studies or on the NP&WS Wildlife Atlas)?
- does the study area support potentially suitable habitats or resources for the threatened species or endangered populations?
- does the subject site support potentially suitable habitats or resources for any threatened species or populations?
- are the resources or habitat features which are to be affected by the development widespread throughout the region or are they restricted to the subject site or its immediate vicinity?
- will an area of "*known habitat*" for a threatened species be modified or removed, as a result of the proposed development?
- is the species or population likely to occur on the subject site or in the study area on other than a transitory basis? and
- is it likely that a "*viable local population*" of the species or population is dependent on the resources or habitats to be "*affected*"?

Details of the habitat and resource requirements of threatened species listed in the D-G's Requirements for this SIS are considered in Chapter 7, and are provided in Appendix F. The relevance of the "*subject species*" to the proposed development, based on the criteria noted above, is considered below and in Appendix F.

A total of twelve threatened fauna species were identified in the study area during investigations for the Karuah Upgrade Project (Table 5.2). In addition to the species actually recorded in the study area, a number of "*subject species*" have been recorded in adjacent areas during recent survey activities, or have been recorded on several previous occasions, as determined by records listed on the NP&WS Wildlife Atlas (Table 6.1). These species are considered relevant to this SIS, despite not being recorded during the field investigations, on the basis of recent records in the locality and the presence of suitable habitat along the alignment. Furthermore, for some species (in particular the Green-thighed Frog) their cryptic nature makes positive identification difficult, and such species have been assumed to be present.

In addition to the species listed in Table 6.1 (the "*affected species*"), a large number of species have been identified by the Director-General of NP&WS as "*subject species*" (Table 5.1).

However, the majority of these "*subject species*" were not recorded in the study area during this or previous investigations, and many are unlikely to occur given a lack of suitable habitats and resources, or because the study area is outside of their currently known distributions. These species are considered in Appendix F, with full justification for their exclusion from Table 6.1 further detailed in Chapter 3 of this SIS.

A number of the "*subject species*" are considered potential users of the habitats and resources in the study area, but are not considered in detail in this SIS. Several highly mobile, wide-ranging, nomadic or migratory bird species are listed as "*subject species*" and may use the subject site as part of a wider home-range, or on a transitory basis. Species such as the Swift Parrot (which breeds in Tasmania and migrates to the mainland over winter), and the Regent Honeyeater (which is nomadic and responds to flowering food trees), are all likely to use the subject site on occasions. However, given the limited extent of potential habitat to be removed and the large area to be retained, the impacts on these species as a result of the proposed Karuah Upgrade is considered extremely limited. Consequently, such species are not considered of relevance to this SIS.

A total of five threatened, rare or ROTAP flora species were identified in the study area, all of which have been identified by the Director-General of NP&WS as "*subject species*" (Table 5.3). An additional three rare species are considered likely to be present, based on the presence of suitable habitats and resources. Of the five flora species of conservation concern recorded, *Tetratheca juncea* was the only threatened flora species (as listed on the TSC Act) recorded in the study area.

From the considerations above and in Appendix F, and on the basis of the detailed s5A Assessments of Significance (Gunninah 1999b), the twenty-one threatened species recorded in the study area are "*likely to be affected by the action*", and are therefore of relevance to the proposed activities. Furthermore, species such as the Brush-tailed Phascogale, Tiger Quoll and Green-thighed Frog which were not recorded in the study area, are considered likely to be present (Table 6.1). These species are discussed in detail below. Whilst there is little likelihood that the highly mobile and wide ranging species, such as the Glossy Black Cockatoo and microchiropteran bats, are "*likely to be affected by the action*" they are also discussed in detail below.

Table 6.1 Species of relevance to this SIS (the "*affected species*"), based on the potential for significant adverse impacts being imposed by the proposal (Gunninah 1999c).

	Species Name	Common Name
Mammals	*Phascolarctos cinereus*	Koala
	Petaurus norfolcensis	Squirrel Glider
	Potorous tridactylus	Long-nosed Potoroo
	Phascogale tapoatafa	Brush-tailed Phascogale*
	Dasyurus maculatus	Tiger Quoll*
	Miniopterus australis	Little Bent-wing Bat
	Scoteanax rueppellii	Greater Broad-nosed Bat
	Miniopterus schreibersii	Common Bent Wing Bat
	Mormopterus norfolkensis	Eastern Freetail Bat
Birds	*Calyptorhynchus lathami*	Glossy Black Cockatoo
	Burhinus grallarius	Bush Stone-curlew
	Tyto novaehollandiae	Masked Owl*
	Ninox strenua	Powerful Owl
	Pandion haliaetus	Osprey
	Hylacola pyrrhopygia	Chestnut-rumped Heathwren
Herpetofauna	*Litoria brevipalmata*	Green-thighed Frog*
Flora	*Blandfordia grandiflora*	Christmas Bells
	Eucalytpus fergusonii ssp *fergusonii*	
	Eucalyptus robusta	Swamp Mahogany
	Hakea bakeriana	
	Tetratheca juncea	Black-eyed Susan

* species not recorded in the study area, but considered likely to be present.

7 CONSERVATION STATUS and HABITAT REQUIREMENTS

The TSC Act requires, under Section 110(2)(c), that a SIS must include the following information:

> *"for each species or population likely to be affected, details of its local, regional and state wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or threat abatement plan applying to it".*

At the time of preparing this SIS, no relevant "*recovery plan*" or "*threat abatement plan*" had been listed in the TSC Act. However, a number of Draft Recovery Plans have been prepared, as detailed in the D-G's Requirements, and those have been made available for consideration.

The Director-General defines threatening processes as "*all processes considered to be threatening, not limited to key threatening processes as defined in the TSC Act*". There are currently six "*key threatening processes*" listed, or under consideration for listing under the TSC Act. Predation by the Red Fox *Vulpes vulpes*, predation by the Plague Minnow *Gambusia holbrooki* and invasion of native plant communities by *Chrysanthemoides monilifera* are listed under the Act. Bushrock removal, loss of butterfly Hilltopping sites and high frequency fire resulting in the disruption of life cycle processes in plants and animals and the loss of vegetation structure and composition are the subject of consideration under Preliminary Determinations. The relevance of the "*key threatening processes*" and of those "*processes considered to be threatening, not limited to key threatening processes as defined in the TSC Act*" is provided in Chapter 7.3. The effects of the activity on 'threatening processes' in general is provided in detail in Chapter 10 of this SIS.

7.1 Local, Regional and State-Wide Conservation Status

The conservation status in national, state-wide (Table 7.1), regional and local terms of those threatened subject species considered "*likely to be affected*" by the proposed activities are provided in the species profiles below. There is no specific or recognised conservation status for any of these species on either a regional or local basis. In general, determination of the local and regional conservation significance of threatened species is problematic, as a result of the scarcity of information for most threatened species.

Table 7.1 State-wide and National conservation status of those subject species considered of relevance to the proposed activities and listed as threatened under the TSC Act and/or ESP Act.

	Species Name	Common Name	Status	
			State (TSC Act)	National (ESP Act*)
Mammals				
	Phascolarctos cinereus	Koala	V	-
	Petaurus norfolcensis	Squirrel Glider	V	-
	Potorous tridactylus	Long-nosed Potoroo	V	-
	Phascogale tapoatafa	Brush-tailed Phascogale	V	-
	Dasyurus maculatus	Tiger Quoll	V	V
	Scoteanax rueppellii	Greater Broad-nosed Bat	V	-
	Miniopterus australis	Little Bent-wing Bat	V	-
	Miniopterus schreibersii	Common Bent-wing Bat	V	-
	Mormopterus norfolkensis	Eastern Freetail Bat	V	-
Birds	*Pandion haliaetus*	Osprey	V	-
	Calyptorhynchus lathami	Glossy Black Cockatoo	V	-
	Burhinus grallarius	Bush Stone-curlew	E	-
	Tyto novaehollandiae	Masked Owl	V	-
	Ninox strenua	Powerful Owl	V	-
	Hylacola pyrrhopygia	Chestnut-rumped Heathwren	-	-

Table 7.1 contd State-wide and National conservation status of those subject species considered of relevance to the proposed activities and listed as threatened under the TSC Act and/or ESP Act.

Species Name	Common Name	Status	
		State (TSC Act)	National (ESP Act)
Herpetofauna			
Litoria brevipalmata	Green-thighed Frog	V	-
Flora			
Blandfordia grandiflora	Christmas Bells	-	-
Eucalyptus fergusonii spp *fergusonii*		-	-
Eucalyptus robusta	Swamp Mahogany	-	-
Hakea bakeriana		-	-
Tetratheca juncea	Black-eyed Susan	V	V

E	Endangered - Schedule 1 of the TSC Act
V	Vulnerable - Schedule 2 of the TSC Act and ESP Act
TSC Act	*NSW Threatened Species Conservation Act 1995*
ESP Act	*Commonwealth Endangered Species Protection Act 1992* .

7.1.1 Koala *Phascolarctos cinereus*

National Status
In eastern mainland Australia the Koala has a distribution from the western side of Victoria to the base of Cape York, comprising a series of large, but disjunct populations, with major concentrations in southeastern Queensland, northeastern New South Wales and in Victoria (Phillips 1990; Gilmore & Parnaby 1994; NP&WS 1999). The Koala is not listed as Endangered or Vulnerable on the ESP Act, and is considered "*common*" (Martin and Handasyde 1995).

State-wide Status
Within NSW, Koala populations are concentrated in the northeastern corner of the state (Phillips 1990), with the foci of Koala density located in the Port Stephens, Port Macquarie, Coffs Harbour and Tweed Shire areas (Phillips 1990; Reed & Lunney 1990). The Koala is listed as Vulnerable on Schedule 2 of the TSC Act, and is considered "*lower risk - near threatened*" by the *1996 Action Plan for Australian Marsupials and Monotremes* (Maxwell *et al* 1996).

Regional Status
The northeast forests of NSW support large populations of Koalas and the species is common throughout this region, including recordings from the Tweed, Brunswick, Richmond, Clarence, Bellinger, Macleay, Hastings, Camden Haven, Manning and Hunter valleys (NP&WS 1999).

Local Status
The Port Stephens area is a stronghold for the Koala and this species is common and widespread in suitable habitat.

7.1.2 Squirrel Glider *Petaurus norfolcensis*

National Status
The Squirrel Glider occurs in a broad band along the east coast of Australia, including coastal Queensland south of the Cape York Peninsular, through coastal NSW to central Victoria (Strahan 1995). The Squirrel Glider is not listed as Endangered or Vulnerable in the ESP Act, but is considered "*rare*" in Australia (Suckling 1995).

State-wide Status
In northern NSW, this species is coastal in distribution, while in southern NSW it occurs further inland (Suckling 1995). This species is listed as Vulnerable on Schedule 2 of the TSC

Act, and is considered "*lower risk - near threatened*" by Maxwell *et al* (1996).

Regional Status
The species is sparsely distributed throughout the region, due to large reductions in suitable habitat. It is most likely to be uncommon and is vulnerable to threatening processes.

Local Status
There are few recent records of the Squirrel Glider from the locality (NP&WS Wildlife Atlas; Gunninah 1997b, 1999b), although this apparent rarity may be in part due to this species similarity and mistaken identification with the common Sugar Glider. Nevertheless, the Squirrel Glider is likely to be locally uncommon.

7.1.3 Long-nosed Potoroo *Potorous tridactylus*

National Status
The Long-nosed Potoroo occurs along the east coast of Australia, from south-east Queensland to south-east South Australia and Tasmania, in a series of disjunct populations (Johnston 1995). This species is not listed as Endangered or Vulnerable in the ESP Act, and is considered "*common*" but "*limited*" in Australia (Johnston 1995).

State-wide Status
The Long-nosed Potoroo occurs in fragmented populations along the entire east coast of NSW. This species is listed as Vulnerable on Schedule 2 of the TSC Act and is considered "*vulnerable*" by the 1996 Action Plan (Maxwell *et al* 1996). The NP&WS considers the species to be "*threatened*" in NSW (Wells 1989).

Regional Status
A number of records of Long-nosed Potoroos exist from the region (Gilmore & Parnaby 1994), with the species occurring in disjunct populations in coastal areas (Johnston 1995). However, it is most likely to be rare to uncommon, and vulnerable to threatening processes within the region.

Local Status
This species was recorded in the study area (Gunninah 1999c), but has not been previously recorded within 10km of the study area (NP&WS Wildlife Atlas), and thus is likely to be rare and uncommon in the area.

7.1.4 Brush-tailed Phascogale *Phascogale tapoatafa*

National Status
The Brush-tailed Phascogale is not listed as Endangered or Vulnerable in the ESP Act. This species has experienced a substantial range reduction and occurs in localised, patchy populations in forested areas around the margin of Australia (Soderquist 1995). Consequently, it is "*uncommon to rare*" nationally and is vulnerable to local extinctions (Soderquist 1995).

State-wide Status
The Brush-tailed Phascogale is found along the eastern edge of New South Wales (Gilmore & Parnaby 1994; NP&WS 1999) and is listed as Vulnerable on Schedule 2 of the TSC Act. Its status has been described as "*lower risk - near threatened*" (Maxwell *et al* 1996).

Regional Status
The species has been recorded from the Brunswick, Richmond, Clarence, Bellinger, Macleay, Hastings, Camden Haven, Manning and Hunter valleys (Gilmore & Parnaby 1994; NP&WS 1994a), and its status is considered to be the same as for State and National.

Local Status
This species has been frequently recorded in the locality, including a number of recent sightings (Gunninah 1997b; NP&WS Wildlife Atlas). This species is likely to be patchily common in suitable habitat in the locality.

7.1.5 Tiger Quoll *Dasyurus maculatus*

National Status
The Tiger Quoll has been found in the Bundaberg area in south-east Queensland, south through NSW to Victoria and Tasmania (Gilmore & Parnaby 1994; NP&WS 1999), and is listed as Vulnerable in the ESP Act. It is "*uncommon to rare*" in the eastern part of its range, and "*probably extinct*" in South Australia (Edgar & Belcher 1995). Many populations throughout its range may be too small and isolated to remain viable (Edgar & Belcher 1995).

State-wide Status
This species has been recorded on both sides of the Great Dividing Range (Gilmore & Parnaby 1994), is listed as Vulnerable on Schedule 2 of the TSC Act and is "*uncommon to rare*" in NSW (Edgar and Belcher 1995). It also is considered "*vulnerable*" by the *1996 Action Plan for Australian Marsupials and Monotremes* (Maxwell *et al* 1996).

Regional Status
The species has been recorded from the Richmond, Clarence, Bellinger, Macleay, Hastings, Camden Haven, Manning and Hunter valleys (Gilmore & Parnaby 1994), and its status is considered to be the same as for State and National.

Local Status
There are scattered records of the Tiger Quoll in the locality, and the species is likely to be rare or uncommon and patchily distributed in the locality and subregion (Gilmore & Parnaby 1994).

7.1.6 Greater Broad-nosed Bat *Scoteanax rueppellii*

National Status
The Greater Broad-nosed Bat is distributed in southern NSW through to south-east Queensland (Gilmore & Parnaby 1994; NP&WS 1999). It is not listed as Endangered or Vulnerable on the ESP Act, but is considered "*uncommon to rare*" in Australia (Hoye & Richards 1995). Its status has been described as "*probably secure*" (Strahan 1992).

State-wide Status
This species has a distribution from southern NSW through to northeast NSW (Gilmore & Parnaby 1994) and is listed as Vulnerable on Schedule 2 of the TSC Act.

Regional Status
Northeast NSW is a population stronghold for the Greater Broad-nosed Bat, although its density is low and thus its status is most likely to be uncommon (Gilmore & Parnaby 1994).

Local Status
Since the species is relatively sparse throughout its distribution, it is probably rare to uncommon in the locality

7.1.7 Little Bent-wing Bat *Miniopterus australis*

National Status
The Little Bent-wing Bat occurs along the eastern coast of Australia, from the northern tip of the Cape York Peninsula in Queensland to approximately the Hawkesbury River (Hall & Richards 1979; NP&WS Wildlife Atlas). The species is not listed as Endangered or Vulnerable in the ESP Act, and is considered "*abundant*" and "*secure*" in Australia (Strahan 1992; Dwyer 1995).

State-wide Status
The Little Bent-wing Bat is known along the east coast of NSW, from the Queensland border to south of Kempsey (Hall & Richards 1979; NP&WS Wildlife Atlas). This species is listed as Vulnerable on Schedule 2 of the TSC Act.

Regional Status
This species is relatively common in the region. Several roosting colonies exists on the North Coast of NSW and the species is regularly recorded in the area (Gilmore & Parnaby

1994). Its status is most likely to be common and secure.

Local Status
Several records of this species exist for the study area (Gunninah 1997a, 1999b, c; NP&WS Wildlife Atlas), and populations are known to roost in the Balickera Tunnel, approximately 16km southwest of the Karuah township (Gunninah 1995). The species is therefore common in the locality and most likely to be reasonably secure.

7.1.8 Common Bent-wing Bat *Miniopterus schreibersii*

National Status
The Common Bent-wing Bat has a distribution from north Queensland to south-east South Australia (Gilmore & Parnaby 1994), and is found east of the Great Dividing Range as well the Top End (Hall and Richards 1979). This species is not listed as Endangered or Vulnerable in the ESP Act, and internationally it has the widest distribution of any bat (Churchill 1998).

State-wide Status
The Common Bent-wing Bat is found east of the Great Dividing Range, along the coast and western slopes (Gilmore & Parnaby 1994) and is listed as Vulnerable on Schedule 2 of the TSC Act.

Regional Status
This species is described as being widely distributed throughout northeast NSW, ranging from the coast to western slopes, and is believed to be widespread and common (NP&WS 1999).

Local Status
This species is regularly recorded in the locality (Gunninah 1997a, 1999b), and its local status (as is the case throughout its distributional range) is common, as for the region.

7.1.9 Eastern Freetail Bat *Mormopterus norfolkensis*

National Status
The Eastern Freetail Bat is distributed from the mid-north coast of NSW to south-east Queensland (Gilmore & Parnaby 1994). This species is not listed as Endangered or Vulnerable in the ESP Act, and is considered "*rare*" in Australia (Allison & Hoye 1995). Although its abundance is "*very sparse*", its status is considered "*secure*" (Strahan 1992).

State-wide Status
This species is listed as Vulnerable on Schedule 2 of the TSC Act. Its distribution lies almost entirely within NSW, and thus its state-wide status is similar to that of its national status.

Regional Status
The species is known to occur in the region and has been positively identified (NP&WS 1994a; NP&WS Wildlife Atlas). Its conservation status is most likely to be rare yet secure.

Local Status
The species is extremely rare in the locality with only a few positive identifications recorded (Ecotone 1995; Gunninah 1997a; 1999a).

7.1.10 Osprey *Pandion haliaetus*

National Status
The Osprey appears to have a disjunct distribution, occurring continuously from Broome in WA, across northern Australia to the south coast of NSW, from Esperance to Cape Keraudren in the west, and from Kangaroo Island to the Great Australian Bight in the south (Marchant & Higgins 1993). The species is not listed as Endangered or Vulnerable in the ESP Act and its status is considered "*probably secure*" in Australia (Lindsey 1992). Its nationwide status is considered to be stable, and has been described as "*well protected, and largely free from contamination*" (Clancy 1991).

State-wide Status
The Osprey generally occurs along the coastal margin, with numbers declining towards the south (Marchant & Higgins 1993). It is listed on Schedule 2 of the TSC Act as Vulnerable. Clancy (1991) describes the Osprey populations as "*currently stable or slowly increasing*".

Regional Status
This species has been recorded in coastal areas throughout the NSW North Coast region, including at Harrington (HBOC 1998 Records), but it is considered regionally uncommon.

Local Status
The Osprey has been sighted several times in the locality (Gunninah 1999b; NP&WS Wildlife Atlas), and is considered a local breeding resident. However, it is uncommon and likely to be locally vulnerable.

7.1.11 Glossy Black Cockatoo *Calyptorhynchus lathami*

National Status
The Glossy Black Cockatoo has a distribution throughout southeastern Australia and is not listed as Endangered or Vulnerable in the ESP Act. However, Garnett (1992a, 1992b) considers the species to be nationally "*rare*". The Kangaroo Island subspecies *Calyptorhynchus lathami halmaturinus* is considered Endangered on the ESP Act.

State-wide Status
In NSW this species is mainly found on the coast and tablelands, and is "*sparsely distributed throughout its range*" (NP&WS 1994a). It is listed as Vulnerable in Schedule 2 of the TSC Act, and is considered '*rare*' by Garnett (1992a).

Regional Status
Northeast NSW supports the largest and most stable populations of this species in Australia (NP&WS 1999), and it is most abundant along the coast in this region. Its regional status is likely to be generally rare to uncommon, but common in areas of suitable habitat.

Local Status
Numerous individuals have been recorded recently and thus the local status is most likely to be common (Gunninah 1999c).

7.1.12 Bush Stone-curlew *Burhinus grallarius*

National Status
The Bush Stone-curlew is not listed as Endangered or Vulnerable in the ESP Act. Garnett (1992a) considers the species to be "*presently secure*" on a national basis, however, Lindsey (1992) describes it as "*vulnerable*".

State-wide Status
The Bush Stone-curlew is classified as Endangered on Schedule 1, Part 1 of the TSC Act and by Garnett (1992a).

Regional Status
This species is rare and susceptible to further population decreases as a result of threatening processes. It is most likely to be vulnerable and rare in the region.

Local Status
Reflecting its regional status, the species is most likely to be vulnerable and rare in the locality.

7.1.13 Masked Owl *Tyto novaehollandiae*

National Status
The Masked Owl is sparsely distributed in coastal regions of Australia (Gilmore & Parnaby 1994). It is not listed as Endangered or Vulnerable in the ESP Act, and is considered "*probably secure*" (Lindsey 1992) but "*rare*" (Garnett 1992a) in the national context. This

species is listed as rare and vulnerable in Victoria and South Australia, respectively (Olsen 1993).

State-wide Status
The Masked Owl is found sporadically along the coast and tablelands, is listed as Vulnerable on Schedule 2 of the TSC Act, and is considered "*rare*" (Garnett 1992a, 1992b) or "*uncommon...rarely encountered*" in NSW (Debus & Chafer 1994). Its rarity, reflected in its status described as "*poorly known*", may in part be caused by detection problems such as similar appearance to other owls and observer unfamiliarity (Debus and Chafer 1994).

Regional Status
It is predicted that coastal regions near the study area are unlikely to support large populations of the species due to unsuitable climatic conditions (Gilmore & Parnaby 1994), however it is most likely to be common in the region and potentially more common further inland.

Local Status
The species has been recorded in the locality on a number of occasions, with one nesting tree and an individual being located recently within the study area (Gilmore & Parnaby 1994; Gunninah 1999c; NP&WS Wildlife Atlas 1999). This species is considered most likely to be rare in the locality .

7.1.14 Powerful Owl *Ninox strenua*

National Status
The Powerful Owl has a distribution in south-eastern Australia from the Tropic of Capricorn in Queensland through NSW and Victoria, to the border of South Australia (Gilmore & Parnaby 1994). This species is considered "rare" nationally by RUOP (Garnet 1992a).

State-wide Status
The species occurs throughout coastal areas (Gilmore & Parnaby 1994), and has been described as widely distributed, though uncommon in NSW (Kavanagh & Peake 1993).

Regional Status
The species is expected to be widespread in suitable habitat in the region, although patchily distributed. On a local basis, the Powerful Owl is likely to be relatively common but vulnerable.

Local Status
The Powerful Owl has been recorded in the locality (NP&WS Wildlife Atlas), and although not found in the study area, it may forage and/or nest in the locality. The local conservation status of the Powerful Owl is considered to be vulnerable, and uncommon (although this may reflect the species' habits, territoriality and large home range size rather than its status).

7.1.15 Chestnut-rumped Heathwren *Sericornis pyrrhopygius*

National Status
The Chestnut-rumped Heathwren is restricted in distribution to the south-east of Australia from the Queensland southern border through eastern NSW and southern Victoria, with an isolated population on the Mt Lofty ranges in South Australia (Gilmore & Parnaby 1994). This species is not listed as Endangered or Vulnerable in the ESP Act.

State-wide Status
Its state wide status is regarded as uncommon and patchy, but common in suitable habitat.

Regional Status
The majority of records for this species are from the tablelands and associated ranges near the Clarence, Manning and Hunter valleys (Gilmore & Parnaby 1994). Its regional status is generally regarded as uncommon and patchy, but common in suitable habitat.

Local Status
Only a few records of the species exist from the locality (Gilmore & Parnaby 1994; Gunninah 1999c; NP&WS Wildlife Atlas), and its local status is regarded as patchy and locally uncommon.

7.1.16 Green-thighed Frog *Litoria brevipalmata*

National Status
The Green-thighed Frog is distributed in coastal NSW to the Conondale Ranges in south-east Queensland (Gilmore & Parnaby 1994), and is not listed as Endangered or Vulnerable in the ESP Act. Tyler (1992) describes this species' national status as '*vulnerable*'.

State-wide Status
This species is described as occurring sporadically from Gosford to the Queensland border (NP&WS 1994). The TSC Act classifies the Green-thighed Frog as Vulnerable, although it is considered "*probably secure*" by Ehmann (1996). This species' cryptic nature and subsequent detection difficulties may account for its apparent rarity in areas of potentially suitable habitat within its known distributional range.

Regional Status
Apparently rare and vulnerable, though poorly known.

Local Status
Local status is difficult to determine given the difficulty in detecting this species and the absence of any known records. No evidence for this species was detected in the study area despite targeted searches, thus the species is considered uncommon to rare in the locality, if it occurs at all.

7.1.17 Christmas Bells *Blandfordia grandiflora*

National Status
Blandfordia grandiflora is restricted to northeast coastal NSW, and southeastern inland Queensland. This species is not listed under the ESP Act or ROTAP (Briggs & Leigh 1996).

State-wide Status
This species is not listed in the TSC Act. Harden (1993) indicates the species is distributed from the Hawkesbury River area, inland to Glen Innes district, including the Central and North Coast and Tableland regions, as well as Queensland. This species is not listed under the TSC Act .

Regional Status
This species is considered to have a "*disjunct*" distribution, but to be common in suitable habitat in northeastern NSW (NP&WS 1995). Populations are currently conserved in five national parks in northeast NSW, including Broadwater, Bundjalung, Gibraltar Range, Yuraygir and Moonee Beach NP's (NP&WS 1995).

Local Status
There are a few records of *Blandfordia grandiflora* in the locality (NP&WS Wildlife Atlas). This species was found to be sporadically distributed in the southwestern part of the study area (Gunninah 1999b) and may be conserved in Wallaroo Nature Reserve. It is likely to be patchily distributed but locally common in areas of suitable habitat in the locality.

7.1.18 *Eucalyptus fergusonii*

National Status
Eucalyptus fergusonii is not listed under the ESP Act. It is endemic to New South Wales with a distributional range of less than 100km. This species is classified as a ROTAP species which is poorly known but conserved (Briggs & Leigh 1996).

State-wide Status
This species is not listed in the TSC Act. Harden (1991) indicates that the species only

occurs in the North Coast and Central Coast regions of NSW. It is conserved in two national parks, Yengo NP (Briggs & Leigh 1996) and Nerong NP 1999 (ERM 1999), and the subspecies *dorsiventralis* is conserved at Wollemi National Park. In the Central Coast region Wardell-Johnson *et al* (1997) list *E fergusonii* as rare in abundance and restricted in range.

Regional Status
The subspecies *fergusonii* has a sporadic distribution between Bulahdelah and Morriset, and has been recorded a number of times in the region (ERM 1998; Gunninah 1999b, NP&WS Wildilfe Atlas. Harden (1991) describes the species as "scattered and sporadic".

Local Status
This species was found at several sites in the locality (Gunninah 1999b), and has previously been recorded within a 10km radius of the study area (NP&WS Wildlife Atlas). It may also occur in the Wollaroo Nature Reserve.

7.1.19 Swamp Mahogany *Eucalyptus robusta*

National Status
Eucalyptus robusta is found from Moruya in northern NSW to southeastern Queensland, and is not listed under the ESP Act.

State-wide Status
This species is found from north Moruya throughout coastal New South Wales. It is not listed in the TSC Act. Harden (1991) describes it as "locally abundant in heath on low swampy sites on sandy soils." Wardell-Johnson *et al* (1997) describe this species as local and scattered in the Central Coast region, with a total range of up to 1000km.

Regional Status
The North Coast Region is in the center of the distribution of this species. Specht *et al* (1995) lists ten national parks or nature reserves in coastal New South Wales with *Eucalyptus robusta* woodland/open forest. This species is common in suitable habitat in the region.

Local Status
There are numerous records of this species throughout the locality (NP&WS Wildlife Atlas), and it was found at several locations within the study area (Gunninah 1999b). It may also be conserved in Wallaroo Nature Reserve. This species is common in suitable habitat in the locality.

7.1.20 *Hakea bakeriana*

National Status
This species is only known from the Central Coast of NSW and is not listed under the ESP Act.

State-wide Status
This species has a limited range in coastal New South Wales, from Newcastle south to the Glenorie district in the northwest of Sydney. It is not listed on the TSC Act.

Regional Status
Occurs in the Central Coast and North Coast regions. Harden (1991) describes its range as south from Newcastle to the Glenorie District. This species is considered "*uncommon*" in the mid-north coast region (Benson 1986).

Local Status
There are no records of this species on the NP&WS Wildlife Atlas (1999), however it was identified in one location within the study area (Gunninah 1999b). The study area is situated north of its published northern distributional range (Harden 1991), and little is known of its status in the locality. On the basis of available records this species is likely to be uncommon to rare in the locality.

7.1.21 Black-eyed Susan *Tetratheca juncea*

National Status
Tetratheca juncea occurs chiefly in coastal districts from Bulahdelah to Lake Macquarie. It has also been recorded from Port Jackson and Botany Bay, from which it is probably extinct (Harden 1992). This species is listed as Vulnerable in the ESP Act.

State-wide Status
This species is listed as Vulnerable in Schedule 2 of the TSC Act and has a ROTAP coding of 3VCa

Regional Status
Three semi-protected populations exist in Bulahdelah, Wallaroo and Awaba SFs, and it is patchily distributed and apparently uncommon to rare in suitable habitat.

Local Status
This species has been recorded at numerous sites in the locality (Gunninah 1997a, 1999b; NP&WS Wildlife Atlas). It is considered locally common in areas of suitable habitat.

7.2 Habitat Requirements

The Director-General requires (Appendix A):

> "*1.9 A description of the habitat requirements of threatened and significant species likely to occur in the study area must be provided. Particular attention must be paid to the following species:*
>
> *Koala Phascolarctos cinereus*
> *Squirrel Glider Petaurus norfolcensis*
> *Yellow-bellied Glider Petaurus australis*
> *Bush Stone-curlew Burhinus grallarius*
> *Green-thighed Frog Litoria brevipalmata*
> *Brush-tailed Phascogale Phascogale tapoatafa*
> *Glossy Black Cockatoo Calyptorhynchus lathami*
> *Tiger Quoll Dasyurus maculatus*"

The habitat requirements of those threatened species "*likely to occur in the study area*" as listed in Table 6.1 (and determined in Chapter 6 and Appendix F), and additional species of conservation significance (as listed in the D-G's Requirements), are discussed in detail below. Discussion of habitats includes, but is not restricted to, those species listed above in the D-G's Requirements, with the exception of the Yellow-bellied Glider which is not "*likely to occur in the study area*", based on the absence of records of this species and the absence of suitable habitats and resources in the study area (Chapter 6 & Appendix F). The habitat requirements of the '*subject species*' not considered relevant to this SIS, such as the Yellow-bellied Glider, are considered in Appendix F.

7.2.1 Koala

The Koala is an arboreal marsupial which lives within Eucalypt forests and woodlands along almost the entire eastern seaboard of Australia, although its distribution is patchy and extremely local (Phillips 1990). The National Koala Survey during 1995-1997 reported that Koalas in NSW are found predominantly in the northeast, with large yet patchy populations around Port Stephens, Coffs Harbour, the Queensland border and Coonabarabran (Gilmore & Parnaby 1994; NP&WS 1999). In the northeast, Koalas prefer regions of higher rainfall, gentle topographic relief and deep soils suitable to support food trees, such conditions being found along river banks or alluvial plains. The cooler, drier regions on the tablelands or the rugged gorge country are not believed to be favourable terrain for the Koala.

The Koala is found on both sides of the Great Dividing Range and is almost entirely dependent on a few species of Eucalypt leaves for food and shelter, however the specific species requirements may vary across its range. To the west of the ranges, the primary food

is *Eucalyptus camaldulensis* (River Red Gum) but along the east coast *E viminalis* (Manna Gum) is favoured. *E ovata* (Swamp Gum) and *E globulus* (Blue Gum) are preferred in the south, and *E camaldulensis*, *E tereticornis* (Red Gums), *E microcorys* (Tallow-wood) and *E robustus* (Grey Gum) in the north (Martin & Handasyde 1995). Koalas are also known to eat other non-eucalypt species (Phillips 1990).

The Koala rests by day for up to 20 hours in the fork of a tree, making no nest. It moves by night along branches in the canopy or along the ground when there is no over-lapping canopy available. Koalas are solitary and territorial, having a home range of between 3 and 30 hectares (Phillips 1990). Young males under 2 years of age will move many kilometres from their natal ranges, and in the process expose themselves to risks such as predation by introduced mammals or road mortality (Smith 1987).

7.2.2 Squirrel Glider

The Squirrel Glider is a small arboreal marsupial, which inhabits dry sclerophyll forest and woodland, including Box-Ironbark, Blackbutt-Bloodwood, Grey Gum-Grey Ironbark-Spotted Gum and River Red Gum communities (Suckling 1995; Maxwell 1996). It is also known to inhabit tall coastal forest and banksia woodland in the northeast of its distribution (Maxwell 1996).

This species feeds on nectar and pollen, acacia gum, the sap of some eucalypts, seeds of the Golden Wattle and insects (Suckling 1995) and generally occurs in vegetation communities which include "*gum-barked and high nectar producing species*" (Menkhorst 1995). It is dependent on the presence of medium size tree-hollows for shelter and nesting, and a number of individuals comprising a family group generally share a single hollow.

The Squirrel Glider can glide for up to 50m in one movement (Gilmore & Parnaby 1994). Maximum nightly movements of this species between foraging and den sites are reported as 500m (Quin 1995) and 1km (Menkhorst 1995), and it has a relatively limited home range of between 20 and 30ha (Gilmore & Parnaby 1994).

7.2.3 Long-nosed Potoroo

The Long-nosed Potoroo is a nocturnal species, which occurs in a range of habitats, including wet sclerophyll forests and woodlands, rainforest, coastal heath and scrub and wet heath. This species generally requires a dense understorey and/or groundcover stratum composed of grasses, ferns, graminoids or shrubs, where individuals generally remain under cover rarely venturing out into open areas. For this reason it is mainly found in areas of high rainfall, >760mm/year (Johnston 1995), along the eastern coast of Australia, including Tasmania, where it is relatively widespread. In NSW, it is most common in the far northeast near the Queensland border, and west of Port Macquarie, both regions supporting high rainfall and dense understorey. Whilst there are no known specific floristic requirements for the Long-nosed Potoroo, it does appear to utilise vegetation mosaics where contrasting microhabitats are found (Bennett 1993), including the availability of fungi and other food sources within suitable habitat. Furthermore, there is evidence that the species also requires suitable habitat over a range of topographic locations (Claridge *et al* 1993), occurring from sea level up to 1500m (Gilmore & Parnaby 1994).

The Long-nosed Potoroo primarily feeds on fungi and seeds, although its diet varies seasonally, with invertebrates, fruits, roots and leaves forming a dietary component when readily available. It rarely ventures far from its daytime vegetation cover (Johnston 1995), emerging to feed about an hour before dusk (Mason 1992). The Long-nosed Potoroo nests in a shallow depression lined with leaves and bark under a dense cover of vegetation. Individuals are predominantly solitary (Croft 1989), commonly with a home-range of 5 to 10 hectares.

In northeast NSW, (as defined from Port Stephens to the Queensland border), Long-nosed Potoroos are predicted to be found in most coastal and tableland regions, although only scattered populations have actually been recorded (Gilmore & Parnaby 1994). Landscapes supporting mesic forests offer potential dense understorey growth suitable for the Long-

nosed Potoroo, with cooler, drier regions unlikely to support this species. Mason (1992) found that the Long-nosed Potoroo is able to utilise narrow corridors of as little as 6m in width, and negotiate barriers such as earth culverts and roads.

7.2.4 Brush-tailed Phascogale

Most commonly found in dry sclerophyll forests and woodlands, this species is also known to inhabit more mesic environments including temperate rainforest and areas of higher elevation on the foothills of the ranges, up to 1500m in subtropical latitudes. This species is also known to exist in semi-urban regions, on farmlands and along roadsides with remnant tree cover. The species prefers a canopy dominated by eucalypt species, with tussocks and forest litter the preferred ground cover (Gilmore & Parnaby 1994; NP&WS 1994a; Menkhorst 1995).

This nocturnal arboreal mammal nests in tree hollows lined with leaves or shredded bark, characterised by small entrances and spacious interiors. Feathers and fur may also be used to construct the nest. Nests may be constructed high up in the tree, or in hollow stumps left by loggers (Gilmore & Parnaby 1994; Menkhorst 1995). This species has a home-range of between 35 and 90ha (Traill & Coates 1993, cited by Williams & Woinarski 1997).

The Brush-tailed Phascogale preys upon insects, spiders, centipedes and small vertebrates, which are extracted from behind bark or from under ground litter. Scavenging for vertebrates may also contribute to its diet, and nectar appears a prized yet rare food source (Scarff *et al* 1998). The southern subspecies is found throughout the coastal parts of southeastern Australia from Rockhampton, south through coastal and adjacent inland NSW, and throughout Victoria. It is thought to be extinct in South Australia, but is known to occur in far southwest Western Australia.

7.2.5 Tiger Quoll

Also known as the Spotted-tailed Quoll or Spot-tailed Quoll, this carnivorous marsupial inhabits a wide range of forests including rainforest, wet eucalypt forests and River Red Gum forests. Its habitat appears to be restricted by the 600mm isohyet, although individuals have been found in drier inland areas along the Murray River and in the rainshadow area of the upper Snowy River (Menkhorst 1995). It prefers cool, moderately rugged regions with high rainfall such as the foothills of the Great Dividing Range in Northern NSW, which are a national stronghold for the species.

The Tiger Quoll is mainly terrestrial but is an adept climber (Gilmour & Parnaby 1994; Menkhorst 1995). It rests in rock crevices or in hollow trees or logs during the day and forages for birds, carrion, arthropods and small to medium-sized ground and arboreal mammals by night. Native prey species include Brushtail and Ringtail Possums, echidnas, wombats, birds and reptiles. Introduced prey species include rabbits and chickens (Belcher 1995), and the Tiger Quoll is also known to scavenge upon cattle and sheep carcasses.

Its distribution ranges from south-east Queensland through to Victoria, and it is most abundant in Tasmania. It is most likely extinct in South Australia, and a subspecies of *D maculatus* exists in far north Queensland. In NSW, Tiger Quolls are found on both sides of the Great Dividing Range, but are rare on the warm coastal plains. Massive habitat destruction has left the distribution patchy and disjunct and removal of vegetation corridors has isolated populations (Mansergh 1983; NP&WS 1994a).

7.2.6 Greater Broad-nosed Bat

The Greater Broad-nosed Bat is primarily distributed along the Great Dividing Range from Victoria to Queensland, but also inhabits coastal environments (Hoye & Richards 1995). Whilst this species occurs in a range of habitats from open woodland to rainforest, it prefers the less dense nature of open forest and woodland communities, which pose fewer obstacles to flight (Hoye & Richards 1995). In more dense vegetation, natural or artificial clearings (such as creeklines, tracks and other cleared areas) are utilised. Milder regions are

preferred, and thus the species does not occur at high altitudes, inhabiting primarily Eucalypt woodlands and open forests communities (Gilmore & Parnaby 1994).

This species gleans insects as it flies within and above the tree canopy (Hoye & Richards 1995), and is also thought to prey on other bats (Woodside & Long 1984). The Greater Broad-nosed Bat roosts in tree-hollows, but may also utilise man-made structures (Hoye & Richards 1995; Gilmore & Parnaby 1994).

The northeast forest region (as defined from Port Stephens to the Queensland border) is considered to be the stronghold of the species' distribution in Australia (Gilmore & Parnaby 1994).

7.2.7 Little Bent-wing Bat

The Little Bent-wing Bat occurs in a range of forest communities, from dry sclerophyll woodland to rainforest, and dense Paperbark closed forest (Dwyer 1995). This species is distributed from Cape York to the NSW central coast (Dwyer 1995), with the study area located near its southern distributional limit.

The Little Bent-wing Bat roosts and breeds in caves, as well as artificial features, such as mine shafts and adits, tunnels, culverts and buildings (Dwyer 1995). This species depends on specific 'nursery' sites, which are used annually. These sites must be warm and high in humidity to ensure that the young are maintained in a warm and constant temperature, and are often found in close proximity to large areas of vegetation. Consequently, in the southern parts of its range, the Little Bent-wing Bat often shares 'nursery' sites with the Common Bent-wing Bat (Dwyer 1995) which appears to be better able to produce and maintain such high temperatures.

The most southerly 'nursery' site for the Little Bent-wing Bat was thought to be in the Macleay River catchment (Dwyer 1995), between approximately Kempsey and Armidale. However, recent investigations of a mine shaft near Lake Macquarie (Gunninah 1998b) have located what appeared to be a breeding colony, and a population is also known to roost in the Balickera Tunnel, south of the subject site.

7.2.8 Common Bent-wing Bat

The Common Bent-wing Bat is a wide-ranging generalist which utilises a broad range of habitats including monsoon forest, open woodland, paperbark forests, open grasslands, rainforest and wet and dry sclerophyll forest (Churchill 1998). This species has a distribution ranging in northern Australia from the Kimberley through the Top End to west of the Gulf of Carpentaria, and in eastern Australia from the Cape York Peninsula, to the south-east corner of South Australia. This species does not occur in arid areas (Churchill 1998).

The Common Bent-wing Bat is a cave-dwelling species, but also utilise comparable artificial structures such as mines and culverts (Churchill 1998). In eastern Australia populations centre on a maternity cave, that is used annually for the birth and development of young (Churchill 1998). Maternity caves are characterised by constantly high temperatures and humidities throughout the year, or shaped in such a way that the air warmed by the bats' activities is retained within the cave (Dwyer 1981). Because it roosts in colonies, destruction of caves and other suitable roosts constitutes a threatening process for the Common Bent-wing Bat.

This species forages on small airborne insects, with moths being the main food source. Foraging activities occur from within 6m of the ground in open areas to many times canopy height in forested areas (Churchill 1998).

7.2.9 Eastern Freetail Bat

The Eastern Freetail Bat inhabits dry eucalypt forests and woodlands of coastal NSW and south-east Queensland, however, little else is known of its preferred habitat. Individuals

have been found in rainforests and in wet sclerophyll forests, and this species is thought to forage for insects over water bodies as well as around and above tree canopies (Allison and Hoye 1995). The Eastern Freetail Bat roosts in tree hollows (Gilmour & Parnaby 1994).

This species distribution range extends from south-east Queensland to southern NSW, and is restricted to the coastal zone and adjacent inland forests (Allison & Hoye 1995). It has been recorded in the Clarence Valley, near Brisbane and from Sydney environments (Gilmour & Parnaby 1994).

7.2.10 Osprey

The Osprey inhabits terrestrial wetlands, coastal lands of tropical and temperate regions, littoral habitats and offshore islands. It requires large areas of clear open water for foraging, and thus is a predominantly coastal species in Australia. Habitats used include bays, estuaries, dunes, mangroves, beaches, cliffs and islands. This species does not range far out to sea, preferring sheltered coastal bays for protection and foraging (Marchant & Higgins 1993).

The Osprey is a worldwide species, occurring in both the northern and southern hemispheres. In Australia, it is found along the entire coastline, being most common along the eastern seaboard at mid latitudes (Marchant & Higgins 1993).

This species is diurnal and feeds mostly on fish, although small terrestrial vertebrates, seabirds and crustaceans are also sometimes eaten. Preferred foraging habitat includes shallow estuaries or bays containing fish (Clancy 1991).

Nests are constructed primarily in the crown of tall dead trees, or on rocky headlands or cliffs protected from predators. The breeding season is in late winter, when two or three eggs are laid. Clancy (1991) suggests that the breeding season may coincide with the migration of Sea Mullet *Mugil cephalus* from Victoria to Queensland.

7.2.11 Glossy Black Cockatoo

The Glossy Black Cockatoo inhabits eucalypt forest and woodland, feeding primarily on the fruit of Allocasuarinas, particularly *Allocasuarina torulosa* and *A littoralis* in northern NSW. The presence of large tree-hollows in tall eucalypt trees, which are used for nesting is another critical habitat requirement for this species.

This species resides mainly in dry sclerophyll forests, and avoids rainforests and other mesic environments. It is limited in its distribution by the availability of its food source and temperature range, preferring warm, dry forests. It has, however, been found at high altitude forests up to 1000m in elevation.

The Glossy Black Cockatoo has been recorded in the Clarence Valley and along the Northern Tablelands, and is predicted to reside in similarly flat, dry regions in central and northeastern NSW.

7.2.12 Bush Stone-curlew

This nocturnal bird prefers lightly timbered, open woodland with little or no understorey. It is associated with woodlands of *Casuarina*, and also found in *Eucalypt*, *Acacia* or *Epolycarpa* communities, but rarely in wetlands, rainforests or on beaches and dunes. It may be found in partly cleared farmland or at edges of rainforests and around lakes and rivers in more inland regions of Australia. It is absent from both treeless environments and dense forests (Smith 1991).

The species is widespread throughout Australia, particularly in riverine areas and to a lesser degree along the coast. In NSW its distribution has been much reduced, most commonly being recorded along the Western Slopes, and in isolated pockets between Gosford and Port Macquarie and along the Queensland border.

This species nests on the ground in short or mown grass under trees in open woodlands, often preferring areas with fallen trees. It is primarily territorial, particularly when breeding, and only local movements have been recorded.

The Bush Stone-curlew forages for insects, molluscs, crustaceans, frogs, lizards and snakes on the ground in open woodlands, and occasionally may eat some vegetation and seeds. It is especially active on moonlit nights (Marchant & Higgins 1993).

7.2.13 Masked Owl

The Masked Owl requires a diverse range of forest habitats for survival, residing in tall or tall open forests. Preferred foraging habitat includes open forest/woodland edges often adjacent to cleared pastures, where there is thick understorey to ensure a stable supply of prey. This species prefers drier regions, and avoids the most mesic, and most arid, habitats including wet coastal plains, rainforests and the central arid zone. Roosting sites are mainly located in eucalypt forest, although are not confined to this type of vegetation (Debus & Rose 1994). Tree-hollows, rock and cliff crevices, caves and thick foliage are preferred nesting sites, with nests often located at forest edges to enable easy access to prey (Debus & Rose 1994; Gilmour & Parnaby 1994).

Prey species comprise small arboreal and terrestrial mammals, including introduced rodents and rabbits, the latter which enable the Masked Owl to persist in areas where native mammal populations have been reduced through clearing for agriculture. Common prey species include the Sugar Glider *Petaurus breviceps*, the Long-nosed Bandicoot *Parameles nasuta* and the Hastings River Mouse *Pseudomys oralis*. Faecal pellet surveys for this species have found that prey appear to be mammal species that most often inhabit forests consisting of mature trees with hollows (Debus & Rose 1994). However, its diet is not restricted to these mammals, with bird and invertebrate remains also recorded in faecal pellets (Kavanagh 1996).

Although the Masked Owl is widespread throughout NSW, its distribution is patchy (Kavanagh & Murray 1996). Debus and Rose (1994) found that, in NSW, the Masked Owl is most common along the Central and North Coast, with its distribution thinning in the south and west. It has been suggested that the Masked Owl inhabits only the coastal strip <300km inland, however, individuals have been recorded on the Nullarbor Plain and in western NSW. This species use of forest edges and partly cleared lands leads it to habitats near roads and pastures, where it is more vulnerable to potential injury or mortality through striking artificial objects (such as powerlines and vehicles).

7.2.14 Powerful Owl

The Powerful Owl inhabits a range of vegetation types including woodland, open/tall open sclerophyll forest, rainforest, dense mountain gullies and coastal forest (Simpson & Day 1993; Gilmore & Parnaby 1994). In NSW the species has most commonly been recorded in tall open and open forest (Debus & Chafer 1994), and in north-east NSW cool to moderate mean annual temperatures and low to intermediate mean annual rainfall are recorded as common habitat features (Gilmore & Parnaby 1994). Roosting sites are primarily located in stands of dense canopy vegetation such as rainforest (Debus & Chafer 1994).

The Powerful Owl feeds mainly on small to medium sized mammals especially the Greater Glider, Common Ringtail Possum and small Brushtail Possums (Debus & Chafer 1994). Insects, large birds and other mammals (including the Flying Fox) also help supplement the diet (Chafer 1992; Kavanagh 1992).

Pairs are recorded as defending large exclusive home ranges, estimated at between 400 - 1450 hectares (Schodde & Mason 1980; Davey 1993). Nesting occurs from late autumn to mid winter (Debus & Chafer 1994), with the species usually only producing two fledglings per pair per year (Debus & Chafer 1994).

7.2.15 Chestnut-rumped Heathwren

The Chestnut-rumped Heathwren is primarily found in heathland, heathy woodland and Eucalypt woodland and forest (Gilmore & Parnaby 1994). This species is known to forage on the ground, generally in thick undergrowth (Blackers *et al* 1984), for small insects and seeds (Cayley 1984). During nesting three freckled pink eggs are laid in a well-hidden nest of bark, rootlets and grasses on or near the ground (Cayley 1984).

7.2.16 Green-thighed Frog

This little known species inhabits a wide range of forest types, including riparian rainforest, wet and dry sclerophyll forest, woodland and open woodland. It prefers environments which consist of a mosaic of vegetation types with partial disturbance such as logging or regrowth (Robinson 1994; Ehmann 1997). Clayish soils with abundant leaf and organic litter are characteristic of the Green-thighed Frog's habitat. Submerged and emerging herbs and grasses are required in shallow still-standing breeding ponds, most of which are temporary pools such as waterholes in creeks, oxbows, depressions and artificial dams (Ehmann 1997). Its breeding activity is most active after prolonged summer rains.

This species occurs from Gosford on the NSW central coast, north to Jimna in Queensland. It is found mainly at lower elevation sites, although is known to inhabit upland regions on the NSW/Queensland border. It is most abundant in four broad localities: Jimna-Crows Nest NP in Queensland, and the Border Ranges, Wauchope and Ourimbah-Creek SF in NSW, where it has most frequently been recorded (Gilmore & Parnaby 1994; Ehmann 1997).

7.2.17 Christmas Bells

Little is known of this species which is not listed as threatened by State of Federal governments. It is reported as occurring in damp habitats such as heath or swampy margins, on moist sand or peat soils (Harden 1993), and flowers around December - January (Fairley & Moore 1995).

7.2.18 *Eucalyptus fergusonii*

Eucalyptus fergusonii is known to occur in wet sclerophyll or woodland and tall open forest on sandy soils (Harden 1991). It has been recorded in vegetation dominated by *E globoidea*, *E microcorys*, *E propinqua* and *Corymbia maculata* (ERM 1999).

7.2.19 Swamp Mahogany

Swamp Mahogany is a coastal species found in heath or forests on low swampy sites on sandy soils rich in organic matter (Harden 1991; NP&WS 1994b). This species prefers swamps and estuaries and is one of the few eucalypts that can tolerate salinity (Keith 1997) and heavy clay (Cremer 1990). This tolerance, coupled with its value as a windbreak and shade tree, makes it a popular recommendation for farmers. In swamp sclerophyll forests and woodlands the species is dominant along drainage lines and depressions, preferring the wet coastal plains along the eastern seaboard to drier more inland environments.

7.2.20 *Hakea bakeriana*

Hakea bakeriana occurs in coastal dry sclerophyll forests, scrub and open forest in sandy soils from Newcastle to Glenorie (Harden 1991), flowering from around May to July (Fairley & Moore 1995).

7.2.21 *Tetratheca juncea*

The habitat requirements of *Tetratheca juncea* have been collated from information gathered during a range of different targeted surveys and general flora investigations,

primarily in the Lake Macquarie area, which has been identified as a stronghold for this species (Payne *in press*).

Vegetation Associations

In general, *Tetratheca juncea* is recorded in vegetation communities that support diverse and well developed understorey and groundcover layers. Previous studies have concluded that this species occurs only in more open woodland communities with less competing vegetation (BHP 1994). In contrast, this investigation located *Tetratheca juncea* in a range of habitats, from open woodland in ridgetop locations with sparse groundcover and understorey layers, to more dense communities on lower slopes with a dense and diverse understorey. However, *Tetratheca juncea* was absent where groundcover consisted of dense, monotypic stands of Kangaroo Grass *Themeda australis*, which often indicates intensive disturbance.

During recent investigations near Lake Macquarie (Gunninah 1998b), fifty quadrats were investigated for the presence of *Tetratheca juncea*. All of the quadrats in which this species was recorded were characterised by the presence of Smooth-barked Apple *Angophora costata* and Red Bloodwood *Corymbia gummifera* as dominant overstorey species. Broad-leaved White Mahogany *E umbra* and Brown Stringybark *E capitellata* were also common species in sites where *Tetratheca juncea* was located, with the former present in all but three and the latter in all but six of the fifty sites. A number of additional overstorey species were found to occur occasionally, including Sydney Peppermint *E piperita* (seven quadrats), Grey Gum *E punctata* and White Stringybark *E globoidea* (two quadrats), and Scribbly Gum *E sclerophylla* and Red Mahogany *E resinifera* (one quadrat).

Common understorey associates were found to include Matchheads *Comesperma ericinum*, Hair-pin Banksia *Banksia spinulosa* var *collina* and *Banksia spinulosa* var *spinulosa*, Rice Flower *Pimelea linifolia* ssp *linifolia*, Myrtle Wattle *Acacia myrtifolia*, Bush Pea *Pultenaea palacea*, Mountain Devil *Lambertia formosa*, Coral Heath *Epacris pulchella* and Grass Tree *Xanthorrhoea* species.

Common groundcover species included *Entolasia stricta*, Fish Bones *Lomandra obliqua*, *Dampiera stricta* and Kangaroo Grass *Themeda australis* (except where this species forms dense stands).

In his studies throughout the Lake Macquarie region, Payne (1993, *in press*) found that *Tetratheca juncea* is primarily located in *Angophora costata* complexes:

Swansea	*Angophora costata-Eucalyptus haemastoma* forest;
Bulahdelah	*A costata-E haemastoma* woodland;
Lake Macquarie	*E haemastoma-Corymbia gummifera-A costata*
woodland	and forest;
Green Point	*Corymbia maculata - E paniculata* Forest;
Munmorah	*A costata - Corymbia gummifera - E capitellata - Allocasuarina littoralis +/- E haemastoma* forest; and
Catherine Hill Bay	*E botryoides - A* spp - *Allocasuarina torulosa* forest.

These findings are consistent with other locations in which *Tetratheca juncea* has been located. In the Kotara area, on the eastern side of Lake Macquarie, *Tetratheca juncea* was recorded in woodland dominated by Scribbly Gum *Eucalyptus haemastoma*, *Angophora costata* and *Corymbia gummifera*, with a well developed understorey and groundcover (Bartrim & Martin 1986).

Winning (1992) located *Tetratheca juncea* in dry open forest or woodland throughout the Lake Macquarie area. Dominant overstorey species included *Angophora costata*, *Corymbia gummifera*, *Eucalyptus piperita*, *E haemastoma* and Black She-oak *Allocasuarina littoralis*. Dominant understorey species included *Acacia myrtifolia*, Sydney Golden Wattle *A longifolia*, *Banksia spinulosa*, *Daviesia ulicifolia*, Heathy Parrot Pea *Dillwynia retorta*, Common Hop Bush *Dodonaea triquetra*, *Lambertia formosa*, Lemon-scented Tea-tree *Leptospermum polygalifolium* and Bush Pea *Pultenaea villosa*. Groundcover commonly consisted of *Themeda australis*, *Chionochloa pallida*, Blady Grass *Imperata cylindrica* and *Entolasia stricta*.

Studies of the population of *Tetratheca juncea* at Jewells Wetland (Travers Morgan 1992) and at Catherine Hill Bay (Gunninah 1997e), both on the eastern side of Lake Macquarie located *Tetratheca juncea* in vegetation communities supporting a similar suite of native species as those listed above.

Fire Regime

Tetratheca juncea appears to be generally absent in areas that have been subjected to recent fire (*ie* within a year). Several studies have observed that frequent fires (*ie* with intervals of one or two years) substantially reduce populations, and are likely to cause local extinction in the long term (Payne 1993, *in press*; Binns 1996). Frequently burnt areas often support dense stands of regenerating grasses, particularly Kangaroo Grass *Themeda australis*, which appear to compete with *Tetratheca juncea*, inhibiting the germination or reshooting of this species. Furthermore, in areas where the secondary canopy is reduced or absent as a result of overly frequent or intense burning, *Tetratheca juncea* is commonly absent.

A number of investigations have concluded that *Tetratheca juncea* does recover following fire (*eg* Payne 1993), but mechanisms of this recovery were previously unknown. Payne (1993) observed that *Tetratheca juncea* appears to require twelve months following a fire to germinate. A detailed investigation has now been conducted regarding the response of *Tetratheca juncea* to fire (BHP 1994).

From detailed studies of mechanisms of recovery after fire, BHP (1994) concluded that *Tetratheca juncea* recovers in three different ways, depending on the intensity of the fire:

- regeneration from rootstock, if the whole plant is destroyed in a very hot fire;
- regeneration from original plant where some plant remains intact; and
- regeneration from seed.

Whilst regeneration from the original plant leads to flowering in the following season, regrowth from rootstock or seed requires two years following fire before flowering (BHP 1994).

On the basis of the above information, *Tetratheca juncea* appears to recover well following moderate intensity, relatively infrequent fires. However, high intensity or overly frequent fires in any one area are likely to lead to the local extinction of this species. Furthermore, it is highly likely that *Tetratheca juncea* will recover rapidly from wildfire (Gunninah 1998b).

Aspect

Of the sites in which *Tetratheca juncea* was located during investigations near Lake Macquarie (Gunninah 1998b), the following patterns were observed regarding the aspect of the sites:

- 31% on southwesterly aspect;
- 27% on southerly aspect;
- 19% on southeasterly aspect; and
- 23% on north, northeasterly or northwesterly aspect.

In summary, 77% of the quadrats in which *Tetratheca juncea* were located were on a southerly aspect, with only 23% on a northerly aspect.

During other investigations, *Tetratheca juncea* has been most commonly located on south-facing slopes, and is generally absent or less common on north-facing slopes, except in more sheltered locations. *Tetratheca juncea* is also largely absent from deep gullies or creek flats, which may be a response to moisture, soil type or dense riparian vegetation out-competing this species.

Disturbance

Tetratheca juncea is absent from areas which have been subjected to extensive disturbance, such as clearing, terrain modification and construction, or areas dominated by colonising species, such as dense stands of Kangaroo Grass *Themeda australis*. It is also absent from areas characterised by frequent fires, as detailed above.

Geology
Tetratheca juncea is found primarily on pH neutral soils (*ie* pH 7), which are generally derived from conglomerates or clays (BHP 1994).

Pollination
There are no data regarding the pollination of *T juncea*, but Payne (*in press*) has hypothesised that this species is pollinated by a native carpenter bee (or bees). Payne has further surmised that the presence of grass-trees and some banksias may be important in the life-cycle of the bees, and their occurrence in the vicinity of stands of *T juncea* may be significant in the reproduction of this plant species.

Few of the known populations of *T juncea* display evidence of seed-set, and populations with seed are therefore regarded as particularly significant. The populations along the Karuah Upgrade alignment were not recorded with seed.

7.3 Threatening Processes

The only relevant "*key threatening process*" listed in the TSC Act, for some species at least (particularly the small to medium-sized mammals and reptiles), is predation by the European Red Fox *Vulpes vulpes*. There are, however, a range of activities which pose threats to the long-term survival of the threatened species of relevance to the proposed upgrade of the Pacific Highway at Karuah. In general, land clearing for agricultural and urban development is a significant threatening process for the majority of the threatened species recorded in the study area, particularly as many of the species occur in small numbers, are frequently located on private property, and are poorly represented in conservation reserves.

7.3.1 Koala

The three main threatening processes influencing Koala population numbers are:

- destruction of habitat;
- death through road kills and predation by introduced mammals; and
- death through disease.

Habitat destruction is seen as the key threatening process to the survival of the Koala in northeastern NSW (Gilmore & Parnaby 1994). The Koala is particularly vulnerable to habitat destruction due to the nature of its diet and the dependence on specific trees for protection. A number of factors contribute to habitat destruction, including natural disasters such as cyclones and storms, bushfires and land clearing by humans. Plant diseases, understorey destruction resulting in increased foliage-eating insect numbers and exotic species infestation of Eucalypt forests also place pressure on Koala habitats. Habitat reduction can result in Koala migration, which may require the crossing of artificial barriers such as roads, railways, swimming pools and fences, exposing individuals to greater risk from introduced predators, misadventure or road mortality. Consequential deaths result from induced trauma and stress (Reed & Lunney 1990). Furthermore, habitat destruction may result in Koala accumulation and isolation in island habitats, which can result in reduced food supplies and eventually death through starvation (Phillips 1990).

A study by Canfield (1987) on mortality of Koalas on the NSW north coast concluded that 43% of the koalas surveyed had some form of organ disease, the most common being urogenital diseases. *Chlamydia psittaci*, a bacterium, is infamous for causing epidemics of conjunctivitis and urinary tract infections in Koalas. At one stage it was feared the bacterium would bring about the extinction of the Koala by the end of this century. Other diseases including pneumonia and leukemia are also key threatening processes to Koala survival (Canfield 1987). Risk of disease is greater under increased stress conditions due to high population number, reduced habitat and introduced predators.

7.3.2 Squirrel Glider

The Squirrel Glider has suffered population fragmentation and reduction in numbers throughout Australia, mainly due to habitat destruction, which continues to be a major threatening process (NP&WS 1999). Loss of genetic diversity caused by fluctuations in numbers due to natural factors such as fire, disease and predation threaten the long-term survival of some small and isolated populations (Mekhorset *et al* 1988). Its preferred habitat is open, dry woodlands in regions of high rainfall. These regions are also prime agricultural areas, and consequently have been extensively cleared over time.

This species is completely dependent on forest communities for survival, sheltering and breeding in tree-hollows and feeding on insects, tree gum, sap, nectar and pollen. The destruction of its habitat has resulted from direct removal of timber, an absence of regenerating trees due to stock grazing and foraging by rabbits and macropods, inappropriate fire regimes, outbreaks of plagues of leaf-skeletonising caterpillars and coastal development.

Unlike its smaller close relative the Sugar Glider *Petaurus breviceps*, the Squirrel Glider has been unable to adapt adequately to its changed habitat, and consequently is in greater danger of extinction. It has been found living in remnant bushland along roadside and pasture edges in Victoria, and the retention of such remnants, particularly alongside rivers and creeks, may be vital to the Squirrel Glider's survival (Suckling 1995). Predation by foxes, cats and owls is also considered a threatening process (NP&WS 1999).

7.3.3 Long-nosed Potoroo

The Long-nosed Potoroo is in the critical weight ratio mammal group (Kennedy 1992) recognised as being most vulnerable to habitat change and predation, and consequently at risk of extinction. Competition from the introduced European rabbit *Oryctolagus cuniculus* also poses problems for the survival of this species. The Long-nosed Potoroo is also particularly vulnerable to poisoning by compound 1080 (sodium monofluoroacetate) used in rabbit poison (Wells 1989)

Habitat destruction from fire and land clearing appear to be the two most important threatening processes, driving the Potoroo out of its home range and exposing it to higher risk from predation and road mortality. Being dependent on a dense understorey for protection, inappropriate fire management practices and partial clearance in wooded pastures also place pressure on suitable available habitat for this species. Since it is regarded as preferring a mosaic of vegetation types, fires that create these vegetation mosaics may actually be of benefit to this species (Mason 1992).

Predation has historically been by the dingo *Canis familiaris dingo*, and to a lesser degree the Tiger Quoll *Dasyurus maculatus*, the Carpet Python *Morelia spilotes* and the Lace Monitor *Varanus varius* (Mason 1992). Introduced predators such as the Red Fox *Vulpes vulpes* and the domestic cat *Felis cattus* are also threatening the species survival. Being nocturnal and preferring dense undergrowth, the Long-nosed Potoroo is less prone to predation by diurnal raptors than other small mammals.

7.3.4 Brush-tailed Phascogale

Loss of suitable hollow-bearing tree habitat through land clearing and fragmentation, logging, mining and inappropriate fire regimes is the most obvious and destructive threatening process for the Brush-tailed Phascogale (NP&WS 1999). Loss of available secure tree-hollows causes this species to nest in hollow tree stumps where it is more vulnerable to predation by goannas *Varanus* spp, the Red Fox and Cat. This species requires large areas (hundreds of hectares) of suitable habitat to support reproductively viable populations, and this coupled with the high rate of male death after mating increases stress on local populations. (Gilmore & Parnaby 1994; Menkhorst 1995; Maxwell *et al* 1996).

7.3.5 Tiger Quoll

Habitat destruction and modification (especially for agriculture and logging purposes), is a major threatening process to the Tiger Quoll, with a large reduction in suitable habitat through land clearance by Europeans (Mansergh 1983; Gilmore & Parnaby 1994; Edgar & Belcher 1995). Logging grazing and burning is a major threatening process, because it may reduce the availability of large hollow-bearing trees and hollow logs, which provide den sites as well as shrub habitat occupied by predators (Watt 1993; Smith *et al* 1995).

Direct competition with the fox *Vulpes vulpes* and feral cats *Felis catus* for food resources is also a threat to the Tiger Quoll. Furthermore, it has been suggested that the Tiger Quoll may be prone to Dingo, wild dog and fox baiting, and rabbit trapping, as a non-target species (Watt 1993; Edgar & Belcher 1995; Smith *et al* 1995).

7.3.6 Greater Broad-nosed Bat

The availability of suitable roosting sites is of primary importance to this species and past forestry management practices have resulted in large reductions of mature hollow-bearing trees along coastal NSW. Gilmore & Parnaby (1994) suggest that pesticide application is also a threatening process.

7.3.7 Little Bent-wing Bat

The key conservation concern for the Little Bent-wing Bat is the maintenance of undisturbed winter nursery sites, of which only five are known to exist in Australia (Dwyer 1995b). Destruction of these caves primarily as a result of limestone mining is a key threat to the species survival. Vegetation destruction, which reduces available foraging habitat and the use of pesticides, are also key threatening process for this species (Gilmore & Parnaby 1994).

A further potential threat to the Little Bent-wing Bat would be a reduction in numbers of *M schreibersii* which are required in maternity colonies to increase and stabilise temperatures (Gilmore & Parnaby 1994).

7.3.8 Common Bent-wing Bat

Major threatening processes for the Common Bent-wing Bat include inappropriate fire regimes, destruction and modification of foraging habitat, especially through adverse impacts on invertebrate food resources. Pesticides and herbicides also pose potential threats to this species, since usage may reduce the number of invertebrates available as a food resource (Gilmore & Parnaby 1994). Disturbance of roosting and maternity caves is also a major threat, especially through destruction of adjacent vegetation or alteration of hydrological regimes.

7.3.9 Eastern Freetail Bat

This species is most vulnerable to habitat destruction and modification (including both clearing for agriculture and logging purposes, and inappropriate fire regimes), especially the removal of hollow-bearing trees and loss of foraging habitat (Gilmore & Parnaby 1994). Changes to the age structure of forests and woodlands is also regarded as a key threat to its survival, through potential loss of hollow-bearing trees. The use of pesticides is also known to threaten this species (Gilmour & Parnaby 1994).

7.3.10 Osprey

Important threatening processes for the Osprey include removal or disturbance of nesting sites, reduction in the quality and quantity of food supplies, pesticide use and collisions with powerlines (Clancy 1991).

The disturbance to nesting sites is of primary importance to the Osprey as the birds often return to the same nesting site each year. Removal of tall dead trees is common practice in the agricultural regions of northeast NSW, and this is seen as a key threatening process. Osprey are known to nest successfully in artificial nesting sites in moderately disturbed areas, although breeding in highly disturbed areas has not been successful (Clancy 1991). Polluted runoff into foraging waters, disturbed wetlands and bays and overfishing by humans are threats to the Osprey's food supply, and acid rain in the northern hemisphere is also known to diminish food supplies and reduce food quality.

Osprey numbers in the northern hemisphere have been severely reduced due to the use of pesticides such as DDE and DDT. Although these chemicals are not used in Australia, the potential for similar impacts is present as other pesticides are widely used in Osprey habitats. Collisions with powerlines have also been recorded and are primarily an important threat to young Osprey (Clancy 1991).

7.3.11 Glossy Black Cockatoo

The state of the Environment Report for the Great Lakes Council (1997/98) lists five key threatening processes for the Glossy Black Cockatoo: food limitation, shortage of suitable nesting hollows, grazing without management, fragmentation and loss of habitat, and fire.

Reduction in forest area and a change in class age structure of trees have been reported as major threatening processes for the Glossy Black Cockatoo (Gilmore & Parnaby 1994). Much of this has resulted from selective logging practices, clearing for agriculture or destruction of regenerating trees through grazing. Localised harvesting of *Allocasuarina* may result in fragmentation of habitat and local extinctions. Altered fire regimes may also have reduced suitable habitat for this species and increased mortality. Competition for food resulting from decreasing supply may also increase mortality rates (Garnett 1992a).

The species requires large areas of forest supporting *Allocasuarina* species and protection from wildfires through appropriate fire management for its survival.

7.3.12 Bush Stone-curlew

The Bush Stone-curlew was once widespread throughout NSW but now its distribution is highly reduced and fragmented, particularly in southern regions (Smith 1991; Gilmore & Parnaby 1994; NP&WS 1999). Most significant is the decline in coastal and catchment regions where woodland clearance for agriculture and urbanisation has been most pronounced. Clearing of woodlands in other regions has contributed to a decline in population numbers, although the species can survive in partially cleared pastures and in vacant urban blocks, cemeteries and golf courses (Marchant & Higgins 1993). The removal of leaf litter from habitat remnants in pastoral and agricultural regions is also known to be a key threatening process (Garnett 1992b).

Other key threatening processes for this species include feral predators, overgrazing and altered fire regimes (Marchant & Higgins 1993; NP&WS 1999). Feral predators include cats, pigs and foxes, which have been blamed for the reduction in population numbers and the movement of the species from the tablelands where they were once widespread to the coastal flatlands (Gilmore & Parnaby 1994). Overgrazing of domestic stock in open woodlands causes trampling of nesting grounds and significantly decreases egg and newborn survival chances.

7.3.13 Masked Owl

Habitat destruction appears to be the key threatening process for the Masked Owl. Removal of suitable roosting sites through logging and land clearing and altered tree-age structure reduces the availability of nesting sites. Furthermore, removal of understorey and partial clearing through selective logging or pasteurisation removes the habitat of potential prey (Gilmour & Parnaby 1994). This is most evident on the tablelands, slopes and plains of inland NSW where drier open forests and woodlands have been cleared and potential prey have disappeared from local regions (Debus & Rose 1994). Such processes are less evident

along coastal NSW where habitat removal has been less extensive and small mammal populations are relatively high, and where introduced species such as rabbits and rats ensure stable prey availability. In fact, partial clearing along coastal NSW may benefit the Masked Owl, which prefers the forest/woodland edges created by partial clearing for foraging (Debus & Rose 1994).

The ecotone created where roads and powerlines traverse forested areas are favoured foraging areas for the Masked Owl, consequently exposing individuals to a higher risk of injury or mortality from striking artificial objects such as powerlines and vehicles (Debus & Rose 1994).

7.3.14 Powerful Owl

Major threatening processes to the Powerful Owl include habitat destruction and modification, through agricultural, logging practices and inappropriate fire regimes (Debus & Chafer 1994; NP&WS 1999). Ongoing clearing of productive forest on relatively flat terrain and hollow-bearing trees becoming a limiting resource, both for the species and prey is also a major threatening process (NP&WS 1994; Ayers 1995). Loss of prey species, such as arboreal marsupials (*eg* Greater Glider) and loss of suitable nesting sites through habitat destruction is considered a threat to the species (Kavanagh & Bankin 1994).

7.3.15 Chestnut-rumped Heathwren

Habitat destruction and modification, reducing the cover of heath and thus nesting and foraging sites and potentially food resources are major threatening processes to the Chestnut-rumped Heathwren (Gilmore & Parnaby 1994). Inappropriate fire regimes and fertiliser usage, may alter the floristic composition of the habitat, therefore posing a threat to the species (Gilmore & Parnaby 1994).

7.3.16 Green-thighed Frog

The Green-thighed Frog has undergone localised population declines, possibly due to altered drainage and hydrological cycles which occur as a result of forest clearing (Gilmore & Parnaby 1994; Ehmann 1997). The alteration of tree-age structures in suitable habitat forests is also recognised as a key threatening process.

The species requires clear, slow-moving or still fresh water which accumulates in ponds after heavy rains. Runoff from pastures and agricultural land containing pesticides, fertilisers and other pollutants into preferred breeding ponds makes the Green-thighed Frog vulnerable to poisoning (Gilmore & Parnaby 1994).

7.3.17 Christmas Bells

The major threats to Christmas Bells may include picking, habitat destruction and alterations to (particularly an increase in) fire regimes.

7.3.18 *Eucalyptus fergusonii*

Although little is known about this species, its limited range would suggest that it is likely to be threatened by habitat destruction, such as clearing for farmland.

7.3.19 Swamp Mahogany

Filling of lowlands for urban development is a threat to this species' habitat, especially around the Tea Gardens area.

7.3.20 *Hakea bakeriana*

Habitat destruction and inappropriate fire regimes may be expected to threaten this species.

7.3.21 *Tetratheca juncea*

Clearing of native vegetation and the subsequent removal of individuals populations and habitats, and the imposition of unsuitable fire regimes, are likely to be the most significant "*threatening process*" for populations of *Tetratheca juncea*. Destruction of populations through residential developments, as well as agricultural and industrial developments, such as quarries and landfills also constitute a threat to this species.

Of potential concern with regard to the long-term conservation of *Tetratheca juncea* is the imposition of inappropriate fire regimes. Previous investigations conducted by Gunninah (1998a, b; 1999b, c) suggest a strong correlation between excessive rates of bushfire, particularly those of high intensity, and the absence of *Tetratheca juncea* from sites which might otherwise have been considered likely to support this species.

8 ABUNDANCE of RELEVANT SPECIES or POPULATIONS

The TSC Act 1995 requires, under Section 110(2)(d), a SIS to include the following information:

> "*an estimate of the local and regional abundance of those species or populations*".

In most instances, information regarding the "*local and regional abundance*" of threatened species is extremely limited or unreliable. Generally, threatened species are present only in relatively low abundances (as may be assumed on the basis of their threatened status), although in some instances threatened species may be at least locally abundant.

8.1 Koala

Local Abundance
Koalas are locally abundant, particularly to the south and east of the proposed Highway, although numbers appear relatively low through most of the study area. Of the almost 6000 Koala records in the region over the past twenty years, 80% are located within 10km of the study area (ERM Mitchell McCotter 1999; NP&WS Wildlife Atlas). Although suitable habitat is present along the proposed Horse Island Route, it is mostly considered 'marginal' habitat (Appendix K), and Koalas appear to be at low densities in this portion of the Local Government Area (LGA) (D Fanning, M Chambers *pers obs*).

To the east of Karuah River, scat and scratch searches indicated the presence of a scattered population of Koalas, although only two Koalas were actually observed during the fauna surveys (Gunninah 1999b, c). Larger Koala numbers have been recorded to the south and southwest of the study area, particularly in forest on sandy soils between the Pacific Highway and the coast (Gunninah 1997b; Lunney *et al* 1998). Furthermore, Koalas were found to be more abundant on privately owned land rather than in the State Forests in the locality (NP&WS 1994a).

The local abundance of Koalas (in the study area) appears low, given the small numbers of individuals located during field investigations and the relatively low densities of scats and scratches on trees. Koalas appear at a greater density and abundance in forested lands to the south and southwest of the study area.

Regional Abundance
The northeast region of NSW is a Koala stronghold and supports some of the largest populations of Koalas in NSW (Callaghan *et al* 1994). Relatively high population densities and abundances of Koalas occur in the Port Macquarie, Coffs Harbour, Tweed and Grafton areas (NP&WS 1994a), as well as in some portions of the Port Stephens LGA (as noted above). In general terms, however, Koalas are not regarded as 'abundant' on a regional basis, rather being locally common in a patchy distribution throughout northeastern NSW.

8.2 Squirrel Glider

Local Abundance
Two Squirrel Gliders were recorded during the fauna surveys in the study area, both within Karuah NR to the north of the Mines Hill Trail (Gunninah 1999b; Figure 5.1). Several sightings have also been obtained since 1993 within 10km of the study area, the closest being a sighting in 1993 near Scobies Hill, south of Karuah (NP&WS Wildlife Atlas). To the west, sightings have been recorded near Ringwood Flat (Gunninah 1997b; NP&WS Wildlife Atlas), where greater numbers of hollow-bearing trees exist. The Squirrel Glider has not been recorded to the east of Karuah River, although there is suitable habitat present (Gunninah 1999b).

The small numbers of Squirrel Gliders recorded during field investigations in the study area (which were conducted over a considerable period) suggests a relatively low abundance of this species in the "*locality*". As is the case with the Koala, Squirrel Gliders appear to be more abundant in forest on sandy substrates to the south and southwest of the study area

(Gunninah 1995, 1997b). The abundance of this species in the "*locality*" appears to be relatively low.

Regional Abundance
As with the Koala, the Squirrel Glider appears to be locally common to abundant in a patchy distribution throughout its range in eastern NSW. Elsewhere, the species is uncommon to rare and occurs at low densities.

8.3 Long-nosed Potoroo

Local Abundance
There are only three records of the species from the locality;

- one identified during fauna surveys for the extension of the Karuah Hardrock Quarry, located approximately 4.5km northwest of Karuah (Gunninah 1999a);
- second from the fauna surveys conducted for this SIS (Gunninah 1999c); and
- a third from fauna surveys conducted for the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999).

No other records are known from the area (NP&WS Wildlife Atlas), and predicted distribution maps (NP&WS 1994a; Appendix K) rate the probability of occurrence of the Long-nosed Potoroo in the study area as low (NP&WS).

The Long-nosed Potoroo is present at only very low densities or abundance levels in the "*locality*". There are only few records of individuals of this species in the "*locality*" or study area, and the abundance on a local basis of the Long-nosed Potoroo around Karuah is regarded as extremely low.

Regional Abundance
Throughout most of coastal NSW and other portions of its distributional range, the Long-nosed Potoroo appears to be present only at relatively low levels of abundance. In most locations, only relatively few individuals have been recorded, although the species is more abundant in a patchy distribution in the northern part of northeastern NSW.

In regional terms, the abundance of the Long-nosed Potoroo is regarded as low and patchy, with only localised areas of relatively high abundance.

8.4 Brush-tailed Phascogale

Local Abundance
The Brush-tail Phascogale appears uncommon to rare in the study area, given the absence of records of this species despite extensive trapping surveys and spotlighting. This species appears to be locally abundant in suitable habitat to the southwest of the study area (Gunninah 1997a), and appears to be common to abundant only in localised patches within the "*locality*". The Brush-tailed Phascogale is widely recorded in the "*locality*" (NP&WS Wildlife Atlas), but there are few data on densities or abundance estimates.

Regional Abundance
Similar circumstances apply with respect to the regional abundance of the Brush-tailed Phascogale as apply to its local abundance. This species occurs widely in coastal NSW, although appears to be patchily distributed, only being common or abundant in localised areas of prime habitat.

8.5 Tiger Quoll

Local Abundance
Although no individuals were recorded in the study area during fauna investigations for this SIS (Gunninah 1997a, 1999b, c), a total of 15 records have been obtained within a 10km radius of the study area (NP&WS Wildlife Atlas). The Tiger Quoll was also recorded in the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999). Most records are in the forests to the immediate south and west of Karuah, and the NP&WS predictive models (Appendix K) indicate 'marginal' to 'intermediate' habitat in Karuah NR and Wallaroo SF.

As for many other threatened forest-dependent mammalian fauna known to occur in the "*locality*", the Tiger Quoll appears to be present general at low densities in a patchy distribution. Given the existing records from the "*locality*", it appears that the Tiger Quoll is rare (and at a low abundance level) in the "*locality*", with patches of more suitable habitat likely to support somewhat higher numbers of the species.

Regional Abundance
There are few data indicating the abundance of the Tiger Quoll throughout its distributional range, or within the "*region*". This species occurs more frequently in the tablelands and higher elevation forest of the NSW North Coast region (NP&WS 1994a) and its 'regional abundance' would appear to be most accurately described as locally common in a patchy distribution throughout more elevated forests within the region.

8.6 Greater Broad-nosed Bat

Local Abundance
The Greater Broad-nosed Bat was identified on two separate Anabat recordings (as "*possible*" and "*probable*"), during surveys for the *Flora & Fauna Assessment* report (Gunninah 1999b) and this SIS (Gunninah 1999c) respectively. It has also been recorded at several locations in the "*locality*" and in Wallaroo SF (NP&WS Wildlife Atlas). Further records exist from the southern end of Grahamstown Storage Dam to the south of the study area, and near Port Stephens (NP&WS Wildlife Atlas).

There are insufficient data to assess the local abundance of the Greater Broad-nosed Bat, as detailed population studies have not been conducted in the "*locality*". However, this species is regularly recorded in the Port Stephens area, and may be regarded as moderately common in this "*locality*".

Regional Abundance
As is the case in terms of local abundance, there are insufficient data to determine the regional abundance of the Greater Broad-nosed Bat. This species is relatively frequently recorded during microchiropteran bat surveys, and is regarded as likely to be relatively uncommon to moderately common over its distributional range, with a relatively even abundance in suitable habitat.

8.7 Little Bent-wing Bat

Local Abundance
The Little Bent-wing Bat was identified from three separate Anabat recordings in the fauna survey for this SIS (Gunninah 1999c), and has been frequently recorded in previous fauna surveys undertaken in the locality (Ecotone 1995; Gunninah 1997a, b, c, 1999b). It is generally found in warmer microclimatic areas at the latitude of the study area, and approximately 100 individuals have been recorded within 10km, including a population of 70 individuals in the Balickera Tunnel on the eastern edge of Grahamstown Storage Reservoir (NP&WS Wildlife Atlas). A population of approximately 500 individuals was also recorded at Yacaaba Head near Port Stephens in 1994 (NP&WS Wildlife Atlas), and investigations of a mine shaft near Lake Macquarie located what appear to be a breeding colony (Gunninah 1998b).

The Little Bent-wing Bat is regularly recorded in microchiropteran bat surveys, particularly in more northerly parts of its distribution, although it is also regularly recorded in the Port Stephens area. In terms of local abundance, this species would generally appear to be relatively common, being more abundant near areas supporting suitable roosting and maternity caves.

Regional Abundance
A large known maternity colony of some 4500 adults exists in a roosting/nursery cave near Kempsey at Willi Willi (Gilmore & Parnaby 1994). The Little Bent-wing Bat appears to be most abundant in the Kempsey area (near the known maternity cave at Willi Willi caves) and in the northern portions of the "*region*". In terms of regional abundance, the Little Bent-wing Bat may be regarded as locally abundant in ares of suitable habitat, particularly around concentrations of maternity and roosting caves. Elsewhere, this species appears to be relatively uncommon or sparse in density.

8.8 Common Bent-wing Bat

Local Abundance
The Common Bent-wing Bat was identified on three separate Anabat recordings during surveys for the *Flora & Fauna Constraints* report (Gunninah 1997a), and on three separate Anabat recordings during surveys for the SIS (Gunninah 1999c). No other records of the species exist for the locality (NP&WS Wildlife Atlas), although the Common Bent-wing Bat is regularly recorded in the "*locality*", and individuals roost in the Balickera Tunnel.

As for the Little Bent-wing Bat, there are few data to provide an accurate assessment of local abundance of this species. However, the Common Bent-wing Bat is regularly recorded during investigation for microchiropteran bat and other fauna, and this species is generally regarded as common to abundant throughout its distributional range. It is considered likely to be common within the study area and "*locality*".

Regional Abundance
As noted above, the Common Bent-wing Bat is regularly recorded during microchiropteran bat surveys in the region and is considered likely to be common to abundant throughout much of its range in northeastern NSW.

8.9 Eastern Freetail Bat

Local Abundance
This rare and little known species was identified on three separate Anabat recordings during surveys for the *Flora & Fauna Constraints* report (1997a), the *Flora & Fauna Assessment* (Gunninah 1999b) and the SIS (Gunninah 1999c). Previously, a "*possible*" identification of the species was made from calls recorded during a fauna study conducted for the *Proposed Upgrade of the Pacific Highway from Raymond Terrace to Karuah* (Gunninah 1997b). No other records of the species exist for the locality (NP&WS Wildlife Atlas).

There are insufficient data to determine the local abundance of the Eastern Freetail Bat, although the species is apparently infrequently recorded and is likely to be present only at low densities. The local abundance of the Eastern Freetail Bat is regarded as low.

Regional Abundance
Similar considerations apply on a regional basis, with insufficient data being available to determine the regional abundance of the species. However, the Eastern Freetail Bat is infrequently recorded during microchiropteran bat surveys, and is likely to be present within the region in a patchy distribution, being locally common but generally uncommon or at low densities or abundance.

8.10 Osprey

Local Abundance
Ospreys have been recorded both north and south of Karuah, with an individual observed flying over the Karuah River (Gunninah 1999b). Four previous records of this species exist within 10km of the study area (NP&WS Wildlife Atlas), and the species is generally uncommon in the "*locality*". Given its habits and distribution, the Osprey is regarded as uncommon, although not at a low level of abundance relative to other areas of suitable habitat.

Regional Abundance
This species has been frequently recorded in the region. At least sixteen birds have been recorded to the southwest near Newcastle (NP&WS Wildlife Atlas), including a nesting pair in 1995 (Morris & Burton 1997). Numerous nesting sites have been recorded in the Port Macquarie district and the coastal Hunter Valley near Forster (Clancy 1991), and the species appears to be common in terms of normal levels of abundance. In regional terms, the Osprey may be regarded as common in appropriate habitat.

8.11 Glossy Black Cockatoo

Local Abundance
Prior to 1989, only one individual had been identified in the locality, to the west of the study area (NP&WS Wildlife Atlas). However over the past ten years at least twelve birds have been observed all year round in the locality, particularly in Wallaroo SF ("*substantial*" numbers in 1995; over ten recorded in 1997 (HBOC 1997). During fauna surveys for this SIS, Glossy Black Cockatoos were identified at four separate locations from the crushed cones of *Allocasuarina* spp (although no individuals were sighted and numbers cannot be determined), and this species was recorded for the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999).

Given the frequency with which the Glossy Black Cockatoo was recorded in the "*locality*", it appears that this species is moderately common in the vicinity of the Karuah Upgrade of the Pacific Highway and generally in the Port Stephens LGA. The Glossy Black Cockatoo is likely to be patchily distributed, however, given the levels of disturbance to forested lands in the "*locality*". It should therefore be regarded as locally common in a patchy distribution in the "*locality*".

Regional Abundance
The Glossy Black Cockatoo is widely distributed throughout coastal and northeastern NSW (NP&WS 1994a), and the species appears to be relatively common (to locally abundant) in the region. Although local populations are scattered across the species' distributional range rather than being generally present at high densities (NP&WS 1994a).

8.12 Bush Stone-curlew

Local Abundance
This species is very uncommon in the region, although a number of confirmed sightings to the west of Karuah in 1995, and to the south in 1996, have been recorded, and calls were also heard south of the proposed alignment near the Karuah township (ERM Mitchell McCotter 1999; NP&WS Wildlife Atlas 1999). Records also exist from a few kilometres north of the town (1989), and a number to the east (1980). Most of the recent records indicate that the species is rare in the "*locality*", yet breeding does occur (HBOC 1998 Records).

Despite the number of records in the "*locality*" around Karuah, the Bush Stone-curlew is rare or uncommon, and is regarded as at a low abundance level (particularly compared with the numbers recorded in the Northern Territory and other more northernly parts of its distributional range). Conversely, compared to other areas of its range within NSW, the population in the "*locality*" around Karuah would appear to be moderately common.

Regional Abundance
A breeding female has been present near Kempsey for almost twenty years, and sightings in the lower Clarence Valley, lower Hunter Valley and the Central Coast indicate that the species is regionally rare and patchily distributed (NP&WS Wildlife Atlas). Similar considerations apply at a regional basis to those pertaining at the local level for the Bush Stone-curlew. This species appears to be patchily distributed and generally rare to uncommon, with only small areas of relatively higher abundance of the species.

8.13 Masked Owl

Local Abundance
An individual Masked Owl was identified and a nest tree confirmed during the fauna surveys conducted for the proposed route (Gunninah 1999c). The species was also recorded in the locality during previous studies near Ringwood Road south of Karuah, east of Balickera Canal (Gunninah 1997a) and for the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999). Individuals have historically been recorded within a 10km radius of Karuah (NP&WS Wildlife Atlas), and the species is known to have a home range of between 500-1000h. Therefore, given the habitat requirements and home ranges of the Masked Owl, this species is regarded as uncommon in the "*locality*", although that circumstance is probably normal.

Regional Abundance
Although nationally its abundance has been described as sparse to uncommon (Lindsey 1992), individuals have frequently been recorded throughout the Newcastle area, with as many as fifteen birds known to inhabit bushland near Newcastle, Raymond Terrace and Lake Macquarie (Kavanagh & Murray 1996). Surveys undertaken during the NEFBS (NP&WS 1994b) found individuals throughout the region, particularly in inland forests on the foothills of the ranges, and Kavanagh *et al* (1995) recorded thirty-five individuals in twenty state forests and one national park in northeastern NSW.

8.14 Powerful Owl

Local Abundance
Although the Powerful Owl was not identified during fauna surveys for this SIS, there are four records of the species in the locality (NP&WS Wildlife Atlas). The Powerful Owl is likely to be present at a relatively low abundance level within the "*locality*", although that circumstance is normal for this species given its large home range and its habitat requirements. In the absence of specific records in the "*locality*", it is difficult to determine the local abundance of the Powerful Owl.

Regional Abundance
The Powerful Owl is frequently recorded in the forests of northeastern NSW (Debus & Chafer 1994), indicating that "*the Powerful Owl is more numerous, flexible and resilient, with a wider habitat, altitudinal and dietary tolerance, than formerly believed*". In regional terms, the Powerful Owl may be described as uncommon, although that circumstance relates in large measure to its home range and habitat requirements, rather than to concerns with the species conservation.

8.15 Chestnut-rumped Heathwren

Local Abundance
A single Chestnut-rumped Heathwren was observed in the study area during fauna surveys conducted for this SIS (Gunninah 1999c). Only one other record of the species exists for the locality (within 10km of the study area), recorded 10km south of the proposed route alignment (NP&WS Wildlife Atlas). Given the records of this species in the "*locality*", the local abundance of the Chestnut-rumped Heathwren is very low.

Regional Abundance
The Chestnut-rumped Heathwren was only recorded twice during the NEFBS investigations (NP&WS 1994a), and the species appears to be at a relatively low abundance in the region. In addition, the Chestnut-rumped Heathwren appears to be patchily distributed in relatively small areas of suitable habitat.

8.16 Green-thighed Frog

Local Abundance
The Green-thighed Frog has been recorded in Nerong SF north of the study site (Baker *pers comm* 1998), and was recorded for the Karuah to Bulahdelah SIS (ERM Mitchell McCotter 1999). There have been no other recent sightings of the species within a 10km radius (*ie* in the "*locality*") and no sightings of the species were obtained during this study nor other recent fauna surveys in the area (Gunninah 1997a, 1999b, c; NP&WS Wildlife Atlas).

Given the absence of records of the species in the "*locality*", the Green-thighed Frog appears to be at extremely low levels of abundance and density in the vicinity of the Karuah Upgrade of the Pacific Highway.

Regional Abundance
There are few records of the Green-thighed Frog in the region, although the species has been recorded at Orimbah, near Bulahdelah and Wauchope, in the upper Clarence and Richmond catchment areas (NP&WS 1994a; Ehmann 1997). This species is regarded as sparse in abundance throughout its distributional range (Tyler 1992), and is likely also to be rare and sparse within the region.

8.17 Christmas Bells

Local Abundance
Christmas Bells were detected during flora surveys conducted for this SIS (Gunninah 1999c), but no other records of the species are contained on the NP&WS Wildlife Atlas. Local abundance is unknown, but is considered to be low given the scarcity of records in the locality.

Regional Abundance
Only four records of Christmas Bells exist for the region (NP&WS Wildlife Atlas). This species was not recorded during recent flora surveys conducted in the region (Gunninah 1997a, b, c, e, 1998a; ERM 1999), and it appears to be generally uncommon (but locally common) throughout its range in the region.

8.18 *Eucalyptus fergusonii*

Local Abundance
Eucalyptus fergusonii was recorded on a number of occasions during recent flora surveys (ERM Mitchell McCotter 1999; Gunninah 1999c), but no other records of the species are contained on the NP&WS Wildlife Atlas (1999). Local abundance of the species is unknown, but is considered to be low given the scarcity of records in the locality.

Regional Abundance
There are only three records of this species in the region listed on the NP&WS Wildlife Atlas (1999), but it has also been recorded along the proposed Karuah to Bulahdelah Pacific Highway Upgrade near the Ayers Rock Restaurant and Mount Karuah (ERM Mitchell McCotter 1999). This species is likely to be locally common in a patchy distribution within suitable habitat in the region.

8.19 Swamp Mahogany

Local Abundance
The Swamp Mahogany was recorded in five quadrats and along four random meanders within the study area for this SIS (Gunninah 1999c). Although it is not a dominant canopy species in the study area, suitable habitat is present and the species is relatively abundant in suitable habitat.

Regional Abundance
Swamp Mahogany is relatively common in the region, even though only three records of the species are on the NP&WS Wildlife Atlas (1999). Most stands of this species are relatively small and sparsely distributed (ERM Mitchell McCotter 1999; Gunninah 1999c).

8.20 *Hakea bakeriana*

Local Abundance
Hakea bakeriana was identified along one random meander survey conducted for this SIS (Gunninah 1999c). There are no other records of the species in the locality (NP&WS Wildlife Atlas), and according to Harden (1991), the locality is out of the known range of the species. This species' local abundance is expected to be very low, given the lack of records in the locality and on the basis of its unusual distributional range. There are insufficient data to provide a quantitative assessment of the regional abundance of *Hakea bakeriana*.

Regional Abundance
There are no regional records of this species on the NP&WS Wildlife Atlas (1999), and it has not been recorded in recent surveys in the region (ERM Mitchell McCotter 1999; Gunninah 1997a, b, c, d, e, 1998a; NP&WS Wildlife Atlas 1999).

8.21 *Tetratheca juncea*

Local Abundance
In the locality, *Tetratheca juncea* has been recorded frequently, including in the vicinity of the Karuah Quarry, near the Karuah Golf Course, near the Aboriginal settlement at Karuah and along the existing Highway to the east of the Karuah River (Gunninah 1999c). Furthermore, suitable habitat for this species is widely distributed throughout the locality. On the basis of the numerous known stands of this species, it is considered to be relatively abundant in the locality within areas of suitable habitat, and the species is also listed often on the NP&WS Wildlife Atlas (1999).

By comparison with other areas of habitat containing *Tetratheca juncea*, this species appears to be relatively common in the "*locality*". However, is the case elsewhere throughout its range this species appears to be patchily distributed with areas of local high abundance, rather than being generally common or abundant throughout the whole area.

Regional Abundance
There are several records of this species in the region (NP&WS Wildlife Atlas). Although relatively abundant throughout its range, *Tetratheca juncea* is restricted to the southern extremity of the North Coast region. Consequently, this species is rare and at a very low level of abundance in the region.

9 HABITAT of RELEVANT SPECIES OR POPULATIONS

The TSC Act 1995 requires, under Section 110(2)(f), that a Species Impact Statement must include the following information:

> "*a full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region.*"

At the time of preparing this SIS, no "*critical habitat*" has been listed within the TSC Act. Consequently, this aspect of Section 110(2)(f) with respect to the SIS cannot be addressed. Furthermore, the Director-General of the NP&WS has directed (Appendix A) that "*there is currently no declared critical habitat*".

The NP&WS D-G's Requirements for this SIS include:

"*1.7 Where suitable habitat is present for subject species in the study area, a description of the habitat characteristics must be provided for each subject species.*

Where the habitat of each subject species within the study area can be clearly delineated, this habitat must be represented on a map of the study area.

NPWS predicted habitat models should be used as an indication of the presence of suitable habitat for subject species in the locality".

"*1.8 The importance of the study area for all life-cycle stages of the subject species in the locality shall be identified and discussed. Particular detail is to be provided concerning the importance of the subject site for:*
Koala Phascolarctos cinereus
Squirrel Glider Petaurus norfolcensis
Yellow-bellied Glider Petaurus australis
Bush Stone-curlew Burhinus grallarius
Green-thighed Frog Litoria brevipalmata
Brush-tailed Phascogale Phascogale tapoatafa
Glossy Black Cockatoo Calyptorhynchus lathami
Tiger Quoll Dasyurus maculatus".

Section 110(2)(f) Requirements

The vegetation communities, habitats and resources present within the study area are described in detail in Chapter 4 of this SIS, and documented for all of the "*subject species*" in Appendix F. Chapter 10 also provides consideration of the "*relative significance*" of habitats and resources in the study area, and addresses the issue of land tenure and the security of resources and habitat features for affected species.

Assessment of "*the type, location, size and condition of the habitat*" for relevant species associated with the Karuah Bypass is based on a number of sources of information and considerations:

- the detailed field investigations conducted for the Karuah Bypass investigation (Chapter 3);
- other investigations in the locality - both by the authors of this SIS (Gunninah 1996, 1997b, c (and others); Ecotone 1995; ERM Mitchell McCotter 1999);
- information from other sources (*eg* State Forests EIS'), regional investigations and databases; and
- the accumulated experience and expertise of the SIS study team as a result of extensive investigations in the locality and region (Appendix M).

The flora species of relevance in the discussion of the Karuah Bypass (the "*affected species*") are characteristic of either dry sclerophyll woodland and forest communities or of slightly moister forest and woodland vegetation. The former group (*Tetratheca juncea, Hakea bakeriana, Eucalyptus fergusonii*) could occur widely through the dry sclerophyll woodland and open forest communities in the study area, although they are not likely to have a

uniform distribution through these areas of vegetation. The plant species which occur in moister sites (the Swamp Mahogany and Christmas Bells) are likely to be more restricted in their distributions within these forest communities, being located primarily in moister sites along drainage lines and in low-lying areas.

The fauna species of relevance generally occupy either forest and woodland vegetation or (in the case of the Osprey) wetland and riverine habitats. The overwhelming majority of fauna species of relevance occur in the forest and woodland communities, with a significant number being dependent upon hollow-bearing trees to provide shelter and roosting or nesting sites.

Specific issues and matters of relevance in considering the relevant habitat of those "*affected species*" in the locality include:

- type - most species of relevance occupy a range of vegetation associations and communities, and the relevant "*type*" of habitat is described in relatively broad terms (*eg* the Koala or Squirrel Glider could utilise most, or all, of the forest and woodland vegetation in the study area). Details of the vegetation communities, particularly within the woodland and forest portions of the study area are provided in Chapter 4 of this SIS, and provide relevant details regarding the floristic and structural nature of the various vegetation communities (at this point in time), which may be of relevance to some of the native fauna of the locality;
- location - the detailed vegetation community map prepared for the SIS (Figures 4.1a, 4.1b) and the aerial photograph of the study area (Figure 2.1) provide details of the location of vegetation communities and habitats along the alignment and in the study area and locality;
- size - assessment of the "*size .. of the habitat*" of "*affected species*" can not readily be quantified. In the first instance, it is unclear to what overall area the "*size*" refers (whether the study area, locality, sub-region or region). Furthermore, without considerable further survey effort, it is possible to indicate no more than potential habitat for "*affected species*" in the locality. Notwithstanding information available from other reports and investigations, and the experience and expertise of the study team, any assessment of the "*size .. of the habitat*" for "*affected species*" must be only an estimation; and
- condition - similar considerations apply to "*condition of the habitat*" as apply to size. Without inspection of all of the potential habitat in the study area, locality or region, it is possible only to provide a general assessment of the "*condition of the habitat*" for the "*affected species*".

As noted above, it is in most instances not possible to quantify the "*type, location, size and condition of the habitat*" for the "*affected species*" of relevance to the Karuah Bypass. Reference to the vegetation mapping for the project (Figures 4.1a, 4.1b), the aerial photograph of the study area and locality (Figure 2.1), the predicted mapping of the NP&WS (Appendix K), and discussion of habitat requirements for those species (Chapters 4 & 10; Appendix F) provide a description of their habitat requirements, their general extent and condition, and the "*relative significance*" of habitats within the area proposed for disturbance.

D-G's Requirements

The "*habitat characteristics*" for the "*subject species*" are described in Chapter 5 and documented in Appendix F of this SIS. For those relevant "*affected species*" this Chapter provides additional detail, and further consideration of their habitat requirements and the significance of the subject site and study area, and of habitats and resources in the locality and region, are provided in Chapter 10 and Appendix F.

The "*NPWS predicted habitat models*" (Appendix K) were used in conjunction with other information from databases and other reports to assist in assessment of potential habitat for "*affected species*" and for "*subject species*". The "*NPWS predicted habitat models*" provide some guidance as to species which could theoretically or potentially occur in an

area, but must be recognised as providing only a broad overview of likely presence. Although it is recognised that the potential exists for most of the "*subject species*" to occur throughout areas of forested land within the study area, the specific habitat requirements of the various species are either present only at scattered locations (*eg* the Koala, Long-nosed Potoroo and Tiger Quoll), which cannot readily be mapped, or are broadly distributed throughout the forest habitats (*eg* foraging resources for microchiropteran bats), which are adequately represented in the aerial photograph and vegetation community mapping. Given the above considerations, "*the habitat of each subject species within the study area*" cannot readily or usefully "*be clearly delineated*", and consequently the habitat for each of the "*subject species*" was not "*represented on a map of the study area*".

Consideration of "*the importance of the study area for all life-cycle stages*" of the relevant "*affected species*", or those which could potentially be affected by the proposed activity to any significant or relevant extent, is included in this Chapter of the SIS. The Yellow-bellied Glider *Petaurus australis* has not been recorded within the study area or locality, and is not regarded as a relevant or "*affected species*" pursuant to the descriptions and definitions in the D-G's Requirements. Given that there is no evidence for the presence of this species in the study area or locality, the habitats and vegetation communities present in the "*study area*" have no "*importance .. for all life-cycle stages*" of the Yellow-bellied Glider. No further discussion of this species is provided.

9.1 Habitat in the Study Area of Relevant Species or Populations

9.1.1 Koala

Type of Habitat
The study area supports open forest and woodland communities, dominated by a range of eucalypt species, providing a variety of suitable and preferred food trees for the Koala (Chapter 4; Appendix F). In particular, the study area supports Tallow-wood *Eucalyptus microcorys*, Grey Gum *E punctata*, Swamp Mahogany *E robusta* and Forest Red Gum *E tereticornis*, all of which are listed as Koala Food Trees on Schedule 2 of *State Environmental Planning Policy No 44 - Koala Habitat Protection* SEPP 44. Other species recorded in the study area that Koalas are known to use in the north coast region include Small-fruited Grey Gum *E propinqua*, White Mahogany *E acmenoides*, White Stringybark *E globoidea* and Spotted Gum *Corymbia maculata* (Reed *et al* 1990).

The *Draft Port Stephens Koala Plan of Management* (Callaghan *et al* 1994) identified areas of potential Koala habitat in the western portions of the study area (beyond Wallaroo Swamp) and prime Koala habitat in and around parts of Karuah NR. The quality of Koala habitat on the eastern side of the River was not assessed in that report. However, the presence of apparently breeding Koalas (R Clarke, local resident, *pers comm*) indicates the presence of suitable Koala habitat in this portion of the study area. However, the proposed Karuah Upgrade project is located mostly in cleared agricultural land east of the Karuah River, and does not affect significant Koala habitat.

Location of Habitat
Suitable habitat for the Koala occurs throughout the forest and woodland communities in the study area, including the steep vegetated hills to the east of the River, and Wallaroo SF and Karuah NR to the west. Koalas were recorded on both sides of the River during surveys for this SIS, and are frequently recorded in the vicinity of Karuah (Callaghan *et al* 1994).

Size of Habitat
Suitable habitat for the Koala in the locality is extensive, covering the majority of the study area, and extending beyond the study area in all directions. The mapping of Koala Habitat by Callaghan *et al* (1994) indicates that Koala habitat is present throughout much of the Port Stephen LGA, and the species is recorded widely in the locality.

Condition of Habitat
The condition of habitat in the study area and locality varies widely, ranging from patches of relatively intact forest vegetation (on the eastern side of the Karuah River) to partially cleared and degraded. Much of the forest and woodland on the western side of the River (on private land and in Wallaroo SF) has also been modified, as a result of selective logging and fire. Habitat for the Koala is relatively continuous on the western side of the River, forming

part of a regional corridor (NP&WS - Figure 4.3). However, clearing for agricultural activities has also caused fragmentation of habitat, particularly on the eastern side of the River, where the alignment is located primarily in cleared agricultural land and affects little or no habitat of particular value for the Koala.

9.1.2 Squirrel Glider

Type of Habitat
The study area supports open forest and woodland communities, cleared agricultural land and wetland habitats (Figure 6.1a, 6.1b; Figure 2.1; Chapter 4). The dry sclerophyll woodland and forest supports tree-hollows of potential value as nesting and shelter habitat for the Squirrel Glider, as well as tree species of value as a foraging resource and mature trees suitable for gliding. Areas used by Squirrel Gliders are likely to change over time, as portions of the forest age or are modified by circumstances (such as fire).

Location of Habitat
The majority of the forest and woodland in the study area and locality supports potential or "*suitable habitat*" for the Squirrel Glider. Moderate sized tree-hollows are present throughout the study area, although they appear relatively uncommon in the State Forests west of the Karuah River. Foraging resources for this species, including sap-producing Acacias and Eucalypts, and other flowering plants, occur in forest and woodland vegetation throughout the study area.

Size of Habitat
Suitable habitat for the Squirrel Glider is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The condition of habitat in the study area and locality varies from relatively intact forest in patches on the eastern side of the River to partially cleared and degraded. The value of habitat for the Squirrel Glider in the more degraded areas is reduced as a result of fewer foraging resources and a low density of hollow-bearing trees. Habitat on the western side of the River forms part of a regional corridor (NP&WS - Figure 4.3).

9.1.3 Long-nosed Potoroo

Type of Habitat
Dense understorey in mesic environments is preferred by the Long-nosed Potoroo, and such habitat is limited in the study area (Appendix F; Chapter 4). The species rarely ventures into open land, and is not common in disturbed locations, particularly where the understorey or groundcover has been depleted.

Location of Habitat
Vegetated areas east of Branch Lane (at the eastern end of the alignment) constitute potentially suitable habitat for the Long-nosed Potoroo. This denser forest vegetation extends eastward beyond the study area on elevated land, where it supports a generally dense understorey. The western boundary of this potential habitat is the cleared private lands (previously grazed by cattle) where understorey density is low. West of the Karuah River, potential habitat occurs around Wallaroo Swamp and in the few vegetated areas currently supporting dense understorey. Such areas are restricted due to logging activities and the fire regime.

Size of Habitat
The amount of suitable habitat present in the study area and locality for the Long-nosed Potoroo appears limited. Predictive modelling of suitable habitat (NP&WS 1994a) indicates that the majority of available habitat lies to the east of the River in undisturbed forest (where understorey growth is dense and diverse). Such habitat extends eastward beyond the study area, where the proposed route meets the existing Pacific Highway (near Karuah Red Quarry).

Condition of Habitat
As noted elsewhere in detail in this report (Chapter 4), the vegetation communities in the study area have been somewhat degraded as a result of frequent fire and long-term logging, grazing and other activities. The forest and woodland vegetation supports relatively few 'old growth' characteristics, with areas of dense understorey being particularly uncommon in lands to the west of the Karuah River. To the east of the River, the understorey has been less disturbed, and areas of dense groundcover and understorey vegetation are more common.

9.1.4 Brush-tailed Phascogale

Type of Habitat
Open dry forest with a sparse groundcover on ridges is the preferred habitat of this species. The study area supports extensive open forest and woodland communities, cleared agricultural land and wetland habitats (Chapter 4). The dry sclerophyll woodland and forest also supports tree-hollows of potential value as nesting and shelter habitat for the Brush-tailed Phascogale.

Location of Habitat
Potentially suitable habitat for the Brush-tailed Phascogale is present throughout the study area and locality, with extensive areas of State Forests and dedicated conservation reserves (Nature Reserves and National Parks) as well as substantial forest and woodland vegetation on Crown Lands and in private tenure. The Brush-tailed Phascogale has been recorded at many locations within the study area and locality, and suitable habitat for this species appears to be relatively widespread in this area. The portion of the Karuah Bypass alignment west of the Karuah River is regarded as the most suitable habitat for the Brush-tailed Phascogale, because of the open nature of this forest and woodland vegetation. Whilst no individuals of the Brush-tailed Phascogale were recorded during the field investigations for this SIS, suggesting that the species is not currently present in this portion of forest (given the ease with which it has been recorded elsewhere in the locality), the forested portions of land west of the Karuah River could potentially provide suitable habitat for this species in the future.

Size of Habitat
Suitable habitat for the Brush-tailed Phascogale is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
As noted elsewhere, the woodland and forest communities west of the Karuah River have been subjected to long-term bushfire and logging activities, which have resulted in some significant modification from their original condition. Conversely, the Brush-tailed Phascogale appears to utilise areas of open forest and woodland with a very sparse understorey, and probably does not require pristine or undisturbed vegetation as habitat. On this basis, the somewhat disturbed condition of the forest and woodland west of the Karuah River is not regarded as a long-term constraint to the Brush-tailed Phascogale, although a too frequent burning regime may explain its current absence from the study area.

9.1.5 Tiger Quoll

Type of Habitat
The Tiger Quoll utilises a range of forest and heathland habitats, including open forest and woodland communities, coastal heathland and shrubland. However, the species appears to prefer dense forest vegetation or heath vegetation in steep topography, where there is a greater density of understorey and groundcover, and an array of logs and caves for shelter and cover.

Suitable habitat for the Tiger Quoll is present particularly on the eastern side of the Karuah River, where the topography is more pronounced and the forest vegetation supports a denser understorey. As noted elsewhere, forest and woodland vegetation to the west of the Karuah

River has long been modified by a frequent burning regime and long-term logging, and is likely to be of less value for Tiger Quolls, notwithstanding their relatively tolerant habitat requirements. In particular, the recent fires west of the River, and the apparently high frequency of fires and other disturbance in this forest area, are likely to have significantly reduced the potential value of that forested land for the Tiger Quoll, compared to the denser and moister forest habitats west of the River.

Location of Habitat
Predictive modelling by the NP&WS suggests that the most suitable habitat for the Tiger Quoll in the study area is located in Wallaroo SF, although the 'intermediate' value of this habitat (Appendix K) is offset by the relatively high level of disturbance and the fire regime. The study area east of the Karuah River supports relatively intact woodland communities, and further east there is extensive open forest on steep and rugged terrain.

Whilst the primary habitat for the Tiger Quoll in the study area is located on the eastern side of the Karuah River (where it was recorded), this species could also occur in the forest and woodland habitats on the western side of the Karuah River, and more widely throughout the forested lands in the locality. Thus, as for most of the other terrestrial mammals in the study area and locality, the extensive forest and woodland vegetation in the area (Figure 2.1) provides potential habitat widely through the landscape.

Size of Habitat
As noted above, the forest and woodland vegetation throughout the landscape generally provides potential habitat for the Tiger Quoll. Whilst portions of the forest and woodland vegetation in the study area and locality have been subjected to long-term forestry activities, grazing and burning, and consequently have relatively disturbed or open understoreys, the Tiger Quoll can utilise these habitats. On that basis, the "*size*" of habitat for the Tiger Quoll is substantial, incorporating thousands of hectares within the study area and locality.

Conversely, if the Tiger Quoll does not utilise the open forest and woodland communities west of the Karuah River (as would be indicated by the lack of records of species within this portion of the study area), suitable habitat for the species would be restricted to the steeper and more densely vegetated landscape east of the Karuah River. There are extensive areas of dense forests and woodland vegetation on steeper land to the east and north of the study area, much of which would provide suitable habitat for the Tiger Quoll. In this instance, there are thousands of hectares of suitable habitat in the locality for this species.

Condition of Habitat
As noted elsewhere, the woodland and forest communities west of the Karuah River have been subjected to long-term bushfire and logging activities, which have resulted in some significant modification from their original condition. Conversely, the Tiger Quoll appears to utilise areas of open forest and woodland with a very sparse understorey, and probably does not require pristine or undisturbed vegetation as habitat. On this basis, the somewhat disturbed condition of the forest and woodland west of the Karuah River is not regarded as a long-term constraint to the Tiger Quoll, although a too frequent burning regime may explain its current absence from the study area.

9.1.6 Greater Broad-nosed Bat

Type of Habitat
The study area supports dry eucalypt woodland and open forest, which constitute prime habitat for this species (Appendix F). Open forest communities are preferred by the Greater Broad-nosed Bat, as they pose fewer obstacles to flight. Creeklines, tracks, partially cleared land and roads in particular are utilised as flight paths, and tree-hollows are required for roosting and nesting, although it may also utilise artificial structures.

Location of Habitat
Suitable habitat for the Greater Broad-nosed Bat occurs throughout the study area, and given the highly mobile nature of this species, it is likely to utilise available habitat on both sides of the Karuah River. NP&WS modelling predicts habitat of highest value in the State Forests to the west of the Karuah River, where partial clearing and logging has created a more open woodland community. However, roosting and foraging habitat is available

throughout the study area and locality, except in the cleared lands on the eastern side of the river.

Size of Habitat
Suitable habitat for the Greater Broad-nosed Bat is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The open nature of the woodland and forest to the west of the River may be of high foraging value to the species, and hollow-bearing trees (although at a relatively low density) are present for roosting in this area. The forest habitat is relatively continuous on the western side of the River, forming part of an alleged regional corridor (NP&WS; Figure 4.3). To the east, the fragmented nature of the remnant forests and woodlands has somewhat reduced the area of available habitat, although the presence of mature hollow-bearing trees increases the potential for breeding by the species.

9.1.7 Little Bent-wing Bat

Type of Habitat
The study area supports dry sclerophyll woodland and forest communities, merging with moister communities along drainage lines and wetlands. These communities provide excellent foraging habitat for the Little Bent-wing Bat, but the study area does not support any caves, tunnels or similar structures utilised as nursery or roosting sites by the Little Bent-wing Bat.

Location of Habitat
The open forest and woodland throughout the study area provides preferred foraging habitat for the Little Bent-wing Bat (Figure 2.1). Whilst the study area does not support any potential roosting or nursery sites for the Little Bent-wing Bat, there are known roosts in the locality (Appendix F).

Size of Habitat
Suitable habitat for the Little Bent-wing Bat is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The open nature of the woodland and forest to the west of the River is likely to be of high foraging value to the species. The forest habitat is relatively continuous on the western side of the River, forming part of a regional corridor (Figure 4.3). To the east, the fragmented nature of the remnant forests and woodlands has somewhat reduced the area of available habitat.

9.1.8 Common Bent-wing Bat

Type of Habitat
The study area supports dry sclerophyll woodland and forest communities, merging with moister communities along drainage lines and wetlands. These communities provide excellent foraging habitat for the Common Bent-wing Bat, but the study area does not support any caves, tunnels or similar structures utilised as nursery or roosting sites by the Common Bent-wing Bat.

Location of Habitat
The open forest and woodland throughout the study area provides preferred foraging habitat for the Common Bent-wing Bat (Figure 2.1). Whilst the study area does not support any potential roosting or nursery sites for the Common Bent-wing Bat, there are known roosts in the locality (Appendix F).

Size of Habitat
Suitable habitat for the Common Bent-wing Bat is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The open nature of the woodland and forest to the west of the River is likely to be of high foraging value to the species. The forest habitat is relatively continuous on the western side of the River, forming part of a regional corridor (Figure 4.3). To the east, the fragmented nature of the remnant forests and woodlands has somewhat reduced the area of available habitat.

9.1.9 Eastern Freetail Bat

Type of Habitat
The study area supports dry eucalypt woodland and open forest, which constitute prime habitat for this species (Appendix F). Open forest communities are preferred by the Eastern Freetail Bat, as they pose fewer obstacles to flight. Creeklines, tracks, partially cleared land and roads in particular are utilised as flight paths, and tree-hollows are required for roosting and nesting, although it may also utilise artificial structures.

Location of Habitat
Suitable habitat for the Eastern Freetail Bat occurs throughout the study area, and given the highly mobile nature of this species, it is likely to utilise available habitat on both sides of the Karuah River. NP&WS modelling predicts habitat of highest value in the State Forests to the west of the Karuah River, where partial clearing and logging has created a more open woodland community. However, roosting and foraging habitat is available throughout the study area and locality, except in the cleared lands on the eastern side of the river.

Size of Habitat
Suitable habitat for the Eastern Freetail Bat is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The open nature of the woodland and forest to the west of the River may be of high foraging value to the species, and hollow-bearing trees (although at a relatively low density) are present for roosting in this area. The forest habitat is relatively continuous on the western side of the River, forming part of a regional corridor (Figure 4.3). To the east, the fragmented nature of the remnant forests and woodlands has somewhat reduced the area of available habitat, although the presence of mature hollow-bearing trees increases the potential for breeding by the species.

9.1.10 Osprey

Type of Habitat
The Osprey utilises the ocean shore, lakes, estuaries, bays and rivers for foraging (hunting fish) and nests in large exposed trees which provide good views of the surrounding land. This species is highly mobile and wide-ranging, and was recorded along the Karuah River during field investigations for this SIS. On the basis of its habitat requirements, the Osprey is likely to be largely confined to the Karuah River and near vicinity within the study area, although it could nest up to 1km from the River under appropriate circumstances.

Location of Habitat
The entire Karuah River and associated wetlands provide suitable foraging habitat for this species, including some of the smaller creeks. Horse Island and wooded areas along both shores provide large trees which may be used for nesting.

Extensive areas of suitable habitat for the Osprey are present in the locality and sub-region, associated with Port Stephens and the extensive lakes and river systems on the central and

mid-north coasts of NSW.

Size of Habitat
As indicated above, suitable habitat for the Osprey (open water for fishing and large trees for nesting) are widespread in the locality and sub-region, although only relatively small areas of these habitats are present within the study area. It is not possible to quantify the "*size .. of the habitat*" for the Osprey, in the study area or in the locality, but on a sub-regional basis, there is clearly extensive potential habitat for this species.

Condition of Habitat
The "*condition*" of the habitat for the Osprey in the locality and sub-region appears highly variable, with some areas (*eg* many urbanised portions of the landscape and heavily utilised portions of the coast) being of relatively poor value for Ospreys, and in a somewhat disturbed condition. Conversely, there are extensive areas of Port Stephens and the Karuah River in particular which are in good to excellent condition, and doubtless provide excellent habitat for the Osprey.

9.1.11 Glossy Black Cockatoo

Type of Habitat
This species prefers dry sclerophyll forests supporting large tree hollows for nesting and *Allocasuarina* species for foraging. Much of the forest and woodland west of the Karuah River is suitable habitat for the Glossy Black Cockatoo, notwithstanding previous disturbances and a somewhat depauperate density of she-oaks as a result of frequent fire. Nevertheless, the presence both of hollow-bearing trees (albeit at a relatively low density) and she-oaks renders portions of the subject site suitable for this species.

Location of Habitat
Forest and woodland supporting *Allocasuarina littoralis* and *A torulosa* are located on both the sides of the study area. Suitable foraging habitat for this species is also located widely throughout the study area and locality, and the wide-ranging nature of the species indicates that the potentially suitable habitat throughout the locality is likely to be utilised as foraging habitat by the Glossy Black Cockatoo.

Whilst the study area does not support a high density of hollow-bearing trees, and many of those present are relatively small, there is some potential for Glossy Black Cockatoos to utilise portions of the study area and locality for breeding purposes. Whilst rare, large hollow-bearing trees are present throughout the study area and landscape generally, and potentially suitable habitat may be described as widely distributed.

Size of Habitat
Suitable habitat for the Glossy Black Cockatoo is extensive, covering the majority of the study area, and extending beyond the study area in all directions. Thousands of hectares of suitable forest and woodland are present in the State Forests and conservation reserves in the locality.

Condition of Habitat
The condition of habitat in the study area and locality varies from relatively intact forest in patches on the eastern side of the River to partially cleared and degraded. The value of habitat for the Glossy Black Cockatoo in the more degraded areas is reduced as a result of fewer foraging resources and a low density of hollow-bearing trees. Habitat on the western side of the River forms part of a regional corridor (NP&WS - Figure 4.3).

9.1.12 Bush Stone-curlew

Type of Habitat
The Bush Stone-curlew inhabits lightly timbered woodlands and open forest, with a grassy understorey and scattered logs. Potentially suitable habitat for this species is present within the study area and locality, and individuals have been recorded calling in the vicinity of the Karuah River (although the specific habitat type in which individuals occurred at this locality is uncertain).

Location of Habitat
Suitable habitat for the Bush Stone-curlew occurs in the extensive open forest and woodland communities on the western side of the Karuah River, although birds were also recorded on the eastern side, apparently in somewhat denser forest and woodland vegetation. This species appears capable of utilising a range of open forest and woodland vegetation communities, and potentially suitable habitat for it is located throughout the open forest and woodland vegetation on relatively low relief in the study area and locality. The Bush Stone-curlew is not likely to occur in the denser forest vegetation on steeper topography to the north and northeast of the study area, and the more appropriate open forest and grassy woodland vegetation is located to the west and northwest, and to the southwest, of the study area.

The NP&WS predictive modelling suggests that high quality habitat may be present around Wallaroo Swamp and near the bend in the River to the north of the proposed Bypass, although suitable habitat for this species is more widely distributed than indicated in that modelling.

Size of Habitat
As for most of the other species which utilise forest and woodland vegetation, there is extensive (thousands of hectares) potentially suitable habitat within the study area and locality. Open forest and woodland communities, often with a grassy understorey and abundant logs, are characteristic of much of the forested land included in State Forests, Crown Lands and on private property on the central and mid-north coast of NSW.

9.1.13 Masked Owl

Type of Habitat
The "*type*" of habitat present in the Karuah Bypass study area is suitable for the Masked Owl, as indicated by the presence of a breeding pair of this species along the alignment on the western side of the Karuah River. Typical habitat for the Masked Owl includes open forest and woodland vegetation, including forest edges and open spaces, with numbers of large hollow-bearing trees (supporting large tree-hollows) for nesting and breeding purposes. This "*type*" of habitat occurs throughout the study area and locality.

Location of Habitat
Suitable habitat for the Masked Owl is present widely throughout the study area and locality, with the open forest and woodland communities west of the Karuah River clearly providing suitable habitat for the species. As the Masked Owl takes a significant proportion of its prey from the ground, areas of forest with a dense understorey are generally not suitable for this species, although it may roost in large hollow-bearing trees in denser forest adjacent to more open lands suitable for hunting.

Suitable habitat for the Masked Owl is clearly present along the Karuah Bypass alignment, and occurs widely throughout the study area, particularly west of the Karuah River. Suitable habitat for this species is also widespread in the locality and sub-region, with apparently suitable forest and woodland vegetation widely distributed to the south and west.

Size of Habitat
The NP&WS predictive modelling indicates substantial areas of suitable or potentially suitable habitat for the Masked Owl in State Forests and other forested areas to the west of the Karuah River. Given the distribution of potentially suitable forest and woodland habitat with an open understorey, and the presence of Masked Owls in the study area and locality, it appears that there is substantial habitat for this species in the locality and sub-region, involving thousands of hectares of suitable forest and woodland vegetation.

Condition of Habitat
Despite long-term timber harvesting and bushfires in the forest and woodland vegetation west of the Karuah River, the "*condition*" of the habitat appears satisfactory for the Masked Owl, given the presence of breeding individuals in this location. Those activities have produced an open forest and woodland community with a relatively sparse understorey, which conditions suit the Masked Owl (as it hunts for terrestrial prey).

A similar "*condition*" of vegetation is typical of much of the forest and woodland vegetation in the vicinity and in the locality and sub-region, particularly to the west and south of the study area. The forest vegetation to the east and north of the subject site (particularly to the north) is located on steeper topography, and tends to support a denser understorey. These habitat conditions are also, however, suitable to varying degrees to the Masked Owl.

9.1.14 Powerful Owl

Type of Habitat
The "*type*" of habitat present in the Karuah Bypass study area is potentially suitable for the Powerful Owl, although no individuals were recorded in the study area. Typical habitat for the Powerful Owl includes open forest and woodland vegetation, with very large hollow-bearing trees (supporting large tree-hollows) for nesting and breeding purposes. This "*type*" of habitat occurs throughout the study area and locality.

Location of Habitat
Potentially suitable habitat for the Powerful Owl is present widely throughout the study area and locality, with the open forest and woodland communities west of the Karuah River clearly providing suitable habitat for the species. Suitable habitat for this species is also widespread in the locality and sub-region, with apparently suitable forest and woodland vegetation widely distributed to the south and west.

Size of Habitat
The NP&WS predictive modelling indicates substantial areas of suitable or potentially suitable habitat for the Powerful Owl in State Forests and other forested areas to the west of the Karuah River. Given the distribution of potentially suitable forest and woodland habitat with an open understorey, there is substantial habitat for this species in the locality and sub-region, involving thousands of hectares of suitable forest and woodland vegetation.

Condition of Habitat
Despite long-term timber harvesting and bushfires in the forest and woodland vegetation west of the Karuah River, the "*condition*" of the habitat appears satisfactory for the Powerful Owl.

A similar "*condition*" of vegetation is typical of much of the forest and woodland vegetation in the vicinity and in the locality and sub-region, particularly to the west and south of the study area. The forest vegetation to the east and north of the subject site (particularly to the north) is located on steeper topography, and tends to support a denser understorey. These habitat conditions are also suitable to varying degrees to the Powerful Owl.

9.1.15 Chestnut-rumped Heathwren

Type of Habitat
The Chestnut-rumped Heathwren utilises open forest and woodland communities with a relatively dense understorey. Whilst much of the forest and woodland west of the Karuah River has long been affected by frequent fire and ongoing timber harvesting activities, and tends to support a relatively sparse understorey, there are patches of shrub and heath understorey in this portion of the study area which could provide suitable habitat for the Chestnut-rumped Heathwren. Suitable habitat is present within the study area, however, as indicated by the recording of the Chestnut-rumped Heathwren within the study area (as noted below).

Location of Habitat
Suitable forest and woodland habitat with a dense understorey is present only in a patchy distribution west of the Karuah River, with much of the understorey along the Karuah Bypass alignment being more open than is preferred by this species. Potentially suitable habitat is, however, present in forest and woodland vegetation to the west and south of the study area, and the extensive State Forests and other forested lands in this locality and sub-region.

Suitable habitat for the Chestnut-rumped Heathwren is also located east of the Karuah River, in the somewhat denser forest and woodland vegetation on steeper topography.

Similar forest and vegetation communities are extensively distributed to the north and east of the study area.

Size of Habitat
As indicated above, potentially suitable habitat for the Chestnut-rumped Heathwren is widely distributed throughout the locality and sub-region, although in many instances appropriate understorey conditions are present only in a patchy distribution through that extensive range. The "*size*" of habitat suitable for the Chestnut-rumped Heathwren in the locality may be described as moderate, and appears likely to occupy many hundreds of hectares. Suitable habitat in the sub-region appears likely to occupy thousands of hectares.

Condition of Habitat
As indicated above, the levels of disturbance (particularly arising from frequent bushfire) in the forest and woodland vegetation west of the Karuah River have somewhat reduced the value of this portion of native vegetation for the Chestnut-rumped Heathwren. The more open grassy type of woodland vegetation in this location is not preferred habitat for the Chestnut-rumped Heathwren, although there are patches of denser understorey which provide potentially suitable habitat for the species.

Conversely, habitat "*condition*" for the Chestnut-rumped Heathwren is generally good to excellent, with relatively low levels of weed infestation and extensive areas or scattered patches of suitable dense understorey throughout the study area and locality.

9.1.16 Green-thighed Frog

Type of Habitat
The Green-thighed Frog inhabits a wide range of habitats, including wet and dry sclerophyll forests, woodlands and open woodlands, and partially cleared or logged land. Breeding sites include irregularly flooded water holes, drainage lines, dams and oxbows containing submerged and emerging herbs and grasses. Potentially suitable habitat for the Green-thighed Frog occurs within the study area, as detailed below, but no individuals of the species were recorded during field investigations for this SIS, despite excellent survey conditions. Given that the species is apparently located in a wide variety of vegetation communities and habitat "*types*" (F Lemckert *pers comm*), it appears that the study area and the Karuah Bypass alignment support potentially suitable habitat for this species.

Location of Habitat
Potential habitat for the Green-thighed Frog occurs widely within the study area and in the broader locality.

Size of Habitat
Assessment of the "*size*" of habitat suitable for the Green-thighed Frog is problematic, because of uncertainties relating to the habitat requirements of this species. Green-thighed Frogs appear to have occupied a range of forest and woodland vegetation, and have been recorded breeding in shallow flooded swales in clear paddocks, ditches and artificial drainage lines. On this basis, it would appear that there is substantial suitable habitat for the Green-thighed Frog in the study area and locality, although it is not possible to provide any meaningful estimate of the "*size*" of habitat (in hectares) because of the inherent variability of apparently suitable habitat for the species, and because of uncertainties regarding its presence in the study area and locality.

No records of the Green-thighed Frog were obtained during field investigations for this SIS, and it is possible that there is not suitable habitat for this species in the study area. Conversely, on the basis of other records of species and observations of other investigators (F Lemckert *pers comm*), potentially suitable habitat in the study area could occupy hundreds of hectares, and in the locality and sub-region there may be thousands of hectares of suitable habitat for the Green-thighed Frog.

Condition of Habitat
Details of the appropriate "*condition*" of habitat for the Green-thighed Frog are unknown at this stage. As indicated, the species utilises artificial ditches and drainage lines for breeding purposes, and clearly does not require pristine or undisturbed habitat for survival or breeding.

9.1.17 Christmas Bells

Type of Habitat
The "*type*" of habitat appropriate for Christmas Bells involves "*damp sandy and peaty soils*" (Harden 1993), with the species generally occurring in low-lying and swampy habitats or along drainage lines and creeklines. This habitat is present throughout the study area, particularly west of the Karuah River, although it is patchily distributed and occurs at scattered locations throughout the study area.

Location of Habitat
As indicated, suitable habitat for Christmas Bells is located in a patchy distribution throughout the study area, and similar potentially suitable habitat for this species occurs to the west, south and east of the study area. Christmas Bells occur at a range of locations within the locality and sub-region, being regularly recorded in moist or damp locations on sandy substrates within several kilometres of the coast.

Size of Habitat
Within the study area, habitat for Christmas Bells is relatively restricted, occurring only in moist or swampy locations. These low-lying areas are not extensive, and the distribution of suitable habitat for this species is patchy although widely distributed. Likely suitable habitat for Christmas Bells in the study area will probably only occupy a few hundred hectares, but there are thousands of hectares of suitable habitat within the locality and sub-region.

Condition of Habitat
There are no measures of the "*condition*" of habitat for Christmas Bells in the study area or locality. This species does occur in areas of disturbance, and has been cited in drainage swales along constructed roads and in other disturbed areas (D Fanning *pers obs*).

Within the study area, most suitable habitat for Christmas Bells is relatively undisturbed and in reasonable condition.

9.1.18 *Eucalyptus fergusonii*

Type of Habitat
The "*wet sclerophyll forest or woodland on sandy soils*" described as the "*type*" of habitat appropriate for *Eucalyptus fergusonii* (Harden 1991) is not common in the study area. This species was recorded in Spotted Gum Open Forest in the study area, and is regarded also as likely to occur in other vegetation communities within the study area and locality.

Location of Habitat
Suitable habitat occurs throughout the open forest vegetation within the study area and locality, including extensive areas of Spotted Gum Open Forest (which are typical of the central coast of NSW). Suitable vegetation communities are present throughout the study area, particularly west of the Karuah River, and extensive stands of these vegetation communities are located to the west, south and east of the study area.

Size of Habitat
As indicated above, extensive areas of the study area and locality support Spotted Gum Open Forest and other similar forest communities, and these vegetation communities are regarded as suitable habitat for *Eucalyptus fergusonii*. On that basis, there are thousands of hectares of potentially suitable habitat in the study area and in the locality, although individuals of this species are not anticipated as likely to occur in all suitable habitat throughout the region.

Condition of Habitat
Whilst the open forest and woodland vegetation west of the Karuah River are somewhat disturbed as a result of frequent fires and previous logging and timber harvesting regimes, these vegetation communities continue to supply suitable habitat for *Eucalyptus fergusonii*. Spotted Gum Forest and other moister forest communities on sandy soils are widespread in the locality and sub-region, and many display similar conditions and levels of disturbance to those present within the study area.

9.1.19 Swamp Mahogany

Type of Habitat
The "*type*" of habitat appropriate for Swamp Mahogany involves "*damp sandy and peaty soils*" (Harden 1993), with the species generally occurring in low-lying and swampy habitats or along drainage lines and creeklines. This habitat is present throughout the study area, particularly west of the Karuah River, although it is patchily distributed and occurs at scattered locations throughout the study area.

Location of Habitat
As indicated, suitable habitat for Swamp Mahogany is located in a patchy distribution throughout the study area, and similar potentially suitable habitat for this species occurs to the west, south and east of the study area. Swamp Mahogany occur at a range of locations within the locality and sub-region, being regularly recorded in moist or damp locations on sandy substrates within several kilometres of the coast.

Size of Habitat
Within the study area, habitat for Swamp Mahogany is relatively restricted, occurring only in moist or swampy locations. These low-lying areas are not extensive, and the distribution of suitable habitat for this species is patchy although widely distributed. Likely suitable habitat for Swamp Mahogany in the study area will probably only occupy a few hundred hectares, but there are thousands of hectares of suitable habitat within the locality and sub-region.

Condition of Habitat
There are no measures of the "*condition*" of habitat for Swamp Mahogany in the study area or locality. This species does occur in areas of disturbance, and has been cited in drainage swales along constructed roads and in other disturbed areas (D Fanning *pers obs*).

Within the study area, most suitable habitat for Swamp Mahogany is relatively undisturbed and in reasonable condition.

9.1.20 *Hakea bakeriana*

Type of Habitat
The "*wet sclerophyll forest or woodland on sandy soils*" described as the "*type*" of habitat appropriate for *Hakea bakeriana* (Harden 1991) is not common in the study area. This species was recorded in Spotted Gum Open Forest in the study area, and is regarded also as likely to occur in other vegetation communities within the study area and locality.

Location of Habitat
Suitable habitat occurs throughout the open forest vegetation within the study area and locality, including extensive areas of Spotted Gum Open Forest (which are typical of the central coast of NSW). Suitable vegetation communities are present throughout the study area, particularly west of the Karuah River, and extensive stands of these vegetation communities are located to the west, south and east of the study area.

Size of Habitat
As indicated above, extensive areas of the study area and locality support Spotted Gum Open Forest and other similar forest communities, and these vegetation communities are regarded as suitable habitat for *Hakea bakeriana*. On that basis, there are thousands of hectares of potentially suitable habitat in the study area and in the locality, although individuals of this species are not anticipated as likely to occur in all suitable habitat throughout the region.

Condition of Habitat
Whilst the open forest and woodland vegetation west of the Karuah River are somewhat disturbed as a result of frequent fires and previous logging and timber harvesting regimes, these vegetation communities continue to supply suitable habitat for *Hakea bakeriana*. Spotted Gum Forest and other moister forest communities on sandy soils are widespread in the locality and sub-region, and many display similar conditions and levels of disturbance to those present within the study area.

9.1.21 *Tetratheca juncea*

Type of Habitat
The "*type*" of habitat suitable for *Tetratheca juncea* within the study area, and throughout its distributional range, generally consists of open forest and woodland with a shrubby (though not dense) understorey. Much of the open forest and woodland west of the Karuah River is or could be suitable for this species, although the high frequency of fires which has occurred in some portions of this forested landscape either has already or has the potential to render the "*type*" of habitat unsuitable. *Tetratheca juncea* prefers areas with a moderately diverse native shrub understorey, and is usually not present where the understorey vegetation is dominated by bladey grass or other grassy understorey.

East of the Karuah River, *Tetratheca juncea* is not found in the denser forest communities on steeper topography, but is recorded in relatively steep topography where open forest or woodland is present with a relatively open understorey vegetation.

Location of Habitat
As noted above, suitable habitat for *Tetratheca juncea* is located in the extensive forest and woodland vegetation west of the Karuah River, and in open forest and woodland with a relatively open understorey east of the River.

Other populations of *Tetratheca juncea* are known to occur around the study area and in the locality, including a substantial population to the east of the alignment, adjacent to the existing Pacific Highway. A significant number of other populations are also known to occur in the sub-region and throughout the distribution of *Tetratheca juncea*, with the extent of suitable habitat for the species in the sub-region occupying tens of thousands of hectares. Doubtless, specimens of *T juncea* are not located in all areas of potentially suitable habitat in the sub-region.

Condition of Habitat
Tetratheca juncea is adversely affected by a frequent fire regime, and it is considered likely that the species is rendered locally extinct where fires occur too often. The relatively high fire frequency within the open forest and woodland vegetation west of the Karuah River is regarded as probably having contributed to the low density of this species recorded during the initial investigations for the Karuah Bypass, and no further evidence of the species was recorded in these extensive open forest and woodland areas following fire prior to the final investigations for the SIS.

Stands of *T juncea* with greater vigour and security were located on Horse Island and at the eastern end of the study area (near the Karuah Quarry). These areas appear to be subjected to less frequent fire regimes, and the "*condition*" of habitat in these locations appears to be somewhat less disturbed or modified. Notwithstanding its susceptibility to frequent fire, however, *T juncea* does occur in areas which have been subjected to modification by slashing, grazing or other disturbance factors.

9.2 Regional Habitats

Section 110(2)(f) of the TSC Act requires "*details of the distribution and condition of similar habitats* [for *'affected species'*] *in the region*". In addition, the Director-General of NP&WS requires:

> "2.3 *A discussion of other populations of affected species in the locality must be provided. A discussion of the long-term security and tenure of other habitats (ie outside the subject site) of affected species must be provided with regards to tenure, zoning and land management practices*".

9.2.1 Koala

The Koala is relatively abundant in the locality, with a known concentration of this species around Port Stephens (Reed *et al* 1990; Callaghan *et al* 1994). The NP&WS habitat modelling for this species predicts 'high quality' habitat to the north of the study area, particularly in Myall Lakes NP, Little Myall River NP and in Nerong and Myall River SFs, as well as north of Bulahdelah. Intermediate quality habitat for the Koala is abundant in the locality,

including small patches in Karuah NR (to the north of Horse Island), and extensive tracts in Moffats Swamp NR, at Nelson Bay, Raymond Terrace and Newcastle Bight. The majority of the study area and immediate vicinity are regarded as 'marginal' habitat by the NP&WS (Appendix K).

Investigations and other reports regarding Koalas in the Port Stephens area (Callaghan *et al* 1994; Gunninah 1995, 1997b) indicate the presence of a substantial, albeit patchy, population of Koalas distributed through the eastern portions of the Port Stephens LGA. The Koala population appears to be concentrated in forests which occur on sandy soils, with population densities apparently lower in the forests on more rocky terrain. The study area for the Karuah Bypass appears to support a relatively low density of Koalas, reinforcing the mapping of this area as 'marginal' habitat by the NP&WS (Appendix K).

Habitat for the Koala in the NSW North Coast region is widely distributed and there are substantial areas of habitat in similar or better condition than that in the study area. In the region, Koala populations are concentrated in several areas, including Port Stephens, Port Macquarie, Coffs Harbour and in the northeastern corner of NSW. These areas are considered to support prime habitat for the Koala (Reed *et al* 1990).

The 1986-1987 Koala survey indicated that less than a quarter of Koala sightings were from conservation reserves or State Forests (Reed *et al* 1990). This situation is unlikely to have changed significantly over the last decade, despite the considerable expansion of the conservation reserve system. It is likely that much of the habitat for Koalas in the region, and in Australia generally, has poor or limited long-term conservation security.

Significant areas of Koala habitat are likely to occur in rural areas, and could be threatened by clearing for agriculture. In coastal areas, urban and rural-residential development poses a threat to Koala habitat. Land management practices, such as logging, fuel reduction fires and clearing, may threaten the quality and extent of habitat for Koalas in the locality and general region. Conversely, current land management practices within State Forests incorporate measures specifically intended to conserve habitat and resources for Koalas in the medium to long-term. Consequently, the State Forests can generally be regarded as employing appropriate "*land management practices*", and the tenure of NSW State Forests is appropriately regarded as relevant to the conservation of Koalas in the locality and region.

Whilst there are no detailed investigations of "*other populations*" of the Koala in the locality, this species is widely recorded in the forested lands within the Port Stephens LGA, and elsewhere in the locality around the study area. Previous investigations in the vicinity, particularly along the Raymond Terrace to Karuah Upgrade of the Pacific Highway (Gunninah 1997b) have indicated the presence of populations of this species, and it appears likely that Koala occur widely in a patchy distribution throughout the study area and "*locality*".

9.2.2 Squirrel Glider

The Squirrel Glider has been recorded near Raymond Terrace, to the southwest of the study area (Gunninah 1997b), and there is potentially suitable habitat available elsewhere throughout the study area. Habitat modelling by the NP&WS predicts 'high' and 'intermediate' quality habitat in most State Forests surrounding the study area, including Medowie, Karuah and Wallaroo SFs and Karuah NR (Appendix K). Further north, similar habitat is present in Nerong SF, Myall Lakes NP, and near Bulahdelah. However, potential habitat must support mature hollow-bearing trees, which are often relatively sparse in forests which have been subjected to previous clearing or long-term burning and logging.

Potential habitat for the Squirrel Glider has been predicted to occur throughout the NSW North Coast region, particularly on the foothills of the ranges. A 'high likelihood' of occurrence of the Squirrel Glider is predicted in dry gorge forests, dry western forests and in the lower Clarence Valley (NP&WS 1994a). However, much of the regional habitat suitable for the species has been cleared or disturbed by logging or for agriculture. Consequently, the available habitat in many instances is fragmented or patchy.

As is the case for the Koala, current timber harvesting practices within State Forests in

NSW are designed to ensure the retention of habitat and resources for relevant biota such as the Squirrel Glider. Given the frequency with which this species is recorded in State Forests, and the implementation of appropriate "*land management practices*" within timber harvesting operations, land in the tenure of NSW State Forests is regarded as relevant for conservation of this species.

With respect to "*the long-term security and tenure of other habitats*" for the Squirrel Glider in the locality and region, there are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species). Whilst these areas are in relatively secure tenure and are managed appropriately for the conservation forest-dependent biota (including the Squirrel Glider), extensive areas of suitable habitat in private tenure are not protected.

Whilst there are no detailed investigations of "*other populations*" of the Squirrel Glider in the locality, this species is widely recorded in the forested lands within the Port Stephens LGA, and elsewhere in the locality around the study area. Previous investigations in the vicinity, particularly along the Raymond Terrace to Karuah Upgrade of the Pacific Highway (Gunninah 1997b) have indicated the presence of populations of this species, and it appears likely that Squirrel Gliders occur widely in a patchy distribution throughout the study area and "*locality*".

9.2.3 Long-nosed Potoroo

Regional habitat is likely to be patchy and fragmented due to the requirement of the Long-nosed Potoroo for forest with a dense understorey. Mesic forests are most likely to provide the understorey requirements of the species, and such habitat may be present only along watercourses or in areas receiving high rainfall which are not disturbed by frequent logging, grazing or clearing for agriculture.

Suitable habitat for the Long-nosed Potoroo may occur in Myall River SF and along some of the watercourses in the Barrington Tops SF, but no suitable habitat is predicted in the immediate vicinity of the study area (Appendix K).

Throughout northeast NSW, Long-nosed Potoroos may occur in mesic forests or wet sclerophyll forests and coastal heaths (NP&WS 1994a, b). Such habitats are relatively uncommon, often highly disturbed and patchily distributed, and occur particularly around the Border Ranges and Gibraltar Ranges NPs, and Round Mountain and Whian Whian SFs (NP&WS 1994a).

With respect to "*the long-term security and tenure of other habitats*" for the Long-nosed Potoroo in the locality and region, there are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species). However, there appear to be only limited areas of suitable habitat for the species in the State Forests and National Parks, and other areas of suitable habitat in private tenure are not protected. There are no data available regarding "*other populations*" of the Long-nosed Potoroo in the locality.

9.2.4 Brush-tailed Phascogale

Potential habitat for the Brush-tailed Phascogale is largely restricted to coastal areas supporting dry sclerophyll woodlands and forests, although more mesic habitat is utilised further inland and at higher elevations (NP&WS 1994a).

In the study area, 'intermediate' and 'marginal' habitat is widespread throughout Karuah and Wallaroo SFs and in the Karuah NR (Appendix K). Suitable habitat is similarly widespread throughout northeast NSW, and 'high quality' habitat is present along much of the coast. Predicted distribution models (NP&WS 1994a) indicate a decrease in habitat quality further inland.

The forested lands in the tenure of the NP&WS and NSW State Forests along the NSW north

coast provide substantial areas of habitat with "*long-term security*" in appropriate "*tenure*" for the conservation of the Brush-tailed Phascogale.

Whilst there are no detailed investigations of "*other populations*" of the Brush-tailed Phascogale in the locality, this species is recorded widely in the forested lands of the Port Stephens LGA, and elsewhere in the locality around the study area. Previous investigations in the vicinity (Gunninah 1995, 1997b) have indicated the presence of "*other populations*" of this species, and it appears likely that the Brush-tailed Phascogale is widely distributed throughout the study area and "*locality*".

9.2.5 Tiger Quoll

The NP&WS habitat model indicates large tracts of high quality habitat for this species in Nerong and Myall River SFs, in Barrington Tops SF, and in forests north of Bulahdelah and east of Wootton (Appendix K). These areas support shrubby Grey Gum, Spotted Gum, and Smooth-barked Apple Forests, in moderately mesic environments.

Northeast NSW is a national stronghold for the Tiger Quoll (NP&WS 1994a), with suitable habitat in relatively undisturbed rainforest and wet sclerophyll forests in the eastern tablelands and adjacent escarpment, and in the foothills of the ranges (NP&WS 1994a). The forests west of Karuah are generally regarded as of only 'marginal' habitat value for the Tiger Quoll (Appendix K), although there are some areas of 'intermediate' value to the northwest of the proposed alignment.

With respect to "*the long-term security and tenure of other habitats*" for the Tiger Quoll in the locality and region, the extensive forested lands regarded as of 'high' and 'intermediate' value for this species (Appendix K) are protected in the tenure of the NP&WS and NSW State Forests. However, other areas of suitable habitat in private tenure are not protected.

There are no data available regarding "*other populations*" of the Tiger Quoll in the locality, although the NEFBS records (NP&WS 1994a) indicate a relatively high density of animals in the forests around Barrington Tops.

9.2.6 Greater Broad-nosed Bat

Potential habitat for the Greater Broad-nosed Bat is relatively widespread throughout the locality and region, and NP&WS predictive habitat maps identify a moderate probability of this species occurrence throughout northeast NSW (NP&WS 1994a). Habitat in the vicinity of the Karuah Bypass is regarded as of 'marginal' to 'intermediate' quality by the NP&WS (Appendix K). Potential habitat for the Greater Broad-nosed Bat is particularly abundant in State Forests and rural or semi-rural areas that support remnant or partially cleared forest, woodland, and tree-lined watercourses (NP&WS 1994a).

As is generally the case, the condition of habitats for this species in the region is variable, with some areas of potential forest habitat having been reduced in value by the loss of or reduction in hollow-bearing trees, but likely to remain of value as foraging habitat by virtue of the presence of a tree canopy.

As noted elsewhere, the "*long-term security and tenure of other habitats*" for the Greater Broad-nosed Bat in the locality and in the region is variable, and includes:

- conservation reserves (National Parks and Nature Reserves), which are dedicated for conservation purposes and have "*long-term security*" under the tenure of the NP&WS;
- appropriately managed lands (including forested land managed by NSW State Forests, the Hunter Water Corporation and other government authorities), which are not dedicated primarily to conservation purposes but which are managed and utilised in a generally sustainable manner, particularly with respect to threatened species and their habitats; and
- private forested land, which generally is regarded as not possessing "*long-term security*" with respect to conservation, notwithstanding the constraints on clearing and development activities imposed by the EP&A Act and TSC Act.

There are no data available regarding "*other populations*" of the Greater Broad-nosed Bat in the locality.

9.2.7 Little Bent-wing Bat

Potentially suitable foraging habitat for the Little Bent-wing Bat is widespread through the forested lands of northeastern NSW. The NSW North Coast region supports extensive areas of suitable mesic and dry forest communities, notwithstanding the relatively sparse distribution of records in the NEFBS investigation (NP&WS 1994). Given the extent of forested lands in northeastern NSW, including extensive conservation reserves and appropriately managed State Forests, as well as extensive private forested lands, there appears to be a substantial distribution of forest habitat in suitable condition for foraging by this species.

Conversely, the reliance of the Little Bent-wing Bat on specific dedicated maternity caves for breeding purposes appears to constitute a limiting factor for the species in the region. Only one known maternity cave is present in NSW (Willi Willi caves, inland from Kempsey - NP&WS 1994), and there are no known maternity caves within the study area.

The Little Bent-wing Bat has been recorded during a number of investigations in the study area, and a known roost site is located at the Balickera Tunnel to the southwest of the proposed Karuah Bypass. Given the known foraging range of this species (at least 14km), it is likely that individuals from the Balickera Tunnel utilise forested woodland along the Karuah Bypass alignment for foraging purposes. However, the extent of "*other populations*" of the Little Bent-wing Bat "*in the locality*" is unknown.

With respect to "*the long-term security and tenure of other habitats*" for the Little Bent-wing Bat in the locality and region, there are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species). Modern forestry practices and the constraints imposed by licensing conditions on forestry activities render State Forests of relevance in term of the "*long-term security and tenure of other habitats*" in the locality and region for this species. Conversely, whilst there are planning and conservation constraints on privately forested lands as a consequence of current NSW planning and conservation legislation, habitats and resources for the Little Bent-wing Bat on private lands are not regarded as secure in the long-term with respect to the conservation of this species, or its habitat and resources.

9.2.8 Common Bent-wing Bat

As for the Little Bent-wing Bat, potentially suitable foraging habitat for the Common Bent-wing Bat is widespread through the forested lands of northeastern NSW. The NSW North Coast region supports extensive areas of suitable mesic and dry forest communities, notwithstanding the relatively sparse distribution of records in the NEFBS investigation (NP&WS 1994a).

Given the extent of forested lands in northeastern NSW, including extensive conservation reserves and appropriately managed State Forests, as well as extensive private forested lands, there appears to be a substantial distribution of forest habitat in suitable condition for foraging by this species. The Common Bent-wing Bat is widely recorded in northeastern NSW, and has been identified in a wide range of forest communities throughout this portion of the State (D Fanning *pers obs*).

Like the Little Bent-wing Bat, the Common Bent-wing Bat relies for breeding purposes on maternity caves, of which only three are known in NSW (Willi Willi caves near Kempsey, at Riverton and Glen Lyon - NP&WS 1994).

The Common Bent-wing Bat is frequently recorded during investigations in the locality and region, and is known to roost in the Balickera Tunnel to the southwest of the proposed Karuah Bypass. As for the Little Bent-wing Bat, it is likely that individuals from the Balickera Tunnel utilise forested woodland along the Karuah Bypass alignment for foraging purposes. However, the extent of "*other populations*" of the Common Bent-wing Bat "*in the*

locality" is unknown.

With respect to "*the long-term security and tenure of other habitats*" for the Common Bent-wing Bat in the locality and region, there are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species). Modern forestry practices and the constraints imposed by licensing conditions on forestry activities render State Forests of relevance in term of the "*long-term security and tenure of other habitats*" in the locality and region for this species.

9.2.9 Eastern Freetail Bat

The Eastern Freetail Bat inhabits dry sclerophyll forest, and also forages in wet sclerophyll forest and over water. The species roosts in tree-hollows, and it is noted that the species is rarely recorded from cleared land (NP&WS 1994a). Potential habitat for the Eastern Freetail Bat is relatively widespread throughout the locality and region, but only two records were obtained during the NEFBS investigations in northeastern NSW (NP&WS 1994a).

As with the other microchiropteran bats, the condition of habitats for this species in the region is variable, with some areas of potential forest habitat having been reduced in value by the loss of or reduction in hollow-bearing trees, but likely to remain of value as foraging habitat by virtue of the presence of a tree canopy.

The extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species) provide for "*the long-term security*" in appropriate "*tenure*" of habitat for the Eastern Freetail Bat in the locality and region.

There are no data available regarding "*other populations*" of the Eastern Freetail Bat in the locality.

9.2.10 Osprey

Suitable habitat for the Osprey (coastal lagoons, lakes and rivers, the ocean foreshore and suitable nest tree adjacent to foraging habitats) are widely distributed in the NSW North Coast region. The Port Stephens area generally is characterised by extensive areas of suitable habitat for this species, and there has been a recent increase in records of and breeding by Ospreys in coastal NSW (S Debus pers comm; D Fanning *pers obs*). Whilst there has been considerable urban development along the east coast of Australia, doubtless leading to some decline in available habitat for the Osprey, the "*distribution and condition of similar habitats* [for the Osprey] *in the region*" appears satisfactory, given recent increases in this species' abundance and observations of Ospreys nesting on artificial structures.

With respect to "*tenure, zoning and land management practices*", it appears that habitat and resources for this species are improving, given the recent increases in its distribution and abundance. Substantial areas of coastal NSW are currently included in the NP&WS conservation reserve system, and there are also areas of suitable habitat for the Osprey contained within State Forests and other appropriately managed land. In some instances in northern NSW, land management practices around urban developments have included the provision of artificial structures for the nesting of Ospreys.

There are no known details of "*other populations*" of the Osprey "*in the locality*", but this species is regularly observed in Port Stephens and on the central and north coast of NSW. Notwithstanding increased pressures for urban development along the coast of NSW, recent initiatives (such as the NSW Coastal Policy and implementation of the TSC Act) contribute positively to the "*long-term security*" of habitat and resources for this species.

9.2.11 Glossy Black Cockatoo

As for other forest-dependent species considered in this SIS, there are extensive forested lands in the NSW North Coast region, providing suitable habitat and resources for the Glossy Black Cockatoo (amongst other species). Forested lands containing she-oaks for food and hollow-bearing trees for nesting and roosting are common and widespread in the National Parks, Nature Reserves, State Forests and other forested lands in the region.

The predictive mapping of the locality by the NP&WS indicates habitat of 'intermediate' and 'high' value throughout Karuah and Wallaroo SFs and in the Karuah NR (Appendix K), including along the proposed alignment. Similarly, suitable habitat is widespread in the locality and sub-region (Appendix K), and throughout northeast NSW (NP&WS 1994a).

As discussed elsewhere, the tenure of these forested lands varies, as does their condition. However, it is noted that the NSW North Coast region supports extensive National Parks and Nature Reserves, State Forests and other crown lands containing suitable habitat for the Glossy Black Cockatoo. Those areas in government tenure, (including National Parks and Nature Reserves, State Forests, Hunter Water Corporation Land and other crown lands) have "*long-term security*" of tenure, and provide an ongoing resource for the Glossy Black Cockatoo and other forest-dependent fauna. Current "*land management practices*" on most crown lands (including State Forests), have, at least as a partial focus, the conservation of habitat and resources for threatened biota.

Although there do not appear to be any available data regarding "*other populations*" of the Glossy Black Cockatoo in the locality, the species is widely distributed on the north and central coasts of NSW.

9.2.12 Bush Stone-curlew

Potentially suitable habitat for the Bush Stone-curlew is present through the forested lands of the NSW North Coast region, and widely through eastern NSW. This species is not frequently recorded, however, reflecting the alterations to suitable habitat which have occurred extensively throughout NSW.

Suitable dry open forest and woodland habitat for the Bush Stone-curlew occurs throughout the study area, with the NP&WS predictive modelling (Appendix K) indicating areas of 'high' quality habitat in Wallaroo SF and west of Clarence Town, as well as widely (though patchily) throughout the locality.

The extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species) provide for "*the long-term security*" in appropriate "*tenure*" of habitat for the Bush Stone-curlew in the locality and region.

There do not appear to be any available data regarding "*other populations*" of the Bush Stone-curlew in the locality.

9.2.13 Masked Owl

Habitat modelling by the NP&WS predicts 'high' and 'intermediate' quality habitat for the Masked Owl in most State Forests surrounding the study area, including Medowie, Karuah and Wallaroo SFs and Karuah NR (Appendix K). Similarly, high value habitat is present in Nerong SF, Myall Lakes NP and near Bulahdelah, and the species is predicted to occur widely in northern NSW (NP&WS 1994a). Suitable habitat for this species must support very large tree-hollows, which can be relatively sparse in forests which have been subjected to previous clearing or long-term burning and logging.

There are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species), which are relevant in terms of "*the long-term security and tenure of other habitats*" for the Masked Owl in the locality and region.

Conversely, extensive areas of potentially suitable habitat in NSW are in private tenure, and are not protected.

Whilst there are no known detailed investigations of "*other populations*" of the Masked Owl in the locality, this species is regularly recorded in the forests of the Port Stephens LGA, and elsewhere in the general sub-region.

9.2.14 Powerful Owl

Suitable habitat for the Powerful Owl occurs in the forested lands surrounding the study area, including Medowie, Karuah and Wallaroo SFs and Karuah NR. Similarly, relevant habitat for this species is present throughout much of the "*region*", and the Powerful Owl is predicted to occur widely in northern NSW (NP&WS 1994a). As for the Masked Owl, suitable habitat for this species must support very large tree-hollows, which can be relatively sparse in forests which have been subjected to previous clearing or long-term burning and logging.

There are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species), which are relevant in terms of "*the long-term security and tenure of other habitats*" for the Powerful Owl in the locality and region.

Whilst there are no known detailed investigations of "*other populations*" of the Powerful Owl in the locality, this species is regularly recorded in the forests of the Port Stephens LGA, and elsewhere in the general sub-region.

9.2.15 Chestnut-rumped Heathwren

The "*distribution and condition*" of habitat for the Chestnut-rumped Heathwren cannot be delineated with any certainty, given the paucity of records of this species in the NSW North Coast region (NP&WS 1994). The species is noted as "*typically found in heathland and heathy woodlands .. generally where the undergrowth is thick*" (Blakers *et al* 1994), and it appears to prefer "*cooler, high elevation areas*" (Gilmore & Parnaby 1994), notwithstanding the record from the Karuah area (NP&WS 1994; this investigation).

It appears that suitable habitat for the Chestnut-rumped Heathwren is not widely distributed "*in the region*", possibly reflecting the pattern of habitat use by the species as noted by the NP&WS (1994), being that of "*a southern species at the northern end of its range*". Conversely, the cryptic nature of the species may mean that it is more widely distributed, and has been simply been not recognised or has been mis-identified.

Potentially suitable habitat for this species is widespread in the State Forests and National Parks and Nature Reserves of the region, given their extent and distribution at higher altitudes. In many instances, it is likely that these areas of habitat are in relatively good condition, given current "*land management practices*", and their location in often relatively inaccessible terrain.

There are no known investigations into the extent or biology of "*other populations*" of the Chestnut-rumped Heathwren, either in the locality or in region.

9.2.16 Green-thighed Frog

This species has been recorded in a wide range of habitats, including riparian rainforest, wet and dry sclerophyll forests, woodlands and open woodlands and partially cleared forests or regrowth. Consequently, it would appear that potential habitat for the Green-thighed Frog occurs widely throughout its known distribution, notwithstanding the infrequency of records.

Habitat modelling by the NP&WS indicates the presence of 'high' quality habitat for the Green-thighed Frog in most State Forests surrounding the study area, including Medowie, Karuah and Wallaroo SFs and Karuah NR (Appendix K). Similarly, apparently 'high' value

habitat is present in Nerong SF, Myall Lakes NP, and near Bulahdelah, despite the paucity of records other than in northern NSW (NP&WS 1994a).

There are extensive forested lands in the tenure of the NP&WS (dedicated for conservation purposes) and NSW State Forests (suitably managed to ensure the long-term survival of threatened biota and other native species) in the locality and region. Whilst these areas provide "*long-term security*" of potential habitat for the Green-thighed Frog, in relatively secure tenure, there are few records of the species in the southern parts of the region.

There are no known investigations into the extent or biology of "*other populations*" of the Green-thighed Frog, either in the locality or in region.

9.2.17 *Blandfordia grandiflora*

The plant *Blandfordia grandiflora* occurs in coastal areas and the nearby tablelands, in "*damp sandy and/or peaty soils*" from the Hawkesbury River to Queensland and west to Glen Innes (Harden 1994).

Potentially suitable habitat is scattered through the creeklines and swamps of the Karuah and Wallaroo SFs and in the Karuah NR, and is similarly likely to be relatively patchily distributed throughout northeast NSW.

The forested lands in the tenure of the NP&WS and NSW State Forests along the NSW north coast provide substantial areas of habitat with "*long-term security*" and relevant "*tenure*" for *Blandfordia grandiflora*.

Whilst there are no known detailed investigations of "*other populations*" of *Blandfordia grandiflora* in the locality, this species is recorded widely in moist sites, including along road verges, in the Port Stephens LGA.

9.2.18 *Eucalyptus fergusonii*

The tree *Eucalyptus fergusonii* occurs in coastal areas, in "*wet sclerophyll forest or woodland on sandy soils*" from Bulahdelah to Morisset (Harden 1992).

Potentially suitable habitat for *Eucalyptus fergusonii* is scattered throughout the forests of the Karuah and Wallaroo SFs and in the Karuah NR, and the species was recorded at scattered locations throughout the study area. The species is similarly likely to be relatively patchily distributed throughout its distribution on the central coast of NSW.

The forested lands in the tenure of the NP&WS and NSW State Forests along the NSW central coast provide areas of habitat with "*long-term security*" in appropriate "*tenure*" for the conservation of habitats for and populations of *Eucalyptus fergusonii*.

There are no known detailed investigations of "*other populations*" of *Eucalyptus fergusonii*.

9.2.19 Swamp Mahogany

The Swamp Mahogany *Eucalyptus robusta* occurs in coastal areas of NSW, in "*low swampy sites on sandy soils*" from Moruah north into Queensland (Harden 1992).
Potentially suitable habitat for the Swamp Mahogany is scattered throughout the coastal forests of the locality, and throughout the north and central coast areas of NSW (NP&WS 1994a).

The forested lands in the tenure of the NP&WS and NSW State Forests along the NSW central and north coasts provide relatively extensive areas of habitat with "*long-term security*" in appropriate "*tenure*" for the conservation of habitats for the Swamp Mahogany.

There are no known detailed investigations of "*other populations*" of Swamp Mahogany in the locality, but suitable habitat is noted as having been "*extensively cleared and fragmented in the far north*" of the NEFBS study area NP&WS 1994a).

9.2.20 *Hakea bakeriana*

The plant *Hakea bakeriana* occurs in "*dry sclerophyll forest on the coast and adjacent ranges*" from Newcastle to Glenorie (Harden 1992).

Potentially suitable habitat for *Hakea bakeriana* is widely distributed throughout the range of this species, including in the forests of the study area.

Substantial areas of potentially suitable forested lands are protected under the tenure of the NP&WS and NSW State Forests within the range of *Hakea bakeriana*, providing areas of potential habitat with "*long-term security*" for the conservation of *Hakea bakeriana*.

There are no known detailed investigations of "*other populations*" of *Hakea bakeriana* in the locality.

9.2.21 *Tetratheca juncea*

The threatened shrub *Tetratheca juncea* occurs in "*swampy heath and dry sclerophyll forest*" on the central coast of NSW, from Bulahdelah to Wyong (Harden 1993).

Potentially suitable habitat for *Tetratheca juncea* is widely distributed throughout the range of this species, including in the forests of the study area, although the species appears to be only patchily distributed throughout the forests within its range (R Payne *in press*; D Fanning *pers obs*). This species was located at several sites along the Karuah Bypass alignment, and has also been recorded in nearby sites, including the Karuah Quarry (Gunninah 1997) and the Karuah to Bulahdelah Upgrade of the Pacific Highway (ERM Mitchell McCotter 1999).

Substantial areas of potentially suitable forested lands are protected under the tenure of the NP&WS and NSW State Forests within the range of *Tetratheca juncea*, but there are significant populations of the species on private lands with no "*long-term security*" for the conservation of *Tetratheca juncea*.

An ongoing detailed investigation of "*other populations*" of *Tetratheca juncea* is currently being conducted through the species' distributional range, including studies of populations of *Tetratheca juncea* in the locality. The large population adjacent to the Pacific Highway to the east of the Karuah Bypass project has largely been protected by appropriate design measures (ERM Mitchell McCotter 1999), and the smaller populations on the Karuah Quarry site are also to be protected (Gunninah *in press*).

10 ASSESSMENT of LIKELY IMPACTS

The TSC Act requires, under Section 110(2)(g), that a Species Impact Statement include:

> *"a full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region".*

Item 2 of the D-G's Requirements for the preparation of this SIS for the Karuah Bypass indicates that "*this section* [of the Requirement] *expands upon Section 110(2) of the TSC Act, points (b) (c) and (g)".*

Section 110(2)(g) has been supplemented by Item 2 of the D-G's Requirements for this SIS (Chapters 10.1 - 10.4). These elements of the D-G's Requirements provide a focus for presenting "*a full assessment of the likely effect of the action*", both in terms of direct and indirect effects.

Interpretation of Section 110(2)(g)

Whilst the meaning and intent of the first part of Section 110(2)(g) is clear, the second part of Section 110(2)(g) is equivocal. The meaning of "*the quantitative effect of local populations in the cumulative effect in the region*" is uncertain, although it would appear to request some attempt to assess the contribution of impacts arising from the activity to the cumulative impacts of development activities throughout the region.

Assuming that interpretation is correct, it is not "*possible*" to determine "*the quantitative effect*" of impacts on local populations in terms of the "*cumulative effect in the region*" on those species, given the lack of sufficient data to quantify those impacts. There are insufficient data to determine "*the quantitative effects*" of the activity except in a few instances (*eg* the approximate number of hollow-bearing trees to be removed). Furthermore, there are no data sufficient to quantify "*the cumulative effect in the region*". Consequently, there is no basis on which to quantify the effect of the proposed Karuah Bypass with respect to the cumulative impacts of development, and conservation, in the region.

10.1 Habitat Removal or Modification

The D-G's Requirements for the Karuah Bypass SIS include:

> *"2.1 For each affected species, the SIS shall state the following:*
>
> - *the location, nature and extent (number of hectares) of each affected species' habitat and vegetation community to be removed or modified as a result of the proposed action;*
> - *the potential impact of the removal or modification of habitat;*
> - *the likely contribution of the proposed action to threatening processes (not restricted to key threatening processes) acting on populations of those species in the locality; and*
> - *an assessment of whether the affected species, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion."*

Habitat Removal and Modification

The "*location, nature and extent*" of habitat "*to be removed or modified as a result of the proposed action*" has been determined by overlaying the road alignment onto the vegetation communities and fauna habitat mapping, and identifying:

- the "*location*" of relevant habitat for each species to be "*removed or modified*";
- the "*nature*" of the habitat to be "*removed or modified*" with respect to the habitat types and the resources present (*eg* hollow-bearing trees, breeding sites *etc*) in the mapped areas; and

- the "*extent (number of hectares)*" of the habitat to be "*removed or modified*" by the use of GIS based calculations of the areas of vegetation communities to be "*removed*" by the road footprint and by construction requirements, and the area to be "*modified*" by including an additional 20m on each side of the footprint[8].

The total footprint of the Karuah Bypass is 55.84 hectares, of which 16.91ha is located within already cleared or highly disturbed land. The project will require the loss of 36.06ha of forested and naturally vegetated land along the alignment, predominantly involving open forest dominated by Spotted Gum, as well as open forest and woodland communities dominated by Smooth-barked Apple and Sydney Peppermint, and by Smooth-barked Apple, Brown Stringybark and Bastard Mahogany. Small areas of moister or riparian forest (dominated by Cabbage Gum, White Stringybark and Rough-barked Apple) and 1.9ha of saline wetlands (both mangroves and salt-marsh) will also be affected by the road footprint, although these latter areas are likely to only involve direct habitat and vegetation loss at the bridge support structure sites, following rehabilitation of construction areas.

Table 10.1 The total area (hectares) of each vegetation community within the study area, to be removed for the proposed Karuah Bypass (Horse Island Route), and an estimate of the extent of 'edge-effects'. Figures are approximate and subject to revision.

Vegetation Community		Total Area within the Study Area hectares	Area to be Removed hectares	'Edge Effect' hectares
1a	Open Forest - Spotted Gum	519.86	11.17	9.2
1b	Open Forest/Forest - Spotted Gum	71.51	1.75	2.8
2	Open Forest - Smooth-barked Apple	193.8	10.38	4.8
3	Woodland/Open Forest - Smooth-barked Apple	145	5.47	4.0
4	Open Forest - White Stringy-bark	111.15	3.99	4.0
5a	Freshwater Wetlands: Sedgelands	43.14	0	0
5b	Low Forest/Closed Low Forest	5.4	1.4	0.4
6a	Estuarine community - Mangrove Open Scrub	94.78	0.6	0.8
6b	Estuarine Wetlands: Saltmarsh	72.61	1.3	0.8
7	Cleared/Disturbed Land	340.43	16.91	N/A
	TOTAL(of native vegetation)	**1597.68**	**36.06**	**26.8**

Potential Impacts

Consideration of "*the potential impacts of the removal or modification of habitat*" for the range of threatened biota relevant to the Karuah Bypass project is based on:

- the extensive field investigations conducted for the project and for this SIS (Chapter 3; Appendices C, D, E);
- information obtained for other reports and projects in the locality and general vicinity (see Bibliography; Chapter 3);
- databases of flora and fauna species recorded in the locality and region; and

8 The impact of 'edge effects' in terms of the modification of habitat "*as a result of the proposed action*" requires a determination of the extent of 'edge effects' which may arise as a result of the activity. Consideration of the vegetation communities and habitats along the Karuah Bypass alignment, and their nature and condition, and the responses of native biota to 'edge effects' (Chapter 10.4) leads to a conclusion that a distance of approximately 20m for the imposition of 'edge effects' is appropriate in the case of the Karuah Bypass.

- consideration of the extent and tenure of lands in the immediate vicinity of the Karuah Bypass and in the locality generally.

As there is no clear quantitative measure by which "*potential impact*" can be determined, factors such as the overall distribution of the species, the condition of habitat and resources to be affected by the project, the distribution of relevant resources and vegetation in the locality, and the relative extent of habitat to be modified or to be removed, has been taken into account in determining "*the potential impacts*" of the project on the "*affected species*".

Threatening Processes

Activities which involve the removal of habitat or resources for native flora and fauna (particularly threatened species) or which contribute to environmental degradation by habitat disturbance or modification (*eg* erosion and sediment discharge), or which increase rates of wildlife mortality, are considered "*threatening processes*" for native biota in general and for threatened species in particular. The "*key threatening processes*" which do or could threaten the fauna and flora species considered of relevance to the proposal are also discussed in Chapter 7.3 of this SIS, as required pursuant to Section 110(2)(c) of the TSC Act.

The proposed Karuah Bypass project clearly has the potential to contribute to the "*threatening processes in the locality*", particularly in relation to:

- habitat and resource loss, particularly for those species dependent upon habitat features or resources of restricted or limited distribution in the environment. Given the nature and condition of the vegetation and habitats along the Karuah Bypass, including the wide distribution and extent of conserved lands in the immediate vicinity, the physical loss of habitat for most species is not regarded as likely to contribute significantly to "*threatening processes in the locality*". For some resources, however, the Karuah Bypass will doubtless contribute to "*the threatening processes in the locality*", most notably with regard to a loss of hollow-bearing trees. Furthermore, there will be an increase in "*threatening processes*" applied to species or individuals immediately adjacent to or along the alignment;
- habitat fragmentation, which can reduce population viability by separating individuals into small isolated populations and limit the potential for dispersal and/or inter-breeding. The Karuah Bypass will doubtless contribute to this "*threatening process*" in relation to a number of species on the western side of the Karuah River (*eg* the Squirrel Glider, Long-nosed Potoroo - if present, and other terrestrial fauna);
- the creation of barriers to movements of animals through the landscape, which also divides populations and resources and creates inter-breeding barriers. This concern is particularly relevant for terrestrial fauna, some arboreal species, and some plants which rely on animal vectors for seed dispersal; and
- an increase in mortalities of native fauna, as a result of animals attempting to cross the roadway and colliding with vehicles.

The Karuah Bypass project has incorporated an array of impact amelioration measures intended to reduce or limit the adverse impacts imposed upon native biota, and to limit the extent to which the Bypass contributes to the "*threatening processes*" affecting threatened species.

Specific design and construction measures have been incorporated (as discussed below) to reduce these "*threatening processes*" on threatened biota.

Conservation Reserves

Undertaking an "*assessment of whether the affected species, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*" is difficult because of a general lack of detailed information with respect to species' distributions and abundances within conservation reserves. Whilst

information is available for a few threatened species in some parts of NSW, generally there are insufficient data to determine whether or not threatened species, or their habitats, "*are adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*".

For most threatened species, it may be assumed that neither the species nor their habitats are "*adequately represented in conservation reserves*", given that less than 10% of NSW is contained in dedicated reserves. On this basis alone, most conservators would suggest that most threatened species and their habitats are clearly not "*adequately represented*". Indeed, if a species and its habitat was "*adequately represented in conservation reserves*", it would presumably not be "*threatened*", by definition.

In addition, there is some debate regarding the definition "*other similar protected areas*", particularly in terms of "*security of tenure*" and with respect to conservation outcomes and the conservation of species and their habitats. Forested lands managed by State Forests of NSW and by other government bodies (such as the Hunter Water Corporation) contribute to the conservation of threatened flora and fauna (notwithstanding their use for other purposes), given the abundance and distribution of threatened biota and their habitats within these lands, and the constraints on current land use activities.

The value of many areas of crown land (such as the State Forests in NSW) for the conservation of threatened biota is unequivocal, given the extent of State Forest lands which have recently been transferred into the tenure of the NP&WS, and the imposition of an array of management measures in the licensing of forestry operations, which are specifically designed to protect threatened biota and their habitats.

Clearly, both State Forests and other crown lands (such as those managed by the Hunter Water Corporation) constitute "*protected areas*" with respect to the conservation and maintenance of populations of threatened biota and their habitats. Even including these other forested areas, however, it is not certain that most threatened species would be "*adequately represented*".

10.1.1 Koala

Habitat Removal and Modification

Koalas occur widely throughout the area traversed by the Karuah Bypass, with records west of the Karuah River (throughout the forested portion of the route) and also at the eastern extremity of the Bypass (in woodland near the existing Karuah Quarry). The Karuah Bypass traverses forested land, which is classified as "*moderate*" Koala habitat (Lunney *et al* 1998), although the numbers of this species in the vicinity of the Bypass seems relatively low.

The Karuah Bypass will remove forest and woodland habitat used by Koalas, although much of the vegetation to be removed (particularly west of the Karuah River) is modified as a result of long-term timber harvesting and burning. Similarly, the woodland and open forest vegetation to be removed east of the Karuah River has been affected by previous land management practices, although it should be noted that regrowth forest does provide suitable resources for Koalas.

The Karuah Bypass will remove approximately 27ha of woodland and open forest vegetation, most of which is or may be used by Koalas.

Potential Impacts

It is likely that some individual Koalas will be adversely affected by the loss of resources resulting from the proposed action. However, the relatively low density of the species within the affected forest areas suggests that the population in the locality will not be significantly affected by direct habitat loss. However, the Bypass may represent a movement barrier for some Koalas, despite the provision for fauna underpasses.

Whilst the Karuah Bypass will involve the removal of some forest resources for Koalas and may reduce the ability of individuals to move freely throughout the

landscape, the potential impact of the project on this species is regarded as relatively low because:

- only a small area of habitat and resources is to be removed relative to that present in the locality and region;
- Koala use of the area through which the Bypass is located appears to be relatively low; and
- impact amelioration measures are to be implemented to reduce the potential impacts upon individual Koalas or on the general population (see below), including the protection of individual animals during the construction process.

Threatening Processes

As noted above, the Karuah Bypass will clearly contribute "*to threatening processes acting on populations*" of the Koala "*in the locality*". Conversely, the relatively small area of habitat to be removed, the large area of suitable resources and habitat "*in the locality*" which is to be retained, the relatively low use by Koalas of the area traversed by the Karuah Bypass, and the impact amelioration measures to be implemented as part of the project, mitigate or reduce "*the likely contribution of the proposed action to threatening processes*" on the Koala.

The implementation of impact amelioration measures, particularly those associated with preventing Koalas gaining access to the roadway and the provision of underpasses for safe passage, may reduce Koala mortalities in the locality. There are currently no appropriate measures implemented along the existing Pacific Highway near Karuah to prevent Koalas gaining access to the road, and as a consequence Koala mortalities regularly occur along this portion of the Highway. The new alignment will be fenced at appropriate locations to prevent Koalas gaining access to the road, and will reduce traffic levels on the existing Pacific Highway. Consequently, Koala roadkills in the locality overall could decline.

With respect to the "*threatening processes*" identified by Gilmore & Parnaby (1994), the Karuah Bypass area generally is not regarded as likely to constitute "*optimum habitat*" for the Koala. This area was not identified as of "*high*" value for Koalas in the Koala Summit Management Plan (Lunney *et al* 1998), and Koala activity along the alignment is relatively low by local standards. Thus, as noted above, the Karuah Bypass is not regarded as likely to significantly contribute to the "*threatening processes*" imposed upon the Koala in this locality, although the road will contribute to "*fragmentation of the habitat*" (Gilmore & Parnaby 1994) in the locality.

Conservation Reserves

Koalas are not likely to be "*adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion*", given the broad distribution of this species and the relatively low frequency of Koala records in reserves compared to on lands of other tenure (Reed & Lunney 1990).

Conversely the State Forests and Hunter Water Corporations lands (which are regarded as relevant with respect to the conservation of Koalas given their management) contribute in a positive manner to the conservation of the Koala in this region. There are few activities in the Water Corporation's lands which would threaten Koalas, and logging in State Forests is subject to strict constraints with respect to this species. Consequently, this species may be regarded as "*adequately represented in conservation reserves (or other similarly protected areas) in the region and subregion*", although a more restrictive application of the term "*conservation reserves (or other similar protected areas)*" would suggest otherwise. It is of particular note that significant areas of State Forests have recently been transferred to the tenure of the NP&WS, doubtless increasing the representation of the Koala within dedicated "*conservation reserves*".

10.1.2 Squirrel Glider

Habitat Removal and Modification

Squirrel Gliders were only located to the west of the Karuah River, although the species could also occur in the woodland and open forest habitats to the east. The area of particular relevance with respect to the habitat for the Squirrel Glider "*to be modified or removed*" is that forest within the newly gazetted Karuah NR, as the proposed Bypass will create a barrier to movement for the species in this area.

The Karuah Bypass will remove forest and woodland habitats, particularly west of the Karuah River, involving a loss of potential foraging habitat and the removal of hollow-bearing trees, which are a specific resource of relevance for this hollow-dependent species. Whilst the forest vegetation west of the Karuah River has been affected by previous timber removal and bushfire activities, the area is clearly of value for this species, given the presence of individuals in these communities and the occurrence of suitable hollow-bearing trees.

A total of 27ha of woodland and open forest vegetation are to be removed along the Karuah Bypass, with the approximately 20ha located west of the Karuah River being of greatest relevance with respect to Squirrel Gliders. Approximately seventy hollow-bearing trees are to be removed, although the alignment does not support a significant or unique resource in this regard.

Potential Impacts

The Karuah Bypass will affect the Squirrel Glider through the loss of some habitat and resources (both woodland and open forest for foraging and hollow-bearing trees for nesting), and could impose a significant movement barrier for this species.

Relative to adjacent foraging and nesting habitat and resources, the area to be affected is small (approximately 27ha of loss and 20ha of 'edge effects'). Given the thousands of hectares of suitable habitat in the locality, the area "*of habitat to be removed or modified as a result of the proposed action*" is not likely to limit the population in the locality or subregion. Nevertheless, measures are to be implemented during the construction of the Karuah Bypass to limit the potential for adverse impacts to be imposed on Squirrel Gliders, particularly associated with protecting individual animals during clearing operations

The potential for the Karuah Bypass to prevent the movement of Squirrel Gliders in an east-west direction has been recognised, and measures have been incorporated into the road design to enable Squirrel Gliders to continue moving through the landscape. The total road width from the outside of the shoulders and including the 11m median strip is approximately 30m. Through the retention of trees adjacent to the roadway and in the median (as detailed in Chapter 12 of this SIS) the distance of 'tree-to-tree' glider crossings will be approximately 20m. This measure may provide the Squirrel Glider with a means of safe passage across the Highway.

On the basis of the impact amelioration measures documented in this SIS, the relatively small area of habitat and resources to be removed compared to their total extent in the locality and region, and the extent of newly gazetted conservation reserves in the vicinity, the Karuah Bypass is likely to have only a relatively limited impact upon a number of individual Squirrel Gliders or family groups in the immediate vicinity of the *alignment*. However, the "*potential impact*" of isolation due to restrictions on animal movements is regarded as of concern.

Threatening Processes

The "*proposed action*" (*ie* the Karuah Bypass) will contribute to some extent *"to threatening processes"* which affect local individuals and populations of Squirrel Gliders "*in the locality*". The project involves the removal of potential Squirrel Glider nesting and foraging habitat, and may restrict the freedom of movement of animals in the locality.

Conversely, the proposed Bypass involves the implementation of measures to limit the removal of habitat and resources, and measures to enable Squirrel Gliders to cross the completed road. Given these approaches to the *"proposed action"*, and the relatively small area of habitat and resources to be removed compared to their extent in the locality, it seems unlikely that the Karuah Bypass will significantly contribute *"to threatening processes acting on populations"* of the Squirrel Glider *"in the locality"*.

Conservation Reserves

Similar considerations apply to the Squirrel Glider as to the Koala (Chapter 10.1.1) with regard to the adequacy of this species representation in conservation reserves. Squirrel Gliders are not generally regarded as "*adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion,*. given the broad distribution of this species and the relatively restricted extent of dedicated regional conservation reserves.

Conversely, the State Forests and Hunter Water Corporation lands (which are relevant with respect to the conservation of Squirrel Gliders, given the constraints placed on their management) contribute in a positive manner to the conservation of this species in this region. These lands contain relevant habitat and resources, and clearly constitute relevant habitat for this species. There are few activities in the Water Corporation's lands which would threaten Squirrel Gliders, and logging in State Forests is subject to strict constraints with respect to this species. Consequently, the species may be regarded as "*adequately represented in conservation reserves (or other similarly protected areas) in the region and subregion*", although a more restrictive application of the term "*conservation reserves (or other similar protected areas)*" would suggest otherwise. It is of particular note that significant areas of State Forests have recently been transferred to the tenure of the NP&WS, doubtless increasing the representation of the Squirrel Glider within dedicated "*conservation reserves*".

10.1.3 Long-Nosed Potoroo

Habitat Removal and Modification

The Long-nosed Potoroo generally prefers areas with a mosaic of dense ground cover and understorey within open forest and woodlands. This species is only likely to be distributed in relatively small localised patches along the proposed Karuah Bypass alignment, given the generally open nature of the understorey in most vegetated areas, and the high frequency of disturbance and fire. Whilst individual Long-nosed Potoroos could theoretically occur throughout much of the open forest and woodland vegetation along the Karuah Bypass alignment, the nature of the vegetation and the lack of evidence for the species' presence (except at the Karuah Quarry), suggests that only a small portion of the vegetation to be removed would be regarded as suitable habitat for the Long-nosed Potoroo.

Given the variable nature and condition of vegetation along the Karuah Bypass alignment, and the limited data with regard to the Long-nosed Potoroo in this locality, it is not possible to clearly define the "*extent (number of hectares)*" of suitable habitat for this species which will be removed by the Karuah Bypass. However, it is likely that only a small proportion (perhaps 10%) of the approximately 27ha of forest and woodland habitat which is to be removed for the Bypass would be suitable for the Long-nosed Potoroo.

Potential Impacts

Whilst the Long-nosed Potoroo was sighted at the eastern end of the proposed Karuah Bypass, the extent of suitable habitat for this species is limited along the alignment. Given that only a few hectares (at most) of potentially suitable dense understorey habitat for this species is to be affected by the proposed activity, the Karuah Bypass is not likely to impose a significant impact upon the species, with respect to "*the removal or modification of habitat*".

Conversely, the proposed Bypass will fragment habitat in the locality, and potential future

habitat for the species in the vicinity could be restricted or isolated by the proposed Bypass. In addition to the loss of potential 'known habitat' for the species along the existing Bypass, construction of the road could restrict future movements of this species, if it is present along the alignment.

Threatening Processes

Habitat loss and habitat modification are likely to be the most significant "*threatening processes*" for the Long-nosed Potoroo, in conjunction with increases in predation due to habitat modification. Only a small proportion of the forest and woodland vegetation along the Karuah Bypass alignment is regarded as of particular value for the Long-nosed Potoroo, given the relatively sparse understorey and groundcover present along most of the proposed alignment.

Given the above considerations, and particularly the relatively small area of habitat regarded as of potential significance for the Long-nosed Potoroo along the Karuah Bypass alignment, it appears that the proposed roadworks are not likely to contribute significantly to "*threatening processes .. acting on populations*" of the Long-nosed Potoroo in the locality or region.

The "*threatening processes*" which apply particularly to the Long-nosed Potoroo (Gilmore & Parnaby 1994) include "*changes in pasture composition and productivity induced by ring-barking of trees, introduction of exotic pasture species, and the changes in standing crop and growth induced by feeding of*" introduced herbivores. The Karuah Bypass will not contribute to these "*threatening processes*", but may reduce habitat availability and freedom of movement to some extent. The Bypass will not affect the likelihood of predation by feral animals on the Long-nosed Potoroo, a phenomenon also regarded as a particular "*threatening process*" for this species.

Conservation Reserves

Notwithstanding the extent of vegetated lands contained in State Forests and the Hunter Water Corporation tenure, and the extent of National Parks, Nature Reserves and other dedicated conservation reserves in the locality and region, the Long-nosed Potoroo is unlikely to be "*adequately represented*" in such reserves.

10.1.4 Brush-tailed Phascogale

Habitat Removal and Modification

The Brush-tailed Phascogale utilises open forest and woodland communities with a relatively sparse understorey, and relies on small to medium tree-hollows for shelter. This species has been recorded to the west of the Karuah Bypass (in Wallaroo and Medowie SFs), but was not recorded in investigations for the Karuah Bypass. The recent and ongoing disturbance to the open forest and woodland communities west of the Karuah River, particularly the frequency of fire and the recent bushfires, are considered likely to have reduced the value of this habitat for the Brush-tailed Phascogale. However, the woodland and open forest vegetation along the Karuah Bypass particularly west of the Karuah River, is regarded as potentially suitable habitat for this species, dependent on an appropriate burning regime.

A total of approximately 27ha of open forest and woodland vegetation are to be removed for the Karuah Bypass, much of which could potentially be used by the Brush-tailed Phascogale, despite the lack of evidence for its presence.

Potential Impacts

The Brush-tailed Phascogale was not recorded in the study area during investigations for the Karuah Bypass, but has been recorded in the locality, including during previous investigations conducted by Gunninah (1997a, b). Given the lack of evidence for this species

in the vicinity of the alignment, particularly in comparison to its apparent relative abundance to the west and southwest, it appears that the vegetation and habitats "*to be removed or modified as a result of the proposed action*" are not of particular significance or relevance for the conservation of the Brush-tailed Phascogale in the vicinity.

Conversely, individuals of this species could potentially utilise portions of the Bypass alignment for foraging, at least, and the forested areas could readily constitute suitable habitat in the future, dependent on appropriate management of the land. On this basis, the Karuah Bypass has the potential to remove suitable habitat for this species.

If there is a population of Brush-tailed Phascogales in the vicinity of the Karuah Bypass, the road would doubtless provide a movement barrier for individuals in the immediate vicinity. Conversely, a number of fauna underpasses have been provided along the alignment (Chapter 12), to provide for continuing movement of individuals of this and other species, if they are present.

Threatening Processes

The loss or modification of habitat and resources for the Brush-tailed Phascogale would, in some circumstances at least, constitute a threat to the conservation and survival of this species. Conversely, the Karuah Bypass study area does not appear to support a population of the Brush-tailed Phascogale, and the road consequently would not appear to contribute in a significant manner to the "*threatening processes*" which are currently imposed upon this species in the locality.

Conversely, transfer of areas of State Forest around the Karuah Bypass into the tenure of the NP&WS will lead to land use management changes, which may render the vegetation adjacent to the Karuah Bypass of greater value for Brush-tailed Phascogales. Under those circumstances, the Bypass would contribute to the "*threatening processes*" imposed upon this species, by the alienation of a portion of the landscape and potentially by mortalities or restrictions on animal movements.

Conservation Reserves

Brush-tailed Phascogales are not likely to be "*adequately represented in conservation reserves or other similar protected areas) in the region and the subregion*", notwithstanding the substantial recent increases in the NP&WS estates in the region. The State Forests and Hunter Water Corporation lands (which are relevant with respect to the conservation of Bush-tailed Phascogales, given their management protocols and regimes), contribute in a positive manner to the conservation of the Brush-tailed Phascogales in this region.

10.1.5 Tiger Quoll

Habitat Removal and Modification

No evidence for the Tiger Quoll was obtained west of the Karuah River, and the disturbed nature of the forest and woodland communities in this area render this portion of the Karuah Bypass alignment of little significance or relevance for this species. On the eastern side of the River, potentially suitable habitat is confined to Mosquito Creek and its tributary which does support dense vegetation and other resources of potential relevance (*eg* rock outcrops and hollow logs) for this species. Whilst Tiger Quolls were not recorded in this part of the study area, they have been recorded from forested portions of land to the south.

Considering the condition of vegetation present along the Karuah Bypass, only a few hectares of potential habitat will be "*removed or modified*" by the roadworks. The total area of open forest and habitat areas to be removed along the Karuah Bypass is approximately 27ha, but only a small proportion of this is regarded as constituting suitable habitat for the Tiger Quoll.

Potential Impacts

Given the nature and condition of habitat along the alignment and the absence of any evidence of the Tiger Quoll in the study area, the *"removal or modification of habitat"* for the Tiger Quoll along the Karuah Bypass is not regarded as likely to significantly affect this species. Impacts on animal movements are unlikely to be significant considering that no suitable habitat will be isolated by the proposed alignment and that the current Pacific Highway forms an existing barrier to the south. The potential for Tiger Quolls to move in a north-south direction along Mosquito Creek and its tributary will be maintained by substantial underpasses at these locations.

Consequently, whilst the removal of vegetation, and of features such as rock outcrops and hollow logs could potentially affect Tiger Quolls, the lack of evidence for the species specifically along the alignment and the limited extent of potential habitat for the Tiger Quoll renders the proposed Karuah Bypass of limited significance in terms of "*the potential impact or the removal or modification of habitat for this species*".

Threatening Processes

As noted above, the removal of forest vegetation and resources such as logs and rock outcrops are generally regarded as *"threatening processes*, particularly with respect to species such as the Tiger Quoll. However, the *"proposed action"* along the Karuah Bypass alignment is not regarded as likely to contribute significantly *to "threatening processes acting on populations"* of the Tiger Quoll "*in the locality*", given the lack of evidence for the species in the study area and the limited habitat of value along the alignment. Whilst Tiger Quolls could theoretically utilise those resources and habitat features which will be affected by the Karuah Bypass, it is unlikely that the alignment constitutes significant habitat or resources for this species or for populations of the Tiger Quoll, *"in the locality"*.

Construction of the Karuah Bypass could potentially impose a movement barrier to Tiger Quolls in the locality, assuming that animals are moving generally throughout the landscape. However, no evidence (neither direct or indirect) has been recorded to indicate this species presence in the study area (nor immediate vicinity) on either a permanent or transitory basis. Given their preference for areas with a relatively dense understorey, the sites most relevant for movements of Tiger Quolls would include Mosquito Creek and its tributary (east of the Karuah River) and small creeklines to the west (if Tiger Quolls are present in this area at all). Whilst roads in general could constitute a "*threatening process*" in terms of restricting animal movements, the large bridge structure over Mosquito Creek and its tributary, and other underpasses along the alignment, are likely to provide suitable crossing points for the Tiger Quoll. As a consequence, the Bypass is not regarded as likely to contribute to the "*threatening processes*" acting upon this species, in terms of restrictions on animal movements.

Conservation Reserves

The Tiger Quoll occurs only at relatively low densities and is sparsely distributed in the region and subregion, and appears particularly sparse in the locality. Conversely, there are significant areas of potentially suitable habitat for this species located within *"conservation reserves and other similar protected areas"* in the region and subregion. It is possible that the Tiger Quoll is adequately represented in such areas, but there are not sufficient population data to determine this issue with any certainty.

As for many other threatened species, State Forests and other forested lands protected by crown tenure (*eg* the Hunter Water Corporation Lands) are likely to contribute significantly to the representation of this species in areas managed either solely or at least appropriately for wildlife conservation purposes. However, it is not clear whether the Tiger Quoll is "*adequately represented in conservation reserves*" in the region or sub-region.

10.1.6 Greater Broad-nosed Bat

Habitat Removal and Modification

The Greater Broad-nosed Bat nests and roosts in tree-hollows, and forages in forested habitats, particularly along water courses and rivers. This species is likely to occur widely along the Karuah Bypass, and could utilise hollow-bearing trees and the open forest woodland communities generally along the alignment.

The forested portions of the Karuah Bypass alignment, particularly west of the Karuah River, have long been utilised for timber harvesting and have been affected by frequent fire and other disturbances. As a consequence, these areas support a relative low density of hollow-bearing trees, and the alignment does not appear to support significant or restricted roosting resources for the Greater Broad-nosed Bat, compared to other portions of forest in the vicinity.

A total of approximately 27ha of open forest and woodland vegetation are to be removed along the Karuah Bypass, most of which could be utilised by the Greater Broad-nosed Bat for both foraging and roosting activities.

Potential Impacts

The "*removal or modification of habitat*" for the Greater Broad-nosed Bat, particularly the loss of hollow-bearing trees and foraging habitat, would adversely affect individuals using these resources. However, the vegetation along the alignment and in the vicinity is not unique, and only a small area of potential habitat and resources, and relatively few individual hollow-bearing trees, will be removed as part of the Karuah Bypass project. Furthermore, the Bypass is not likely to adversely affect movement of animals through the locality, considering the highly mobile nature of this species.

Consequently, although the removal of hollow-bearing trees and potentially suitable foraging habitat for the Greater Broad-nosed Bat may adversely impact upon individuals of this species, the Karuah Bypass is not likely to be significant in terms of the conservation of the Greater Broad-nosed Bat in the general locality or region. Impacts on the species are likely to be localised and limited in extent.

Some limited potential for direct mortality of roosting trees is recognised; habitat checks prior to felling have been incorporated to ameliorate this impact.

Threatening Processes

As indicated above, the removal of habitat and resources for the Greater Broad-nosed Bat will clearly contribute "*to threatening processes acting on populations*" of this species "*in the locality*", assuming that some individuals or groups of this species will be directly affected by the loss of vegetation. Conversely, the habitats and resources present along the Karuah Bypass are widely distributed in the locality, and are well-conserved in dedicated reserves and the State Forest and crown lands under other tenure.

Conservation Reserves

Given the extent of potentially suitable habitat available "*in the region and the subregion*" for the Greater Broad-nosed Bat, the frequency with which this species is recorded during microchiropteran bat surveys, and the distribution and extent of "*conservation reserves (and other protected areas)*", it appears likely that this species may be "*adequately represented*" in such reserves. Even excluding State Forest and other crown reserved land (which support resources for individuals or populations of the Greater Broad-nosed Bat), this species is likely to be adequately represented in conservation reserves.

10.1 7 Little Bent-wing Bat

Habitat Removal and Modification

There are no suitable roosting resources for the Little Bent-wing Bat along the Karuah Bypass alignment, but the open forest vegetation, particularly in the denser and moister locations along the creeklines and gullies, constitutes suitable foraging habitat for this species.

The open forest and woodland communities which are to affected by the Karuah Bypass, and which could constitute foraging habitat for the Little Bent-wing Bat, involves an area of approximately 27ha.

Potential Impacts

The "*removal or modification of habitat*", particularly foraging habitat, for the Little Bent-wing Bat would adversely affect individuals utilising those resources. However, the area of suitable habitat to be removed along the Karuah Bypass is likely to comprise only a small component of a much wider foraging resource utilised by this species. Furthermore, the Bypass is not likely to effect the movement of the Little Bent-wing Bat through the locality, given the highly mobile nature of this species.

Whilst, the removal of potential foraging habitat may adversely affect some individuals of this species in the vicinity of the Bypass, the proposed Karuah Bypass is not likely to significantly effect the conservation of the Little Bent-wing Bat in the general locality or in the region. Impacts on this species are likely to be localised and limited in extent.

Threatening Processes

The most significant "*threatening processes*" for the Little Bent-wing Bat are related to the disturbance and removal of roosting sites and large maternity caves, upon which the species depends for breeding success. Whilst the removal of foraging habitat, particularly moist forest communities, may constitute a threat to the species in general terms, the substantial areas of forest and woodland vegetation in the vicinity of the Karuah Bypass are well conserved in dedicated conservation reserves and the State Forest and crown lands under other tenure.

Given that no roosting or breeding sites will be disturbed or removed by the Karuah Bypass, and that only a small area of open forest and woodland vegetation (relative to that present "*in the locality*") is to be removed, the Karuah Bypass is not likely to significantly contribute to those "*threatening processes acting on the population*" of the Little Bent-wing Bat "*in the locality*".

Conservation Reserves

Given the extent of the forest lands contained within "*conservation reserves (and other similar protected areas) in the region and subregion*", including State Forests and other crown reserve lands which are managed (to some extent at least) for conservation purposes, it would appear likely that habitat and resources for the Little Bent-wing Bat are "*adequately represented*" in the conservation estate (and in the state generally). However, with respect to the Little Bent-wing Bat, the reliance of the species on relatively few maternity caves for breeding success suggests that the species, or at least significant elements of its habitat requirements, are not "*adequately represented*" in the region.

Whilst the Little Bent-wing Bat may not be "*adequately represented in conservation reserves (and other similar protected areas) in the region and subregion*", the Karuah Bypass is not regarded as likely to adversely affect the conservation status of this species or to adversely impact upon the adequacy of its representation "*in conservation reserves*".

10.1.8 Common Bent-wing Bat

Habitat Removal and Modification

There are no suitable roosting resources for the Common Bent-wing Bat along the Karuah Bypass alignment, but the open forest vegetation, particularly in the denser and moister locations along the creeklines and gullies, constitutes suitable foraging habitat for this species.

The open forest and woodland communities which are to affected by the Karuah Bypass, and which could constitute foraging habitat for the Common Bent-wing Bat, involves an area of approximately 27ha.

Potential Impacts

The "*removal or modification of habitat*", particularly foraging habitat, for the Common Bent-wing Bat would adversely affect individuals utilising those resources. However, the area of suitable habitat to be removed along the Karuah Bypass is likely to comprise only a small component of a much wider foraging resource utilised by this species. Furthermore, the Bypass is not likely to effect the movement of the Common Bent-wing Bat through the locality, given the highly mobile nature of this species.

Whilst, the removal of potential foraging habitat may adversely affect some individuals of this species in the vicinity of the Bypass, the proposed Karuah Bypass is not likely to significantly effect the conservation of the Little Bent-wing Bat in the general locality or in the region. Impacts on this species are likely to be localised and limited in extent.

Threatening Processes

The most significant "*threatening processes*" for the Common Bent-wing Bat are related to the disturbance and removal of roosting sites and large maternity caves, upon which the species depends for breeding success. Whilst the removal of foraging habitat, particularly moist forest communities, may constitute a threat to the species in general terms, the substantial areas of forest and woodland vegetation in the vicinity of the Karuah Bypass are well conserved in dedicated conservation reserves and the State Forest and crown lands under other tenure.

Given that no roosting or breeding sites will be disturbed or removed by the Karuah Bypass, and that only a small area of open forest and woodland vegetation (relative to that present "*in the locality*") is to be removed, the Karuah Bypass is not likely to significantly contribute to those "*threatening processes acting on the population*" of the Common Bent-wing Bat "*in the locality*".

Conservation Reserves

Given the extent of the forest lands contained within "*conservation reserves (and other similar protected areas) in the region and subregion*", including State Forests and other crown reserve lands which are managed (to some extent at least) for conservation purposes, it would appear likely that habitat and resources for the Common Bent-wing Bat are "*adequately represented*" in the conservation estate (and in the state generally). However, with respect to the Common Bent-wing Bat, the reliance of the species on relatively few maternity caves for breeding success suggests that the species, or at least significant elements of its habitat requirements, are not "*adequately represented*" in the region.

Whilst the Common Bent-wing Bat may not be "*adequately represented in conservation reserves (and other similar protected areas) in the region and subregion*", the Karuah Bypass is not regarded as likely to adversely affect the conservation status of this species or to adversely impact upon the adequacy of its representation "*in conservation reserves*".

10.1.9 Eastern Free-tail Bat

Habitat Removal and Modification

The Eastern Free-tail Bat is likely to occur widely through the study area and could utilise hollow-bearing trees for roosting, and areas of the open forest and woodland communities for foraging, both of which occur generally along the alignment and widely through the locality. However, as discussed earlier in this SIS, the forested portions of the Karuah Bypass alignment, particularly west of the Karuah River, have long been utilised for timber harvesting and have been affected by frequent fire and other disturbances. As a consequence, hollow-bearing trees do not appear at a high density and the area of suitable habitat to be removed along the Karuah Bypass is likely to comprise only a small component of a much wider foraging resource utilised by this species.

A total of approximately 27ha of open forest and woodland vegetation are to be removed along the proposed Karuah Bypass. Most of these areas could be utilised by the Eastern Free-tail Bat for both foraging and roosting activities.

Potential Impacts

Clearly, the "*removal or modification of habitat*", particularly hollow-bearing trees and foraging habitat, may adversely affect individuals of the Eastern Freetail Bat, and thus potentially reduce the availability of necessary resources for individuals in the locality. However, the locality and region support extensive areas of suitable habitat for the Eastern Free-tail Bat, and the condition and nature of the vegetation present along the Karuah Bypass is not regarded as unique or of special value for this species.

Given these considerations it is not considered likely that potential impacts arising from the proposed Karuah Bypass will be significant with respect to the conservation of the Eastern Free-tail Bat in the locality, subregion or region, especially considering the high mobility of the species.

Threatening Processes

As indicated above, the removal of habitat and resources for the Eastern Free-tail Bat will clearly contribute "*to threatening processes acting on populations*" of this species "*in the locality*", assuming that some individuals or small groups of this species will be directly affected by the loss of habitat and resources. Conversely, the habitats and resources present along the Karuah Bypass are widely distributed in the locality, and well conserved either in dedicated conservation reserves or in State Forest and crown lands under other tenures. Those present along the alignment are not unique or regarded as of special value for the Eastern Freetail Bat.

On this basis, and given the relevantly small areas which are to be adversely affected by the proposed Karuah Bypass compared to the forest and woodland present in the locality and region, it does not appear likely that the Bypass will contribute in a significant manner to those "*threatening processes*" (including the removal of habitat and resources) acting on the populations of the Eastern Free tail Bat "*in the locality*".

Conservation Reserves

Given the extent of potential suitable habitat available "*in the region and the subregion*" for the Eastern Free-tail Bat, and the distribution and extent of "*conservation reserves (and other protected areas)*", it appears likely that this species is "*adequately represented*" in the region, although it is not frequently recorded. The Karuah Bypass is not regarded as likely to adversely affect the representation of the Eastern Freetail Bat in conservation reserves, to any significant extent if at all.

10.1.10 Osprey

Habitat Removal and Modification

Suitable habitat for the Osprey in the study area is restricted to the River, and its immediate proximity. Relevant habitat for this species includes large emergent trees, in which the species construct nests, particularly trees with dead or bare upper branches which provide a view of the surrounding landscape.

The Karuah Bypass incorporates a substantial bridge across the Karuah River, but does not involve the removal of any existing Osprey nests or trees utilised by the species. Whilst the Karuah Bypass will alienate a small area of the River and its environment from use by the Osprey, the Bypass affects only an insignificant proportion of the available habitat for this species in the locality and surrounding region.

It is not possible to specifically identify the area of habitat which will be "*removed or modified as a result of the proposed action*", although the bridges and their approaches along the Karuah Bypass involve only a few hectares which could theoretically include nest trees for this species. Considering the high mobility of this aerial species, the proposed Bypass is not considered to significantly impact on the conservation status of the species.

Potential Impacts

The total area of potential habitat that will be removed or modified by the Karuah Bypass, with respect to the requirements of the Osprey, is extremely small compared to the extent of suitable habitat in the locality. As a consequence "*the potential impact of the removal or modification of habitat for this species*" is regarded as minimal. Additionally, stringent design and environmental management measures are incorporated into the project to protect water quality in the River and other waterbodies.

It is not considered likely that any Ospreys would be adversely affected to any significant extent by the construction or operation of the proposed Karuah Bypass.

Threatening Processes

As noted above, the extent of habitat for the Osprey that will be affected by the Karuah Bypass is extremely small, particularly relative to the extent of habitat and resources for this species in the locality and in the surrounding region. Notwithstanding the loss of a small area of potential habitat for the Osprey, the Karuah Bypass is not regarded as contributing in any significant or meaningful manner to "*threatening processes acting on populations*" of the Osprey "*in the locality*". Neither individuals nor populations of this species are regarded as likely to be significantly affected by the Karuah Bypass.

Conservation Reserves

Notwithstanding the extent of the coastal conservation reserves, particularly in the northern part of NSW where the Osprey is most common, it is not likely that this species would be "*adequately represented in conservation reserves (or other similar protected areas) in the region or subregion*". Ospreys are relatively sparse throughout their distribution, and despite the recent increase in numbers, distribution and breeding success, this species remains susceptible to nest disturbance and potential loss of food resources due to fishing activities. Conversely, Ospreys are known to build nests on artificial structures including roosting platforms, power poles and breakwaters. The Karuah Bypass is not likely to have any significant effect on the conservation status of the Osprey, or its representation in conservation reserves.

10.1.11 Glossy Black Cockatoo

Habitat Removal and Modification

The Glossy Black Cockatoo was recorded in the study area, but not in open forest and woodland communities along the proposed Karuah Bypass alignment. Furthermore, the modified nature of most of the open forest and woodland vegetation along the alignment (supporting relatively low densities of she-oaks and large tree-hollows) are not considered of particular or special value for this species.

The total area of open forest and woodland vegetation to be removed for the Karuah Bypass is 27 hectares, although the areas to be disturbed are regarded as of relatively low value for the Glossy Black Cockatoo.

Potential Impacts

As noted above, most of the vegetation along the Karuah Bypass is of only limited value for the Glossy Black Cockatoo, given the relatively low densities of preferred food trees and hollow-bearing trees for nesting. Whilst Glossy Black Cockatoos could occur in many locations along the alignment, the area which is to be affected by the Karuah Bypass is not critical for the survival of individuals of this species in the locality or region.
The "*potential impact of the removal and modification of habitat*" for the Glossy Black Cockatoo along the Karuah Bypass is not regarded as significant for this species, on the basis that:

- only a small area of potentially suitable habitat is to be removed in comparison with the considerable extent of habitat in the locality and the region;

  substantial areas of suitable habitat for the Glossy Black Cockatoo are included within dedicated conservation reserves and State Forests in the locality;

- there is no evidence of intensive use or breeding activities by Glossy Black Cockatoos along the Karuah Bypass alignment, although individuals may do so on occasions; and

- the Karuah Bypass alignment does not constitute significant or restricted habitat for this species in the locality.

Threatening Processes

On the basis of the considerations outlined above, the Karuah Bypass is not likely to contribute significantly to the "*threatening processes acting*" on the Glossy Black Cockatoo "*in the locality*". Whilst a loss of foraging resources and hollow-bearing trees for nesting generally constitutes a threat to the survival of the species, the limited extent and value of those resources in the vicinity, and along the Karuah Bypass alignment in general, mitigates against the proposed action significantly exacerbating the "*threatening processes*" acting on the Glossy Black Cockatoo "*in the locality*".

Conservation Reserves

The Glossy Black Cockatoo is not regarded as likely to be "*adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*". Notwithstanding the extent of coastal reserves in NSW, and the extent of State Forest and other Crown Lands, the Glossy Black Cockatoo is regarded as vulnerable because of a reduction in resources throughout its distribution.

10.1.12 Bush Stone-curlew

Habitat Removal and Modification

The Bush Stone-curlew was recorded in the study area, in the vicinity of Karuah, although it was not recorded in habitats along the alignment. This species uses open forests and

woodlands with a grassy understorey and scattered logs, which is typical of the vegetation along the alignment. However, the high frequency of fires in the locality may have compromised the potential value of both foraging and nesting habitat and resources along the Karuah Bypass for this species, given that the species is largely terrestrial, and nests on the ground.

The total area of open forest and woodland vegetation that could be utilised by the Bush Stone-curlew which is to be removed for the Karuah Bypass is approximately 27ha. This constitutes only a very small proportion of the area of similar habitat present in the locality, a significant proportion of which is now conserved.

Potential Impacts

The "*removal or modification of habitat*" for the Bush Stone-curlew clearly has significant adverse impacts on the species in a general sense. The removal of open forest and woodland vegetation with a grassy understorey is regarded as being responsible for the significant decline of the species in NSW, along with the effects of feral predators.

The Bush Stone-curlew was not recorded along the Karuah Bypass alignment, but has been recorded in the locality. Whilst the levels of habitat disturbance (particularly fire) are likely to have reduced the value of portions of the study area for this species, its presence near Karuah indicates that the proposed Karuah Bypass has the potential to adversely affect individual birds or a part of the local population by:

- the removal of habitat, both for foraging and nesting, along the alignment (total of approximately 27ha);
- a potential for road mortalities, given that this is a highly terrestrial species; and
- the provision of a barrier to movements of individuals animals within home ranges, although Bush Stone-curlews regularly flock and fly, at least locally, during the non-breeding season.

Given the relative low to moderate value of the habitat and resources along the Karuah Bypass alignment for the Bush Stone-curlew, and the extent of similar potentially suitable habitat in the locality and region, it is not considered likely that the proposed action will impose a significant adverse impact on this species.

Threatening Processes

The removal of open forest and woodland vegetation is one of the "*threatening processes*" acting upon the Bush Stone-curlew. Conversely, the species was not recorded along the Karuah Bypass alignment, and the area of vegetation which is to be removed is not unique or apparently of special value for the species. Given the limited records of this species in the locality, the extent of similar vegetation in the vicinity which is to be retained, the extent of habitat which is now contained within local conservation reserves and the assumed appropriate management of those lands by the NP&WS, the Karuah Bypass is regarded as only contributing to the "*threatening processes acting on populations*" of the Bush Stone-curlew "*in the locality*" to a limited extent.

Other "*threatening processes*" for the Bush Stone-curlew include disturbance to suitable habitat (particularly as a result of bushfire) and predation by feral animals. The Karuah Bypass project is not likely to affect or exacerbate either of these "*threatening processes*", and will not contribute to their impacts upon the Bush Stone-curlew in this locality.

Conservation Reserves

The Bush Stone-curlew is not regarded as "*adequately represented in conservation reserves (or other similar protected areas) in the region and the sub-region*". Notwithstanding the recent substantial increases in the extent of "*conservation reserves*" in the locality, and in the region, the Bush Stone-curlew is not likely to be "*adequately represented*" in such reserves, given its relatively low densities and scattered distribution, and its susceptibility

to disturbance (*eg* bushfire) and predation by feral cats, dogs and foxes.

10.1.13 Masked Owl

Habitat Removal and Modification

The open forest and woodland communities along the Karuah Bypass alignment, particularly west of the Karuah River, provide suitable foraging habitat for the Masked Owl, as well as nesting habitat (in the hollow-bearing trees present). This species is not likely to occur other than irregularly in cleared agricultural lands to the east of the Karuah River, but is regarded as likely to occur widely in the open forest and woodland vegetation to the west. Conversely, Masked Owls do utilise cleared areas and forest/woodland edges for hunting, and the forest edges adjacent to the alignment could potentially provide suitable foraging habitat (notwithstanding the negative effects of noise and light associated with traffic on the road).

A pair of Masked Owls was located nesting in a large hollow-bearing tree along the Karuah Bypass alignment, in supplementary investigations conducted in August 1999. The proposed Bypass will require the removal of the Masked Owl nest tree, although there are a number of other trees in the vicinity of the alignment, and elsewhere through the landscape, which are likely to be suitable for breeding and nesting by the Masked Owl. The Karuah Bypass will involve the removal of a number of hollow-bearing trees suitable for this species, as well as open forest and woodland vegetation, which supports prey species. Conversely, these resources and habitats are widely distributed in the locality, and the Karuah Bypass alignment is not of special or particular value in this regard.

The total extent of open forest and woodland vegetation which is to removed along the Karuah Bypass alignment is 27ha, most of which may be utilised by the Masked Owl.

Potential Impacts

The recording of breeding Masked Owls along the Karuah Bypass alignment indicates that this species does utilise the open forest and woodland vegetation in the vicinity and in the locality. Removal of the large hollow-bearing tree currently being utilised by the Masked Owls for nesting and breeding purposes will doubtless constitute a significant impact upon that pair, although it should be noted that Masked Owls are known to use more than one tree for nesting or breeding purposes (Debus & Rose 1994).

Furthermore, given that nest trees are generally senescent, natural circumstances (either the eventual falling of the tree or bushfire) would force Masked Owls to seek new or alternative nesting or breeding trees within their home range. The vegetation types and relevant resources (hollow-bearing trees) are widespread in the locality, and are well conserved following the recent gazettal of conservation reserves under the management of the NP&WS.

The Masked Owl occupies a large home range (500-1000 hectares), and the proposed Karuah Bypass will remove only a very small proportion (approximately 27ha or 2.7-5.4%) of the home range for even a single pair. Given the high mobility of this species, the limited area of habitat to be removed, and the extent of suitable habitat and resources to be retained in the locality (including within the conservation reserves), the Karuah Bypass is not likely to impose a significant impact upon the Masked Owl as a result of the "*removal or modification of habitat*" for the species.

Conversely, the Bypass will clearly adversely affect the pair of Masked Owls which are currently nesting in a large hollow-bearing tree along the alignment, and the project could result in the abandonment of eggs or chicks if clearing activities occur during the breeding season for this pair. The project requires the removal of the nest tree, but the Masked Owl pair is likely to have other suitable nesting or breeding trees in the vicinity, or elsewhere within their home range.

Whilst the forest edges along each side of the alignment could potentially provide suitable foraging habitat for the Masked Owl, the levels of noise and light disturbance associated

with vehicle use are likely to limit the value of this resource. Consequently, although the Karuah Upgrade project presents the potential for an increase in Owl mortalities along the road, the impact is likely to be small or unrealised.

Threatening Processes

In general terms, the removal of open forest and woodland vegetation can be regarded as a "*threatening process*" for species such as the Masked Owl. The Karuah Bypass, however, will involve the removal of only a small area of habitat for the Masked Owl, compared with the extent of similar habitat in the locality, subregion and region. The substantial tracts of State Forest and conservation reserves in the locality, and throughout the "*region and subregion*", will not be adversely affected to a significant extent by the Karuah Bypass, and the "*proposed action*" is regarded as contributing in only a limited extent to "*threatening processes acting on populations*" of the Masked Owl "*in the locality*".

The loss of a functioning nest tree as a result of the Karuah Bypass doubtless contributes to the "*threatening processes*" imposed upon individuals and the local population of the Masked Owl. Conversely, this species will need to respond to the loss of nesting trees under natural circumstances (due to decay of old hollow-bearing trees), and pairs have been recorded using more than one nest tree within their home ranges (Debus & Rose 1994).

Conservation Reserves

There are insufficient data to determine whether or not the Masked Owl is "*adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion*". Given the wide distribution of this species and of suitable habitat, and the distribution of conservation reserves in the region and subregion, it is not regarded as likely that the Masked Owl would be "*adequately represented*" in such dedicated "*conservation reserves*".

Conversely, this species occurs widely in State Forests and other Crown Lands, and these areas of vegetation clearly contribute to the conservation of the Masked Owl. The presence of a breeding pair of Masked Owls along the Karuah Bypass alignment demonstrates the ability for State Forests lands to support the Masked Owl, and supports the contention that land under this tenure should be included within the definition of "*conservation reserves (or other similar protected areas)*", particularly given the implementation of specific management measures in timber harvesting operations designed to protect habitat and resources for the Masked Owl.

Irrespective of the inclusion or otherwise of State Forests and other Crown Lands within the definition of "*conservation reserves (or other similar protected areas)*", it is not regarded as likely that the Masked Owl would be considered "*adequately represented*" in such reserves "*in the region and the subregion*". Conversely, the Karuah Bypass is not regarded as likely to adversely affect the conservation status of this species.

10.1.14 Powerful Owl

Habitat and Modification

As for the Masked Owl, the open forest and woodland communities in the study area provide potentially suitable foraging habitat for the Powerful Owl, although the very large tree-hollows required for nesting are uncommon. The Powerful Owl was not recorded in the study area, and generally utilises denser forest and woodland vegetation than that present along the alignment.

Furthermore, the Bypass alignment does not support features or habitats which are restricted or limited in distribution, with the vegetation types and resources present along the alignment being widely distributed in the locality.

The total extent of open forest and woodland vegetation which is to be removed along the Karuah Bypass alignment is 27ha, some or all of which may be utilised by the Powerful Owl.

Potential Impacts

Powerful Owls could potentially utilise the open forest and woodland vegetation along the Karuah Bypass alignment. Conversely, the vegetation and community type is widespread in the locality, and well conserved following recent gazettal of conservation reserves under the management of the NP&WS.

The Powerful Owl occupies a large home range, of up to 1000 hectares (Debus & Rose 1994), and the proposed Karuah Bypass will remove only a very small proportion of potentially suitable habitat within any pairs local home-range (approximately 27ha or 2.7%). Given the high mobility of this species, the limited area of habitat to be removed, and the extent of suitable habitat and resources which are to be retained in the locality (including in the conservation reserves), it does not appear likely that the Karuah Bypass will impose a significant impact upon the Powerful Owl as a result of "*removal or modification of habitat*" for the species, even if it is present.

Threatening Processes.

In general terms, the removal of open forest and woodland vegetation can be regarded as a "*threatening process*" which impacts upon species such as the Powerful Owl. The loss of habitat for this species could potentially affect its distribution and abundance.

The Karuah Bypass, however, will involve the removal of only a small area of potential habitat for the Powerful Owl, compared with the extent of similar habitat in the locality and surrounding regions. The "*proposed action*" is regarded as likely to contribute to only a limited extent to "*threatening processes ... acting on populations*" of the Powerful Owl "*in the locality*".

Conservation Reserves

There are insufficient data to determine whether or not the Powerful Owl is "*adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion*". The Powerful Owl is, however, regularly recorded in forests in the region (including dedicated conservation reserves, State Forests and on other lands), and this species may be "*adequately represented*" in "*conservation reserves*".

As noted above, this species occurs widely in State Forests and other Crown Lands, and these areas of vegetation clearly contribute to the conservation of the Powerful Owl. The regular recording of Powerful Owls in State Forests throughout NSW supports the contention that land under this tenure should be included within the definition of "*conservation reserves (or other similar protected areas)*", particularly given the implementation of specific management measures in timber harvesting operations to protect habitat and resources for the Powerful Owl.

10.1.15 Chestnut-rumped Heathwren

Habitat Removal and Modification

Suitable habitat for the Chestnut-rumped Heathwren occurs in scattered patches along the Karuah Bypass alignment, and will vary in extent and quality according to the history of bushfires at any one location. This species prefers heath and eucalypt woodland and open forest, where the understorey is dense, and is generally not located in areas of sparse groundcover or those characterised by recent or frequent fire.

The Karuah Bypass project will remove some areas of suitable habitat for the Chestnut-rumped Heathwren, although suitable vegetation for this species is widely (although localised) distributed throughout the forested lands in the locality. Of particular significance is the recent transferral of substantial areas of State Forest into the NP&WS estate, with the likely result that changes in land management practices will increase the extent of habitat suitable for the Chestnut-rumped Heathwren in the locality.

The Karuah Bypass will remove some relatively small areas of suitable or potentially suitable habitat for this species, but management activities within the road easement (including habitat rehabilitation following the completion of construction) may also increase the availability of habitat suitable for this species.

The Chestnut-rumped Heathwren could occur widely west of the Karuah River provided that management practices within the forested lands permit the development of a dense understorey. A total of 27ha of open forest and woodland are to be removed along the alignment, predominantly to the west of the Karuah River, some or all of which could potentially constitute habitat for the Chestnut-rumped Heathwren. Conversely, as noted above, additional habitat for this species could be created by appropriate management activities along the road easement, supplementing the changes in understorey which will occur as a result of the tenure of the NP&WS.

Potential Impacts

The removal of habitat for the Chestnut-rumped Heathwren from the Karuah Bypass alignment would doubtless constitute an adverse impact upon this species. Conversely, the area to be affected by the Bypass is small compared to the extent of open forest and woodland vegetation in the vicinity and in the locality, and there are extensive areas of suitable habitat for the Chestnut-rumped Heathwren in the extensive forested lands in the locality and region.

As a consequence of the small area of habitat to be removed, the extent of potentially suitable habitat present in the locality and region, the extent of forested lands recently transferred into the estate of the NP&WS, and appropriate management of vegetation along the Bypass alignment, the "*potential impacts*" of the Karuah Bypass on the Chestnut-rumped Heathwren are regarded as likely to be relatively minor.

Threatening Processes

The "*threatening processes*" identified for the Chestnut-rumped Heathwren (Gilmore & Parnaby 1994) will be exacerbated to a limited extent by the proposed Karuah Bypass, although some environmental management measures associated with the activity have the potential to increase habitat for this species. With respect to the individual identified "*threatening processes*":

- "*ongoing clearance of habitat*" - suitable habitat for the Chestnut-rumped Heathwren is scattered and relatively sparse along the Karuah Bypass alignment, but the road will doubtless remove some potential habitat for this species. Conversely, environmental management (particularly habitat rehabilitation) along the easement has the potential to provide supplementary habitat for this species. Furthermore, modifying land uses within the locality, particularly associated with transfer of forested lands to the estate of the NP&WS, are likely to improve the extent of habitat for this species in the locality;
- "*grazing which reduces the cover of the heath*" - the proposed Karuah Bypass will not contribute to grazing pressure in the area;
- "*too frequent fire regimes*" - will not be modified directly by the Karuah Bypass, but may be modified by alterations to the tenure of forested lands in the vicinity, particularly with the gazettal of the Karuah NR around the Karuah Bypass; and
- "*fertiliser addition*" which "*alters the floristic composition of the habitat*" - will not be modified by the Karuah Bypass, given the water quality management measures to be implemented as part of the project.

As indicated above, the Karuah Bypass does not appear likely to contribute to any significant extent to the "*threatening processes*" on the Chestnut-rumped Heathwren "*in the locality*".

Conservation Reserves

The Chestnut-rumped Heathwren is not likely to be adequately represented in conservation reserves, and the species is noted as having been recorded from only a few scattered sites in northeastern NSW (NP&WS 1994a).

The recent gazettal of the Karuah NR and of other forested lands in the tenure of the NP&WS in the locality and region are likely to have increased the representation of this species "*in conservation reserves*", although it is unclear as to whether this species is "*adequately represented*" in such reserves.

10.1.16 Green-thighed Frog

Habitat Removal and Modification

The Green-thighed Frog, was not recorded during any of the extensive fauna searches conducted in the study area (Chapter 3). This species uses the moist forest floor, drainage lines, paddock depressions and shallow ponds, and could occur in or around Wallaroo Swamp, or elsewhere in forested habitats (F Lemckert *pers comm*). Although the Bypass will not directly affect Wallaroo Swamp, the drainage lines which flow from the south-east (areas of cleared paddocks) into Wallaroo Swamp, and the paddocks themselves, may constitute habitat for this species.

Similarly, forested areas and adjacent moist grassy swales east of the Karuah River could constitute potential habitat for this species, although there is no evidence of its presence. Green-thighed Frogs have been recorded breeding in and calling from drainage ditches, flooded grassland in paddocks and small depressions (F Lemckert *pers comm*), and the species could theoretically occur widely throughout the landscape. Conversely, the Green-thighed Frog was not recorded during field investigations over a number of years along the Karuah Bypass alignment, including during and after periods of heavy rainfall.

Furthermore, the total area of potentially suitable habitat for the Green-thighed Frog which will be adversely affected by the Karuah Bypass is relatively small, because the Bypass affects only short lengths of the existing watercourses and does not directly remove significant areas of ponding or likely breeding habitat. The habitats and vegetation to be removed by the project are not unique or restricted, and are not likely to be of special value for the Green-thighed Frog.

Potential Impacts

Given the small area of suitable potential habitat for the Green-thighed Frog which will be subjected to "*removal or modification*" as a result of the Karuah Bypass, it is unlikely that the project will impose a significant adverse impact upon this species, even if it is present. Only small areas of permanent creeklines or watercourses will be disturbed by the project, and strict sediment and erosion control measures are to be implemented to maintain water quality and riparian habitats at these locations.

The Karuah Bypass could, theoretically, affect the Green-thighed Frog (if it is present) by imposing a barrier to movement of this species through the landscape.

Threatening Processes

If the Green-thighed Frog occurs in the locality, the Karuah Bypass could effect the species by altering hydrologic regimes and by affecting periodic animal movement patterns. Changes to water quality, both from construction and subsequent use of the road, could also potentially affect the Green-thighed Frog in the locality.

Whilst some adverse impacts cannot be avoided in the construction of major roads, the Karuah Bypass can be constructed in a manner which limits the potential for adverse impacts to be imposed on the Green-thighed Frog. Strict control of sediment and contaminant discharge during the construction process, and the implementation of

measures to maintain water quality following completion of the road (the water quality control ponds), are integral elements of the proposal. Similarly, the provision of underpasses and drainage culverts for use by Green-thighed Frogs as movement conduits should ensure that animals can continue moving through this portion of the landscape, if they currently do so.

Based on the implementation of appropriate impact amelioration measures, the Karuah Bypass is not likely to contribute in a significant manner *to "threatening processes"* on the Green-thighed Frog, if a population of this species is present in the vicinity. Whilst there is some potential for adverse impacts to be imposed upon a population of this species (if one is present), the *"likely contribution of the proposed action to threatening processes"* on the Green-thighed Frog is limited by the small area of habitat to be affected, and the extent of other suitable habitat and resources *"in the locality"*.

Conservation Reserves

The Green-thighed Frog is not regarded as likely to be *"adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion"*. This species has only been recorded in one dedicated *"conservation reserve"* the Border Ranges National Park (Ehmann 1997), although it has been recorded in or is likely to occur in a number of State Forests in northeastern NSW.

10.1.17 Christmas Bells

Habitat Removal and Modification

Only limited areas of suitable habitat for Christmas Bells (*"damp sandy and peaty soils"* - Harden 1993) are present along the Karuah Bypass alignment. Most of the areas where Christmas Bells have been recorded or are likely to occur are in drainage lines and low-lying areas, which are scattered sparsely throughout the Karuah Bypass alignment, particularly west of the Karuah River.

The Karuah Bypass will remove only a relatively small area of habitat for Christmas Bells, particularly compared to the extent of potential or suitable habitat in the vicinity and locality.

Some modification of habitat for this species may be expected immediately adjacent to the new road, as a result of altered hydrologic regimes and/or the discharge of sediments or contaminants from the Karuah Bypass construction. However, the proposal involves the implementation of impact amelioration and environmental management measures, including the protection of hydrologic regimes as far as possible and the implementation of water quality controls to avoid the discharge of contaminants or sediments into adjacent habitats. As a consequence, only a limited area of habitat will be *"modified or removed"* as a result of the Karuah Bypass.

Potential Impacts

The *"potential impacts of the removal or modification of habitat"* for Christmas Bells, as for many other plant species, include direct impacts (the loss of habitat and individuals) and indirect impacts (alterations to habitat) *"downstream or downslope of the activity"*.
The extensive forested lands in the vicinity and locality (including new areas of nature reserve) provide substantial areas of potentially suitable habitat for Christmas Bells. The small area of suitable habitat which will be removed by the Karuah Bypass is not regarded as of particular significance with regard to the conservation of this species, given the extent of reserved lands and suitable habitat in the locality. Similar considerations apply to the small number of individuals of this species which will be removed.

As noted above, the Karuah Bypass has been designed to implement a range of environmental management and impact amelioration measures intended specifically to avoid or limit the discharge of contaminants or sediments into the landscape. This approach will benefit local populations of Christmas Bells, by maintaining water quality

and water flows into habitat adjacent to the Bypass. There is likely to be some short-term impact during construction of the Bypass, but the project is intended to ensure the long-term survival of habitat for this and other species in the vicinity.

In terms of the conservation of Christmas Bells, the "*potential impact of the removal or modification of habitat*" is regarded as relatively low, given the extent of suitable habitat for this species and the implementation of appropriate impact amelioration and environmental management measures.

Threatening Processes

The removal of habitat for Christmas Bells along the Karuah Bypass alignment and in the vicinity will contribute, to some extent, to the "*threatening processes .. acting on populations*" of this species. Similarly, alterations in hydrologic regimes or the discharge of contaminants or sediment into habitat for this species would also constitute one of the "*threatening processes*" which are affecting the species.

As noted above, only a small area of potential or known habitat for the Christmas Bells is to be removed by the proposed Karuah Bypass, and measures are to be implemented in the construction and operational phases of the project to mitigate the potential for indirect impacts upon the species. As a consequence, and given the extent of suitable habitat in the immediate vicinity and in the locality (much of which is to be protected in the Karuah NR or in areas of State Forest), the Karuah Bypass is not regarded as contributing significantly to the "*threatening processes*" which are affecting Christmas Bells in this locality.

Conservation Reserves

There are insufficient data to determine whether or not Christmas Bells are "*adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*". Doubtless, the transfer of large areas of State Forest in the locality into the tenure of the NP&WS increases the representation of Christmas Bells "*in conservation reserves*", but the adequacy of that representation is not clear.

10.1.18 *Eucalyptus fergusonii*

Habitat Removal and Modification

Only limited areas of suitable habitat for *Eucalyptus fergusonii* ("*wet sclerophyll forest or woodland on sandy soils*" - Harden 1991) is present along the Karuah Bypass alignment, although this species has been recorded at a number of sites scattered along the alignment, particularly west of the Karuah River.

The Karuah Bypass will remove only a relatively small area of habitat for *Eucalyptus fergusonii*, particularly compared to the extent of potential or suitable habitat in the vicinity and locality.

The potential for the modification of habitat for *Eucalyptus fergusonii* adjacent to the Karuah Bypass is regarded as low. The proposal includes the implementation of specific impact amelioration and environmental management measures, including the avoidance or limiting of indirect impacts on habitat downslope or downstream of the activity to protect habitats adjacent to the road.

Potential Impacts

The "*potential impacts of the removal or modification of habitat*" for *Eucalyptus fergusonii*, as for other plant species, include direct impacts (the loss of habitat and individuals) and indirect impacts (alterations to habitat) "*downstream or downslope of the activity*".

The Karuah Bypass will require the removal of only a small area of suitable habitat for

Eucalyptus fergusonii. This "*removal*" of habitat and of individuals is not regarded as of particular significance for the conservation of this species, given the extent of reserved lands and of suitable habitat in the vicinity.

The range of environmental management and impact amelioration measures to be implemented along the Karuah Bypass are intended specifically to avoid or limit the discharge of contaminants or sediments into the landscape. Whilst there is likely to be some short-term impact during construction of the Bypass in the immediate vicinity, the likely impact on habitat for *Eucalyptus fergusonii* in the vicinity is regarded as slight.

In terms of the conservation of *Eucalyptus fergusonii*, the "*potential impact of the removal or modification of habitat*" is regarded as relatively low, given the extent of suitable habitat for this species and the implementation of appropriate impact amelioration and environmental management measures.

Threatening Processes

The removal of habitat for *Eucalyptus fergusonii* along the Karuah Bypass alignment and in the vicinity will contribute, to a limited extent, to the "*threatening processes .. acting on populations*" of this species.

Only a small area of potential or known habitat for *Eucalyptus fergusonii* is to be affected by the proposed Karuah Bypass, and measures are to be implemented in the construction and operational phases of the project to mitigate indirect impacts on the environment. As a consequence, and given the extent of suitable habitat in the immediate vicinity and in the locality (particularly in the Karuah NR and in areas of State Forest), the Karuah Bypass is not regarded as likely to contribute in a significant manner to the "*threatening processes*" which are affecting *Eucalyptus fergusonii* in this locality.

Conservation Reserves

There are not sufficient data to determine whether or not *Eucalyptus fergusonii* is "*adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*". The transfer of large areas of State Forest in the locality into the tenure of the NP&WS doubtless increases the representation of *Eucalyptus fergusonii* "*in conservation reserves*", but the adequacy of that representation is not clear.

10.1.19 Swamp Mahogany

Habitat Removal and Modification

The Swamp Mahogany occurs at scattered locations along the Karuah Bypass alignment, generally associated with drainage lines, swamps and low-lying areas, particularly west of the Karuah River. The Karuah Bypass will remove only a relatively small area of habitat for the Swamp Mahogany (probably less than a hectare), particularly compared to the extent of potential or suitable habitat in the vicinity and locality.

There is also some potential for the modification of habitat for this species, as a result of altered hydrologic regimes and/or the discharge of sediments or contaminants during construction of the Bypass. However, the proposal involves the implementation of an array of impact amelioration and environmental management measures to avoid the discharge of contaminants or sediments into adjacent habitats. As a consequence, only a very small area of habitat for the Swamp Mahogany will be "*removed or modified*" as a result of the Karuah Bypass.

Potential Impacts

The "*potential impacts of the removal or modification of habitat*" for the Swamp Mahogany, as for many other plant species, include direct impacts (the loss of habitat and individuals) and indirect impacts (alterations to habitat) "*downstream or downslope of the*

activity".

Given the extensive forested lands in the vicinity and locality (including substantial new areas of Nature Reserve), the very small area of suitable habitat and the relatively few individuals which will be removed by the Karuah Bypass, and the distribution of Swamp Mahogany in the study area, the Karuah Bypass is not regarded as likely to impose a significant adverse impact on the conservation of this species.

The Karuah Bypass includes a range of environmental management and impact amelioration measures intended specifically to avoid or limit the discharge of contaminants or sediments into the landscape. Whilst there may be some short-term impacts immediately adjacent to the roadworks during construction of the Bypass, the project is intended to ensure the long-term survival of habitat for this and other species in the vicinity.

The "*potential impact of the removal or modification of habitat*" for the Swamp Mahogany is regarded as likely to be very low, given the extent of suitable habitat for this species "*in the* locality", and the implementation of appropriate impact amelioration and environmental management measures.

Threatening Processes

The removal of some habitat for the Swamp Mahogany along the Karuah Bypass alignment will contribute, to a limited extent, to the "*threatening processes .. acting on populations*" of this species. Alterations in hydrologic regimes or the discharge of contaminants or sediment into habitat for this species could (if permitted) also contribute to the "*threatening processes*" impacting upon the species.

As noted above, only a very small area of potential or known habitat for the Swamp Mahogany is to be removed by the proposed Karuah Bypass, and measures are to be implemented in the construction and operational phases of the project to ameliorate the potential for indirect impacts upon the species. As a consequence, and given the extent of suitable habitat in the immediate vicinity and in the locality (much of which is to be protected in the Karuah NR or in areas of State Forest), the Karuah Bypass is not regarded as contributing significantly to the "*threatening processes*" which are affecting the Swamp Mahogany in this locality.

Conservation Reserves

Whether or not the Swamp Mahogany is "*adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*" is not known. However, the transfer of large areas of State Forest in the locality into the tenure of the NP&WS increases the representation of the Swamp Mahogany "*in conservation reserves*", and it is likely that the species is "*adequately represented*" in the extensive areas of conserved and appropriately managed lands in the locality and the region.

10.1.20 *Hakea bakeriana*

Habitat Removal and Modification

Suitable habitat for *Hakea bakeriana* is abundant along the Karuah Bypass alignment in areas of dry sclerophyll forest and woodland. The Karuah Bypass project will remove only a relatively small area of habitat for *Hakea bakeriana* (approximately 27ha at most), particularly compared to the extent of potential or suitable habitat in the vicinity and locality.

The possible modification of habitat for this species along the Karuah Bypass construction would be associated with indirect effects and impacts immediately adjacent to the alignment. However, the total effect of the Karuah Bypass in terms of the extent of habitat "*to be removed or modified*" is limited because of the significant extent of suitable habitat for the species in the locality.

Potential Impacts

The "*potential impact of the removal or modification of habitat*" for *Hakea bakeriana* as a result of the Karuah Bypass is regarded as low, given the considerable extent of apparently identical and suitable habitat for this species "*in the* locality" and region, and the implementation of appropriate impact amelioration and environmental management measures as part of the project. Since no significant stands of *Hakea bakeriana* were located along the alignment, it does not appear likely that the project will involve the loss of significant numbers of individuals.

Threatening Processes

As for other plant species, the removal of habitat for *Hakea bakeriana* along the Karuah Bypass alignment and in the vicinity will contribute, to some extent, to the "*threatening processes .. acting on populations*" of this species. Conversely, only a small area of potential or known habitat for *Hakea bakeriana* is to be removed by the proposed Karuah Bypass, particularly with respect to the extent of suitable habitat in the locality and region. Furthermore, measures are to be implemented in the construction and operational phases of the project to ameliorate the potential for indirect impacts upon the species through habitat alteration or disturbance.

As a consequence, and given the extent of suitable habitat in the immediate vicinity and in the locality, including that which is protected in the Karuah NR or in areas of State Forest, the Karuah Bypass is not regarded as contributing significantly to the "*threatening processes*" which are affecting *Hakea bakeriana* in this locality.

Conservation Reserves

There are insufficient data to determine whether or not *Hakea bakeriana* is "*adequately represented in conservation reserves (or other similar protected areas) in the region and subregion*". Doubtless, the transfer of large areas of State Forest in the locality into the tenure of the NP&WS increases the representation of *Hakea bakeriana* "*in conservation reserves*", but the adequacy of that representation is not clear.

10.1.21 *Tetratheca juncea*

Habitat Removal or Modification

A total of 70 - 100 "clumps" of *Tetratheca juncea* were located on Horse Island (on the western side of the Karuah River) and a further 40 "clumps" located near the Karuah Red Gravel Quarry on the eastern side of the Karuah River. The species has previously been located in Wallaroo SF, but was unable to be relocated during recent field surveys due to bushfires in 1997/98 (Gunninah 1998b). Wallaroo SF has been subjected to on-going timber removal and bushfire, and the high frequency of fire may explain the relatively low density of the previously located population of *Tetratheca juncea* in the State Forest. Whilst the sub-populations near the Karuah Quarry and that on Horse Island are moderately dense and discrete, the plant was present (previously) as scattered individuals in Wallaroo SF. None of the populations on the Karuah Quarry site will be affected by the proposed Karuah Bypass, but any individuals present within Wallaroo SF will be removed and a portion (approximately 50%) of the population on the Horse Island.

Construction activities on Horse Island will involve the removal of approximately thirty plants (or 'clumps') of *T juncea* and its habitat. However, more than 60% of the population appears likely to be retained, and it is highly likely that there are other individuals or sub-populations of *T juncea* in areas of suitable habitat on Horse Island.

A total of approximately 20ha of potential habitat for *Tetratheca juncea* is to be removed as a result of the Karuah Bypass west of the Karuah River. East of the Karuah River, only a very small area of potential habitat is to be removed where the Karuah Bypass rejoins the existing Pacific Highway.

Potential Impacts

Due to the scattered distribution and low density of the population of *Tetratheca juncea* west of the Karuah River, the Bypass will not involve the removal of a significant area of habitat or a significant number of individual plants. As a consequence, "*the removal or modification of habitat*" for the *T juncea* west of the Karuah River is not regarded as of particular significance in terms of the "*potential impact*" upon the species or upon that population. East of the Karuah River, the Karuah Bypass does not appear to require the "*removal or modification of habitat*" for *Tetratheca juncea*, or of any plants.

The loss of a portion of the population of *T juncea* on Horse Island constitutes a local impact, at least on that sub-population of the species. Conversely, there are substantial stands of *T juncea* in the locality, and the majority of the sub-population on Horse Island is to be retained.

One potential effect of the Karuah Bypass west of the Karuah River may be the isolation of populations of *Tetratheca juncea* to the west and east of the Bypass. It is possible that due to the subsequent distance between populations of *T juncea*, pollinators may concentrate on only one, thus potentially limiting the transfer of genetic material between the two populations (pollinators allegedly one or more species of native sonicating bees - R Payne *pers comm*), thus effectively isolating the populations from each other. There are, however, no definitive data on pollinators of this species or their susceptibility to becoming isolated by major roads.

Threatening Processes

The clearing of habitat constitutes a "*threatening process*" for *Tetratheca juncea* affecting the distribution and abundance of this species on a local scale.

The clearing required for the Karuah Bypass primarily involves habitat which appears to be of relatively poor quality, and the project will not contribute significantly to the 'threat' of habitat or individual plant removal, with the possible exception of the population on Horse Island. Frequent fire also appears to constitute a "*threatening process*" for this species. The Karuah Bypass may reduce the frequency of burning as a result of changed land management practices in the locality, and because the Highway will act as a firebreak.

Since the plants to be removed constitute only a small percentage of the existing population in the locality, the Karuah Bypass is not considered as contributing significantly to those "*threatening processes*" acting on populations of *Tetratheca juncea* as a whole.

Conservation Reserves

Tetratheca juncea is not regarded as "*adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion*" at present. Whilst this species has been recorded in several dedicated "*conservation reserves*", many populations are present in State Forests and on private or other crown land, which are generally not regarded as "*conservation reserves*" in the strict sense. Nevertheless, extant populations of this species in these lands indicate that other areas have a significant role in the conservation of *Tetratheca juncea*.

10.2 Other Populations and Habitats

The D-G's Requirements for this SIS (Appendix A) include:

> "*2.3 A discussion of other populations of affected species in the locality must be provided. A discussion of the long term security and tenure of other habitats (ie outside the subject site) of affected species must be provided with regards to tenure, zoning and land management practices. The relative significance of the subject site for affected species in the locality must be provided*".

The "*relative significance of the subject site for affected species*" is considered in Chapters 5

and 9, and in Appendix F, of this SIS.

10.2.1 Koala

Other Populations

The Koala is widely, though patchily, distributed "*in the locality*", with significant populations occurring in the Port Stephens area (Lunney *et al* 1998). The densities of Koalas "*in the locality*" appears highest in the low-lying forests on sand in the Port Stephens area, with substantial populations known from the southern side of Port Stephens and lands to the south and southwest of the Bypass study area.

The Koalas in Wallaroo SF and on land to the east of the Karuah River are likely to be part of a larger sub-population of the species "*in the locality*", which is fragmented to varying degrees by conflicting land use practices. The fragmentation of habitats in the locality and in the region, and the imposition of barriers to movements of Koalas are likely to have reduced the levels of interaction between sub-populations of Koalas in the locality, and may (in some instances) reduce the viability of local populations. Nevertheless, there is likely to be some interaction and/or movements of animals between populations in Wallaroo SF and lands to the north and south, as well as through the landscape east of the Karuah River.

Security and Tenure

As a result of the recent gazettal of a number of additional conservation reserves in the locality and in the local subregion (including the Karuah and Wallaroo NRs), a substantial area of habitat and resources for the Koala has been dedicated for conservation purposes. The "*long term security and tenure*" of these additional areas of forested habitat, with respect to conservation, is now assured under the management of the NP&WS (Figure 1.3).

A substantial area of habitat and resources for the Koala is also included within State Forests, and in the tenure of the Hunter Water Corporation and other public bodies in the locality. Whilst these areas are utilised to varying extents for other purposes, they also provide a significant and relevant conservation function, as is clear from the frequency of threatened species records within them and the transfer of parts of these estates into the tenure of the NP&WS (which presumably would not have occurred had they not been characterised as of conservation value). It should also be noted that whilst some land management practices on some of the other crown lands may, at times, compromise conservation values to some extent, the constraints imposed upon these lands and the management practices conducted upon them (including licence conditions associated with forestry practices) are sufficient to justify their inclusion in the broad biodiversity conservation estate.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Koala is regarded as low, because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves;
- the species was recorded only at low densities in the vicinity of "*the subject site*", and is known to occur at much higher densities elsewhere in "*the locality*";
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species; and
- there are underpasses provided so, whilst there may be some reduction in the movement of Koalas, the road will not prevent movement entirely.

10.2.2 Squirrel Glider

Other Populations

Other populations of the Squirrel Glider are known to occur throughout the central coast of NSW, although there are only limited data regarding other populations of this species within "*the locality*" of the Karuah Bypass. However, given the extent and nature of suitable vegetation communities and habitats in "*the locality*" and in the subregion, it is likely that this species is widely distributed throughout the State Forests and conservation reserves. Squirrel Gliders were recorded between Karuah and Raymond Terrace during investigations for the upgrading of the Pacific Highway in that area (Gunninah 1997b) as well as at Tommago (Gunninah 1995), indicating the apparently wide distribution of populations of this species "*in the locality*".

Security and Tenure

As for the Koala, the "*long term security and tenure of other habitats*" of potential or known relevance to the Squirrel Glider are regarded as satisfactory, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on *management practices*" of State Forests and other lands "*in the locality*".

Furthermore, individuals recorded in the Raymond Terrace study were on Hunter Water Corporation land and thus considered secure. The land is used for ground water extraction for surrounding townships and is therefore protected and under no threat of development.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Squirrel Glider is regarded as low, because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.3 Long-nosed Potoroo

Other Populations

The Long-nosed Potoroo was observed during spotlighting surveys conducted for the Karuah Bypass, in the vicinity of the Karuah Quarry. However, there are no other records of this species from the locality. It is not known whether "*other populations*" of the Long-nosed Potoroo are present in "*the locality*" (NP&WS, 1994a), but the species is not regarded as likely to be present in the forested lands west of the Karuah River, given their current condition.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Long-nosed Potoroo is unknown, however vegetated areas along the alignment are not considered suitable habitat for this species. Substantial areas of forested land have recently been included in the conservation reserve system.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Long-nosed Potoroo is regarded as low because:

- the Karuah Bypass will not affect areas regarded as potential or known habitat for this species; and
- this species was not recorded along the alignment itself, and little habitat is present in the vicinity of "*the subject site*".

10.2.4 Brush-tailed Phascogale

Other Populations

Similar considerations apply to the Brush-tailed Phascogale as to the Squirrel Glider. Given the extent and nature of vegetation communities and habitats in "*the locality*" and in the subregion, it is likely that this species occurs widely through the State Forests and conservation reserves of "*the locality*", although probably in a patchy distribution determined by conditions and fire history. Brush-tailed Phascogales were recorded between Karuah and Raymond Terrace during investigations for the upgrading of the Pacific Highway in that area (Gunninah 1997b), as well as at Tomago (Gunninah 1995), indicating the presence of "*other populations in the locality*".

Security and Tenure

As for the Koala, the "*long term security and tenure of other habitats*" of potential or known relevance to the Brush-tailed Phascogale are regarded as satisfactory, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on *management practices*" of State forests and other lands "*in the locality*".

Relative Significance

The "*relative significance of the subject site in the locality*" for the Brush-tailed Phascogale is regarded as low because:

only a relatively small area of potential or known habitat is to be removed by the Karuah Bypass;

- substantial areas of suitable habitat for this species occur in "*the locality*," including significant areas protected within conservation reserves;
- the species was not recorded on "*the subject site*" or along the alignment, although it is known to occur nearby; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.5 Tiger Quoll

Other Populations

The only evidence for the Tiger Quoll obtained during investigations for the Karuah Bypass are sightings by a local resident (R Clarke *pers comm*). There are no other verified records of the species from the locality and it is not known whether "*other populations*" of the Tiger Quoll are present in "*the locality*" (NP&WS 1994a).

Security and Tenure

Lands containing habitat for the Tiger Quoll east of the Karuah River are largely in private ownership, although there are also extensive State Forests further to the north and east. Lands to the west of the Karuah River are contained within a mosaic of Nature Reserves, State Forests and Crown Lands, as well as private property, and these areas also contain potential habitat for the Tiger Quoll.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Tiger Quoll is regarded as very low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass. Most of the vegetation along the alignment is more open than that referred by the Tiger Quoll, at least in its current condition;
- the species was not recorded on or in the immediate vicinity of "*the subject site*" and there is little suitable habitat on "*the subject site*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.6 Greater Broad-nosed Bat

Other Populations

Little information is available regarding populations of the Greater Broad-nosed Bat "*in the locality*," but the species has been recorded within 10km of the "*subject site*" (NP&WS Wildlife Atlas). Without an extensive radio-tracking survey and a considerable research program, it is not possible to provide a detailed consideration of "*other populations*" of the Greater Broad-nosed Bat "*in the locality.*" This species was recorded at Tomago (Gunninah 1995), and populations are likely to be present throughout both "*the locality*" and "*the region.*"

Security and Tenure

As a result of the recent gazettal of a number of additional conservation reserves in the locality and in the local subregion, a substantial area of habitat and resources for the Greater Broad-nosed Bat has been dedicated for conservation purposes. The "*long term security and tenure*" of these additional areas of forest habitat has been secured under the auspices of the NP&WS (Figure 1.3).

A substantial area of habitat and resources for the Greater Broad-nosed Bat is also included within State Forests, and in the tenure of the Hunter Water Corporation and other public bodies. Whilst these areas are utilised to varying extents for other purposes, they also provide a significant and relevant conservation function, as is clear from the frequency of threatened species records within them, and the transfer of parts of these estates into the tenure of the NP&WS (which presumably would not have occurred had they not been characterised as of conservation value). It should also be noted that whilst some land management practices on some of the other crown lands may, at times, compromise conservation values to some extent, the constraints imposed upon these lands and the management practices conducted upon them (including licensing conditions for forestry activities) are sufficient to justify their inclusion in the broad biodiversity conservation estate.

Relative Significance

The "*relative significance of the subject sit in the locality*" for the Greater Broad-nosed Bat is regarded as low, because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass in absolute terms and compared to the extent of suitable habitat "*in the locality*";
- substantial areas of suitable habitat for this species are protected within conservation reserves in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.7 Little Bent-wing Bat

Other Populations

The Little Bent-wing Bat is widely recorded in "*the locality*" and in the subregion around Port Stephens, and there is a known colony of this species which roosts in the Balickera Tunnel (Gunninah 1995). Given the proximity of the "*subject site*" to the Balickera Tunnel, individual Little Bent-wing Bats recorded on the subject site could be derived from that roost. Furthermore, a 'nursery' site has been identified in the Macleay River catchment between Kempsey and Armidale (Dwyer 1995), and possibly another in a mine shaft near Lake Macquarie (Gunninah 1998b).

There are no detailed investigations on the Little Bent-wing Bat in "*the locality*", although some radio-tracking of individuals has occurred. However, this species is regularly recorded in field investigations conducted in the Port Stephens and surrounding areas.

Security and Tenure

Similar considerations regarding the "*long term security and tenure*" of forested habitats and the "*tenure, zoning and land practices*" of lands "*in the locality*" apply with respect to the Little Bent-wing Bat as to the Greater Broad-nosed Bat. The extent of forested lands which are managed for conservation purposes in the tenure of the NP&WS, and the extent of other forested lands under state control which are managed (in part at least) for conservation purposes (including State Forests and the Hunter Water Corporation lands) guarantee the "*long term security*" of habitat for this species.

The Karuah Bypass alignment does not support caves or roost habitats for the Little Bent-wing Bat.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Little Bent-wing Bat is regarded as low, because;

- only a small area of potential or known habitat is to be removed by the Karuah Bypass in absolute terms and compared to the extent of suitable habitat "*in the locality*";
- substantial areas of suitable habitat for this species are protected within conservation reserves in "*the locality*";
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species; and
- the "*subject site*" does not support any roosting or maternity caves for the Little Bent-wing Bat.

10.2.8 Common Bent-wing Bat

Other Populations

The Common Bent-wing Bat is widely recorded in "*the locality*" and in the subregion around Port Stephens, and indeed is commonly recorded throughout its distributional range. This species roosts in caves and in artificial structures, and is likely to occur throughout the landscape generally.

Given the presence of the Common Bent-wing Bat widely in "*the locality*" and in the region, and given its high mobility and wide-ranging habits, it is not certain that discrete "*other populations*" can be defined.
Security and Tenure

The extent of forested lands which are managed for conservation purposes in the tenure of the NP&WS (including the recent substantial additions to that estate), and the extent of

other forested lands under state control which are managed (in part at least) for conservation purposes (including State Forests and the Hunter Water Corporation lands) guarantee the "*long term security*" of habitat for this species.

The Karuah Bypass alignment does not support caves or roost habitats for the Common Bent-wing Bat, but foraging habitat (*ie* forest and woodland vegetation) is now well conserved "*in the locality*".

Relative Significance

The "*relative significance of the subject site in the locality*" for the Common Bent-wing Bat is regarded as very low, because:

- only a small area of potential or known foraging habitat is to be removed by the Karuah Bypass in absolute terms and compared to the extent of suitable habitat "*in the locality*";
- the "*subject site*" does not support any roosting or maternity caves for the Common Bent-wing Bat;
- the Common Bent-wing Bat is widely distributed and apparently abundant throughout its distributional range;
- substantial areas of suitable habitat for this species are protected within conservation reserves in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.9 Eastern Free-tail Bat

Other Populations

Little information is available regarding populations of the Eastern Free-tail Bat "*in the locality*", but this species has been recorded within 10km of the "*subject site*" (NP&WS Wildlife Atlas). It is not possible to provide a detailed consideration of "*other populations*" of the Eastern Free-tail Bat "*in the locality*", although this species was recorded at Tomago (Gunninah 1995), and populations are likely to be present throughout both "*the locality*" and "*the region*".

Security and Tenure

Similar considerations regarding the "*long term security and tenure*" of forested habitats and the "*tenure, zoning and land practices*" of lands "*in the locality*" apply with respect to the Eastern Free-tail Bat as to the Greater Broad-nosed Bat. The extent of forested lands which are managed for conservation purposes in the tenure of the NP&WS, and the extent of other forested lands under state control which are managed (in part at least) for conservation purposes (including State Forests and the Hunter Water Corporation lands) guarantee the "*long term security*" of habitat for this species.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Eastern Free-tail Bat is regarded as low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass in absolute terms and compared to the extent of suitable habitat "*in the locality*";
- substantial areas of suitable habitat for this species are protected within conservation reserves in "*the locality*"; and

- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.10 Osprey

Other Populations

Whilst no detailed information regarding other populations of the Osprey "*in the locality*" are known, this species is widely recorded along the NSW coast, and is regularly sighted in Port Stephens (D Fanning *pers obs*). The Osprey is generally sparsely distributed along the NSW coast, with numbers of individuals and breeding success apparently increasing over recent decades (Debus 1994).

Given the extent of relatively undeveloped and lightly disturbed lands around Port Stephens and the Karuah River, and the extent of suitable waters for fishing, the "*locality*" is likely to constitute quality habitat for the Osprey. Consequently, it may be regarded as likely that the population of Ospreys in the Port Stephens "*locality*" will continue to expand.

Security and Tenure

There are substantial areas of the Karuah River and Port Stephens foreshores which are protected pursuant to SEPP 14 - Coastal Wetlands, as well as areas contained within State Forests and conservation reserves (Figure 1.4). On this basis, significant areas which provide roosting and nesting habitat for the Osprey are currently protected, and are afforded "*long term security*" for the conservation of this species. The SEPP 14 - Wetlands and the conservation reserves are zoned and are largely subjected to "*land management practices*" which are appropriate for their long term conservation, and areas of State Forest immediately adjacent to waterways also provide conservation and land management value.

The Karuah River and the Port Stephen waterways are substantial in area, and are under the tenure of the NSW State Government. Despite relatively high levels of recreational and fishing use of Port Stephens, Ospreys are able to utilise the waterways for fishing purposes, as occurs elsewhere throughout their range in NSW.

Relative Significance

The "*subject site*" (*ie* the area which will be affected by the Karuah Bypass) is of extremely low value or "*relative significance*" for the Osprey. Only an extremely small area of waterway will become unavailable for fishing by Ospreys, and few potential (and no known) nest trees will be removed.

10.2.11 Glossy Black Cockatoo

Other Populations

The Glossy Black Cockatoo is widely, though patchily, distributed "*in the locality*" with significant populations (or a metapopulation) occurring in the Port Stephens area (Lunney *et al* 1998). The densities of Glossy Black Cockatoo "*in the locality*" appear highest in the low-lying forests on sand in the Port Stephens area, with substantial populations known from the southern side of Port Stephens and lands to the south and southwest of the Karuah Bypass.

The relationship between Glossy Black Cockatoos in the vicinity of the Karuah Bypass and "*other populations*" of this species "*in the locality*" is unknown. However, the Glossy Black Cockatoo is a highly mobile and wide-ranging species, and there are extensive areas of suitable forest habitat "*in the locality*" that provide resources for this species.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Glossy Black Cockatoo appear to be assured, given the extent of such "*habitats*" recently

transferred to the tenure of the NP&WS, and the controls on the land use and "*management practices*" in State Forests and on other lands "*in the locality*" and throughout the region and subregion.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Glossy Black Cockatoo is regarded as low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.12 Bush Stone-curlew

Other Populations

It is not known whether "*other populations*" of the Bush Stone-curlew are present "*in the locality*", nor the extent of the "*population*" recorded during investigations for the Karuah Bypass.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Bush Stone-curlew appear to be assured, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on the land use and "*management practices*" in State Forests and on other lands "*in the locality*" and throughout the region and subregion.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Bush Stone-curlew is regarded as low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves;
- the species was recorded only at low densities in the vicinity of "*the subject site*", and is known to occur at much higher densities elsewhere in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.13 Masked Owl

Other Populations

Consideration of "*other populations*" of the Masked Owl "*in the locality*" is problematic, because it is unclear what boundaries there may be to any such "*populations*" (given the size of the home ranges of Masked Owls). This species has been recorded from lands to the south (Gunninah 1995), and is known to occur throughout the Hunter Valley and in areas of forested lands to the north. Populations of the Masked Owl generally appear to be of relatively low density, and the concept of "*populations*" of the species is not readily addressed.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Masked Owl appear to be assured, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on the land use and "*management practices*" in State Forests and on other lands "*in the locality*" and throughout the region and subregion.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Masked Owls regarded as low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species. Whilst the alignment supports a nest tree for this species, this resource is widely distributed (although not common) in the locality.

10.2.14 Powerful Owl

Other Populations

Consideration of "*other populations*" of the Powerful Owl "*in the locality*" is problematic, because it is unclear what boundaries there may be to any such "*populations*" (given the size of the home ranges of the Powerful Owl). This species has been recorded in forested lands throughout the Hunter Valley, and in areas of forested lands to the north, but the interaction between 'populations' or 'sub-populations' of the species is not known.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Powerful Owl appear to be assured, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on the land use and "*management practices*" in State Forests and on other lands "*in the locality*" and throughout the region and subregion.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Powerful Owl is regarded as low because:

- only a small area of potential habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.15 Chestnut-rumped Heathwren

Other Populations

There are no known "*other populations*" of the Chestnut-rumped Heathwren "*in the locality*". However, suitable habitat for this species is widely distributed in the locality and in the region and there are extensive tracts of potentially suitable habitat under the tenure of State Forests of NSW and the NP&WS. On that basis, it appears likely that "*other*

populations" of the Chestnut-rumped Heathwren are present "*in the locality*", although there are no data regarding their distribution or abundance.

Security and Tenure

The "*long term security and tenure of other habitats*" of potential or known relevance to the Chestnut-rumped Heathwren appear to be assured, given the extent of such "*habitats*" recently transferred to the tenure of the NP&WS, and the controls on the land use and "*management practices*" in State Forests and on other lands "*in the locality*" and throughout the region and subregion.

Relative Significance

The "*relative significance of the subject site in the locality*" for the Chestnut-rumped Heathwren regarded as low because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in "*the locality*", including significant areas protected within conservation reserves; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.16 Green-thighed Frog

Other Populations

There are no known "*other populations*" of the Green-thighed Frog "*in the locality*", nor is there any evidence that the Green-thighed Frog is present in Wallaroo Swamp or along the alignment of the Karuah Bypass. The nearest known populations of the Green-thighed Frog are in Nerong SF (approximately 20km to the northeast - ERM Mitchell McCotter 1999) and Wattagan SF (40km or more to the southwest).

Security and Tenure

Substantial tracts of forested lands "*in the locality*" are contained within conservation reserves administered by the NP&WS and/or in forests managed by NSW State Forests. The relevant areas of potential habitat for the Green-thighed Frog associated with the Karuah Bypass include Wallaroo Swamp and adjacent drainage lines, and low-lying areas in nearby paddocks. Potential habitat also occurs in moister vegetation east of the Karuah River, particularly around Mosquito Creek and its tributary. Whilst Wallaroo Swamp and the adjacent creeklines are contained within Wallaroo SF, and consequently can be regarded as having "*long term security and tenure*", the cleared land to the southwest and is proposed as the site of a Sewage Treatment Plant for Karuah.

In terms of "*tenure, zoning and land management practices*", Wallaroo Swamp and the adjacent creeklines can be regarded as secure with respect to habitat for the Green-thighed Frog. If the Green-thighed Frog is present at this location, it has clearly survived forestry operations and frequent burning over a long period. The additional "*long term security*" of habitats in the general vicinity, as a result of the transfer of areas of State Forest to the NP&WS, suggests a likely improvement in the conservation of the Green-thighed Frog, if it is present at this location.

Relative Significance

The "*subject site*" (*ie* the alignment and footprint of the Karuah Bypass) is not of itself regarded as of particular "*significance*" for the Green-thighed Frog, even if the species is present at this location. Only a small area of a few small creeklines will be affected directly by the roadworks, and stringent erosion and sediment control protocols and water quality

management programs are to be implemented to maintain habitat and water quality for amphibians in general, and the Green-thighed Frog (if it is present) in particular.

10.2.17 Christmas Bells

Other Populations

No information was available regarding "*other populations*" of Christmas Bells "*in the locality*". However, suitable habitat for this species occurs throughout "*the locality*", and "*other populations*" are likely to be scattered widely through the landscape.

Security and Tenure

Substantial areas of native forest "*in the locality*" and "*in the region*" are contained within dedicated conservation reserves managed by the NP&WS (including considerable areas of recent Nature Reserves) and in the forested lands managed by State Forests. In this latter instance, "*land management practices*" are implemented in forestry operations to ensure the protection and conservation of native fauna and flora, and contribute to the "*long term security and tenure of other habitats*" of threatened and other flora and fauna.

Relative Significance

The "*relative significance of the subject site in the locality*" for Christmas Bells is regarded as very low, because:

- only a small area of potential or known habitat for this species is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- areas of suitable habitat for this species are protected within the extensive conservation reserves in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.18 *Eucalyptus fergusonii*

Other Populations

No data regarding "*other populations*" of *Eucalyptus fergusonii* was available "*in the locality*". However, suitable habitat for this species occurs throughout the study area and "*the locality*", and "*other populations*" are likely to be scattered widely through the landscape, given the habitat requirements of this species.

Security and Tenure

Substantial areas of native forest "*in the locality*" and "*in the region*" are contained within dedicated conservation reserves managed by the NP&WS (including considerable areas of recent Nature Reserves) and in the forested lands managed by State Forests. In this latter instance, "*land management practices*" are implemented in forestry operations to ensure the protection and conservation of native fauna and flora, and contribute to the "*long term security and tenure of other habitats*" of threatened and other flora and fauna.

Relative Significance

The "*relative significance of the subject site in the locality*" for *Eucalyptus fergusonii* is regarded as low, because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the considerable extent of habitat in the locality;

- substantial areas of suitable habitat for this species occur in *"the locality"*, including significant areas protected within conservation reserves; and
- the "*subject site*" does not appear to support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.19 Swamp Mahogany

Other Populations

Swamp Mahogany is widely distributed in eastern NSW, but there are no specific data regarding "*other populations*" of the Swamp Mahogany "*in the locality*". However, suitable habitat for this species is scattered throughout the study area and "*the locality*", and "*other populations*" are likely to occur in suitable habitat (drainage lines, swamps and low-lying areas) widely throughout the landscape.

Security and Tenure

Substantial areas of native forest "*in the locality*" and "*in the region*" are contained within dedicated conservation reserves managed by the NP&WS (including considerable areas of recent Nature Reserves) and in the forested lands managed by State Forests. In this latter instance, "*land management practices*" are implemented in forestry operations to ensure the protection and conservation of native fauna and flora, and contribute to the "*long term security and tenure of other habitats*" of threatened and other flora and fauna.

Relative Significance

The "*relative significance of the subject site in the locality*" for Swamp Mahogany is regarded as low, because:

- only a very small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur within conservation reserves in *"the locality"*;
- the species was recorded widely in suitable habitat in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.2.20 *Hakea bakeriana*

Other Populations

No information is available regarding "*other populations*" of *Hakea bakeriana* which may be present "*in the locality*". However, suitable habitat for this species occurs throughout the dry sclerophyll forests of "*the locality*", and "*other populations*" are likely to be scattered widely through the landscape.

Security and Tenure

Substantial areas of native forest "*in the locality*" and "*in the region*" are contained within dedicated conservation reserves managed by the NP&WS (including considerable areas of recent Nature Reserves) and in the forested lands managed by State Forests. In this latter instance, "*land management practices*" are implemented in forestry operations to ensure the protection and conservation of native fauna and flora, and contribute to the "*long term security and tenure of other habitats*" of threatened and other flora and fauna.

Relative Significance

The "*relative significance of the subject site in the locality*" for *Hakea bakeriana* is regarded as very low, because:

- only a very small area of potential or known habitat (dry sclerophyll forest) is to be removed by the Karuah Bypass compared to the considerable extent of this habitat type in the locality;
- substantial areas of suitable habitat for this species are protected within conservation reserves in "*the locality*"; and
- the "*subject site*" does not support features or habitat resources of restricted distribution or unusually high quality for this species (given the low reporting rate for the species in the study area).

10.2.21 *Tetratheca juncea*

Other Populations

Other investigations have revealed the presence of "*other populations*" of *Tetratheca juncea* "*in the locality*", including on land around the Karuah Quarry and in forested land adjacent to the Karuah to Bulahdelah upgrade of the Pacific Highway (ERM Mitchell McCotter 1999). Several sub-populations of *T juncea* are located in the Karuah Quarry area (Gunninah 1998a), and a substantial population is located adjacent to the existing Pacific Highway, west of the Karuah Bypass. This latter population is regarded as significant, and may constitute the largest currently known population of *T juncea*.

Populations of *T juncea* near the Karuah Quarry and to the east of the Karuah Bypass proposal are regarded as of considerably greater value than those present along the Karuah Bypass. The population of *T juncea* west of the Karuah River is very sparse, and appears to be widely distributed within the Karuah SF. No evidence of this species has been obtained since the extensive bushfires in 1997/98, and it is known that fire can destroy populations of this species. The population of *T juncea* on Horse Island is more dense, and appears to number about 90 clumps. The stands of *T juncea* in and around the Karuah Quarry are to be protected, as part of the Quarry Development (Gunninah 1998a).

Construction activities on Horse Island will involve the removal of individuals of *T juncea* and its habitat. Approximately thirty plants (or 'clumps') of the species will be removed, although more than 60% of that population appears likely to be retained, and it is likely that there are other individuals or sub-populations of *T juncea* in areas of suitable habitat on Horse Island.

Security and Tenure

As discussed in some detail above, substantial areas of native forest "*in the locality*" and "*in the region*" are contained within conservation reserves managed by the NP&WS or the forested lands managed by State Forests. In this latter instance, "*land management practices*" are implemented in forestry operations to ensure the protection and conservation of native fauna and flora, providing "*long term security and tenure of other habitats*" for *T juncea*.

Whilst the sub-populations of *T juncea* and their habitat on the Karuah Quarry site is under private tenure, the "*land management practices*" of the quarry operators have been specifically designed to retain and protect populations of the species on the site (Gunninah 1998a). Thus, whilst this site is in private ownership, and is therefore not regarded as secure with respect to conservation outcomes, appropriate "*land management practices*" are being implemented on the site for the conservation of *T juncea*.

Relative Significance

The "*relative significance of the subject site in the locality*" for the *T juncea* is regarded as low, because:

- only a small area of potential or known habitat is to be removed by the Karuah Bypass compared to the extent of habitat in the locality;
- substantial areas of suitable habitat for this species occur in *"the locality"*, including significant areas protected within conservation reserves;
- the species was recorded only at low densities in the vicinity of *"the subject site"*, and is known to occur at much higher densities elsewhere in *"the locality"*; and
- the *"subject site"* does not support features or habitat resources of restricted distribution or unusually high quality for this species.

10.3 Movement Corridors

The D-G's Requirements for the Karuah Bypass SIS (Appendix A) include:

> *"2.4 If local or regional habitat corridors for affected species are present within the subject site, the impact of the proposal on these areas must be discussed."*

The NP&WS has indicated that the land traversed by the Karuah Bypass is part of an *"area incorporating Medowie, Wallaroo and Karuah SF that has been identified by NPWS as a regionally significant wildlife corridor, that provides a link from the coastal plains to the hinterland"* (L Baker NP&WS *pers comm*; Figure 4.3). On the basis of this assessment, the proposed Karuah Bypass would impose a barrier to fauna movements in a north-south direction through a part of the identified *"corridor"*, at least for those species which are less mobile (*eg* particularly terrestrial mammals, amphibians and reptiles). For the more mobile fauna groups (*eg* microchiropteran bats and birds), however, the proposed Karuah Bypass is not likely to constitute a barrier to movements of individual animals, at least in most instances.

Conversely, it should be noted that the existing Pacific Highway and the village of Karuah already provide a barrier to wildlife movements (north-south) in this locality. Consequently, whilst the proposed Karuah Bypass will provide an additional barrier to some fauna movements (notwithstanding the implementation of fauna underpasses and other impact amelioration measures), that phenomenon is not a novel impact on fauna of the locality and region.

In addition, the most extensive and contiguous tracts of native vegetation to the west of Karuah River involve (as noted by NP&WS) Karuah, Wallaroo and Medowie SFs, including the portion of those State Forests which have recently been transferred to the tenure of the NP&WS (Figure 1.3). The majority of these areas of native vegetation are located to the west of the proposed Karuah Bypass, and the project will consequently affect the north-south migration or movements of most native fauna species to only a limited extent.

There will, however, be some impact on fauna movements in the immediate vicinity of the Karuah Bypass, and in the general locality. In particular, the Bypass has the potential (west of the Karuah River) to constrain movements along the mangroves and foreshore communities, and between the eastern portion of the Karuah NR and forested lands to the west of the Bypass.

The proposed Bypass may impose a barrier to or restriction on the movements of several groups of native fauna, particularly terrestrial mammals, reptiles and amphibians, as well as those bird species which avoid open habitats. In addition, some arboreal mammals (particularly the Koala and smaller gliders, as well as possums) are likely to be constrained in their movements in the immediate vicinity, notwithstanding the installation of fauna underpasses specifically designed for animal movements, and the dedicated glider crossings, provided particularly for the Squirrel Glider.

The proposed Karuah Bypass may therefore isolate the area of vegetation between it and the existing Pacific Highway for a number of fauna species. The potential for the Karuah Bypass to impose movement barriers on individual species is discussed in detail in Chapter 10.1, and impact amelioration measures designed to mitigate this potential impact are described in Chapter 12. The Bypass clearly has the potential to isolate sub-populations of some species, to limit the opportunities for dispersal of individuals of some species, and to

restrict inter-breeding opportunities between sub-populations on each side of the alignment.

To the east of the Karuah River, the proposed Bypass is located primarily in cleared grazed land. For the majority of native fauna species, the proposed Bypass to the east of the River is therefore unlikely to constitute a significant barrier to movements. However, the Bypass does cross two creeklines east of the River (Mosquito Creek and a tributary - Figure 1.2), and traverses a partially forested ridgeline. These features may provide some fauna movement corridor functions, at least on a local basis. Whilst specific engineering and design features have been incorporated into the proposed Karuah Bypass at these locations, there remains the possibility of some reduction of fauna movements for macropods and some arboreal mammals, at least.

Given the location of the existing Pacific Highway and the village of Karuah, and the nature of the landscape through which the existing Highway and the proposed Bypass are located, it appears unlikely that the proposed Karuah Bypass will significantly affect any possible or likely regional wildlife movement corridors. As noted above, extensive forested lands in the State Forests and Nature Reserves in the immediate vicinity are located to the west of the proposed Karuah Bypass alignment, and the existing Highway and village of Karuah already impose a constraint to wildlife movements (for the less mobile fauna species, at least).

Those fauna species which are likely to utilise regional wildlife corridors in terms of "*a link from the coastal plains to the hinterland*" are highly mobile, and are not likely to be disrupted in their essential behavioural patterns by the Karuah Bypass. Conversely, the Bypass does represent a potential barrier to long-term movement of species through the landscape, although it does not sever any vegetated link or wildlife corridor in totality.

The proposed Karuah Bypass will involve some restriction to wildlife movements in the immediate vicinity and locality, particularly west of the Karuah River in a northwest-south-east direction. Measures to provide for wildlife movements in this locality across the proposed Karuah Bypass are described in detail in Chapter 12 of this SIS.

10.4 Indirect Effects

The D-G's Requirements for the Karuah Bypass include:

> "*1.5 In defining the study area consideration shall be given to possible indirect effects of the development on the area surrounding the subject site, for example habitat fragmentation, vegetation corridors, altered hydrological regimes, soil erosion or pollution, and increased human presence*".

Both the construction and the subsequent operation of the proposed Karuah Bypass have the potential to impose "*indirect effects on the areas surrounding the subject site*". Indirect impacts on surrounding areas and on areas of adjacent habitat, including areas of vegetation and habitat which are to be retained for conservation purposes, may include:

- fragmentation of habitat. The proposed Bypass will impose a barrier to the movement of some fauna species (in particular terrestrial and arboreal mammals, such as the Koala and Squirrel Glider), notwithstanding the provision of measures designed to facilitate fauna crossings of the roadways. Currently connected areas of native vegetation and fauna habitat may be severed, preventing or limiting the movement of animals, and possibly isolating some areas of habitat for some species (see discussion below, and Chapter 10.1);
- loss of vegetation links or corridors, or restrictions on animal movements (see detailed discussion in Chapter 10.3). A "*regional vegetation corridor*" has been identified by the NP&WS (as discussed above) on the western side of the Karuah River (Figure 4.3). Whilst the majority of the study area appears to be outside of this "*corridor*", the westernmost portion of the proposed Bypass encroaches into the "*corridor*", creating a barrier to some fauna movements in this area.

- The "*corridor*" identified by the NP&WS extends for some distance to the west of the study area, however, and the potential fragmentation as a result of the Bypass is not considered likely to significantly reduce its regional value. On the eastern side of the Karuah River, Mosquito Creek is considered to form a local corridor between large stands of relatively intact vegetation on either side of the proposed Bypass. There is some potential for the degradation of this corridor, preventing or limiting fauna movement between these areas;
- alterations to hydrological regimes. Whilst hydrologic regimes in the study area have been altered historically by the clearing of land for agriculture, and to a lesser extent possibly by forest activities, the Bypass may further alter the quality and quantity of water entering natural ecosystems. The proposed Bypass will involve an increase in impermeable surfaces, and will result in some decrease in infiltration of rainfall and an increase in volume and velocity of runoff. Furthermore, runoff from the proposed Bypass will contain pollutants, such as oils and surfactants, although water quality control ponds are included in the project design (for detailed consideration of stormwater management and hydrological regimes, refer to the EIS and Working Paper No 5 - *Hydrology, Water Quality and Flooding*);
- erosion and sediment discharge. The proposed activities have the potential to involve erosion and sediment discharge, particularly during construction activities. Stockpiles and areas cleared of vegetation are vulnerable to erosion, which may potentially result in sedimentation of creeklines and sediment deposition into the Karuah River design (for detailed consideration of stormwater management and erosion and sediment discharge management, refer to the EIS and Working Paper No 5 - *Hydrology, Water Quality and Flooding*);
- increased human presence. Given that the proposed Bypass will not involve rest areas or interchanges (other than at each end), the potential for indirect impacts as a result of increased human presence is limited. However, litter could reduce the quality of adjacent habitats (to some extent), and there is a risk of wildfire as a result of cigarette butts being thrown from vehicle windows; and
- 'edge-effects', which may alter the vegetation communities and species assemblages along the alignment, and render some areas unsuitable for those species which are not tolerant of more exposed sites or of alterations to habitats or environmental features (see discussion below).

Measures to avoid or reduce the "*indirect impacts*" which could potentially be imposed on threatened species or their habitats along the Karuah Bypass have been incorporated into the design of the proposed Highway (as detailed in Chapter 12 of this SIS). In particular, measures to avoid the discharge of sediments and contaminants and of contaminated stormwater runoff are incorporated into the project design and construction, and are to be stringently implemented. Furthermore, the project involves measures to stabilise exposed soil surfaces as rapidly as possible, and to rehabilitate disturbed sites so as to avoid the discharge of sediment or pollutants into adjoining habitats.

Strict management of exposed soils, stockpiles, erosion and sediment discharge will be features of the construction phase of the proposal. In particular, sensitive locations such as the Karuah NR, SEPP 14 Wetlands and native vegetation in general, will be protected by stringent and strictly enforced management measures. Whilst there is some potential for limited sediment discharge during the construction process, measures to avoid or minimise any such indirect effects on adjoining habitats are to be applied to the proposal.

With respect to contaminant discharge, specific measures are also to be applied during the construction process to avoid the discharge of contaminants into adjacent natural habitats and areas of high sensitivity. Measures will include bunding of storage sites for fuels and other contaminants, avoiding discharges into sensitive sites and locations, and a contingency plan for contaminant spills.

With respect to the completed Bypass and local road system, there is (as elsewhere throughout NSW) the potential for contaminant discharges as a result of oil, fuel and chemical spills along the Bypass. Whilst the current Pacific Highway does not incorporate measures for the control and management of fuel or contaminant spills, the Karuah Bypass

does include design features intended to reduce or avoid the potential for contaminant discharges into the Karuah River and other sensitive environments.
Fauna movement structures have been incorporated into the design of the road (as detailed in Chapter 12), to reduce or limit the potential impacts of habitat fragmentation, barrier creation and the loss of movement corridors.

Habitat Fragmentation

The proposed Karuah Upgrade project will involve the fragmentation of habitat and vegetation in the vicinity of the alignment, creating two fragments of moderate size in the forested lands to the west of the Karuah River. The proposed alignment will create:

- an isolate of approximately 127ha between the proposal, the existing Pacific Highway and the proposed Sewerage Treatment Plant; and
- a second isolate of approximately 175 ha between the proposal the Karuah River and the proposed Sewerage Treatment Plant.

As discussed elsewhere in this SIS, the more mobile fauna species (most birds and bats) will be able to cross the proposed alignment, and the fragmentation of habitat is not likely to significantly affect such species directly. However, for less mobile species, habitat fragmentation can lead to isolated populations of fauna and flora species with only limited opportunities for interactions with other populations in the vicinity.

The two fragments to be created, however, are likely to support viable populations of most of the species currently present, given their sizes (approximately 127ha and 175ha). Additionally, for the more significant species (particularly threatened fauna) for which the alignment will constitute a barrier, features are incorporated into the project design to permit animal movements across the alignment, thus reducing the potential effects of habitat fragmentation. Underpasses are provided at several locations between the fragments and forested lands to the northwest of the alignment, and dedicated Squirrel Glider crossings have also been designed for the project (see Chapter 12).

Notwithstanding the implementation of appropriate impact amelioration measures, however, the Karuah Upgrade project will involve some additional habitat fragmentation. Conversely, extensive areas of unfragmented habitat and vegetation will remain in the locality, including most of the Karuah NR and adjacent State Forests.

The 'Edge Effect'

The 'edge-effect' involves an array of physical and biological changes which occur when an artificial edge has been created within a vegetation community or area of habitat, and two distinctly contrasting environments are juxtaposed (Andrews 1990; Laurance 1997). The vegetation adjacent to such edges often experiences changes in microclimate, floristic composition and structure, and is more prone to invasion by exotic species or weeds, or to disturbances by humans. Edges may also create barriers and may separate populations or increase the risk of predation during activities such as migration and dispersal, foraging, breeding or searching for mates (Andrews 1990; Laurance 1997). Conversely, some flora and fauna species are adapted to edges, and readily utilise these habitat features, contributing to altered floristics and fauna assemblages in the vicinity.

Abrupt changes in floristic structure, such as that created by fragmentation and forest edges, are generally characterised by a reduction in forest canopy cover and by an abundance of exotic species, native weeds and other disturbance-adapted plant species (Laurance 1997). Increased wind speeds and the formation of wind-tunnels can effect vegetation well within the forest, away from the disturbed edge (Laurance 1997).

This phenomenon is particularly marked in the instances of vegetation communities and habitats which are sensitive to alterations in light levels and humidity. Consequently, 'edge-effects' are often more significant and substantial in rainforest or wet sclerophyll forests than in dry forest and woodland communities. In this regard, the relatively open and dry forest and woodland communities typical of the Karuah Bypass alignment are likely to be less susceptible than rainforest or other vegetation communities, as they are

already characterised by relatively high light levels and exposure to winds.

There are conflicting data regarding the impact of 'edge effects' on fauna, and species will respond differently to edges. For example, although there is evidence that increased forest fragmentation and decreased fragment size increases the predation rates and reproductive failure of forest-nesting birds, the effect of edges on predation is still uncertain (Keyser *et al* 1998; King *et al* 1998). Paton (1994) concluded that there is a greater risk of nest predation within 50m of the forest edge, but Keyser *et al* (1998) identified no alterations in predation rates near the forest edge.

Responses to 'edge-effects' and habitat fragmentation also vary widely for mammal species. Whilst some small mammal species (such as the Grassland Melomys *Melomys cervinipes*) increase significantly near forest edges, the Bush Rat *Rattus fuscipes* declined (Goosem & Marsh 1997; Laurance 1997). The forest edge habitat also favours some arboreal mammals and fast-flying open-forest microchiropteran bats. Conversely, forest-dwelling bats favouring dense understorey decline (Laurance 1997, cited in Crome & Richards 1988).

Similarly, McCann (1992) recorded a distinct variability in the ability of some macropods to adapt to forest edges and habitat fragmentation. Species such as the Red-necked Wallaby *Macropus rufogriseus*, the Eastern Grey Kangaroo *Macropus giganteus* and the Common Wallaroo *Macropus robusta* were able to adapt readily to edge-creation, and to utilise the newly formed open spaces. Other macropods (such as the Swamp Wallaby *Wallabia bicolor)* were only able to adapt mildly to edge-creation and preferred habitat closer to the forest edges or in thicker undergrowth, such as bracken. The Long-nosed Potoroo *Potorous tridactylus* was unable to utilise the forest edges and open pastures, and its preferred habitat was negatively affected by edge-creation.

The extent of 'edge-effects' into the adjacent vegetation is also determined to a significant extent by environmental management practices and the long-term management of the adjoining vegetation. Whilst it has been noted that "*infestations of introduced grasses and herbaceous species frequently extend up to 50 m beyond the road reserve, particularly into the dry open forest types*" (ERM Mitchell McCotter), that situation pertains along the existing Pacific Highway, which was not subjected to the rehabilitation and environmental management measures which are current 'best practice'.

With respect to the Karuah Upgrade project, is intended that the margins of the forest and woodland along the alignment be rehabilitated following the disturbance caused by the road construction, and that native forest and woodland be re-established to near the road edge. Complementary management of land by the NP&WS, and the design and nature of the activity, will limit the 'edge-effect' on vegetation to a short distance into these open vegetation communities, estimated to be a distance of approximately 20 metres. This distance also provides a reasonable average 'edge effect' for native fauna, given the positive and negative impacts on different species.

11 ALTERNATIVES to the PROPOSAL

The TSC Act requires, under Section 110(2)(h), that a SIS includes the following information:

> *"a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development".*

11.1 Feasible Alternatives - the Route Selection Process

The Karuah Bypass (Horse Island Route) which is detailed in the EIS prepared by Ove Arup (1999), and which is discussed in detail in this SIS, was selected as the preferred route for the upgrading of the Pacific Highway in the vicinity of Karuah route from a number of options. The various route options were identified and evaluated in a 'route selection' process addressing a range of "*biophysical, economic and social*" criteria.

The route selection process (described in detail in the EIS) included consideration of a number of route options between the existing Pacific Highway and the Horse Island route, to the north of Karuah. For topographic and environmental reasons, there are no "*feasible alternatives*" for the Pacific Highway upgrade to the south of Karuah. The reasons for selecting the Horse Island route from the "*feasible alternatives*" are described in detail in the EIS, and addressed in Chapter 11.2[9] (below).

The option of either not upgrading the Pacific Highway through Karuah or not constructing a Bypass around it (the 'Do Nothing' option), was considered in the original selection process but was not regarded as a "*feasible alternative*", given the high volume of traffic on the Pacific Highway, the consequent existing social and safety issues, and the planned upgrading of substantial sections of the Pacific Highway between Sydney and Brisbane.

11.2 Justification of Proposed Action

The EIS contains a detailed justification of the proposed Karuah Bypass (Horse Island route) "*in the manner proposed, having regard to biophysical, economic and social considerations*". Matters of particular relevance in determining the preferred alignment included:

- ecological considerations - particularly the avoidance of portions of native vegetation of high ecological or conservation value, areas which contain significant habitat and features for threatened flora and fauna species, and areas of high sensitivity. The alignment has been located, wherever possible, in previously disturbed or degraded forest areas, or in cleared paddocks, and to minimise the area of SEPP 14 wetlands which will require clearing or disturbance;
- physical and topographical constraints - particularly associated with the crossing of the Karuah River and the traversing of a steep ridge on the eastern side of the River. In this regard, the alignment was, in part, located by a preference to minimise the length of the River crossing;
- economic issues - associated with engineering requirements for the Bypass and the cost of bridging the Karuah River, and with the relationship between the Highway and the local economy of the township of Karuah; and
- social issues - particularly associated with the town of Karuah and the impacts of existing Highway traffic on the community. In addition, the Bypass had to be located so as to avoid division of the community into separate areas by the road.

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9 The Horse Island route involves a greater ecological impact than some of the "*feasible alternatives*" (such as an upgrade of the Pacific Highway through the town). However, those "*alternatives*" have been rejected on other grounds (including for social, safety and efficiency reasons). The proposed Bypass alignment has, wherever possible, utilised cleared lands in preference to forested areas.

Social and economic factors are significant elements in the justification of constructing a Bypass of the Pacific Highway around the town of Karuah (Chapter 4 of the EIS), particularly relating to social amenity and safety. Environmental considerations are also relevant to the existing Pacific Highway through Karuah, however, in terms of the use of fuel, particularly by large vehicles. Traffic volumes at peak times (weekends and holidays) can result in extensive traffic delays, with concomitant additional use of fuel by all vehicles. In addition, the existing Pacific Highway imposes significant risks in terms of spillage of contaminants, as there are no containment facilities associated with the existing Highway. A newly constructed Pacific Highway would incorporate features designed to contain contaminant spills.

11.3 Ecologically Sustainable Development

Ecologically Sustainable Development (ESD) involves the concept that decision-making should be based on sound environmental management principles, which involve consideration of both present and future impacts in terms of the conservation of biodiversity and ecological integrity, the pursuit of social equity, and the effective and efficient use of resources (DUAP 1995). The promotion of ESD is based on the application of four interrelated principles:

- conservation of biological diversity and ecological integrity;
- social equity, including inter-generational equity;
- improved valuation, pricing and incentive mechanisms; and
- the precautionary principle.

The Karuah Bypass implements the principles of ESD, by applying sound design and management principles, and by incorporating environmental management and impact amelioration measures into the design and construction processes for the project. Similarly, long-term management of the environment is addressed by the application of 'best practice' in the road design and in its construction, and the implementation of a range of appropriate environmental protection measures.

Conservation of Biological Diversity and Ecological Integrity

Whilst the upgrading of the Pacific Highway in the vicinity of Karuah by re-construction along or the near existing Highway alignment would have imposed a lesser impact on biodiversity and ecological integrity than the Horse Island route, the former option was not acceptable on a range of grounds, including social and economic issues.

The Karuah Bypass (via Horse Island) has been designed and located, within the constraints of engineering and road safety requirements, so as to limit or reduce adverse impacts on the conservation of biodiversity and on the ecological integrity of the landscape by:

- locating the road within cleared paddocks and agricultural lands wherever possible, and avoiding features of higher biodiversity or ecological value wherever possible (*eg* Wallaroo Swamp);
- selecting an alignment which attempts to limit adverse impacts on the SEPP 14 wetlands along the Karuah River;
- preferentially disturbing or removing areas of native open forest and woodland which have been affected by timber removal and burning activities over a long period, so as to avoid other portions of land with higher "*biological diversity and ecological integrity*" qualities (such as Wallaroo Swamp) and to limit fragmentation in certain locations (*eg* by confining the roadworks to the southern tip of Horse Island); and
- implementing an array of measures to ameliorate or reduce adverse impacts upon the natural environment (below those which might otherwise pertain), including limiting vegetation clearing wherever possible, providing underpasses for fauna to cross the alignment, and providing appropriately spaced trees for gliders to cross the new road.

Given the ecological, topographic, social and economic constraints on potential alignments for the Karuah Bypass, the route which has been selected is designed, to the greatest extent 'reasonably practicable' within the constraints of engineering and road safety requirements, and the practicalities of economic parameters and social needs, to limit or reduce adverse impacts on the "*conservation of biological diversity*" and on the "*ecological integrity*" of vegetation communities, species and habitats in the locality.

The Karuah Bypass will involve the loss of native vegetation and fauna habitat, and individual animals and plants will be lost or will need to be removed for the project. Conversely, it is not considered likely that the Karuah Bypass will significantly reduce biodiversity in the locality, given the nature of the landscape and the implementation of impact amelioration and environmental management measures. Furthermore, it is not regarded as likely that any native species would be rendered even locally extinct as a result of the project.

As discussed in Chapter 10 of this SIS, the Karuah Bypass will involve the additional fragmentation of habitat and of vegetation communities in the locality, and will impose a barrier to the movement of some animals through the landscape. Conversely, as noted above, the Bypass has been located and designed to limit or reduce impacts on ecological integrity, by locating the road as far as possible within areas of cleared land or already disturbed vegetation and by implementing measures to facilitate fauna movements through the area and ameliorate potential impacts.

Intergenerational Equity

As indicated in Chapter 4 of the EIS, upgrading the Pacific Highway in the vicinity of Karuah will provide a "*more efficient road system*", which reduces the use of fossil fuels by vehicles and which removes the substantial quantity of traffic (particularly of heavy vehicles) from the centre of Karuah. In local terms, Bypassing the town of Karuah presents an "*opportunity for potential urban improvement in the township*" and "*could enhance local economic activity through new and diverse recreational and tourism activities*", thus providing local employment and an improved urban amenity.

In addition, the project has incorporated a series of measures designed to limit the imposition of adverse impacts on the natural environment, and to minimise environmental disturbance within the constraints of engineering and safety requirements.

Improved Valuation, Pricing and Incentive Mechanisms

As indicated in Chapter 4 of the EIS, "*the consideration of environmental issues in the early stages of project planning has assisted in achieving improved valuation and pricing of environmental resources as it will ensure that these issues are given equal or more important consideration than other issues such as strategic planning or engineering issues*". Environmental issues have been a significant consideration in the location and design of the Karuah Bypass and in establishing the environmental management measures associated with the project's construction and subsequent operation.

The Precautionary Principle

The Precautionary Principle (IGAE 1992) states that:

> "*where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*
>
> *In the application of the precautionary principle, public and private decisions should be guided by:*
>
> - *careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and*
> - *an assessment of the risk-weighted consequences of various options*".

The Precautionary Principle requires that "*measures to prevent environmental degradation*" be implemented "*where there are threats of serious or irreversible environmental damage*", irrespective of "*full scientific certainty*" regarding their efficacy in ameliorating environmental impacts. In this regard, the Karuah Bypass incorporates a range of measures to limit or reduce potential impacts upon native biota and their habitats, some of which have not been rigorously evaluated in scientific terms. Notwithstanding this "*lack of full scientific certainty*", measures such as fauna underpasses, fauna-proof fencing and the re-use of chipped native vegetation material are to be implemented along the Karuah Bypass to limit or to reduce adverse impacts on native biota and to contribute to the prevention of "*environmental degradation*".

The location and specific design elements of the Karuah Bypass have been developed "*to avoid, wherever practicable, serious or irreversible damage to the environment*". The Horse Island route for the Karuah Bypass involves some "*damage to the environment*", including for threatened species, but the project has been located and designed "*wherever practicable*" to avoid the imposition of "*serious or irreversible damage*" by:

- location of the proposed Bypass predominantly in cleared agricultural lands to the east of the Karuah River;
- selection of a largely cleared saddle between the Karuah River and Mosquito Creek, rather than a more southerly route which would have affected greater areas of native vegetation;
- positioning of the Bypass on the southern end of Horse Island, to limit the fragmentation of that feature of the landscape;
- the avoidance of Wallaroo Swamp; and
- location of the Bypass in an area of uniform and somewhat degraded native vegetation west of the Karuah River.

The Karuah Bypass (Horse Island route) imposes some risk in terms of the fragmentation of populations of native biota and a possible decline in inter-breeding opportunities between sub-populations on either side of the alignment. In this regard, the Horse Island route imposes a greater risk than some potential alternative routes. Conversely, there are essentially no options which would involve all possible risks in this regard, and the project has incorporated measures to limit the environmental risks within the constraints of road development projects.

Within the constraints imposed by social and economic issues, and engineering requirements, the potential consequences of the proposal on native biota and on the natural environment were included in the design process for the Karuah Bypass. This process involved consideration of the likely risks of environmental damage, including the loss of habitats and resources for a range of species and the fragmentation of habitats and populations.

12 IMPACT AMELIORATION MEASURES

The TSC Act requires, under Section 110(2)(i), that a SIS include the following information:

> *"a full description and justification of the measures proposed to mitigate any adverse effect of the action on the species and populations, including a compilation (in a single section of the statement) of those measures".*

The Director-General of the NP&WS also requires the Karuah Bypass SIS to detail Item 3 of Appendix A, that:

> *"3.3 Details must be provided of the measures proposed to mitigate the effect of the proposal. Measures for minimising the number of road kills of affected species should be identified. These may include fauna over- or underpasses, exclusion fencing, tunnels, retention of median vegetation for arboreal species, and appropriate revegetation and habitat restoration in adjacent areas. The techniques used must employ current best practice and be supported by a literature review".*

12.1 Amelioration Measures - A Review

The potential impacts of roads on native wildlife are well recognised, and are generally considered a significant element in the degradation of natural habitats and in species conservation, at least in certain instances and for some species. A range of studies both in Australia and overseas have addressed the impacts of roads on native animal populations, including investigations of the contribution of road construction and use to habitat fragmentation and degradation, to direct animal mortality, to the restriction of animal movements, and to an increased 'edge effect' (Hodson 1966; Bellis & Graves 1971; Vestjens 1973; Oxley *et al* 1974; Jefferies 1975; Burke & Sherburne 1982; Wilkins 1982; Adams & Geis 1983; Swihart & Slade 1984; Mansergh & Scotts 1989; Andrews 1990; Evink 1990). Detailed reviews of the literature regarding the effects of roads on wildlife in general have been compiled by Bennet (1991) & Andrews (1990) - which consider all elements of this issue, and by Fanning (1992) - reviewing all issues and addressing the concerns of Koala mortalities.

Measures which have been adopted to reduce or prevent animal road kills, particularly in the United States and Great Britain, can be divided into two broad groups - those directed at altering the behaviour of the animals (*eg* by preventing their access to the roadway, or by providing safe alternative crossings), and those directed at altering the behaviour of vehicle drivers (*eg* by increasing their awareness of the possibility of animals on the roadway and/or by reducing vehicle speeds).

12.1.1 Managing Animal Movements

Fencing

In the USA, fences 2.4m in height have been installed along major highways at several locations where there is a history of or the possibility of collisions between vehicles and deer (Reed *et al* 1974a,b; Ward 1982). Fences have been installed where the known migration routes of animals intersected with the highways, and the routes generally involve sites with a relatively narrow concentration of animal activity along the road frontage.

In an evaluation of their effectiveness by the Colorado Division of Wildlife (Reed *et al* 1982), it was determined that the annual deer kill on Colorado Highway No. 82 was reduced by 61% in the first year after the installation of a 1.8 kilometre length of 2.4m-high fence. Other examples of the successful use of fences to control animal movements include the funnelling of deer (Reed *et al* 1974, 1975; Ward 1982), Koalas (Pieters 1992; Prevett *et al* 1992) and Badgers (Clark *undated*), as discussed below.

Electric fence trials for controlling wallaby and possum populations have been undertaken with mixed results. The most effective electric fence trialed by Stratham (1994) to control wallaby movements involved the lowest wire following the contours of the ground, at most 75mm from the ground surface. An important factor in controlling possum movements was the selection of the electrified wires, with a greater success rate where the lower wires were

electrified (Clapperton & Matthews 1996). Electric fencing reduced possum movements by 60-80%, although fence reliability is reduced by shortages caused by wind-blown debris and water accumulation (Cowan & Rhodes 1992; Stratham 1994).

Research into suitable fencing by Prevett *et al* (1992) resulted in Koala-proof electric fence use in Victoria. The study demonstrated that whilst barbed wire posed no deterrent to Koalas, fences equipped with electric wires were a deterrent. Prevett *et al* (1992) noted that a compromise must be found between electric fences acting as a deterrent and a stress inducer for the method to be successful.

Underpasses and Culverts

Many native mammal species will use tunnels and culverts constructed underneath a road or railway if the conditions around and throughout the structure are suitable (Andrews 1990; Bennett 1991). The principal factor contributing to the use of such structures is the extent of native vegetation growth in and around the tunnel or culvert, and the ground surface material (Hunt *et al* 1997; Ward 1982). The scattering of logs and rocks around and in the structures appears to enhance their use, and earth floors were preferred by deer over concrete floors (Ward 1982). Predation by feral species is higher around unvegetated structures, and these appear to be less frequently used by native mammals (Hunt *et al* 1987).

Burnett (1992) recognised that a variety of tunnel sizes provides movement corridors for different sized mammals. However, that tunnels and culverts should be avoided where possible and long bridges should preferably be constructed over gullies and waterways, with the retention of natural vegetation. Vegetation and other features (rocks and logs) beneath bridges can be used as shelter or protection for animals passing underneath the road, and the risk of predation in open spaces evident in tunnels and culverts is reduced (Burnett 1992).

Funnelling wildlife into tunnels through the use of fencing has been widely recognised as the most effective method of encouraging the use of alternative crossing routes for migrating deer in Europe and the US (Reed *et al* 1974; Reed *et al* 1975; Ward 1982). Similar trials in Australia on Koalas have also met with success (Prevett *et al* 1992). Koalas have been found to use the 'funnel-tunnel' structures without being coerced into them (Prevett *et al* 1992).

Pieters (1992) has adapted an existing culvert under the Pacific Highway at Gaven in south-east Queensland for the use of wildlife, particularly for Koalas. The modification involved installation of a 1.8 link-mesh fence for 150 metres along each side of the Highway to direct animals into the culverts for safe passage across the roadway - the so-called 'funnel-tunnel'. The pre-existing culvert system consisted of five box-culverts under each carriageway (each of approximate dimensions 4m wide by 3.4m high by 10m long), which constitute a substantial underpass for animals (and humans). During a one-month survey period, twelve species were recorded using the culverts, although the Koala was not amongst them. According to Pieters, at least two species were directed towards the culverts by the fencing.

Tunnels built for multiple-species use were found to be less frequented by animals, and similarly culverts used for dual purposes (such as drainage and wildlife corridors) have also been found to be less used by mammals (Prevett *et al* 1992). If culverts carrying water are to be used for Koala passage corridors, box culverts placed at a 5^0 angle or round culverts with a concrete floor at a 5^0 angle are preferred. Factors which may inhibit tunnel use include diameter, length, light intensity, wind speed, stale air and odour (Prevett *et al* 1992).

Overpasses

Deer in Europe do not readily use overpasses (Putman 1997), and the use of such crossings is determined largely by the width of the bridge (up to 30m wide bridges have been used and the extent of vegetation on the overpass. However, deer were found to prefer underpasses rather than overpasses (Putman 1997).

Conversely, Koalas appear to readily use a vegetated bridge or a pedestrian bridge, (but not a vehicular bridge), with the funnelling of animals by fencing being a benefit in encouraging

their use of the structures (Prevett *et al* 1992).

'Psychological' Barriers: Light Reflectors & Scent-fences

Two basic types of reflectors have been utilised - one where flashes of white light reflected from the headlights of cars act as warning signals to wildlife, and a second (Swareflex) where reflectors are placed such that they create a continual barrier of red or white light (Putman 1997; O'Rourke 1990). However, wildlife quickly habituate to the first type of reflector, and these therefore have limited efficacy (Putman cited in Gilbert 1997).

Trials in Australia of the Swareflex type reflector resulted in a reduction of road-hits of kangaroos in NSW, although vandalism and theft proved to be major hindrances to the economic viability of such reflectors during the trials (O'Rourke 1990). Swareflex reflectors provide a temporary 'psychological' barrier to crossing wildlife when it is dangerous for them to cross, and thus may only be effective on irregular or relatively light traffic flow roads, since animals may force a crossing where a 'continuous' barrier exists on high traffic flow roads (Putman 1997). The success of this technique is dependent on the species of wildlife, with species reliant on vision (*eg* deer and kangaroos) being more likely to respond than those which utilise scent (*eg* badgers, koalas and wombats).

Scent-fences are formed by spraying an organic foam onto the roadside, which disintegrates in daylight and releases volatile compounds. The use of appropriate odours can stimulate wildlife, and cause them to pause and become more alert. Limited trials have been undertaken in Europe on deer, with some success (Putman 1997).

Roadside Vegetation

Burnett (1992) recommends that where possible, the tree canopy should be left intact such that arboreal and scansorial mammals are able to cross the road through the canopy. Such measures are obviously more feasible for narrow roads, however and less so for dual carriage highways. Vegetation in and around tunnels, culverts and on overpasses are also regarded as vitally important to the use of such structures. Conversely, landscape vegetation planted along roadsides and particularly along motorways may encourage wildlife to road edges and reduce driver visibility (Putman 1997). Additionally, the 'edge-effect' created by the road may itself be favourable habitat for some species, and may increase the incidence of wildlife crossing and mortalities (Putman 1997)

12.1.2 Managing Vehicles

The alternative approach to reducing the road-related mortality of wildlife is to alter the behaviour of drivers, by increasing their awareness of the presence of animals, by reducing vehicle speeds or improving the visibility of animals on the roadways.

The installation of highway lighting at known deer crossing sites, however, is apparently ineffective in reducing the number of deer kills. Pojar *et al* (1975) reported that, after the installation of highway lighting on a portion of Colorado Highway No. 82, the number of deer-vehicle accidents actually increased.

In a trial of lighted, animated deer crossing signs, Green *et al* (1973) and Pojar *et al* (1975) indicated that no reduction in the number of deer kills, and very little reduction in vehicle speeds, occurred in response to their presence. Conventional (unlighted) warning signs were twenty times cheaper, and satisfied public relations and liability requirements (although apparently having little effect on the incidence of wildlife mortality), and were therefore recommended by these studies.

In Australia, warning signs are regularly used to alert drivers to the potential presence of wildlife on roads. However, despite the presence of warning signs along the Hume Highway in an area with a high density of wombats, animal mortalities remains high (Fanning 1988), and other measures are being investigated to reduce wombat mortality. Coulson (1982) noted that the presence of warning signs did not reduce the number of kangaroos being killed along a 20km stretch of highway in Victoria, and the concentration of

mortalities appeared to be related simply to proximity of appropriate habitats. Similar observations are provided by Tartowski (*unpubl*) with respect to wombats and kangaroos in South Australia.

12.2 Environmental Management and Impact Amelioration

The impact amelioration and environmental management measures to be implemented with respect to flora and fauna issues along the Karuah Upgrade alignment will be detailed and documented in an Environmental Management Plan (EMP) to be prepared for the project, as consistent with other upgrade projects along the Pacific Highway. The EMP will provide details of the specific measures to be implemented for flora and fauna, and their habitats and resources, both during the construction process and during subsequent rehabilitation and ongoing maintenance of the road.

12.2.1 Impact Avoidance

The route selection process for the Karuah Bypass, and some specific design features of the final road alignment, have included consideration of the location of the road and of design elements of the Bypass "*to mitigate the effect of the proposal*". Both the specific location of the Bypass and elements of the engineering design have been developed to mitigate or reduce possible adverse effects on the natural environment as a result of:

- location of the Bypass to avoid direct impacts on Wallaroo Swamp;
- location of the roadworks on the southern end of Horse Island which limits the extent of 'cut' and 'fill' which are necessary;
- engineering design responses to mitigate impacts on SEPP 14 wetlands and wetland vegetation;
- location of the alignment east of the Karuah River generally to utilise cleared and disturbed agriculture lands rather than forest communities; and
- location of the Bypass through a largely cleared saddle between the Karuah River and Mosquito Creek, to limit the clearing of vegetation required and to maximise opportunities for the provision of fauna underpasses and corridors for fauna movement.

In addition to mitigating or reducing potential adverse impacts on the natural environment by selecting the most appropriate location and design of the Karuah Bypass (within the constraints of the 'preferred' alignment), a range of general and specific environmental management (impact amelioration) measures are incorporated into the activity "*to mitigate the effect of the proposal*".

General measures and protocols which will be implemented during the construction of the Karuah Bypass (including water quality control measures, contaminant discharge management, acid sulphate soil management and other general environmental protection measures), will have the effect of limiting adverse impacts on the natural environment (Chapter 12.1.2). In addition, a range of specific environmental measures are to be implemented, including specific activities for threatened flora and fauna species (and their habitats and resources), the protection of SEPP 14 Wetlands, and minimising the extent of the construction footprint in the vicinity of the Karuah NR (Chapter 12.1.3).

12.2.2 General Impact Mitigation and Amelioration

A range of general environmental management (impact 'mitigation' or 'amelioration') measures are included as part of the Karuah Bypass proposal, designed to contribute to the avoidance of or reduction in potential adverse impacts which will or may be imposed on native fauna and flora. General mitigation measures to be implemented along the proposed Bypass are:

- the minimisation of vegetation clearing at all locations, limiting the removal of vegetation to the minimum necessary for the road's construction;

- 'best practice' management of erosion and sediment discharges during the construction phase, to ensure that there is no significant discharge of sediment into watercourses or vegetation communities downslope and downstream of the roadworks. A range of measures are to be implemented during construction, including the use of silt fences, sediment ponds and hay bales, and the covering and protection of exposed soil surfaces as rapidly as possible (as described in the relevant Working Papers and in the EIS);
- appropriate management of acid sulphate soils, to prevent the potential for adverse impacts on habitats or species downstream. This measure is of particular relevance in the vicinity of the Karuah River;
- the construction and use of water quality control ponds, incorporating macrophyte vegetation, to ensure that the water quality of adjacent watercourses and waterbodies does not deteriorate as a consequence of discharges from the construction and operational phases of the proposed Bypass, particularly in the vicinity of Wallaroo Swamp, the Karuah River and Mosquito Creek;
- the implementation of a rehabilitation and replanting program (as part of the Landscape and Urban Design Concept Plan) along the completed road, involving the use of indigenous native species;
- the collection and propagation of seed and fruit from native plant species cleared along the full length of the proposal, for utilisation in replanting and rehabilitation projects in the vicinity, and for landscaping along the alignment. All suitable removed native plant material[10] should be collected and chipped, to be used as a mulch and groundcover in landscaping and rehabilitation areas, to promote the regrowth of native and endemic plant species, and to assist in soil stability and conditions;
- the retention of topsoil, where possible, and its use on areas of landscaping and rehabilitation in the immediate vicinity of the roadworks. In addition to retaining the native seedbank, the use of existing topsoil from the locality in rehabilitation will retain tubers, bulbs and other vegetative material from which native plants can regenerate, and will also provide the microbial and mycorrhizal biota which are of relevance in the establishment and maintenance of native vegetation;
- the propagation and planting of plant species of conservation significance, in consultation with the NP&WS;
- the location of all works sites, stockpile areas, storage facilities, vehicle parking and maintenance areas on already disturbed land, wherever possible, avoiding the additional clearing of vegetation for these activities;
- no stockpiling of materials or parking of vehicles, or other unnecessary disturbance, beneath vegetation and trees which are to be retained along the alignment; and
- the management of general construction activities along the alignment to prevent the loss or discharge of waste into remnant vegetation, including:
    - the collection and removal of excess contaminants;
    - the bunding of sites containing potential liquid contaminants;
    - the appropriate disposal of rubbish and general waste materials; and
    - the provision of appropriate ablution and work-shed facilities to prevent the discharge of contaminants into native vegetation.

12.2.3 Specific Environmental Management Measures

In addition to the general measures for protection of the natural environment discussed above, a number of specific environmental management and impact amelioration

10 Note that weeds and invasive plant species (*eg* some wattles) will not be included in chipped material, but will be disposed of appropriately.

measures are to be incorporated into the project. These measures are part of the proposed activity, and will have the effect of ameliorating impacts which could potentially be imposed in their absence.

These environmental management measures also include activities designed to enhance habitats and features of the natural environment, where possible. Particular measures are to be applied with respect to the SEPP 14 Wetlands and the Karuah Nature Reserve, the prevention of fauna mortality, and the protection of threatened biota in particular.

SEPP 14 Wetlands

In addition to the features which have been incorporated into the design to limit the area of wetland vegetation to be affected (by selective location of the Bypass), specific protocols are to be applied during the construction phase and as part of the long-term management of the road to protect these communities:

- a construction protocol which requires that all earthworks, machinery and personnel be strictly controlled, and be restricted to the Bypass alignment footprint in the vicinity of all wetlands. There is to be no disturbance to the environment beyond the footprint, and no machinery or personnel are to be permitted beyond that area without the approval of the Project Manager (RTA);
- stringent application of erosion and sediment discharge control measures, to avoid sediment discharge into wetlands and wetland vegetation communities adjacent to the roadworks or downstream;
- implementation of a comprehensive weed removal, control and management program, to remove weeds from wetland areas adjacent to the roadworks, thus enhancing the habitat in these areas. Weed control programs are also required to avoid the introduction of new weeds or infestations in the vicinity;
- the removal of litter and rubbish from areas adjacent to the roadworks; and
- the implementation of a specific rehabilitation and replanting program to enhance the adjacent wetlands, and to ensure that wetlands do not become degraded or weed-infested in the long term.

These measures are to apply in particular to:

- SEPP 14 Wetland No 743, on the western shores of the Karuah River (Figure 1.4);
- the eastern shore of the Karuah River;
- Mosquito Creek; and
- Wallaroo Swamp, located to the west of the proposed Bypass alignment.

Detailed documentation of the measures to be applied at these locations will be included in the Construction Environment Management Plant (CEMP).

Karuah Nature Reserve

Appropriate environmental management and impact amelioration measures will be applied along the alignment through the Karuah NR. In this regard, stringent application of the erosion and sediment control measures, water quality and stormwater discharge measures, and minimisation of vegetation clearing protocols will apply, as will the implementation of long-term habitat enhancement and rehabilitation programs.

Particular measures to be applied through the Karuah NR involve:

- the collection of propagules of threatened, ROTAP and regionally significant plant species which are to be removed prior to any clearing operations, and their propagation for use in rehabilitation and replanting programs, in consultation with the NP&WS;

- a pre-clearing inspection of all vegetation in the vicinity, to avoid adverse impacts upon individuals of native, particularly threatened, fauna species (as documented below) and to identify and flag plant species of conservation significance;
- the implementation of stringent construction protocols, limiting the extent of clearing within the Reserve to the minimum possible. No movement of personnel or machinery beyond the Bypass footprint (*ie* beyond that area which is directly disturbed for the finished roadworks) will be permitted;
- the collection and destruction of all weed material (if any) from the roadworks area and the road corridor;
- the collection and shredding of cleared native plant material and its redistribution into the Reserve or other appropriate areas of native vegetation, in consultation with the NP&WS and/or NSW Forests; and
- the implementation of a dedicated rehabilitation and replanting program, utilising appropriate plant species (as recommended by the NP&WS).

Flora

As noted above, specific environment management measures are to be implemented with respect to native vegetation, including (in all locations) minimisation of vegetation removal within the design requirements and engineering constraints of the project. Specific measures to be applied along the proposed alignment with respect to those plants of conservation significance addressed in this SIS (where relevant) are:

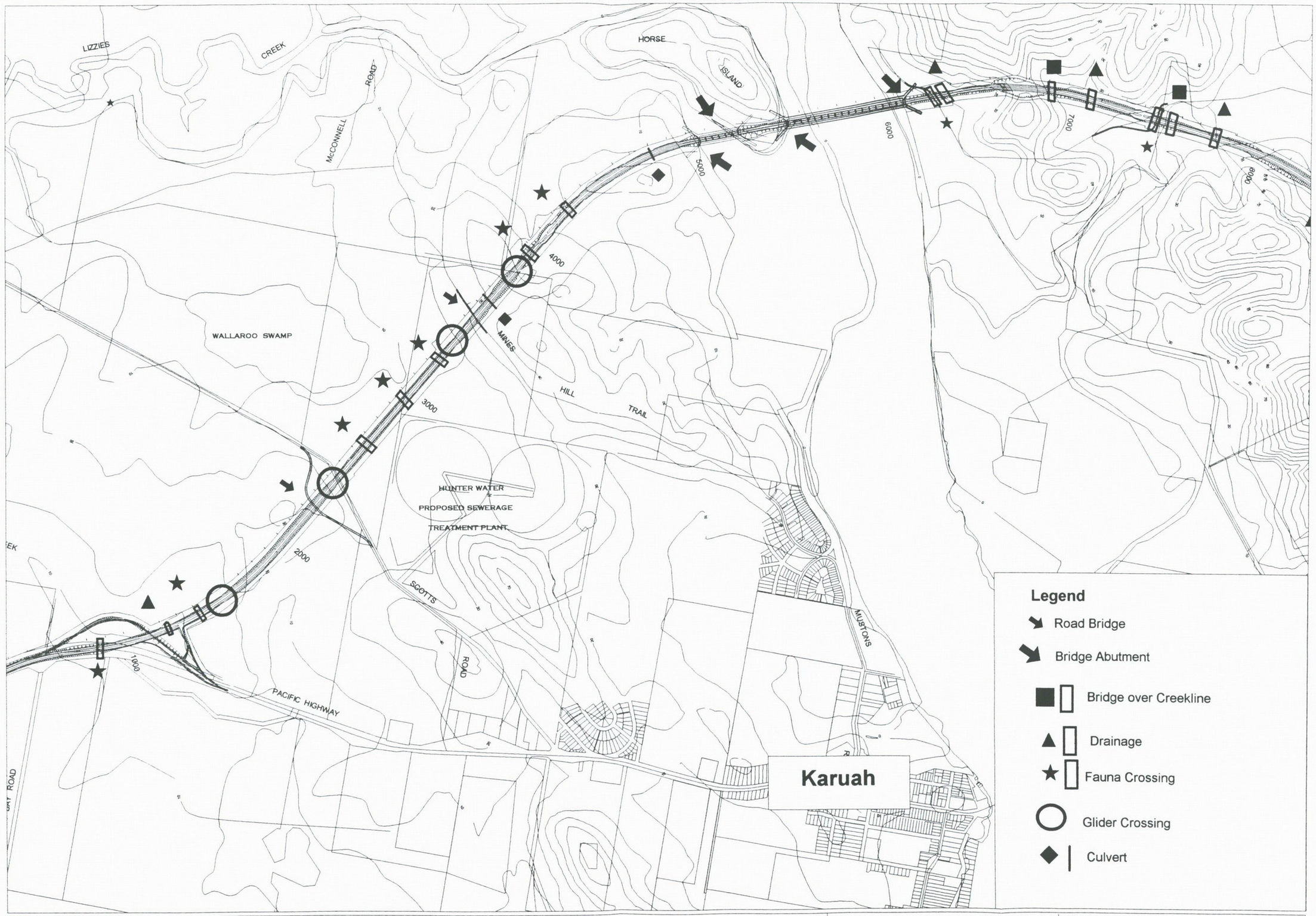
- a comprehensive and detailed inspection of areas which are to be cleared or disturbed for the roadworks, to identify and ultimately to collect or protect any threatened or significant plants present;
- the collection and subsequent relocation of individual plants of conservation significance where appropriate (depending on the individual species and as advised by the NP&WS) where it is not possible to avoid them in the clearing and construction phases of the project;
- the collection of seeds or plant material from plant species of conservation significance (where appropriate) which are to be affected, and their propagation for use in replanting and rehabilitation programs (along the alignment or in relevant reserves, as advised by the NP&WS);
- the implementation of specific maintenance measures for propagated seedlings of threatened plant species, as part of the rehabilitation and management program for the proposal;
- the protection and management of plant species of conservation significance which are to be retained in situ along the alignment during construction. Protective fencing, maintenance and monitoring, signage, and education of construction workers should be implemented during construction at appropriate locations and subsequently removed;
- the avoidance of individual plants wherever possible, by the use of appropriate structures and design to enable individual plants to be retained (*eg* by using a retaining wall rather than a fill embankment) if that approach enables the retention of individuals of significant plant species;

  the appropriate design of water quality ponds and stormwater discharge points along the roadway, to prevent plants of conservation significance being affected by alterations to drainage and water discharge;
- the treatment of water derived from the construction and operation of the road to avoid the discharge of contaminants or nutrients onto plant species of conservation significance or into their habitats; and
- contribution by the RTA to the establishment of areas of compensatory habitat as a means of offsetting environmental impacts imposed by the proposal (see below).

Fauna

Specific measures are proposed to address issues of relevance for native fauna, which will be detailed in the Construction EMP and Operational EMP for the project. In addition to the general measures proposed for the environmental management of the project, a number of specific measures and protocols are to be implemented, namely:

- pre-clearing surveys along the road reserve of native vegetation in accordance with relevant RTA guidelines, wherever required, to identify individual fauna species or populations which require collection and relocation;
- specific searches within the road reserve for fauna of particular concern immediately prior to clearing activities in accordance with relevant RTA guidelines, with particular attention paid to the Koala, Squirrel Glider and forest owls, including nests, large hollow-bearing trees and hollow-dwelling species. Measures to deal with fauna located prior to clearing will be included in the CEMP;
- the retention of habitat features and resources for native fauna (such as hollow-bearing trees, hollow logs *etc*) where possible, consistent with the proposed road design and construction activities;
- during completion of construction the provision of stags (derived from trees felled for the Bypass) or the retention of existing trees at appropriate locations within the median strip between the two carriageways (and protected by safety fencing) to enable gliding species (such as the Squirrel Glider) to traverse the widened roadway (Figure 12.1a, 12.1b; Table 12.1);
- re-use of elements of potential value for native fauna (such as hollow-bearing trees, hollow logs, rocks *etc*) in suitable areas in the landscaping (possibly including the Karuah NR, if deemed appropriate by the NP&WS); and
- the installation of fauna-proof fencing (particularly designed for terrestrial fauna and Koalas) to limit the opportunities for animals to gain access to the new road, and to direct animals to underpasses for safe crossing. Fauna-proof fencing should be installed at sites where fauna underpasses are located, and at other relevant locations (Figure 12.1a, 12.1b; Table 12.1), including:
    - the Karuah River;
    - Mosquito Creek and its tributary (east of the Karuah River);
    - the Karuah NR; and
    - through the forested lands between the Karuah River and the Pacific Highway west of Karuah;
- design of the bridge abutments at the Karuah River and Mosquito Creek crossings (retaining a section of the watercourse banks), and appropriate contouring, landscaping and rehabilitation of the banks, to provide fauna movement underpasses at these localities (Figure 12.1a, 12.1b). In both instances, the use of appropriate vegetation plantings, rocks and logs, and other features such as will be required to encourage native species to utilise the underpasses and to provide protection from feral predators;
- the detailed design of all fauna underpasses to include raised sections or varying floor heights so that fauna movements can continue during periods of moderate stream flow, as well as appropriate treatments (Koala escape poles, the use of rocks, logs and dirt in underpasses, the provision of appropriate vegetation plantings in landscaping to the entrances of underpasses, and special features for certain fauna species, if required) to facilitate and encourage animal use of the underpasses and provide shelter and protection from predation by feral predators; and
- maintenance by the construction contractor of communication links with local NP&WS officers, WIRES and/or other relevant local wildlife carer groups, to deal with individual animals during the construction phase of the project, if necessary.



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 12.1a Location of Mitigation Measures along the Proposed Karuah Bypass (Horse Island Route) of the Pacific Highway.

Version 1 20 September 1999

Figure 12.1a



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Figure 12.1b Location of Mitigation Measures along the eastern section of the Proposed Karuah Bypass (Horse Island Route) of the Pacific Highway.

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Figure 12.1b

Fauna Crossings of the Bypass

Specific measures to facilitate fauna crossings of the new road are to be implemented at a number of locations along the Karuah Bypass (Figure 12.1a, 12.1b; Table 12.1). These measures target species which are terrestrial, as well as the Squirrel Glider, for whom the Bypass will be likely to constitute a significant barrier to movements through the landscape.

Engineering requirements for the Karuah Bypass and topographic features of the landscape constrain the locations at which fauna crossing features can be installed, both for engineering and for financial reasons. The topography along the alignment, for example, provides few opportunities for the installation of fauna overpasses, and constrains the locations for underpasses to portions of the alignment which are on fill. Similarly, the size of fauna underpasses is in part determined by the depth of fill, and there are significant constraints placed on changes in the height of the road surface with respect to engineering and safety concerns, and financial issues.

Elements of the Karuah Bypass alignment design which have been incorporated or modified to facilitate fauna crossings on the Highway include:

- increasing the size of drainage culverts, or using larger box culverts, at drainage sites to provide appropriately-sized underpasses for native fauna;
- the inclusion of box culverts at a number of locations (Table 12.1) specifically for fauna crossing purposes, where drainage culverts are not required;
- the design of bridge abutments to retain areas of creek bank or River shoreline, to promote fauna movements;
- modifications to engineering and construction activities at several locations to ensure the retention of large trees adjacent to the two sides of the road, as well as in the median strip, to provide a crossing point for Squirrel Gliders and other gliding mammals; and
- landscaping and the provision of specific features to facilitate fauna access and protection (including 'escape poles' for Koalas, vegetation planting and the provision of rocks and logs for cover).

Specific features are of relevance for different "*affected species*" (if present) along the Karuah Bypass alignment:

large culverts and dedicated fauna underpasses	Tiger Quoll, Long-nosed Potoroo, Brush-tailed Phascogale, Koala, Green-thighed Frog;
bridge abutment design and landscaping	Tiger Quoll, Long-nosed Potoroo, Brush-tailed Phascogale, Koala, Green-thighed Frog, Squirrel Glider;
dedicated Glider crossings	Squirrel Glider.

These features are also regarded as providing safe crossing sites for a range of other native terrestrial species which occur along the alignment, including amphibians and reptiles, small and medium terrestrial mammals (native rodents, dasyurids and the Echidna), and in some instances macropods.

The potential to provide a 'fauna overpass' in the saddle on the eastern side of the Karuah River was considered in some detail, and preliminary designs were developed for a constructed overpass, to be covered with soil and vegetated. However, the topographic features at this location provided serious constraints to the size of overpass which could be constructed, resulting in a structure only 15m wide across the Karuah Bypass, linking the ridge to the north and south of the road.

Because of the small size of the structure and the consequent constraints on soil depth and on the size of trees which could be permitted on it (for safety reasons), and following consultation with the NP&WS, the overpass was deleted from the road design. In addition to

being severely restricted in size because of topographic relief at this locality, the vegetation on either side of the Bypass is not regarded as particularly significant in conservation terms. Furthermore, there are features for Koalas and other native wildlife to pass beneath the Bypass at Mosquito Creek and its tributary, nearby. As a consequence, the proposed overpass was deemed to be of little value for wildlife passage.

Table 12.1 Mitigation measures for fauna crossings to be implemented along the proposed upgrade of the Pacific Highway at Karuah, Horse Island Route.

Chainage	Purpose	Features	Comments
869	Drainage	Existing drainage culvert across Pacific Highway; 2 x (3000w x 1500h)	Likely to be used only by amphibians, reptiles and possibly small mammals. Larger terrestrial fauna can attempt to cross the existing Highway at grade.
877	Fauna crossing	Dedicated fauna underpass; 3000w x 3000h	Sufficient in size for all native terrestrial fauna.
1134	Bridge over Bypass		Not relevant for fauna crossings.
1230	Drainage	Drainage culvert; 2 x (2400w x 600h)	Can be used by reptiles, amphibians and small mammals. Leads into small island of land surrounded by roads (not particularly suitable location for wildlife).
1400	Fauna crossing	Small fauna culvert 3000w x 1800h	Suitable for small to medium terrestrial mammals, reptiles and amphibians. Not likely to be utilised by large kangaroos or wallabies.
1500 - 1580	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in median strip.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
2238	Bridge over Bypass for Scotts Road		Low traffic volumes on Scotts Road will enable to road to be used by wildlife, to some extent at least. Of potential relevance for macropods, echidnas, other medium to large terrestrial mammals, larger reptiles.
2370 - 2430	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in median strip.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
2645	Fauna crossing and Drainage	Combined drainage culvert and fauna underpass; 3000w x 2400h	Over-sized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for most terrestrial fauna, including smaller macropods, Koalas, small to medium terrestrial mammals, reptiles and amphibians.
2901	Fauna crossing and Drainage	Combined drainage culvert and fauna underpass; 3000w x 1200h	Over-sized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for Koalas, small to medium terrestrial mammals, reptiles and amphibians.
3244	Fauna Crossing	Small fauna culvert 3000w x 1800h	Suitable for small to medium terrestrial mammals, reptiles and amphibians. Not likely to be utilised by large kangaroos or wallabies.
3340 - 3400	Glider Crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in median strip.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
3530	Bridge over Bypass for Mines Hill Trail	Standard two-lane traffic bridge.	Low traffic volumes on Mines Hill Trail will enable to road to be used by wildlife, to some extent at least. Of potential relevance for macropods, echidnas, other medium to large terrestrial mammals, larger reptiles.

Table 12.1 cont Mitigation measures for fauna crossings to be implemented along the proposed upgrade of the Pacific Highway at Karuah, Horse Island Route.

Chainage	Purpose	Features	Comments
3647	Drainage	Drainage culvert; 600mm diameter	Can be used by reptiles, amphibians and possibly small mammals.
3850 - 3890	Glider crossing	Retention of large trees adjacent to and retention of trees or placement of 'glider poles' and young trees in median strip.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
3907	Fauna crossing	Fauna underpass; 3000w x 3000h	Of potential value for most terrestrial fauna, including macropods, Koalas, small to medium terrestrial mammals, reptiles and amphibians.
3945	Drainage	Drainage culvert 900mm diameter	Over-sized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Can be used by reptiles, amphibians and possibly small mammals.
4268	Fauna Crossing and Drainage	Combined drainage culvert and fauna underpass; 3000w x 1500h	Suitable for small to medium terrestrial mammals, reptiles and amphibians. Not likely to be utilised by large kangaroos or wallabies.
4799	Drainage	Drainage culvert; 600mm diameter	Can be used by reptiles, amphibians and possibly small mammals.
5067	West abutment of Horse Island wetlands bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 12.1m Setback - 14m	Bridge abutment is located 10 - 15m back from the edge of the wetlands, providing a strip of land for use by fauna. This area can be landscaped and rehabilitated if necessary using native vegetation to provide secure and safe fauna crossings at the edge of the wetlands. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
5267	East abutment of Horse Island wetlands bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 12.5m Setback - 26m	Bridge abutment is located 10 - 15m back from the edge of the wetlands, providing a strip of land for use by fauna. This area can be landscaped and rehabilitated if necessary using native vegetation to provide secure and safe fauna crossings at the edge of the wetlands. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
5530	West abutment of Karuah River bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 8.6m Setback - 20m	Bridge abutment is located 10 - 15m back from the edge of the wetlands, providing a strip of land for use by fauna. This area can be landscaped and rehabilitated if necessary using native vegetation to provide secure and safe fauna crossings at the edge of the wetlands. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
6142	East abutment of Karuah River bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 13.9m Setback - approx. 20m	Bridge abutments are to be constructed so as to retain a strip of bank, which will need rehabilitation. These areas are to be landscaped and rehabilitated with native vegetation to provide secure and safe fauna crossings along the banks. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
6295	Underpass for local access	Low traffic volumes on the local access underpass will enable its use by fauna, on occasions.	Most likely to used by Koalas (if present), kangaroos and wallabies, Echidnas, goannas and other large terrestrial fauna which utilise open landscapes.
6345	Drainage	Drainage culvert; 1050mm diameter	Can be used by reptiles, amphibians and possibly small mammals.

Table 12.1 cont Mitigation measures for fauna crossings to be implemented along the proposed upgrade of the Pacific Highway at Karuah, Horse Island Route.

Chainage	Purpose	Features	Comments
6911	Bridge over Mosquito Creek Tributory	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 3 - 4m Span - 15m	Bridge abutments are to be constructed so as to retain a strip of bank, which will need rehabilitation. These areas are to be landscaped and rehabilitated with native vegetation to provide secure and safe fauna crossings along the banks. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
7088	Drainage and fauna crossing	Drainage culvert; 1200w x 1200h	Likely to be used only by amphibians, reptiles and possibly small mammals. Larger terrestrial fauna can cross the existing Highway at grade.
7476	Underpass for local access	Low traffic volumes on the local access underpass will enable their use by fauna, on occasions.	Most likely to used by Koalas, kangaroos and wallabies, Echidnas, goannas and other large terrestrial fauna which utilise open landscapes.
7545	Bridge over Mosquito Creek	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, groundcover vegetation *etc*) Clearance - 4 - 5.2m Span - 20m	Bridge abutments are to be constructed so as to retain a strip of bank, which will need rehabilitation. These areas are to be landscaped and rehabilitated with native vegetation to provide secure and safe fauna crossings along the banks. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
7807	Drainage culvert	Drainage; 1050mm diameter	Can be used by reptiles, amphibians and possibly small mammals.
8446	Drainage and fauna crossing	Drainage culvert; 3000w x 600h	Likely to be used only by amphibians, reptiles and possibly small mammals.
8710	Drainage and fauna crossing	Drainage culvert; 900w x 900h	Likely to be used only by amphibians, reptiles and possibly small mammals.
9651	Bridge over Branch Lane	Span of approximately 25m	Potential for use by larger native fauna during the evenings or other periods of low traffic flow.
10129	Fauna crossing and drainage	Combined drainage culvert and fauna underpass; 3000w x 1800h	Over-sized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for most terrestrial fauna, including macropods, koalas, small to medium terrestrial mammals, reptiles and amphibians.
10440	Drainage and fauna crossing	Existing drainage culvert across Pacific Highway; 3600w x 900h	Likely to be used only by amphibians, reptiles and possibly small mammals.

12.2.4 Compensatory Habitat

The RTA has, in previous upgrade projects along the Pacific Highway and elsewhere in NSW, demonstrated a commitment to impact mitigation associated with roadworks by the provision of 'compensatory habitat', amongst a range of other impact amelioration measures. Further, the RTA has developed a *Draft Compensatory Habitat Policy and Guidelines* (1998) intended to focus and direct the consideration of compensatory habitat as an integral element of the environmental management and impact amelioration program.

The *Draft Compensatory Habitat Policy and Guidelines* indicate that "*the planning and construction of roads should, in order of consideration, endeavour to:*

1. *avoid impacts on habitat, through the planning process;*
2. *minimise impacts on habitat, through the planning process; and*
3. *mitigate impacts on habitat, through the use of a range of amelioration measures*".

The cascading sequence of environmental management considerations outlined in the policy and in the guidelines has been applied in the case of the Karuah Bypass, as documented above, by:

- he avoidance of impacts on native biota and their habitats, wherever possible, along the Karuah Bypass by locating the Bypass in areas of existing cleared agricultural land or otherwise disturbed forest and woodland vegetation, and by avoiding significant habitat features (such as Wallaroo Swamp). Whilst some impacts on native biota are inevitable (given the forested nature of the landscape through which much of the Bypass is located), the imposition of adverse impacts upon the natural environment has been avoided, wherever possible, within the constraints of the Bypass location (Chapter 12.1.1);
- the minimisation of impacts on native biota and their habitats along the alignment, by the implementation of '*best practice*' erosion and contaminant controls, minimal clearing of native vegetation at all locations, and the re-use of vegetation and resources removed from the alignment (Chapters 12.1.2, 12.1.3); and
- the application of an array of impact mitigation measures, including habitat rehabilitation, landscaping and revegetation, and specific fauna crossing measures (Chapters 12.1.2, 12.1.3).

With respect to the mitigation of impacts which will unavoidably be imposed upon the natural environment and on native biota, the RTA's *Draft Policy and Guidelines* identify a number of measures which can be "*employed to mitigate impacts on habitat*". With respect to the Karuah Bypass of the Pacific Highway, impact mitigation measures that have been incorporated into the project include:

- "*reducing construction zones*" — the minimisation of vegetation clearing at all locations, and the sitting of activities on already disturbed land, wherever possible (Chapter 12.1.2);
- fauna "*underpasses*" — as discussed in Chapter 12.1.3; Figure 12.1a, 12.1b;
- fauna "*overpasses*" — which have been considered for the Karuah Bypass but rejected as unlikely to be effective in terms of conservation goals (Chapter 12.1.3);
- "*exclusion fencing*" — as documented in Chapter 12.1.3; Figure 12.1a, 12.1b;
- "*landscaping and revegetation*" — to be conducted along the alignment, following the completion of roadworks (Chapters 12.1.2, 12.1.3);
- "*site rehabilitation*" — to be implemented along the full length of the alignment (Chapters 12.1.2, 12.1.3);
- "*compensatory habitat*" — as discussed below;
- "*traffic control*" — of limited value along the Karuah Bypass alignment because of the nature of the road, but measures will include advisory signs regarding injured wildlife;
- "*driver education and awareness*" — involving signage, particularly at interchanges.

The RTA's *Draft Policy and Guidelines* define "*compensatory habitat*" as "*an area or areas of land containing one or more key habitats which are required and/or committed by the RTA for the purposes of nature conservation, to make up for the loss of one or more key habitat(s)*". In addition, the RTA *Policy and Guidelines* define "*key habitat*" as "*the natural environment inhabited by native flora and/or fauna species, populations or ecological communities which are deemed to be of significance*". Given the extent of vegetation communities and habitats identical to those to be affected by the project, and the difficulties in identifying habitat or resources "*deemed to be of significance*" for individual

species, the approach adopted in this assessment is to regard all habitat to be removed as "*key habitat*" for one or more species.

The Karuah Bypass will involve the removal or loss of approximately 32ha of native vegetation, excluding mangroves and salt marsh communities[11], and 'edge effects' over an additional approximately 20ha (Chapter 10). The areas of forest and woodland vegetation, and riparian habitat, which are to be removed do not all constitute "*key habitat*", given the levels of disturbance and previous habitat modification which has occurred as a result of agricultural and forestry activities, and fire frequency. Nevertheless, the area to be affected by the proposed Bypass is utilised by threatened fauna species (such as the Squirrel Glider, Koala, Microchiropteran bats and Powerful Owl) and portions of the Bypass alignment are habitat for the threatened plant *Tetratheca juncea.*

As noted above, and as detailed in Chapter 12.1 of this SIS, "*a range of amelioration measures*" is incorporated into the Karuah Bypass project. For most species, the project will not involve the loss of or disturbance to significant areas of "*key habitat*", given the extent of native vegetation in the locality, and the recent considerable expansion of the conservation reserve network. For some species, however, the Karuah Bypass will involve either the loss of habitats and resources, or will impose additional restrictions on the movement of individuals through the landscape. Threatened or "*subject species*" of relevance in this regard (Chapter 10) include:

- *Tetratheca juncea* — loss of individuals from one population on Horse Island (approximately thirty individuals, or half the population, are located in the footprint); the loss of potential or previously occupied habitat between Horse Island and the western end of the alignment (although plants have not been recorded subsequently to the fire and previously were only sparsely distributed).
- Squirrel Glider — loss of some hollow-bearing trees (potential nesting habitat), although this resource is well distributed through the extensive forests in the locality; the loss of forest and woodland vegetation (a foraging resource); constraints to movement between lands to the south-east and northwest of the alignment (notwithstanding the provision of dedicated crossing points for gliders across the road).
- Koala — loss of forest and woodland, particularly trees preferred as a foraging resource(Tallow-wood, Grey Gum, Swamp Mahogany); restrictions on potential movements through the area.
- microchiropteran bats — loss of forest and woodland (as foraging habitat); loss of hollow-bearing trees (a roosting resource for some species).
- Masked Owl — loss of forest and woodland vegetation (supporting prey species); loss of large hollow-bearing trees (including one known nest tree located along the alignment).
- Glossy Black Cockatoo — loss of forest and woodland with she-oaks (foraging resource); loss of large hollow-bearing trees (potential nesting resource).

The species (above) considered as of particular relevance with respect to the provision of "*compensatory habitat*" are those which have been recorded along the alignment or are regarded as likely to be significantly affected, at least by impacts on individuals of the species. For these species, elements of vegetation or habitats along the alignment are regarded as "key habitat".

A number of other "*subject species*" or threatened flora or fauna species are also known to occur in the area, and individuals of these species could also be disadvantaged by the loss of habitat or resources, or by restrictions on movements, notwithstanding the provision of features intended to permit fauna movements across the road (Chapter 10). For these

[11] Issues relating to compensatory habitat within the SEPP 14 wetland, including saltmarsh and mangrove communities, are being addressed pursuant to SEPP 14 in consultation with DUAP.

species, however, the impacts are regarded as likely to be only minor or not significant (Appendix F), and the alignment is not regarded as "key habitat".

To compensate for the loss of habitat and resources which will inevitably arise as a result of the Karuah Bypass, the RTA proposes to provide "*compensatory habitat*", following negotiations with the NP&WS. The provision of "*compensatory habitat*" will have regard to:

- the provision of habitat similar to that which is to be removed as a result of the roadworks (*ie* predominantly forest and woodland vegetation);
- the provision of vegetation in good condition, with the implementation of a habitat rehabilitation program if necessary;
- the provision of resources and habitat features characteristic of the areas which are affected by the proposed Bypass (particularly large hollow-bearing trees, stands of she-oak and relevant Koala food trees); and
- the array of recently gazetted conservation reserves and any proposed additions, as determined by the Comprehensive Regional Assessment and Regional Forest Agreement processes in NSW. In this regard, areas of "*compensatory habitat*" will preferably be targeted to supplement the newly created reserve system, and, if possible, link areas of conservation reserves that are currently separated, subject to consultation with the NP&WS.

With respect to the relevant habitat features and resources (particularly hollow-bearing trees and the presence of relevant foraging resources), it should be noted that much of the forest and woodland vegetation in the locality is of a similar nature and condition as that present in the areas which are to be affected by the roadworks. Consequently, there do not appear to be any specific sites where "*compensatory habitat*" should necessarily be targeted, at least with respect to habitat features and resources.

The area of "*compensatory habitat*" which is appropriate with respect to the Karuah Bypass should be no less than 52ha (excluding mangrove and SEPP 14 wetland areas), replacing the equivalent area of vegetation which is to be removed or affected by edge effects (see above). As noted above, the location of "*compensatory habitat*" should be with respect to the availability of land for purchase and protection, and with regard to long-term management requirements, and issues relating to reducing habitat fragmentation and improving connectivity between existing conservation reserves, if possible.

12.3 Long-Term Management

The Director-General of the NP&WS requires that the Karuah Bypass SIS addresses "*long term management strategies*" for the study area.

> "*3.4 Consideration must be given to developing long term management strategies to protect areas within the study area which are of particular importance for the affected species. These must include proposals to restore or improve habitat, and/or to provide compensatory habitat. The strategies should identify the long term objectives for the subject site*".

In broad terms, the Karuah Bypass proposal has incorporated a range of design features and impact amelioration measures intended to minimise or reduce potential adverse impacts being imposed upon native biota, including threatened species and their habitats (Chapters 10 & 12.1). The Operational Environmental Management Plan (OEMP) for the proposal will provide details of particular measures to provide long-term protection for the natural environment, including water quality control, site rehabilitation and the provision of habitats and resources for threatened species.

The construction and operational EMPs for the proposal (to be developed following approval of the activity) will provide details of the long-term and short-term management protocols and measures, as well as details of measures to minimise fauna road mortalities and consideration of compensatory habitats. The EMPs will facilitate implementation of the environmental management and impact amelioration measures contained in the SIS,

EIS and other relevant documents (*eg* the recommendations of the water quality and soil/sediment reports).

12.3.1 Long-term Management Strategies

With respect to "*long term management strategies to protect areas within the study area which are of particular importance for the affected species*" in the study area, considerations include:

- recognition that the NP&WS is the primary conservation agency, with responsibility for management of the Karuah NR and of threatened species in the locality, and recognition that the RTA is neither a land management authority nor a conservation organisation. The RTA has responsibilities with respect to the provision and maintenance of the main road infrastructure of NSW for the benefit of the state and its people (pursuant to the Roads Act), and has a commitment to fulfilling its charter in an environmentally responsible manner, employing 'best practice' measures;
- design of the proposal and of stormwater treatment ponds to mitigate adverse impacts upon threatened species and their habitats in both the short-term and long-term, and to contribute (where possible) to their conservation in the general locality;
- the implementation of measures to propagate threatened and significant plant species which will be affected by the proposal, including the use of cuttings, seed and other propagules, and the use of propagated plants in rehabilitation and landscaping (where appropriate), or in replanting programs in the Karuah NR and/or compensatory habitat, in consultation with the NP&WS; and
- the implementation of appropriate landscaping and rehabilitation programs, in consultation with the NP&WS, to improve the condition of habitats in the vicinity and to contribute to the quality and value of the Karuah NR.

As indicated above, the RTA is not a land management authority, and is consequently not in a position to implement "*long term management strategies*" except with regard to the operation of the Karuah Bypass. Consequently, the "*long term management strategies*" associated with the Karuah Bypass involve:

- mitigating impacts on the natural environment by careful location of the Bypass (where possible) and by the implementation of measures to minimise clearing and indirect impacts on the natural environment;
- the implementation of rehabilitation and landscaping programs, both associated with habitat restoration following disturbance for the Bypass and as compensation for habitat loss;
- the provision of compensatory habitat, to complement the Karuah NR and other conservation strategies in the vicinity; and
- the incorporation into the design of measures to mitigate the ongoing effects of the road on flora and fauna, particularly by controls on water quality and by facilitating fauna movements across the Highway.

Several "*proposals to restore or improve habitat, and/or to provide compensatory habitat*" are detailed in Chapter 12.1 of this SIS.

12.3.2 Long-term Objectives

The "*long term objectives for the subject site*" (*ie* the Karuah Bypass of the Pacific Highway) are:

- to provide a safe and effective element of the Pacific Highway, which contributes to the economic and social welfare of the NSW and concurrently limits and mitigates impacts on the natural environment within the constraints of road design requirements;

- to limit or mitigate adverse impacts on the natural environment as a result of the road construction and operation, by the implementation of appropriate environmental management and impact amelioration measures;
- to undertake the road's construction and to manage its long-term operations in a manner which protects the natural environment by the incorporation of 'best practise' measures;
- to contribute, where possible, to the conservation of natural habitats and of native (particularly threatened) biota; and
- to limit and mitigate long-term and ongoing impacts on threatened biota and their habitats.

12.4 Monitoring

The Director-General of the NP&WS requires (pursuant to Item 3 of Appendix A):

> "*3.5 Proposals for the monitoring of the effectiveness of the proposed mitigation measures and the impact of the proposal on affected species must be provided and discussed. Details of such monitoring must be provided including the site location, frequency of monitoring and duration of program. A discussion of possible options for changes to mitigation measures in the light of monitoring results must be included*".

A program of "*monitoring of the effectiveness of the proposed mitigation measures*" will be implemented in both the construction and operational phases of the Karuah Bypass, in conformance with the detailed monitoring program to be incorporated into the Construction Environmental Management Plan (CEMP) and the Operational Environmental Management Plan (OEMP). Monitoring of the mitigation measures during the construction phase will be the responsibility of an environmental manager appointed by the RTA for the project (as is the case with other Pacific Highway projects). Long-term monitoring of mitigation measures (such as water quality control ponds, habitat restoration and landscaping) will be conducted pursuant to the OEMP, as part of the ongoing management and monitoring of the Pacific Highway.

Construction phase monitoring of "*the effectiveness of the proposed mitigation measures*" will be conducted by the project environmental manager, particularly in relation to:

- clearing activities along the alignment, to ensure that vegetation which is to be retained is not adversely affected and that clearing activities are restricted to the alignment footprint, wherever required;
- ensuring the protection of threatened or significant plant species and individuals adjacent to the roadworks, as required as part of the CEMP;
- ensuring that all environmental management and impact amelioration measures (such as soil and erosion control measures, and water quality control ponds) are properly installed and maintained; and
- implementing measures in the CEMP for the protection of individuals of native fauna species before and during the construction process.

The monitoring measures are also intended to assess "*the effectiveness of the proposed mitigation measures .. on affected species*", during the construction period. Monitoring activities during construction will be conducted along the full length of the Karuah Bypass, on an ongoing basis through the construction period.

Monitoring of "*the impact of the proposal on affected species*", including the efficacy of fauna underpasses, the use of retained or planted trees within the median strip (particularly for the Squirrel Glider), and the effectiveness of structures to prevent animal access to the road (fauna-proof fencing, F type traffic barriers *etc*) will also be conducted as part of the OEMP for the Karuah Bypass project. However, the implementation of an individual monitoring program for these features on a 'project by project' basis is not regarded as a reasonable approach, given the number of upgrade projects currently being proposed or

conducted along the Pacific Highway. Rather, an integrated approach which monitors the effectiveness of mitigation measures for wildlife along road projects is recommended as the most appropriate approach.

Given the size and nature of the Karuah Bypass project, there are only limited "*options for changes to mitigation measures in the light of monitoring results*". Some "*changes to mitigation measures*" can readily be implemented, if necessary, including changes to the landscaping and vegetative cover in approaches to underpasses, supplementation of glider trees or poles, and modifications to rehabilitation projects, the treatment of wetlands and the use of tree-hollows. However, options for "*changes to mitigation measures*" which require significant engineering would be more constrained, or in some instances not possible without significant financial cost and the potential for imposing other adverse environmental effects.

12.5 Habitat Restoration and Rehabilitation

The Director-General of the NP&WS requires (pursuant to Item 3 of Appendix A):

> "*3.6 Details of any habitat restoration or improvement programmes proposed for the study area must be provided, including the proposed timeframe for habitat restoration/improvement, and the likely impact on flora and fauna, particularly during the time between the impact on the habitat and any habitat restoration/improvement. Where possible, habitat restoration and rehabilitation works should commence before the project completion*".

A number of "*habitat restoration*" and rehabilitation measures are proposed for the Karuah Bypass, as detailed in Chapter 12.1. The "*habitat restoration/improvement*" program will predominantly occur following the completion of construction activities, although possible incorporation of habitat restoration or rehabilitation as part of the compensatory habitat package for the project could commence earlier, depending on consultation with the NP&WS with respect to the location and nature of habitat rehabilitation programs.

With respect to "*the likely impact on flora and fauna, particularly during the time between the impact on the habitat and any habitat restoration/improvement*", impacts which will or may arise as a result of the Karuah Bypass have been discussed in detail in Chapter 10 of this SIS. The impacts of vegetation clearing and disturbance as a result of the roadwork will prevent most individuals of most fauna species utilising the disturbance area during construction activities, and will involve removal of most plants from the construction zone. Habitat rehabilitation and restoration adjacent to the new road will involve redressing any damage to nearby native vegetation, and the landscaping and planting of batters and other created structures. Only the most disturbance-tolerant native species will utilise habitats and vegetation immediately adjacent to the road alignment.

The program of "*habitat restoration/improvement*" and the "*habitat restoration and rehabilitation works*" to be implemented along the Karuah Bypass project involves two essentially separate elements:

- the "*rehabilitation*" of areas which had been disturbed during the construction process for the Karuah Bypass, essentially all of which are immediately adjacent to the road (including newly created batters and areas cleared for access and for stormwater management ponds); and
- the implementation of a "*habitat restoration/improvement*" program as part of the compensatory habitat package.

The program of rehabilitating areas disturbed during the construction activity, whilst intending to regenerate native vegetation and habitats, is not intended to provide 'key' or 'core' habitat for native fauna or flora. Whilst some elements of that rehabilitation program will contribute to native, including threatened, fauna species (by the provision of cover to underpasses and crossing points for Squirrel Gliders), the proximity of the road is likely to deter many species from utilising this rehabilitated vegetation.

The provision of "*habitat restoration and rehabilitation*" away from the alignment, particularly as part of the compensatory habitat package, is intended to provide additional and supplementary habitat and resources for native fauna and to enhance habitat for

native flora species. These measures, as noted above, will be dependent on consultation and agreement with the NP&WS, but it is considered that no adverse impact is likely to imposed upon native flora and fauna "*during the time between the impact on the habitat and any habitat restoration/improvement*".

13 ADDITIONAL INFORMATION

The TSC Act requires, under Section 110(2)(j), that a SIS include;

> *"a list of any approvals that must be obtained under any other Act or Law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or populations".*

Other "*approvals that must be obtained under any other Act or Law before the action may be lawfully carried out*" are detailed in Table 13.1.

The NP&WS Director-General also requires (Item 4.1 of Appendix A) information regarding:

- *"any consents required under Part IV of the Environmental Planning and Assessment Act 1979 including the name of the consent authority and when it is proposed to make the development application; or*
- *any approvals required under Part V of the Environmental Planning and Assessment Act 1979 including the name of the determining authority(ies), the basis for the approval and when these approvals are proposed to be obtained".*

13.1 Part 4 of the EP&A Act

The proposal constitutes an activity, which is permitted without development consent under *State Environment Planning Policy No 4 - Development without Consent* (SEPP 4). Consequently, the proposed Karuah Bypass is generally subject to the provisions of Part 5 of the EP&A Act, rather than Part 4.

However, the proposal does involve disturbance to one SEPP 14 Wetland (No 743) on the western side of the Karuah River. In accordance with the provisions of SEPP 14, the portion of the proposal which will affect the SEPP 14 Wetland is 'designated development', and requires consent from Port Stephens Shire Council. In providing development consent to the disturbance of SEPP 14 Wetlands, Council requires the concurrence of the Director-General of DUAP. Development consent by Council is determined under Part 4 of the EP&A Act.

The Development Application for disturbance to SEPP 14 Wetlands will be prepared in accordance with Part 4 of the EP&A Act and lodged with Port Stephens Shire Council as the consent authority at the time of display of the EIS for the proposed Karuah Bypass. The decision of Council with respect to development consent for the SEPP 14 Wetland will be included in the representations report of the RTA (under Part 5 of the EP&A Act), which is to be forwarded to the Minister for Urban Affairs & Planning for approval.

13.2 Part 5 of the EP&A Act

As noted above, the proposal is generally subject to the provisions of SEPP 4, and development consent from Council is not required (with the exception of the SEPP 14 Wetlands matter discussed above). The proposal is subject to the provisions of Part 5 of the EP&A Act, which requires approval from the Minister for Urban Affairs & Planning and subsequent determination of the proposal by the Chief Executive of the RTA.

As indicated in Sections 111 and 112 of the EP&A Act, the determining authority (*ie* the RTA) is obliged to "*examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity*", and to consider whether the proposal "*is likely to significantly affect the environment*".

The RTA as determining authority has concluded that the proposal may have an effect on the environment, and has consequently prepared an EIS (Ove Arup 1999). This SIS has also been prepared to satisfy the requirements of the EP&A Act with respect to the proposal, pursuant to s.5A of the Act. Approval by the Minister for Urban Affairs and Planning will be based on the EIS and SIS, consideration of submissions to the EIS and SIS, and a representations report prepared by the RTA, in accordance with Section 115A of the EP&A Act.

Table 13.1 Approvals and legislative requirements necessary under State legislation for construction of the Pacific Highway Upgrade at Karuah (the Horse Island Option) "*before the action may be lawfully carried out*", and relevant authorities,

Approval or Licence	Legislation	Authority
Construction of road across Crown land and the Karuah River.	*Crown Lands Act 1989*	Department of Land & Water Conservation
Keeping certain chemicals.	*Environmentally Hazardous Chemicals Act 1985*	Environment Protection Authority
Development Approval.	*Environmental Planning & Assessment Act 1979*	Approval of the Minister for Urban Affairs & Planning; Determination by the Chief Executive of RTA
Amendments of zoning of road reserves, Wallaroo SF & Karuah NR.	*Environmental Planning & Assessment Act 1979*	Port Stephens and Great Lakes Councils
SEPP 14 - Coastal Wetlands.	*Environmental Planning & Assessment Act 1979*	Port Stephens and Great Lakes Councils; concurrence of the Director-General of DUAP.
SEPP 4 -Koala Habitat Protection.	*Environmental Planning & Assessment Act 1979*	Port Stephens Council
Fish Passage and Removal of Mangroves.	*Fisheries Management Act 1994*	NSW Fisheries
Management of timber production on areas of Crown Land.	*Forestry Act 1919*	NSW Forests
Amendment to the boundaries of Wallaroo SF.	*Forestry Act 1919*	NSW Forests
Approval to expose or move a relic.	*Heritage Act 1977*	Heritage Council of NSW
Site buildings & effluent disposal.	*Local Government Act 1993*	Port Stephens and Great Lakes Councils
Archaeological Sites and Relics.	*National Parks & Wildlife Act 1974*	NP&WS
License to harm protected fauna or to pick native plants.	*National Parks & Wildlife Act 1974*	NP&WS
Vegetation loss & amendment of boundaries in Karuah NR, land transfer to RTA.	*National Parks & Wildlife Act 1974*	NP&WS
State protected land & native vegetation identified by the Minister for Land & Water Conservation.	*Native Vegetation Conservation Act 1997*	Department of Land & Water Conservation
Navigable waters of the proposed bridge over the Karuah River.	*Navigation Act 1901*	Department of Land & Water Conservation; Minister for Ports
Control noxious weeds on the construction site and road reserve.	*Noxious Weeds Act 1993*	Department of Land & Water Conservation
Development of navigable waters of the proposed bridge over the Karuah River.	*Ports Corporatisation and Waterways Act 1995*	Ports & Marine Office
Discharge of Pollutants and Contaminants.	*Protection of the Environment (Operations) Act 1998*	Environment Protection Authority
Noise	*Protection of the Environment (Operations) Act 1998*	Environment Protection Authority

Table 13.1 Approvals and legislative requirements necessary under State legislation for construction of the Pacific Highway Upgrade at Karuah (the Horse Island Option) *"before the action may be lawfully carried out"*, and relevant authorities,

Approval or Licence	Legislation	Authority
Air Pollution	*Protection of the Environment (Operations) Act 1998*	Environment Protection Authority
Excavation within 40m of the bed or banks of a river or lake under Part 3A	*Rivers & Foreshores Improvement Act 1948*	Department of Land & Water Conservation
Bush fire risk management plan; measures to be implemented to ensure road verges are maintained to prevent fire spread from road corridor	*Rural Fires Act 1997*	NSW Fire Service
Threatened Species	*Threatened Species Conservation Act 1995; Environmental Planning & Assessment Act 1979*	Minister for the Environment (consultation by Minister for Urban Affairs & Planning)
Compliance with conditions included in SIS	*Threatened Species Conservation Act 1995*	National Parks & Wildlife Service (NP&WS)
Disposal and Transport of Waste Materials	*Waste Minimisation & Management Act 1995*	Environment Protection Authority
Extraction of Water and Stream re-alignment	*Water Act 1912*	Department of Land & Water Conservation
Permit for temporary earthworks or structure across a floodplain (SEPP 14)	*Water Act 1912*	Water Corporation

13.3 Fauna & Flora Locality Data

The NP&WS Director-General requires (Appendix A) that:

> *"4.2 Flora and fauna locality data recorded during surveys must be provided. This information is to be provided on NPWS data recording cards to NPWS GIS Division for entry on the NSW Wildlife Atlas, and include information for all fields listed on these cards. In addition, the information listed in Appendix 3 Section 3 of this document is to be recorded and provided to the NPWS".*

Detailed fauna and flora records have been provided to the NP&WS, as requested, as a separate bound volume of information.

14 QUALIFICATIONS and EXPERIENCE

Section 110(4) of the TSC Act requires that:

> *"a Species Impact Statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement".*

The qualifications and experience of the principal author of this SIS (F Dominic Fanning of Gunninah Environmental Consultants), and of other relevant individuals, are included in Appendix M of this SIS.

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GLOSSARY

Definitions for the Pacific Highway Upgrade at Karuah SIS (derived from the NP&WS Director-General's requirements (Appendix A)):

abundance	means a quantification of the population of the species or community
activity	means: (a) the erection of a building; (b) the carrying out of a work in, on, over or under land; (c) the use of land or of a building or work; and (d) the subdivision of land, and includes any act, matter or thing for which provision may be made under section 26 and which is prescribed for the purposes of this definition, but does not include: (e) any act, matter or thing for which development consent under Part 4 is required or has been obtained; or (f) any act, matter or thing which is prohibited under an environmental planning instrument.
affected species	means the subject species likely to be affected by the proposal
conservation status	is regarded as the degree of representation of a species or community in formal conservation reserves
development	in relation to land, means: (a) the erection of a building on that land; (b) the carrying out of a work in, on, over or under that land; (c) the use of that land or of a building or work on that land; and (d) the subdivision of that land, but does not include any development of a class or description prescribed by the regulations for the purposes of this definition.
Director-General	means the Director-General of National Parks and Wildlife.
locality	means the area within a 10km radius of the study area.
NPWS	means the NSW National Parks and Wildlife Service.
proposal	is the development, activity or action proposed. For the Karuah Bypass, the "proposal" includes the roadworks, finished road, stormwater treatment features, rehabilitation and landscaping, and the compensatory habitat package.
region	*"means a bioregion defined in a national system of bioregionalisation that is determined (by the Director-General by order published in the Gazette) to be appropriate for those purposes".* For the purpose of this SIS, the relevant Bioregion for the Karuah pacific Highway Bypass is the NSW North Coast region as defined by the *Interim Biogeographic Regionalisation of Australia* (IBRA).
significant species	means species not listed in the *TSC Act* but considered to be of regional or local significance.
subregion	means an area based around Raymond Terrace to the South and Bulahdelah to the North. Catchment or subcatchment boundaries may be used to help define the subregion.
study area	is the subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly.
subject site	means the area which is proposed for development/activity.
subject species	means those threatened and significant species which are considered known or likely to occur in the "*study area*".
threatening process	includes all processes considered to be threatening, not limited to key threatening processes as defined in the *TSC Act*.

All other definitions are as contained in the *TSC Act*.

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX A

NP&WS Director-General's Requirements

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

21 ~~15~~ October 1998

RECEIVED
26 OCT 1998
MAJOR PROJECTS
NEWCASTLE

7809

NSW NATIONAL PARKS AND WILDLIFE SERVICE

Graham Kinnear
Project Manager
Roads and Traffic Authority
Major Projects
PO Box 469
NEWCASTLE NSW 2300

98/1389;LB;3050-2

Our reference:
Your reference:

Dear Mr Kinnear,

AAK → GUNNINAH
28/10 → HW

RE: DIRECTOR-GENERAL'S REQUIREMENTS FOR A SPECIES IMPACT STATEMENT FOR KARUAH UPGRADE OF THE PACIFIC HIGHWAY

Thank you for your letter dated 8 October 1998 requesting the Director-General's (DGRs) requirements for a Species Impact Statement (SIS) for the development cited above.

Sections 109 and 110 of the *Threatened Species Conservation Act 1995* (TSC Act) describe the form and content of a SIS. Pursuant to Section 111 of the TSC Act, I have limited and modified these matters and provided additional matters to be addressed, as described below:

Definitions

The definitions given below are relevant to these requirements:

- ***abundance*** means a quantification of the population of the species or community.
- ***activity*** has the same meaning as in the *Environmental Planning and Assessment Act 1979*
- ***affected species*** means subject species likely to be affected by the proposal
- ***conservation status*** is regarded as the degree of representation of a species or community in formal conservation reserves.
- ***development*** has the same meaning as in the *Environmental Planning and Assessment Act 1979.*
- ***Director-General*** means the Director-General of National Parks and Wildlife.
- ***locality*** means the area within a 10 km radius of the study area.
- ***NPWS*** means the NSW National Parks and Wildlife Service.
- ***region*** has the same meaning as that contained in the TSC Act.
- ***significant species*** means species not listed in the TSC Act but considered to be or regional or local significance.
- ***subregion*** means an area based around Raymond Terrace to the South and Bulahdelah to the North. Catchment or subcatchment boundaries may be used to help define the subregion.
- ***study area*** is the subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly.

Northern Zone
GIO House
24 Moonee Street
Coffs Harbour NSW
Australia
PO Box 914
Coffs Harbour 2450
Tel: (02) 6651 5946
Fax: (02) 6651 6187

Head Office
43 Bridge Street
Hurstville NSW
Australia
PO Box 1967
Hurstville 2220
Tel: (02) 9585 6444
Fax: (02) 9585 6555

- ***subject site*** means the area which is proposed for development/activity.
- ***subject species*** means those threatened and significant species which are considered known or likely to occur in the study area.
- ***threatening process*** includes all processes considered to be threatening, not limited to key threatening processes as defined in the TSC Act.

All other definitions are the same as those contained in the TSC Act.

Matters which have been limited or modified

I consider that the following Section 110 matters need **not** be addressed by your SIS.

- All reference to endangered populations and endangered ecological communities. The TSC Act does not currently list any endangered populations or ecological communities within the locality.
- Section 110(2)(e). This section is a replication of 110(2)(a).
- All reference to critical habitat. There is currently no declared critical habitat in NSW.

Matters to be Addressed

The SIS must meet all the matters specified in Sections 109 and 110 of the TSC Act with the exception of those matters limited above. In clarification of these sections (refer Appendix 1), I require the matters described below to be addressed. Previous surveys and assessments may be used to assist in addressing these requirements. All references used throughout the SIS must be cited and listed in a bibliography.

Format of SIS

The SIS must be formatted to follow the sections and subsections provided in Sections 109 and 110 of the TSC Act, and the DGRs as described below.

1. Description

The SIS must include the information requested below:

Study area.

All maps should be presented at the same scale so that they can be overlain.

1.1 The nature of the action proposed must be detailed. This must include the timetable for the carrying out of the proposed development, the number of hectares affected, the number of hectares of each vegetation type within the study area, details of the location of any auxiliary infrastructure and all components of the proposed development.

1.2 A vegetation map of the study area must be provided. This map will show the location and type of vegetation communities present within the study area and the scale of the map. The map must be presented in colour. The vegetation units mapped should follow a standard classification such as Walker and Hopkins (1990), and include dominant species in each vegetation unit.

1.3 An aerial photograph (or reproduction of such a photograph), preferably colour, of the locality must be provided, separate to the vegetation map. This aerial

photograph should clearly show the study area and the scale of the photograph, and be include an outline of the proposed corridor.

1.4 A topographic map of the locality at an appropriate scale must be provided. This map will detail the location of the proposal, major land tenure units such as National Parks, Nature Reserves, and State Forests, boundaries of the study area and areas of high human activity such as townships, regional centres and major roads.

1.5 In defining the study area consideration shall be given to possible indirect effects of the development on the area surrounding the subject site, for example habitat fragmentation, vegetation corridors, altered hydrology regimes, soil erosion or pollution, and increased human presence.

1.6 In describing the study area, consideration must be given to the previous land uses and the effect of these land uses on the study area. Relevant historical events may include sand mining, fire history, clearing, logging, recreational use and agricultural activities. Reference to the zoning or any proposed rezoning, and any relevant government planning initiatives (e.g. Interim Deferred Forest Areas, reserve proposals, etc) of the study area must be made.

Threatened and significant species habitat assessment.

1.7 Where suitable habitat is present for subject species in the study area, a description of the habitat characteristics must be provided for each subject species. Where the habitat of each subject species within the study area can be clearly delineated, this habitat must be represented on a map of the study area. NPWS predicted habitat models should be used as an indication of the presence of suitable habitat for subject species in the locality. These can be provided by the contact officer listed in this document.

1.8 A description of fauna and flora habitat components such as the frequency and size of tree hollows and stags, density of understorey vegetation, substrate and presence and nature of wetlands, rock outcrops etc. must be given. Particular attention must be given to which areas are used in the study area, and for what purposes these areas are used (e.g. roosting, feeding, nesting or breeding, etc.). The location of tree hollows and stags within the study area must be mapped.

The condition of the habitat within the study area must be discussed, including the prevalence of introduced species. The importance of the study area for all life-cycle stages of the subject species in the locality shall be identified and discussed. Particular detail is to be provided concerning the importance of the subject site for:
Koala *Phascolarctos cinereus,*
Squirrel Glider *Petaurus norfolcensis*
Yellow-bellied glider *Petaurus australis*
Bush Stone-curlew *Burhinus grallarius*
Green-thighed Frog *Litoria brevipalmata*
Brush-tailed Phascogale *Phascogale tapoatafa*
Glossy Black Cockatoo *Calyptorhynchus lathami*
Tiger Quoll *Dasyurus maculatus*

1.9 A description of the habitat requirements of threatened and significant species likely to occur in the study area must be provided. Particular attention must be paid to the following species:
Koala *Phascolarctos cinereus*
Squirrel Glider *Petaurus norfolcensis*
Yellow-bellied glider *Petaurus australis*
Bush Stone-curlew *Burhinus grallarius*
Green-thighed Frog *Litoria brevipalmata*
Brush-tailed Phascogale *Phascogale tapoatafa*
Glossy Black Cockatoo *Calyptorhynchus lathami*
Tiger Quoll *Dasyurus maculatus*

1.10 A list of subject species must be provided. In determining these species, consideration shall be given to the habitat types present within the study area, records of subject species in the locality and their known distribution. Criteria to be used to assess the conservation significance of species include those outlined by Sheringham and Westaway (1995) (Table 1).

Table 1. Criteria for identifying species of Conservation Significance (Source: Sheringham and Westaway, 1995)

1. **Nationally Rare or Threatened.** Taxa included on the current working list of Rare or Threatened Australian Plants (ROTAP) (Briggs & Leigh 1996.).

2. **Uncommon throughout distribution.** Taxa which occur in Upper North East NSW that have small populations and/or are sparsely distributed over their known Australian range and that may be inadequately reserved.

   Criteria for selection: few confirmed locality records for the taxon throughout its recorded distribution. May include taxa worthy of consideration for ROTAP listing, or previously listed species which have subsequently been removed.

3. **Rare in NSW.** Taxa which occur in Upper North East NSW with small populations and sparse distributions within this state.

   Criteria for selection: fewer than five known locations for the taxon in NSW; the taxon may be more common elsewhere in its distribution.

4. **Regionally Uncommon.** Taxa that are uncommon in Upper North East NSW, but are common or widespread elsewhere; taxa not listed in 1-3 above.

   Criteria for selection: fewer than five known localities for the taxon in the region, with restricted distributions and small population sizes.

5. **Depleted habitat / Sparse.** Sparse taxa not falling into categories 1-4 but which occur in habitats that have been extensively cleared or modified. These taxa are not well recorded in plot-based surveys in the region and may be under-represented in conservation planning exercises based on coarse filter sampling.

   Criteria for selection: fewer than twenty records in Upper North East NSW, and restricted to habitats that are threatened with ongoing depletion and degradation.

6. **Endemic.** Taxa with presently known distribution entirely within Upper North East NSW.

   Criteria for selection: all records for species confined to Upper North East NSW Audit region

7. **Disjunct.** Taxa either with population(s) remote from other populations within Upper North East NSW or taxa whose distributional stronghold is remote from the population(s) within the Audit region.

   Criteria for Selection: nearest populations are more than 100 km away.

8. **Distributional limit.** Taxa reaching the limit of their natural geographic distribution in Upper North East NSW (8N northern limit; 8S southern limit).

9. **Atypical habitat.** Taxa which include populations occurring in habitats not normally recorded for that species.

1.11 The subject species must consider, but need not be limited to, the following species:

FAUNA

Koala *Phascolarctos cinereus*
Squirrel Glider *Petaurus norfolcensis*
Yellow-bellied glider *Petaurus australis*
Bush Stone-curlew *Burhinus grallarius*
Green-thighed Frog *Litoria brevipalmata*
Brush-tailed Phascogale *Phascogale tapoatafa*
Glossy Black Cockatoo *Calyptorhynchus lathami*
Tiger Quoll *Dasyurus maculatus*
Powerful Owl *Ninox strenua*
Masked Owl *Tyto novaehollandiae*
Black-necked Stork *Ephippiorhynchus asiaticus*
Barking Owl *Ninox connivens*
Grass Owl *Tyto capensis*
Green and Golden Bell Frog *Litoria aurea*
Wallum Froglet *Crinia tinnula*
Eastern Chestnut Mouse *Pseudomys gracilicaudatus*
Black Bittern *Ixobrychus flavicollis*
Swift Parrot *Lathamus discolor*
Turquoise Parrot *Neophema pulchella*
Regent Honeyeater *Xanthomyza phrygia*
Common Wombat *Vombatus ursinus* (locally significant species)
Common Bent-wing Bat *Minopterus schreibersii*
Large-footed Mouse-eared Bat *Myotis adversus*
Little Bent-wing Bat *Minopterus australis*
Greater Broad-nosed Bat *Scoteanax rueppellii*
Osprey *Pandion haliaetus*
Lesser Sand Plover *Charadrius mongolus*
Pied Oystercatcher *Haematopus longirostris*
Sooty Oystercatcher *Haematopus fuliginosus*
Australasian Bittern *Botaurus poiciloptilus*
Chestnut-rumped Heathwren *Hylacola pyrrhopygia* (NEFBS priority species)
New Holland Mouse *Pseudomys novaehollandiae* (NEFBS Priority species)

FLORA

Black-eyed Susan *Tetratheca juncea*
Hakea bakeriana
Christmas Bell *Blandfordia grandiflora*
Swamp Mahongany *Eucalyptus robusta*
Eucalyptus fergisonii

Gonocarpus salsoloides
Syzygium paniculatum
Grevillea guthrieana (*obtusiflora*)

Databases such as the NPWS Atlas of NSW Wildlife and NPWS predictive habitat models should be used to assist in compiling the list. For information from the NPWS Atlas of NSW Wildlife, contact the Data Licensing Officer at NPWS Head Office on 02 9585 6684. For information on the NPWS predictive habitat models, contact Lynn Baker at NPWS Northern Zone office on 02 66598 240.

Survey methods.

1.12 A fauna and flora survey is to be conducted in the study area. Targeted surveys must be conducted for all subject species. As a minimum, survey methods must follow those detailed in Appendix 3, unless justification for variation from these methods can be provided to the satisfaction of NPWS. Field survey and identification of species and habitat must be undertaken by suitably qualified and experienced persons. Species of taxonomic uncertainty must be confirmed by a recognised authority such as the Australian Museum or NSW National Herbarium.

1.13 A full description of the methods used in the fauna and flora surveys and habitat assessment must be provided, including survey techniques employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and prevailing weather conditions. Where appropriate this information must be provided in map format at the same scale as previous maps. Surveys must be undertaken during seasons in which the subject species are most likely to be detected and, where possible, in appropriate climatic conditions. A table must be provided indicating compliance with survey methods provided in Appendix 3.

1.14 The impact of the season, prevailing weather conditions, and limitations of survey techniques employed must be considered and discussed with respect to the results of the survey.

1.15 Any areas which may act as local or regional corridors between the study area and adjacent areas of likely habitat for subject species must be identified and described. NPWS may be able to provide some detail on values of corridors in the subject area.

1.16 A full list of the protected fauna and native plant species (as defined by the *National Parks and Wildlife Act 1974*) found during the course of surveys must be included. Such information is indicative of the habitat quality of the site. This list must indicate whether the species is introduced, significant or threatened and the site or habitat in which each species was recorded.

Survey results and discussion

1.17 The location of the subject species recorded during the SIS survey and other recent surveys where available must be represented on a map of the study area. The map base must include the topographic features shown on the vegetation map and be provided in map format at the same scale as previous maps.

1.18 Where available, threatened species information provided must include species name, date recorded, name of person who made the record, type of record (e.g. scat identification, trapped, sighted), specific use of habitat (e.g. nesting, roosting,

foraging), and number of individuals recorded. This information must be presented on the proformas provided in Appendix 4.

1.19 Discussion and justification must be included in the determination of which of the subject species are regarded as affected species for the purposes of the SIS.

2. Assessment of likely impacts

This section expands upon Section 110(2)of the TSC Act, points (b)(c) and (g).

The assessment matters listed below must be addressed:

2.1 For each affected species, the SIS shall state the following:

- the location, nature and extent (number of hectares) of each affected species' habitat and vegetation community to be removed or modified as a result of the proposed action;
- the potential impact of the removal or modification of habitat; and
- the likely contribution of the proposed action to all threatening processes (not restricted to key threatening processes) acting on populations of those species in the locality.
- an assessment of whether the affected species, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion.

2.3 A discussion of other populations of affected species in the locality must be provided. A discussion of the long term security and tenure of other habitats (ie outside the subject site) of affected species must be provided with regards to tenure zoning and land management practices. The relative significance of the subject site for affected species in the locality must be provided.

2.4 If local or regional habitat corridors for affected species are present within the subject site, the impact of the proposal on these areas must be discussed. Impacts of barrier effects must be discussed for both flora and fauna.

2.5 Consideration must be given to possible indirect effects of the action on the area surrounding the subject site, for example, edge effects on vegetation and habitat, altered hydrological regimes, soil erosion or pollution.

3. Mitigation

The following issues must be addressed:

3.1 Where a draft recovery plan prepared in accordance with the NSW TSC Act is relevant to any affected species, consideration must be given to the information contained in these plans and whether any draft recovery plan recommendation is applicable to the proposal.

3.2 In discussing alternatives to the proposal, justification must be provided for the decision to select the current proposal.

3.3 Detail must be provided of the measures proposed to mitigate the effect of the proposal. Measures for minimising the number of road kills of affected species should be identified. These may include fauna over- or underpasses, exclusion

fencing, tunnels, retention of median vegetation for arboreal species, and appropriate revegetation and habitat restoration in adjacent areas. The techniques used must employ current best practice and be supported by a literature review.

3.4 Consideration must be given to developing long term management strategies to protect areas within the study area which are of particular importance for the affected species. These must include proposals to restore or improve habitat, and/or to provide compensatory habitat. The strategies should identify the long term objectives for the subject site.

3.5 Proposals for monitoring the effectiveness of the proposed mitigation measures and the impact of the proposal on affected species, must be provided and discussed. Details of such monitoring must be provided including site location, frequency of monitoring and duration of program.A discussion of possible options for changes to mitigation measures in the light of monitoring results must be included.

3.6 Details of any habitat restoration or improvement programmes proposed for the study area must be provided, including the proposed timeframe for habitat restoration / improvement, and the likely impact on flora and fauna, particularly during the time between the impact on the habitat and any habitat restoration / improvement. Where possible, habitat restoration and rehabilitation works should commence before project completion.

4. Additional Information

4.1 A list of approvals required must be provided, including:

- any consents required under Part IV of the *Environmental Planning and Assessment Act 1979* including the name of the consent authority and when it is proposed to make the development application; or
- any approvals required under Part V of the *Environmental Planning and Assessment Act 1979* including the name of the determining authority(ies), the basis for the approval and when these approvals are proposed to be obtained.

4.2 Flora and fauna locality data recorded during surveys must be provided. This information is to be provided on NPWS proformas provided in Appendix 4, and include information for all fields listed on these proformas.

Should you require any further information please contact Lynn Baker on (02) 66598 240, Northern Zone NPWS.

Yours sincerely

GARY DAVEY
Manager Threatened Species
Northern Zone
21 October 1998

References:

Walker, J. & Hopkins, M. S. (1990) 'Vegetation'. In *Australian Soil and Land Survey Field Handbook*, 2nd edition, eds R. C. McDonald, R. F. Isbell, J. G. Speight, J. Walker & M. S. Hopkins, Inkata Press, Melbourne, pp. 58-86.

Briggs, J. D. and Leigh, J. H. 1996. *Rare or Threatened Australian Plants*, Prepared for Commonwealth Industrial and Scientific Organisation and the Australian Nature Conservation Agency, Centre for Biodiversity Research, CSIRO Division of Plant Industry, Canberra.

Sheringham, P. and Westaway, J. 1995. *Significant vascular plants of upper north east New South Wales.* Report to the Natural Resources Audit Council. New South Wales National Parks & Wildlife Service, Sydney.

Appendix 1: Sections 109 and 110 of the Threatened species Conservation Act 1995 as of 1/1/96.

Division 2 Species impact statements

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109 Form of species impact statements

(1) A species impact statement must be in writing.

(2) A species impact statement must be signed by the principal author of the statement and by:

(a) the applicant for the licence, or

(b) if the species impact statement is prepared for the purpose of the Environmental Planning and Assessment Act 1979, the applicant for the development consent or the proponent of the activity proposed to be carried out (as the case requires).

110 Content of Species Impact statements

(1) A species impact statement must include a full description of the action proposed, including it's nature, extent, location, timing and layout and, to the fullest extent reasonably practicable, the information referred to in this section.

(2) A species impact statement must include the following information as to threatened species and populations:

(a) a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action,

(b) an assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action,

(c) for each species or population likely to be affected, details of its local, regional and Statewide conservation status, the key threatening processes generally affecting it, its habitat requirements, and any recovery plan or threat abatement plan applying to it,

(d) an estimate of the local and regional abundance of those species or populations,

(e) a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action,

(f) a full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region,

(g) a full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region,

(h) a full description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic, and social considerations and the principles of ecologically sustainable development,

(2) (cont):

(i) a full description and justification of the measures proposed to mitigate any adverse effect of the action on the species and populations, including a compilation (in a single section of the statement) of those measures,

(j) a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or population.

(3) A species impact statement must include the following information as to ecological communities:

(a) a general description of the ecological community present in the area that is the subject of the action and in any area that is likely to be affected by the action,

(b) for each ecological community present, details of its local, regional and Statewide conservation status, the key threatening processes generally affecting it, its habitat requirements, and any recovery plan or any threat abatement plan applying to it,

(c) a full description of the type, location, size and condition of the habitat of the ecological community and details of the distribution and condition of similar habitats in the region,

(d) a full assessment of the likely effect of the action on the ecological community, including, if possible, the quantitative effect of local populations in the cumulative effect in the region,

(e) a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic, and social considerations and the principles of ecologically sustainable development,

(f) a full description and justification of the measures proposed to mitigate any adverse effect of the action on the ecological community, including a compilation (in a single section of the statement) of those measures,

(g) a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the ecological community,

(4) A species impact statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement.

(5) The requirements of subsections (2) and (3) in relation to information concerning the State-wide conservation status of any species or population, or any ecological community, are taken to be satisfied by the information in that regard supplied to the principal author of the species impact statement by the National Parks and Wildlife Service, which information that Service is by this subsection authorised and required to provide.

Appendix 2: Draft Recovery Plans available as of 1/3/98.

Recovery Plans for Threatened Species occurring in New South Wales

A recovery plan delineates, justifies and schedules the research and management actions necessary to support recovery of the threatened species, population or ecological community.

The following recovery plans have been prepared in conjunction with the Australian Nature Conservation Agency (ANCA) and cover the range of the species in NSW.

Under the NSW *Threatened Species Conservation Act 1995*, these plans are considered as drafts and will go through the process as outlined in the Act.

SPECIES	COMMON NAME
Plants	
Acacia ruppii	
Angiopteris evecta	Giant Fern
Astrotricha roddii	
Diospyros mabacea	Red-fruited Ebony
Eleocharis tetraquetra	Square-stemmed Spike Rush
Eucalyptus pachycalyx ssp. *banyabba*	
Grevillea beadleana	
Grevillea masonii	
Lindsaea incisa	
Melichrus hirsutus	
Olearia flocktoniae	Dorrigo Daisy Bush
Phaius tankervilliae and *Phaius australis*	Swamp Orchids
Quassia sp. Mooney Creek	
Triplarina imbricata (=Baeckea camphorata)	
Tylophora woollsii	
Wollemia nobilis	Wollemi Pine
Zieria prostrata	
Animals	
Mormopterus beccarii	Beccari's Freetail-bat
Miniopterus schreibersii	Common Bent-wing Bat
Syconycteris australis	Common Blossom-bat
Cyclopsitta diophthalma coxeni	Coxen's Double-eyed Fig Parrot
Vespadelus troughtoni	Eastern Cave Bat
Falsistrellus tasmaniensis	Eastern False Pipistrelle
Mormopterus norfolkensis	Eastern Freetail-bat
Nyctophilus bifax	Eastern Long-eared Bat
Nyctimene robinsoni	Eastern Tube-nose Bat
Mixophyes fleayi	Fleay's Frog
Mixophyes iteratus	Giant Barred Frog
Kerivoula papuensis	Golden-tipped Bat
Scoteanax rueppellii	Greater Broad-nosed Bat
Nyctophilus timoriensis	Greater Long-eared Bat
Pseudomys oralis	Hastings River Mouse
Chalinolobus nigrogriseus	Hoary Wattled Bat
Vespadelus baverstocki	Inland Forest Bat
Chalinolobus dwyeri	Large-eared Pied Bat
Myotis adversus	Large-footed Mouse-eared Bat
Miniopterus australis	Little Bent-wing Bat
Chalinolobus picatus	Little Pied Bat

Placostylus bivaricosus	Lord Howe Island Land Snail
Tyto novaehollandiae	Masked Owl
Litoria piperata	Peppered Frog
Ninox strenua	Powerful Owl
Tyto tenebricosa	Sooty Owl
Mixophyes balbus	Stuttering Frog
Litoria castanea	Yellow Spotted Bell Frog
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat

Appendix 3: Survey methods

The following survey techniques have been developed to survey threatened and protected species in a cost-effective manner, and to reflect methods currently used. They are to be regarded as a minimum requirement; additional survey should be undertaken if perceived to be necessary.

An important component of a comprehensive survey is the initial stage of fauna habitat assessment. In situations where all fauna habitats will not be surveyed, fauna habitat assessment is critical to determine optimal habitat for survey.

Should the survey employ methods which differ from those detailed below the reasons for variation should be provided in the survey report.

Fauna

Introduction

Objectives for fauna surveys for the Pacific Highway upgrade include:

- determine species presence in the area and within each habitat type within the area;
- obtain measures of the abundance (relative or absolute) of species within the area and within each habitat type in the area;
- characterise the fauna communities within the area and within each habitat type within the area; and
- determine the presence of threatened species and the extent of their habitat within the area.

The information obtained should allow for identification of important habitats eg. high species richness or abundance, unusual or rare fauna assemblages and particular elements that may be significant for threatened species eg roost or nest sites and important food resources.

The survey methods detailed below comprise a number of general survey methods for fauna including threatened species and a number of methods that target particular threatened species or groups of threatened species.

To achieve the objectives above, surveys should be conducted in a systematic manner, each habitat type within the area should be sampled, the survey method and survey effort must be recorded. Within the study area survey methods should be standardised or at least comparable between survey sites.

The survey methods can be broadly grouped as targeting:

- nocturnal or crepuscular species (spotlighting, call playback, dusk censuses, stag watching);
- small to medium terrestrial and scansorial mammals (hair tubing, trapping (pitfall, Elliott's and cage traps) and scat and tracks searches);
- reptiles and amphibians;
- microchiropteran bats (ultrasonic recording and trapping (harp and mist netting)); and
- diurnal birds.

Within these survey methods particular methods targeting threatened species are provided. In particular, survey methodology for Koala is provided.

In this document the required survey effort is usually expressed as a percentage of potential habitat to be sampled. Depending upon the survey method the study area is defined as the road corridor or within some distance of the road corridor. The sample effort should take into account the amount of habitat available within the study area. Where large areas of habitat occur a sample of 20% of the habitat is usually considered sufficient. Where there is only a small area of habitat then all of the habitat should be surveyed. Similarly, where large contiguous expanses of habitat occur then a representative sample of the habitat is considered sufficient. Where there are a number of small patches of habitat then each habitat patch should be sampled.

nocturnal or crepuscular species: methods appropriate for this group include spotlighting, call playback, dusk censuses and stag watching (note specific techniques for microchiropteran bats are provided separately, similarly spotlighting is an appropriate method for reptiles and amphibians and call playback for amphibians, details of these are provided later).

Survey methods can be used in isolation, however best results are likely to be achieved using a combination of techniques.

Target species: arboreal mammals, medium to large terrestrial and scansorial mammals, nocturnal birds including Powerful, Masked, Sooty, Barking and Grass Owls, Marbled Frogmouth and Bush Thick-knee. Tree mounted Elliott traps can be used to survey for Squirrel Glider refer to later section.

Survey methods

1.0 Spotlighting and associated census techniques

Survey Effort: For each technique a minimum of 20 % of potential habitat must be sampled following habitat assessment to determine optimal habitat for survey.

Optimum conditions for spotlighting are still, warm and overcast nights. Windy, cold and rainy conditions are to be avoided.

1.1 Spotlighting on foot

- To be conducted in suitable habitat within 1 kilometre of the road corridor.
- Spotlights on foot should involve walking slowly (traversing 500 metres in 30 minutes).
- The minimum survey effort should be 30 minutes of spotlighting on foot.
- Small discrete patches of habitat are best sampled using a random meander searching as much of the patch as possible. Larger patches of habitat are better sampled using transects oriented in such a way as to maximise the coverage of the patch, ie. no overlap of the transect.

1.2 Vehicle spotlighting

- Vehicle spotlighting should be conducted in suitable habitat on roads and tracks within 5 kilometres of the road corridor.
- The vehicle speed should not exceed 5 kilometres per hour.
- The minimum survey effort should be 2 hours of vehicle spotlighting.

The distance and duration of each spotlight survey should be recorded. The number of each species observed should be recorded as well the perpendicular distance from the transect. This data can be used to calculate relative abundance of species.

say 10km bag –
5km each side =
110 km² = 11000ha

1.3 Call playback

- Call playback should be conducted in suitable habitat within 5 kilometres of the road corridor. Where large continuous areas of habitat exist 20% should be sampled, where patches of habitat exist then all habitat should be sampled. For the purposes of determining sampling effort a broadcast distance of 500 metres is assumed. As an example of calculating survey effort:

  Assume that there is 5000 hectares of suitable habitat within 5km of the road corridor. Sampling 20% of 5000 hectares would mean that 1000 hectares needs to be sampled. Assuming the broadcast radius is 500m, then each survey sample covers about 75 hectares. The number of survey sites is then calculated by dividing 1000 ha habitat by sample area of 75ha giving a requirement of around 13 sample sites. Survey sites should be evenly spread throughout the habitat. The survey design needs to ensure that each habitat type present is sampled.

- Call playback sites should be located at least 1 kilometre apart.
- The call playback survey should comprise 10 minutes listening, followed by 5 minutes call of a species followed by 5 minute listening and spotlighting. Spotlighting should be conducted within 100 metres of the site. A final listening period of ten minutes should occur after the call broadcasting is conducted. The calls are to be played from a good quality portable recorder and amplified through a nine volt megaphone (note this configuration is considered the minimum, there are other better quality systems available). The list of species targeted will depend upon the location and the habitat present.
- Call playback censuses are to be conducted at least twice at each of the sites over a minimum of two non-consecutive nights. Windy rainy conditions should be avoided. Optimum conditions are still, warm and overcast.
- Call broadcast surveys for Squirrel and Yellow-bellied Gliders should be conducted between September and March.
- Call playback censuses for Bush Stone-curlew should be conducted after a dusk census. Call playback sites should be conducted at 500m intervals within suitable habitat. Call playback should be combined with a slow walk to flush birds and to search for nests.
- When using call playback to census owls it is recommended to play the Powerful Owl call first as this species often takes a long time to respond to the call.

Call playback can be used as a survey technique for a wider range of fauna including frogs and diurnal and cryptic wetland birds, which are described later in this document.

1.4 Dusk censuses and stag watching

These survey techniques are most appropriate to detect roost and nest sites for owls and other hollow dependent fauna such as arboreal mammals, bats etc.

Dusk census involves listening in potential habitat from at least 30 minutes prior to sunset and up to 60 minutes after sunset. Owls and Yellow-bellied Gliders are known to call when leaving nests, roosts and dens. Dusk censuses are most appropriately conducted in small discrete areas such as gullies, patches of rainforest and old growth forest. Having three or more people conducting dusk censusing allows for triangulation to be used to pin point roost, nest or den sites.

Stag watching involves individuals watching hollow bearing trees, alive or dead, starting 30 minutes prior to sunset until 60 minutes after sunset. The person needs to be in a position to

allow a good view of the tree to be obtained, preferably silhouetted against the sky. Animals leaving hollows can either be heard or observed and their identity confirmed through spotlighting. This a relatively time intensive technique and is most appropriate where there are a few scattered hollow bearing trees along the road corridor.

1.5 Macropod Surveys

Surveys for threatened macropod species including the Black-striped Wallaby, Parma Wallaby, Red Legged Pademelon, Long-nosed Potoroo, and Rufous Bettong should be undertaken in areas of suitable potential habitat. Appropriate survey methods include:

- Spotlighting from a slow-moving vehicle along roads and tracks through areas of suitable potential habitat. (note: for the first three species searches, spotlight watches should also target forest-pasture edges).
- Collection and identification of macropod scats.
- Late evening and dusk watches at likely foraging areas where scats have been found.

2.0 Koala survey

The aims of Koala survey for this study are to identify and delineate local Koala populations, areas of preferred and utilised Koala habitat including the boundaries of those social groups likely to be directly impacted by the proposed action, and locations of Koala movement corridors likely to be further dissected by the road corridor (evidenced by roadkills and occurrence of habitat). Survey requirements for Koalas must include the following components:

- **Information review**. This must include NPWS Wildlife Atlas database search, a literature review of any other relevant studies for the general locality (not restricted to the immediate study area), including, but not restricted to: Koala Management Plans, REFs, EISs, university reports, interviews with local residents, wildlife carers (e.g. WIRES), community groups (e.g. Friends of the Koala, Australian Koala Foundation, etc) and locations of known Koala roadkills, sightings and rescues.
- **Habitat assessment:** The vegetation of the study area must be mapped to identify habitat types with a potential to support Koalas. The target vegetation will vary depending on the location but may include the following species: Forest Red Gum *Eucalyptus tereticornis*, Small-fruited Grey Gum *E. propinqua,* Swamp Mahogany *E. robusta,* Tallowwood *E. microcorys,* Flooded Gum *E. grandis*, Forest Oak (*Allocasuarina* sp.), and areas of Paperbark *Melaleuca quinquenervia* which fringe Swamp Mahogany forest. Some ironbark species, black Butt, red mahogany, stringy barks and spotted gums may be included in certain areas.
- **Field survey:** Field survey within areas identified above must include daytime scat, scratch and sighting searches, and night spotlighting to search for Koalas. This should involved walking transects through selected potential habitat with searches concentrated on identified preferred tree species. All suitable habitat types must be surveyed at least once.
- The field survey must include a walked transect through all patches of potential habitat either side of/along the road corridor. In every 100 metres of transect at least ten trees should be inspected with the ten trees being spread along the 100 metres.
- Trees selected for inspection should preferably be those species listed above, and of the larger size classes (>30cm dbhob); where species above are not present then those species present should be selected.
- The base of each tree should be searched for Koala scats (as a guide 1 metre around base for 1 minute). Where scats are detected the location of the tree should be marked on an appropriately scaled map (1:25,000 or larger). A further search of trees initially within 100 metres of the tree should undertaken to determine the extent of Koala use.

- Where it appears the area of use extends beyond the 100 metre radius, searching should continue to determine the total extent of Koala use.
- As a guide, it would be most appropriate to complete the original transect and then return to areas where scats have been detected to undertake the further searches. Such surveys provide information on the presence of koalas in the area, the extent of the area used by Koalas, and the tree preferences exhibited by Koalas which may then assist in targeting other potential habitat in the study area.
- **Reporting:** Areas where field survey was undertaken must be marked on a map of 1:25,000 scale or larger. Assessment must include appraisal of the information review and habitat assessment together with the field survey and radio-tracking results. Mapping of identified Koala habitat, including an analysis of Koala habitat usage in the area and identification of historical, current and potential Highway crossing points.

In addition, it is recommended that the methodology used on the Tandy's Lane Pacific Highway Project be consulted (Kinhill Pty Ltd 1997: Proposed Upgrade of the Pacific Highway at Tandy's Lane - Koala Issues) and utilised if considered appropriate.

3.0 Surveying small to medium terrestrial and scansorial mammals

3.1 Hairtubes

Hairtubes are used to identify the following species: Brush-tailed Phascogale (tree-mounted hair tubes), Rufous Bettong, Spotted-tailed Quoll and Long-nosed Potoroo.

- Hair funnels or 90mm PVC units are appropriate for the above target species.
- Hair tubes are to remain in the field for 10 nights.
- All hair samples must be forwarded for identification to a person suitably experienced in native mammal hair analysis.
- Hair tubes can be laid evenly spaced in a linear or grid pattern. If laid in a line, the line should traverse the longest axis of the vegetation patch.

Spotted-tailed Quoll and Brush-tailed Phascogale

- Survey all potential habitat;
- Ten (10) hair tubes are to be laid per 2km of transect and are to remain in the field for 10 nights;
- Survey effort should comprise a minimum of one transect per 50 hectares of habitat;
- Hair tubes are to sample potential habitat up to 5km from the route;
- If habitat is not contiguous, hair tubes are to be placed in all vegetation patches;
- Tree mounted hair tubes are to be used to target the Brush-tailed Phascogale.
- Hair tubes are to be baited with a meat based product *eg* chicken wings, blood and bone, tinned sardines.

Long-nosed Potoroo and Rufous Bettong

- Survey all potential habitat;
- In homogenous habitat ten (10) hair tubes are to be laid per 100m transect. Where there is evidence of activity such as diggings, scats etc then the hair tubes should be placed to target these areas.
- Survey effort should comprise a minimum of one transect per 10 ha in contiguous habitat. Where habitat is present is small patches, one transect should be laid per habitat patch.

3.2 Trapping

3.2.1 Tree-mounted traps

Tree mounted Elliott traps (size B) should be used to survey for Brush-tailed Phascogale and Squirrel Glider.

- A minimum of 20 tree-mounted "B" Elliott traps to be set for a minimum of four nights at each study site. Note: Trapdoors of "B" Elliot traps may need adjustment to ensure animals are not able to pull them open and escape or be injured (tail stripping etc). All potential sites in the study area must be surveyed with a maximum of five such sites for each species to be surveyed.
- Traps to be baited with peanut butter, oats and honey. A diluted honey mixture to be sprayed on trees around mounted traps.
- Traplines should be set on tree trunks or major branches. Traplines should sample areas of potential habitat in woodland and open forest within the study area.

Squirrel Glider

Site selection for trapping for Squirrel Glider should target those areas with a diverse tall shrub layer especially Banksia etc. It is in these areas that Squirrel Gliders come down low enough to potentially encounter traps

3.2.2 Ground based trapping

- Ground trapping with standard Elliott traps (size A) should be used to sample the small terrestrial mammals and targeted to survey for Eastern Chestnut Mouse.
- Trapping should be set for four nights.
- Trapping effort will depend upon the amount and configuration of suitable habitat. As a guide, a minimum survey effort would be 400 trap nights (100 traps for four nights).
- Ground trapping with cage traps should be used to target Tiger Quoll and Long-nosed Potoroo.
- Ten cage traps are to be laid per 2km of transect when targeting Tiger Quoll and Long-nosed Potoroo.
- Cage traps should be baited with appropriate bait for the target species, *ie* chicken wings, cooked meat, sardines etc for Tiger Quoll. Bait comprising peanut butter, oats and honey is considered suitable for Long-nosed Potoroo.

3.2.3 Pitfall trapping

- Dry pitfall trapping must be conducted in suitable habitat along a minimum of two transects for the Common Planigale *Planigale maculata*. Suitable habitat ranges from rainforest and sclerophyll forest to heathland and grassland. Pitfall trapping is the only known technique for reliable detection of this species.
- Each pitfall line should contain ten pits over 50 metres with fencing.
- At least one pitfall line should be placed in each habitat patch.

3.3 Scat and tracks survey

Scat (including owl pellets) and tracks surveys must be used to target the following species; Powerful owl, Sooty Owl, Masked Owl, Brush-tailed Phascogale, Long-nosed Potoroo, Koala and Spotted-tailed Quoll.

- Scat, track and owl pellet surveys should be conducted by dedicated searches and opportunistically along transects, roads and tracks and in the course of undertaking other survey work.
- For dedicated searches one or two persons should walk slowly along the edge of roads or tracks looking for scats in open areas, in and beneath vegetation on verges, at the base of habitat trees and on large logs. Observers should also look for fresh tracks along roads.
- All predator scats and owl pellets should be collected for analysis to determine prey species. Scats must be forwarded for identification to a person suitably experienced in scat and pellet analysis.
- Scats from non-predators need not be sent for identification unless identification of the source of the scats is doubted.

4.0 Microchiropteran bat surveys

4.1 Ultrasonic call recording

Ultrasonic call recording to be conducted targeting the following species: Common Bent-wing Bat *Miniopterus schreibersii,* Eastern Little Mastiff Bat *Mormopterus norfolkensis,* Greater Broad-nosed Bat *Scoteanax rueppellii,* Hoary Bat *Chalinolobus nigrogriseus,* Little Bent-wing Bat *Miniopterus australis,* Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*, Large Pied Bat *Chalinolobus dwyeri* and Beccarii's Freetail Bat *Mormopterus beccarii.*

The following methodologies should be undertaken for all microchiropteran bat surveys:

- Surveys should be conducted on fine, calm nights (adverse weather conditions eg. wind, fog, rain and low temperatures should be avoided).
- Surveys to be conducted in the first two hours after dark.
- Sites to be spaced throughout the study area, encompassing a representative range of habitats.
- Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris,* Greater Broad-nosed Bat *Scoteanax rueppellii,* Eastern Little Mastiff Bat *Mormopterus norfolkensis,* and Hoary Bat *Chalinolobus nigrogriseus:* survey must involve walking slowly along a transect (eg. road, creek) at each site for 30 minutes on at least three nights and pausing to record calls where bat activity levels are high.
- Little Bent-wing Bat *Miniopterus australis* and Common Bent-wing Bat *M. schreibersii: s*urvey must consist of ultrasonic call recording of 30 minutes duration on at least three nights, commencing at dusk. Call detection units should be placed at the entrances of likely roosts eg. under bridges or culverts, and along potential flyways.
- Surveys should be conducted between October and March inclusive.

4.2 Harp trapping

Harp traps are the most appropriate detection equipment for Golden-tipped Bat *Kerivoula papuensis,* Common Bent-wing Bat *Miniopterus schreibersii,* Greater Broad-nosed Bat *Scoteanax rueppellii,* Large-footed Myotis *Myotis adversus*, Eastern Cave Bat *Vespadelus troughtoni*, Little Bent-wing Bat *Miniopterus australis,* Hoary Bat *Chalinolobus nigrogriseus,* Large Pied Bat *Chalinolobus dwyeri*, Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris* and Northern Long-eared Bat *Nyctophilus bifax.*

- Harp traps must be set before dusk.
- Surveys to be undertaken for a minimum of three nights.
- Harp traps to be set across creeks and across potential flyways. Supplementary screening (such as branches or hessian) may be used where necessary to increase the chance of trap success.
- Windy, cold and wet weather conditions should be avoided.

Queensland Blossom Bat *Syconycteris australis* survey

- Surveys to use a minimum of six mist nets opened on moonless nights.
- Surveys to be conducted in areas where appropriate food plants are in blossom, eg. *Banksia*, *Melaleuca* spp.
- This species can also be identified by spotlighting and detected using harp traps (though with much lower success).

Eastern Tube-nosed Bat *Nyctophilus bifax* and Black Flying Fox *Pteropus alecto* survey

- Spotlighting should be conducted in areas of suitable potential habitat.
- These species can be targeted during arboreal mammal spotlighting surveys.

not sure that this is the case with the tube nose bat. The Black Flying Fox is probably best detected by searching for camps within the road corridor. Information obtained from spotlighting identifies foraging habitat, which again probably should be focussed on the road corridor.

4.5 Roosting sites

Where threatened bat species are recorded within the study area, a reasonable effort should be made to identify any roost sites present within the study area. This may be done by identification of potential roost sites and subsequent investigation by stag watching, targeted ultrasound recording at dusk or direct examination of potential roost sites for evidence of bat presence. Potential roost sites include caves, basal hollows in trees, under tree bark, bridges and in drainage structures eg. culverts and pipes. Diurnal investigations of bridges and drainage structures (culverts and pipes) are to be conducted specifically targeting Large-footed Myotis *Myotis adversus*.

5.0 Diurnal birds

The objective of the general bird censuses is to characterise the bird communities in each of the habitat types in the study and identify significant or unusual bird communities (particularly high densities, species richness).

General bird censuses should be conducted sampling all habitat types present. There are a range of survey methods available see Davies (1984) *Methods of Censusing Birds in Australia RAOU*.

- The following species must be specifically searched for in suitable habitat:
  i) Wetland surveys: Australasian Bittern, Black Bittern, Black-necked Stork, Brolga and Comb-crested Jacana: Diurnal searches of wetland and riparian areas to be conducted. A minimum of 25% of all wetland areas should be sampled. Call

playback surveys for Australasian Bittern and Black Bittern should be undertaken at dusk in potential habitat as per methods described above in call playback.

ii) Bush Hen: Surveys to target dense vegetation (including Lantana) which is close to water. (consideration should be given to surveying for Black Bitterns as well).

iii) Double-eved Fig-parrot: Searches to be undertaken in rainforest, particularly in areas which contain native fruiting figs.

iv) Glossy Black-Cockatoo: Ground of foraging habitat (dry to moist sclerophyll forest and woodland with a moderate to high density of *Allocasuarina* spp.) to be searched for evidence of chewed cones.

Listening to be conducted at dusk by a person familiar with the calls of the species. If survey is conducted during the breeding season (March to August), adults should be watched in foraging areas and, if possible, followed to locate the nest tree.

Surveys to detect nest sites involve following birds (pairs) at or near dusk to their roost/nest site, then with follow up searches at dawn to determine the location or proximity of the nest tree, through hearing the young begging.

v) Raptor nests: searches for raptor nests should be undertaken in the road corridor. Where raptor, or potential raptor nests are found surveys should undertaken to determine the species of raptor using the nest. Nests of Osprey should be reasonably easy to distinguish from other raptors. Other species of threatened raptors include Square-tailed Kite and Red Goshawk.

vi) Barred Cuckoo-shrike and Superb, Wompoo and Rose-crowned Fruit Doves: Searches of fruiting rainforest trees, particularly figs, to be undertaken in potential habitat (sub-tropical rainforest, or moist sclerophyll forest with a well-developed mesic understorey). Call playback for Fruit Doves should also be undertaken in areas containing mature, fruiting laurels and figs.

vii) Black-breasted Button-quail: Searches to be conducted in potential habitat for characteristic pivot feeding marks (platelets). Where pivot feeding marks are located, further target survey and call playback must be conducted. Call playback to consist of 2 minutes of call followed by five minutes of listening. Calls to be played three times.

viii) White-eared Monarch: Early morning search in suitable habitat (this species forages in the outer canopy of rainforest and wet sclerophyll forest, particularly along edges and ecotones).

ix) Ground Parrot: searches for Ground Parrots should be conducted within suitable habitat in the road corridor and in suitable habitat within 500 metres of the road corridor. Suitable habitat is low heath, optimal habitat is graminoid heath that has not been burnt within the last 5 years.

Survey methods involve dusk listens starting 30-60 minutes before sunset and 30-60 minutes after sunset. Ground Parrots have a distinctive call.

Call playback should also be undertaken, using the methodology outlined previously.

If Ground Parrots are detected in an area then more intensive survey should undertaken using three or more people, depending upon the size of the habitat patch. The people should be spaced well apart, >100 metres, and details of the time of call heard and direction and distance of call recorded by each individual to allow for size and distribution of the population to be estimated by triangulation.

6.0 Reptile survey

- A minimum of 2 hours diurnal and 2 hours nocturnal foot-based searching must be spent per 10 hectares of suitable habitat specifically looking for reptiles.
- Surveys should be conducted between October and March inclusive.

- Nocturnal, foot-based searches must be undertaken on tracks and around potential shelter sites (examination of waterbodies where frogs are active may also be productive). Where possible vehicle spotlight surveys can be used to complement ground survey.
  i) Pale-headed Snake: Nocturnal foot-based searches of senescent trees and along creek and drainage lines. Examination of arboreal epiphytes and tree hollows on fallen trees. Diurnal searches around shelter sites.
  ii) Stephen's Banded Snake: Nocturnal, foot-based searches of shelter sites, such as rock crevices, strangler fig hollows, the rocky edges of waterbodies where frogs are active, and senescent trees. Diurnal searches around shelter sites (such as buttressed trees, strangler figs and senescent trees).
  iii) White-crowned Snake: Diurnal searches of shelter sites (such as lifting rotting logs and rocks partially embedded in soil or litter, and raking through deep leaf litter), nocturnal, foot-based spotlighting during warm nights. Pitfall trapping and placement of artificial shelter (dropboards) should be conducted in suitable habitat. Dropboards should be left for 10 nights and checked daily.
  iv) Three-toed Snake-toothed Skink: Diurnal searches of shelter sites (such as lifting rotting logs and rocks partially embedded in soil or litter, and ranking through deep leaf litter) and dry pitfall trapping (note large pitfall buckets are required).
- Roads and tracks in the study area should be checked for roadkills.

7.0 Frog surveys

7.1 General

Tadpole surveys should be carried out in all suitable waterbodies, with tadpoles being identified by a suitably experienced person.

7.2 *Crinia tinnula* and *Litoria olongburensis*

- Surveys for *Crinia tinnula* to be conducted in acid paperbark swamps, sedge swamps, Swamp Mahogany and swamp sclerophyll forest usually on sandy substratum. Surveys for *Litoria olongburensis* to be conducted in sedge swamps and creek margins in Wallum habitat.
- Survey requires listening for calls, spotlighting and specimen capture and identification where possible.
- A minimum of 30 minutes per hectare survey must be conducted in suitable habitat sites as described above.
- Calls to be played for two minutes followed by a five minute listening period. When an observer is unsure of a species' identification, the call responses should be taped to allow verification by a person familiar with the call of the target species (*C. tinnula* and *C. parainsignifera* have very similar calls).
- Surveys must be conducted over at least three non-consecutive nights.
- Surveys must not be conducted in cold, windy conditions.
- *C. tinnula* should be detectable by call during daylight and at night in suitable weather conditions
- Surveys for *C. tinnula* should preferably be conducted in autumn or winter, and for *L. olongburensis*, in spring or summer following rainfall.

7.3 *Litoria aurea*

Frog experts disagree on the most appropriate techniques for surveying *Litoria aurea* and the success of different techniques varies between locations. As such, the following survey

methodology is provided as a guide. Any variation in this survey technique must be clearly documented.

- Permanent swamps or ponds of greater than one ha surface area to be surveyed for a minimum of one hour, both day and spotlighting at night. A minimum of a 30 minute survey replicated at both day and night, is required for all swamps and ponds less than one ha in size.
- Night survey to be conducted over a minimum of three nights.
- Calls to be played for two minutes, followed by a five minute listening period. When an observer is unsure of a species' identification, the call responses should be taped to allow verification by a person familiar with the call of the target species.
- Surveys should be carried out during or within two days of significant rain (>1cm), and must not be conducted in cold, windy conditions.
- Survey should be conducted between September and March inclusive.
- Surveys should be specifically conducted for tadpoles, with tadpoles being identified by a suitably experienced person.

7.4 *Litoria brevipalmata*

- A minimum of one hour night survey to be conducted for every one ha surface area of temporarily flooded areas or ponds. A minimum of 30 minutes survey is to be conducted for each swamp and pond less than one ha surface area.
- Night survey to be conducted over a minimum of three nights.
- Spotlighting, listening for calls and call playback should be conducted in areas of suitable potential habitat, on warm nights within two days of heavy rainfall events (greater than fifty mm in a 24 hour period).
- Calls to be played for two minutes followed by a five minute listening period. When an observer is unsure of a species' identification, the call responses should be taped to allow verification by a person familiar with the call of the target species.
- Surveys should be conducted between October and March inclusive.
- Surveys should be specifically conducted for tadpoles, with tadpoles being identified by a suitably experienced person.

7.5 *Mixophyes iteratus, M. balbus* and *M. fleayi*

Surveys should be undertaken in areas of suitable potential habitat along and within 50m of watercourses in rainforest and moist eucalypt forest.

- Spotlighting and listening for calls should be conducted on warm nights, particularly following rain. The species may be detected at a distance by eyeshine when spotlighting.
- Call playback should be employed in conjunction with spotlighting. Calls to be played for two minutes, followed by a five minute listening period. When an observer is unsure of a species' identification, the call responses should be taped to allow verification by a person familiar with the call of the target species.
- Surveys should be conducted at night between September and April inclusive.
- Night survey to be conducted over a minimum of three nights.
- Surveys should be specifically conducted for tadpoles, with tadpoles being identified by a suitably experienced person.

8.0 Threatened fauna features

In addition to the above surveys, road corridor and potential habitat 200m either side of the corridor must be surveyed for the following features indicative of the presence of the named threatened fauna species:

i) Nest and roost sites of large forest owls.

ii) Pellets and whitewash from large forest owls.

iii) Nests or dens of threatened hollow-dependent fauna (eg. Squirrel Glider, Brush-tailed Phascogale, Yellow-bellied Glider, Glossy Black Cockatoo).

iv) Trees incised for sap-feeding by Yellow-bellied Gliders

v) Latrine and den sites of the Spotted-tailed Quoll

vi) Crushed cones beneath *Allocasuarina* spp. indicating utilisation by the Glossy Black Cockatoo.

vii) Accessible basal tree hollows in likely bat roost trees (>80cm dbh dead stags or large trees with accessible base hollows). Look (and smell) for the presence of bat droppings inside the base of the tree.

viii) Raptor nest sites.

Table 1 : Survey requirements for threatened fauna.

Species Name	Spot light	Call Play back	Hair tubes	Scat, pellet & track	Mist net	Harp trap	Ultrasonic call recording	Species specific	Elliot Trap	Pitfall
Amphibians										
Crinia tinnula	X	X						X		
Litoria aurea	X	X						X		
Litoria brevipalmata	X	X						X		
Litoria olongburensis	X	X						X		
Mixophyes iteratus	X	X						X		
Reptiles										
White-crowned Snake	X							X		
Three-toed Snake-toothed Skink								X		
Pale-headed Snake	X							X		
Stephen's Banded Snake	X							X		
Flying Mammals										
Black Flying Fox *Pteropus alecto*	X									
Common Bent-wing Bat *Miniopterus schreibersii*						X	X			
Eastern Little Mastiff Bat *Mormopterus norfolkensis*							X			
Golden-tipped Bat *Kerivoula papuensis*						X		X		
Greater Broad-nosed Bat *Scoteanax rueppellii*						X	X			
Hoary Bat *Chalinolobus nigrogriseus*						X	X			
Large Pied Bat *Chalinolobus dwyeri*						X	X			
Large-footed Myotis *Myotis adversus*						X		X		
Little Bent-wing Bat *Miniopterus australis*						X	X			

Beccarii's Freetail Bat *Mormopterus beccarii*							X			
Eastern Tube-nosed Bat *Nyctimene robinsoni*	X									
Northern Long-eared Bat *Nyctophilus bifax*						X				
Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*					X	X	X			
Queensland Blossom Bat *Syconycteris australis*	X				X	X				
Eastern Cave Bat *Vespadelus troughtoni*						X				
Non-flying Mammals										
Brush-tailed Phascogale	X		X						X	
Common Planigale										X
Koala	X			X				X		
Long-nosed Potoroo	X		X	X				X		
Rufous Bettong	X		X	X				X		
Squirrel Glider	X	X						X		
Spotted-tailed Quoll	X		X							
Yellow-bellied Glider	X	X						X		
Birds										
Australasian Bittern								X		
Barred Cuckoo Shrike								X		
Black Bittern								X		
Black-breasted Button Quail								X		
Black-necked Stork								X		
Brolga								X		
Bush Hen								X		
Bush Stone-curlew		X						X		
Comb-crested Jacana								X		
Double-eyed Fig-parrot								X		
Eastern Grass Owl	X	X		X						
Masked Owl	X	X		X						
Osprey								X		
Powerful Owl	X	X		X						
Red Goshawk								X		
Rose-crowned Fruit Dove								X		
Sooty Owl	X	X		X						
Square-tailed Kite								X		
Superb Fruit Dove								X		
White-eared Monarch								X		
Wompoo Fruit Dove								X		
Glossy Black Cockatoo								X		

Flora:

1.0 Field Methodology

- A desktop study using 1:25,000 or finer scale aerial photography to be conducted prior to the field survey to identify and delineate the range of vegetation types present in the study area. Vegetation type descriptions must include the dominant plant species

present, and use a recognised vegetation association classification (e.g. Forestry Commission 1989; National Parks and Wildlife Service 1995; Walker & Hopkins 1990). vegetation associations, where applicable, should be compared with their counterparts in the vegetation association classification used in the Interim Assessment Process.

- A minimum of one full floristic quadrat (minimum size 20m x 20m) must be conducted in each vegetation association identified during the desktop study.
- In addition to the full floristic quadrats, a "random meander" search (Cropper 1993) must be conducted throughout the study area. A "random meander" search involves traversing the study area in a random manner, visiting the full range of habitats identified in the desktop review.
- A minimum of 30 hours of random meander flora survey must be conducted throughout the study area.
- The timing of flora surveys should take into account flowering or fruiting periods of the threatened flora species being surveyed where fertile material is necessary for identification.

2.2 General requirements:

Species that are unfamiliar to the surveyor must be collected and identified or verified by a recognised herbarium (e.g. NSW National Herbarium) or a suitably experienced person.

3. Data recording requirements

Data recorded during surveys must be provided on the attached proformas and included in the survey report. In addition, a copy of the completed proformas must be sent to NPWS GIS Division for entry on the NSW Wildlife Atlas. A map at 1:25,000 or finer scale must be provided with survey points or transects marked.

3.1 Threatened flora

For threatened flora species, the following details must be provided additional to those recorded on the attached proformas:

i) Name of person (or herbarium) conducting identification.
ii) Number of individuals of threatened taxa at a site (indicate whether count or estimate).
iii) Extent of population (in hectares).
iv) Whether taxa is flowering or fruiting.

4. Licensing requirements

Persons conducting flora and fauna surveys must have appropriate licenses or approvals under relevant legislation. The relevant legislation and associated licenses and approvals that may be required are listed below:

National Parks and Wildlife Act 1974:

General Licence (Section 120) to harm or obtain protected fauna (this may include threatened fauna).

Licence to pick protected native plants (Section 131).

Threatened Species Conservation Act 1995:

Licence to harm threatened animal species, and/or pick threatened plants and/or damage the habitat of a threatened species (Section 91).

NSW Animal Research Act 1985:

Animal Care and Ethics Committee approval.

References:

Cropper, S. (1993) *Management of Endangered Plants*. CSIRO, Melbourne.
Davies (1984) *Methods of Censusing Birds in Australia RAOU*.

Forestry Commission of NSW (1989) *Forest types in New South Wales*. Research Note 17, Forestry Commission of NSW, Sydney.

National Parks and Wildlife Service (1995) *Vegetation survey and mapping of upper north east New South Wales*. A report by the NSW National Parks and Wildlife Service for the Natural Resources Audit Council. NSW NPWS, Sydney.

Walker, J. and Hopkins, M. (1990) *Vegetation*. Pp 58-86 in R. McDonald, R. Isbell, J. Speight, J. Walker and M. Hopkins (eds). Australian Soil and Land Survey Handbook, Inkata Press, Melbourne.

Appendix 4 - Flora and fauna survey proformas

FLORA SURVEY PROFORMA:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

SITE DETAILS:

AMG (to 100m): Easting (6 digit) | | | | | | |

Northing (7 digit) | | | | | | | |

Site Number: _____ Quadrat or random meander: _____

Locality description: _____

_____

FLORISTIC DATA:

Scientific name:	SC*	Scientific name:	SC*

*SC = Significance category (e.g. TSC Act (1995) (Schedule 1 or 2); Briggs & Leigh (1995) *Rare or Threatened Australian Plants*, ANPWS, Canberra, or other significance category as per Sherringham & Westaway (1994) *Significant plants of upper north-east NSW*. NPWS, Sydney.

DIURNAL HERPETOFAUNA / AMPHIBIAN SURVEY PROFORMA:

SITE DETAILS:

Site Number: _____

Locality description: _____

_____

SURVEY DETAILS:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

Target fauna group (e.g. frogs or reptiles): _____

Name of species for which calls played (if relevant): _____

Climatic conditions at time of commencement of survey (see standard reporting codes):

Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Species name:	Obs type*	MH type*	AMG (to nearest 100m): Easting	Northing

* See standard reporting codes

NOCTURNAL CALL PLAYBACK / SPOTLIGHT SURVEY PROFORMA:

SITE DETAILS:

AMG (to 100m):

Start transect:	Easting (6 digit)	
	Northing (7 digit)	
Finish transect:	Easting (6 digit)	
	Northing (7 digit)	

Site Number: _____

Locality description: _____

_____

TRANSECT DETAILS:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

List of calls played: _____

_____

Climatic conditions at time of commencement of survey (see codes):

Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Species name:	Obs type*	MH type*	AMG (to nearest 100m): Easting	Northing

* See standard reporting codes

ULTRASONIC CALL RECORDING SURVEY PROFORMA:

SITE DETAILS:

Site Number: _____

AMG (to 100m): Easting (6 digit) | | | | | | |
Northing (7 digit) | | | | | | | |

Locality description: _____

_____

SURVEY DETAILS:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

Sensitivity level: _____

Name of person analysing calls: _____

Climatic conditions at time of commencement of survey (see codes):
Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Scientific name:	Definite	Probable	Possible

* See standard reporting codes

HARP TRAPPING/MIST NETTING SURVEY PROFORMA:

SITE DETAILS:

Site Number: _____

AMG (to 100m): Easting (6 digit) | | | | | | |
Northing (7 digit) | | | | | | | |

Locality description: _____

_____

TRANSECT DETAILS:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

Number and type of trap (include length if mist net): _____

Climatic conditions at time of commencement of survey (see codes):
Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Scientific name:	**Comments:**

* See standard reporting codes

ELLIOT / CAGE / PITFALL TRAPPING SURVEY PROFORMA:

SITE DETAILS:

Site Number: _____

AMG (to 100m): Easting (6 digit) | | | | | | |
Northing (7 digit) | | | | | | | |

Locality description: _____

_____

TRANSECT DETAILS:

Name of surveyor: _____

Date of survey: _____

Survey start time and finish time: St: _____ Fin: _____

Number and type of trap: _____ Bait used: _____

Climatic conditions at time of commencement of survey (see codes):

Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Scientific name:	**AMG (to nearest 100m):**	
	Easting	**Northing**

* See standard reporting codes

HAIR TUBE SAMPLING / ANALYSIS SURVEY PROFORMA:

SITE DETAILS:

Site Number: _____

Locality description: _____

_____

SURVEY DETAILS:

Name of surveyor: _____

Date of survey: _____ Size of hair tube (cm diam): _____

Name of person conducting identification: _____

Climatic conditions at time of commencement of survey (see codes):

Wind: _____ Rain: _____ Night light: _____ Temperature: _____

THREATENED SPECIES RECORDED:

Scientific name:	**AMG (to nearest 100m):**	
	Easting	**Northing**

* See standard reporting codes

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX B

Compliance of the Species Impact Statement with the TSC Act and with the Requirements of the NP&WS Director-General

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX B Compliance of the Species Impact Statement for the proposed Karuah Upgrade of the Pacific Highway with the TSC Act and with the requirements of the NP&WS Director-General.

Table 1 Compliance with requirements of the *Threatened Species Conservation Act 1995.*

SECTION	ISSUE	LOCATION
109(1)	A Species Impact Statement must be in writing	complies.
109(2)	A Species Impact Statement must be signed by the principal author of the statement and by the applicant	Declaration at front of SIS.
110(1)	A Species Impact Statement must include a full description of the action proposed, including its nature, extent, location, timing and layout and, to the fullest extent reasonably practicable, the information referred to in this section	Chapter 2
110(2)	A Species Impact Statement must include:	
110(2)(a)	a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action;	Chapter 5
110(2)(b)	an assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action;	Chapter 6
110(2)(c)	for each species or population to be affected, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or threat abatement plan applying to it;	Chapter 7
110(2)(d)	an estimate of local and regional abundance of those species or populations;	Chapter 8
110(2)(e)	a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action;	not relevant [identical to 110(2)(a)].
110(2)(f)	a full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region;	Chapter 9
110(2)(g)	a full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region;	Chapter 10
110(2)(h)	a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development;	Chapter 11
110(2)(i)	a full description and justification of the measures proposed to mitigate any adverse effect of the action on the species and populations, including a compilation (in a single section of the statement) of those measures;	Chapter 12

Table 1 contd Compliance with requirements of the *Threatened Species Conservation Act 1995.*

SECTION	ISSUE	LOCATION
110(2)(j)	a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or population.	Chapter 13
110(3)	A Species Impact Statement must include information as to "*ecological communities*".	no relevant "*ecological communities*" yet defined; Director-General's requirements.
110(4)	A Species Impact Statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement.	Chapter 14
110(5)	The requirements of subsections (2) and (3) in relation to information concerning the State-wide conservation status of any species or population, or any ecological community, are taken to be satisfied by the information in that regard supplied to the principal author of the Species Impact Statement by the NP&WS, which information that Service is by this subsection authorised and required to provide.	noted.
111	Director-General's Requirements	see Table 2.

APPENDIX B contd Compliance of the Species Impact Statement for the proposed Karuah Upgrade of the Pacific Highway with the TSC Act and with the requirements of the NP&WS Director-General.

Table 2 Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
1	**Description** *Study Area*	
1.1	• *The nature of the action proposed must be detailed. This must include the timetable for the carrying out of the proposed development, the number of hectares affected, the number of hectares of each vegetation type within the study area, details of the location of any auxiliary infrastructure and all components of the proposed development.*	Chapter 2; Section 4.3
1.2	• *A vegetation map of the study area must be provided. This map will show the location and type of vegetation communities present within the study area and the scale of the map. The map must be presented in colour. The vegetation units mapped should follow a standard classification such as Walker and Hopkins (1990), and include dominant species in each vegetation unit.*	Section 4.3; Figure 4.1a & b
1.3	• *An aerial photograph (or reproduction of such a photograph), preferably colour, of the locality must be provided, separate to the vegetation map. This aerial photograph should clearly show the study area and the scale of the photograph, and be* [sic] *include an outline of the proposed corridor.*	Figure 2.1
1.4	• *A topographic map of the locality at an appropriate scale must be provided. This map will detail the location of the proposal, major land tenure units such as National Parks, Nature Reserves, and State Forests, boundaries of the study area and areas of high human activity such as townships, regional centres and major roads.*	Figure 1.3 & 2.2
1.5	• *In defining the study area consideration shall be given to possible indirect effects of the development on the area surrounding the subject site, for example habitat fragmentation, vegetation corridors, altered hydrology regimes, soil erosion or pollution, and increased human presence.*	Section 10.4
1.6	• *In describing the study area, consideration must be given to the previous land uses and the effect of these land uses on the study area. Relevant historical events may include sand mining, fire history, clearing, logging, recreational use and agricultural activities. Reference to the zoning or any proposed rezoning, and any relevant government planning initiatives (eg. Interim Deferred Forest Areas, reserve proposals, etc) of the study area must be made.*	Section 4.2

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
	Threatened and significant species habitat assessment	
1.7	• *Where suitable habitat is present for subject species in the study area, a description of the habitat characteristics must be provided for each subject species. Where the habitat of each subject species within the study area can be clearly delineated, this habitat must be represented on a map of the study area. NPWS predicted habitat models should be used as an indication of the presence of suitable habitat for subject species in the locality. These can be provided by the contact officer listed in this document.*	Section 9.1; Appendix K
1.8	• *A description of fauna and flora habitat components such as the frequency and size of tree-hollows and stags, density of understorey vegetation, substrate and presence and nature of wetlands, rock outcrops etc. must be given. Particular attention must be given to which areas are used in the study area, and for what purposes these areas are used (e.g. roosting, feeding, nesting or breeding, etc.). The location of tree hollows and stags within the study area must be mapped.*	Section 4.3.3; Figure 4.2; Appendix J
	• *The condition of habitat within the study area must be discussed, including the prevalence of introduced species. The importance of the study area for all life-cycle stages of the subject species in the locality shall be identified and discussed. Particular detail is to be provided concerning the importance of the subject site for:* Koala *Phascolactos cinereus* Squirrel Glider *Petaurus norfolcensis* Yellow-bellied Glider *Petaurus australis* Bush Stone-curlew *Burhinus grallarius* Green-thighed Frog *Litoria brevipalmata* Brush-tailed Phascogale *Phascogale tapoatafa* Glossy Black Cockatoo *Calyptorhynchus lathami* Tiger Quoll *Dasyurus maculatus*	Section 4.2.3 & 4.3.3; Tables 4.1 & 4.2; Chapter 9
1.9	• *A description of the habitat requirements of threatened and significant species likely to occur in the study area must be provided. Particular attention must be paid to the following species:* Koala *Phascolactos cinereus* Squirrel Glider *Petaurus norfolcensis* Yellow-bellied Glider *Petaurus australis* Bush Stone-curlew *Burhinus grallarius* Green-thighed Frog *Litoria brevipalmata* Brush-tailed Phascogale *Phascogale tapoatafa* Glossy Black Cockatoo *Calyptorhynchus lathami* Tiger Quoll *Dasyurus maculatus*	Section 7.2; Appendix F

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
1.10	• *A list of subject species must be provided. In determining these species, consideration shall be given to the habitat types present within the study area, records of subject species in the locality and their known distribution. Criteria to be used to assess the conservation significance of species include those outlined by Sheringham and Westaway (1995) (Table 1).*	Sections 5.1 & 5.2; Table 5.1 & 5.3; Appendix F
1.11	• *The subject species must consider, but need not be limited to, the following species:* FAUNA Koala *Phascolactos cinereus* Squirrel Glider *Petaurus norfolcensis* Yellow-bellied Glider *Petaurus australis* Bush Stone-curlew *Burhinus grallarius* Green-thighed Frog *Litoria brevipalmata* Brush-tailed Phascogale *Phascogale tapoatafa* Glossy Black Cockatoo *Calyptorhynchus lathami* Tiger Quoll *Dasyurus maculatus* Powerful Owl *Ninox stenua* Masked Owl *Tyto novaehollandiae* Black-necked Stork *Ephippiorhynchus asiaticus* Barking Owl *Ninox connivens* Grass Owl *Tyto capensis* Green and Golden Bell Frog *Litoria aurea* Wallum Frog *Crinia tinnula* Eastern Chestnut Mouse *Pseudomys gracilicaudatus* Black Bittern *Ixobrychus flavicollis* Swift Parrot *Lathamus discolor* Turquoise Parrot *Neophema pulchella* Regent Honeyeater *Xanthomyza phrygia* Common Wombat *Vombatus ursinus* (locally significant species) Common Bent-wing Bat *Minopterus schreibersii* Large-footed Mouse-eared Bat *Myotis adversus* Little Bent-wing Bat *Minopterus australis* Greater Broad-nosed Bat *Scoteanax rueppellii* Osprey *Pandion haliaetus* Lesser Sand Plover *Charadrius mongolus* Pied Oystercatcher *Haematopus longirostris* Sooty Oystercatcher *Haematopus fuliginosus* Australasian Bittern *Botaurus poiciloptilus* Chestnut-rumped Heathwren *Hylacola pyrrhopygia* (NEFBS priority species) New Holland Mouse *Pseudomys novaehollandiae* (NEFBS priority species) FLORA Black-eyed Susan *Tetratheca juncea* *Hakea bakeriana* Christmas Bell *Blandfordia grandiflora* Swamp Mahogany *Eucalyptus robusta* *Eucalyptus fergusonii* *Gonocarpus salsoloides* *Syzygium paniculatum* *Grevillea guthrieana (obustiflora)*	Chapter 3; Tables 3.1 & 3.4

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
1.11 contd	• *Databases such as the NPWS Atlas of NSW Wildlife and NPWS predictive habitat models should be used to assist in compiling the list.*	Appendix K
	Survey Methods	
1.12	• *A fauna and flora survey is to be conducted in the study area. Targeted surveys must be conducted for all subject species. As a minimum, survey methods must follow those detailed in Appendix 3, unless justification for variation from these methods can be provided to the satisfaction of NPWS. Field survey and identification of species habitat must be undertaken by suitably qualified and experienced persons. Species of taxonomic uncertainty must be confirmed by a recognised authority such as the Australian Museum or NSW National Herbarium*	Section 3.1.2 & 3.1.3; Tables 3.1, 3.3 & 3.4; Appendix C
1.13	• *A full description of the methods used in the fauna and flora surveys and habitat assessment must be provided, including survey techniques employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and prevailing weather conditions. Where appropriate, this information must be provided in map format at the same scale as previous maps. Surveys must be undertaken during seasons in which the subject species are most likely to be detected and, where possible, in appropriate climatic conditions. A table must be provided indicating compliance with survey methods provided in Appendix 3.*	Section 3.1; Tables 3.1, 3.2 & 3.5; Figures 3.2, 3.2a & b ; Appendix C
1.14	• *The impact of the season, prevailing weather conditions, and limitations of survey techniques employed must be considered and discussed with respect to the results of the survey.*	Section 3.2; Appendix D
1.15	• *Any areas which may act as local or regional corridors between the study area and adjacent areas of likely habitat for subject species must be identified and described. NPWS may be able to provide some detail on values of corridors in the subject area.*	Section 4.4; Figure 4.3
1.16	• *A full list of the protected fauna and native plant species (as defined by the National Parks and Wildlife Act 1974) found during the course of surveys must be included. Such information is indicative of the habitat quality of the site. This list must indicate whether the species is introduced, significant or threatened and the site or habitat in which each species was recorded.*	Section 4.5; Table 4.3; Appendicies G, H & I
	Survey results and discussion	
1.17	• *The location of the subject species recorded during the SIS survey and other recent surveys where available must be represented on a map of the study areas. The map base must include the topographic features shown on the vegetation map and be provided in map format at the same scale as previous maps.*	Chapter 5; Figures 5.1 & 5.2, Appendix I

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
1.18	• *Where available, threatened species information provided must include species name, date recorded, name of person who made the record, type of record (e.g. scat identification, trapped, sighted), specific use of habitat (e.g. nesting, roosting, foraging), and number of individuals recorded. This information must be presented on the proformas provided in Appendix 4.*	Sections 5.1 & 5.2; Tables 5.2, 5.5 & 5.6; Appendix I
1.19	• *Discussion and justification must be included in the determination of which of the subject species are regarded as affected species for the purpose of the SIS.*	Chapter 6
2	**Assessment of likely impacts**	
2.1	*For each affected species, the SIS shall state the following:* • *The location, nature and extent (number of hectares) of each of the species' habitat and vegetation community to be removed or modified as a result of the proposed action;* • *the potential impact of the removal or modification of habitat; and* • *the likely contribution of the proposed action to all threatening processes (not restricted to key threatening processes) acting on populations of these species in the locality.* • *as assessment of whether the affected species, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region and the subregion.*	Section 10.1
2.3	• *A discussion of other populations of affected species in the locality must be provided. A discussion of the long term security and tenure of other habitats (ie outside the subject site) of affected species must be provided with regards to tenure, zoning and land management practices. The relative significance of the subject site for affected species in the locality must be provided.*	Section 10.2
2.4	• *If local or regional habitat corridors for affected species are present within the subject site, the impact of the proposal on these areas must be discussed. Impacts of barrier effects must be discussed for both flora and fauna.*	Section 10.3
2.5	• *Consideration must be given to possible indirect effects of the action on the area surrounding the subject site, for example, edge effects on vegetation and habitat, altered hydrological regimes, soil erosion or pollution.*	Chapter 10.4

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
3	**Mitigation**	
3.1	• *Where a draft recovery plan prepared in accordance with the NSW TSC Act is relevant to any affected species, consideration must be given to the information contained in these plans and whether any draft recovery plan recommendation is applicable to the proposal.*	advised by both Hurstville and Northern Zone NP&WS offices that draft recovery plans are not available as yet.
3.2	• *In discussing alternatives to the proposal, justification must be provided for the decision to select the current proposal.*	Chapter 11
3.3	• *Detail must be provided of the measures proposed to mitigate the effect of the proposal. Measures for minimising the number of road kills of affected species should be identified. These may include fauna over- or underpasses, exclusion fencing, tunnels, retention of median vegetation for arboreal species, and appropriate revegetation and habitat restoration in adjacent areas. The techniques used must employ current best practice and be supported by a literature review.*	Section 12.1
3.4	• *Consideration must be given to developing long term management strategies to protected areas within the study area which are of particular importance for the affected species. These must include proposals to restore or improve habitat, and/or to provide compensatory habitat. The strategies should identify the long term objectives for the subject site.*	Section 12.2
3.5	• *Proposals for monitoring the effectiveness of the proposed mitigation measures and the impact of the proposal on affected species, must be provided and discussed. Details of such monitoring must be provided including site location, frequency of monitoring and duration of program. A discussion of possible options for changes to mitigation measures in the light of monitoring results must be included.*	Section 12.3
3.6	• *Details of any habitat restoration or improvement programmes proposed for the study area must be provided, including the proposed timeframe for restoration/improvement, and the likely impact on flora and fauna, particularly during the time between the impact on the habitat and any habitat restoration/improvement. Where possible habitat restoration and rehabilitation works should commence before project completion.*	Section 12.4

APPENDIX B contd Compliance of the Species Impact Statement for the proposed Karuah Upgrade of the Pacific Highway with the TSC Act and with the requirements of the NP&WS Director-General.

Table 2 contd Compliance with requirements of the Director-General of the NSW NP&WS.

SECTION	ISSUE	LOCATION
4	**Additional Information**	
4.1	*A list of approvals required must be provided, including:* • *any consents required under Part IV of the Environmental Planning and Assessment Act 1979 including the name of the consent authority and when it is proposed to make the development application; or* • *any approvals required under Part V of the Environmental Planning and Assessment Act 1979 including the name of the determining authority(ies), the basis for the approval and when these approvals are proposed to be obtained.*	Chapter 13
4.2	• *Flora and fauna locality data recorded during surveys must be provided. This information is to be provided on NPWS proformas provided in Appendix 4, and include information for all fields listed on these proformas.*	NP&WS Northern Zone Office
Appendix 3	• *the following survey techniques have been developed to survey threatened and protected species in a cost-effective manner, and to reflect methods currently used. They are to be regarded as a minimum requirement; additional survey should be undertaken if perceived to be necessary.*	Chapter 3; Appendix C & E

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX C

Flora & Fauna Survey Methods

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX C Details of flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah for the Route Selection - Flora & Fauna Constraints report (Gunninah 1997a), Proposed Horse Island Route - Flora & Fauna Assessment report (Gunninah 1999b), and Karuah Bypass - Species Impact Statement (Gunninah 1999c).

Part A Proposed Pacific Highway Upgrade Karuah, NSW, Route Selection-Flora & Fauna Constraints report (Gunninah 1997a). Details of the total flora and fauna effort (transects and trap nights/hours) invested into each survey method and months over which they were conducted are outlined in Table A.4 for Part A (Gunninah 1997a) and as a total for Parts A, B and C (Gunninah 1997a, 1999b & c) in Table C.12.

1 FLORA

A general botanical survey of the study area was conducted on the 24th and 25th of April 1997. The study area was traversed by walked random meander surveys (Cropper 1993), with all vegetation communities being described and mapped, and the species composition of each community being listed (Appendix H). Plant communities were classified by structural and floristic characteristics according to Specht (1970). Plant species identifications accord with the recent nomenclature of Harden (1990, 1991, 1992 and 1993), and classifications described in *Telopea* and *Cunninghamia*.

Particular attention was paid to the possible presence of threatened flora species known to occur in the region. The conservation significance of plant communities and individual plant species in the national context was established with reference to Briggs & Leigh (1996), and in the state context according to Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and State Environmental Planning Policy 14 - Coastal Wetlands (SEPP 14).

Targeted surveys for *Tetratheca juncea*, a threatened species which has been recorded recently at several locations near Karuah (Ecotone 1995; Gunninah 1997a) were conducted in areas of suitable woodland/open forest habitat within the study area. Particular attention was also paid to the possible presence of *Gonocarpus salsoloides*, another threatened species known to occur in the general area (NP&WS Wildlife Atlas).

Other botanical investigations conducted previously in the general vicinity were reviewed for information regarding the flora in this locality and in the surrounding area (Ecotone 1995; Gunninah 1997b, c). These references were checked for descriptions of similar vegetation types, and for records of threatened plant species which could possibly occur in the study area. Records of threatened flora species recorded within 10km of the study area and which could possibly occur in the vicinity were also obtained from the National Parks & Wildlife Service (NP&WS) Wildlife Atlas.

2 FAUNA

Specific fauna survey methods and survey effort are detailed below, with survey locations indicated in Figure 1. Results of the fauna surveys are provided in Appendix I. Details of weather conditions throughout the survey are provided in Appendix D.

2.1 Trapping Transects

Trapping surveys for small and medium-sized mammals were conducted in areas of suitable habitat within the study area and immediate vicinity from the 22nd-26th of April 1997. A combination of standard fauna trapping techniques were utilised at a maximum of nine survey transects at selected representative survey locations (Table A.1; Figure 1). Survey effort is outlined in Table A.2.

2.2 Microchiropteran Bat Surveys

Microchiropteran bat surveys were conducted using one direct method (harp trapping) and one indirect method (Anabat II ultrasonic call recording), in suitable habitat within the study area and immediate vicinity.

2.2.1 Anabat II microchiropteran bat call detectors

- eight survey sites located in woodland/open forest communities (Table A.3; Figure 1);

- conducted over four nights (21st-24th of April 1997 inclusive);
- all night recording at six of the survey locations, 3.5 and 3.75 hours recorded at the two remaining sites (24/4/97), due to adverse conditions (rain & wind); and
- tapes sent to Mr Glenn Hoye[1] for analysis.

2.2.2 Harp traps

- four trap locations, two trap-nights at each location (Table A.3; Figure 1);
- conducted over four nights (22nd-25th of April 1997), total of eight trap-nights; and
- traps placed in likely fly-ways or gullies (where appropriate).

Table A.1 Details of the trapping transects indicating the number of different trap types deployed at each transect.

Transect	Elliott traps (ground-based)	Elliott traps (tree-mounted)	Cage traps	Hair Tubes
1	21	3	1	2
2	20	3	1	2
3	23	-	1	1
4	19	3	1	1
5	16	8	1	1
6	18	6	1	3
7	-	-	-	5
8	-	-	-	6
9	-	-	-	6

Table A.2 Details of mammal trapping survey effort.

Method	Trap-nights	Bait
Ground-based Elliott traps	468	Peanut butter/honey/rolled oats
Tree-mounted Elliott traps	83	Peanut butter/honey/rolled oats
Cage traps	24	Peanut butter/honey/rolled oats OR Chicken
Hair tubes*	119	Peanut butter/honey/rolled oats OR Chicken

* hair samples sent to Mr AB Rose[2] for analysis.

[1] Glenn Hoye-Fly By Night Bat Surveys Pty Ltd, Belmont NSW.

[2] Anthony Rose-Hair Tube, bone and predator scat identifications and analysis, Fortser NSW.

Table A.3 Location of Anabat and harp trap sites within the study area and immediate vicinity (Figure 1).

Date	Anabat Recording Location (AMG)		Harp Trap Locations Location (AMG)	
21/4/97	402210 402250	6386920 6386800	no trapping conducted	
22/4/97	401100 401300	6386800 6387150	400900 400950	6387000 6386780
23/4/97	401100 401800	6387100 6386500	400900 400950	6387050 6386700
24/4/97	402040 402010	6386110 6386500	401100 401980	6387050 6386700
25/4/97	no Anabat recording		401100 401980	6387050 6386700

2.3 Spotlighting

Extensive spotlighting surveys, including both walked and driven surveys, conducted throughout the study area and immediate vicinity, but were concentrated in areas of less disturbed woodland/open forest surrounding the freshwater wetland and in the western portion of the study area.

- spotlighting over four nights (21st-24th of April 1997 inclusive);
- total of approximately thirteen person-hours; and
- records maintained of all species observed or identified by calls.

2.4 Herpetological Surveys

- active diurnal searches were conducted throughout habitats within the study area and immediate vicinity, but were concentrated in areas of less disturbed woodland/open forest surrounding the freshwater wetland and in the western portion of the study area;
- searches involved turning logs, rocks and unnatural debris (such as building materials, tyres, rubble stock piles *etc*), searching decorticating and fallen bark, rock outcrops, leaf-litter and other suitable substrates;
- nocturnal surveys were conducted during spotlighting surveys and were concentrated around wet soaks in paddocks, along roads after rain, along the edge of the freshwater wetland and under vegetative debris (such as fallen logs) and refuse (*eg* plastic); and
- records maintained of all species observed or identified by call.

2.5 Bird Surveys

- general diurnal bird surveys conducted within all habitats in the study area, including estuarine wetlands (saltmarsh and mangroves, freshwater wetlands, woodland/open forest and agricultural and other disturbed areas);

- spotlighting surveys for nocturnal species (as for spotlighting details above);
- records maintained of all species observed or identified by call; and
- owl call playback was attempted but was unsuccessful due to equipment failure.

2.6 Koala Surveys

- four Koala survey transects selected in representative areas of potential habitat (Figure 1);
- a total of seventy-eight trees were examined for signs of Koala scratches and for the presence of Koala scats located around their bases; and
- trees with a Diameter at Breast Height (DBH) of >30cm were selected where available and preferred Koala food trees targeted, including Forest Red Gum *Eucalyptus tereticornis*, Grey Gum *E propinqua*, Spotted Gum *Corymbia maculata* and Stringybark and Ironbark species. Where preferred food trees were not present, other healthy mature trees were selected for survey.

2.7 General Habitat Searches

- habitat searches to detect the presence or absence of tree-hollows and tree-hollow sizes and other features of relevance for native fauna within the study area;
- general habitat searches for indirect evidence of fauna, including diggings, scratchings, remains, scats, prints *etc*; and
- scats, bones or hair collected sent to Mr AB Rose for analysis.

2.8 Opportunistic Observations

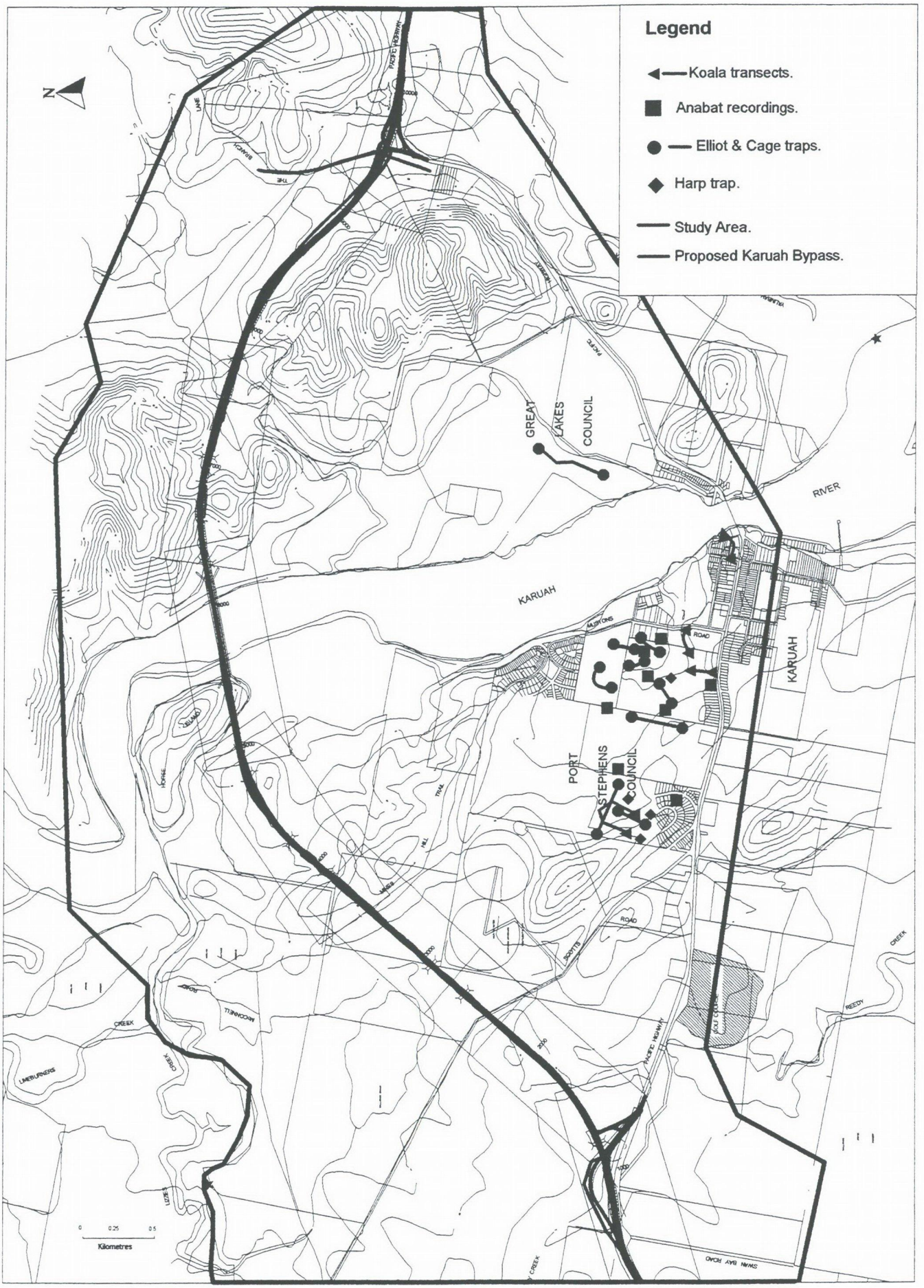
- records maintained of all species observed or identified from calls whilst conducting all survey work and travelling between survey sites.

APPENDIX C contd Details of flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah for the Route Selection - Flora & Fauna Constraints report (Gunninah 1997a), Proposed Horse Island Route - Flora & Fauna Assessment report (Gunninah 1999b), and Karuah Bypass - Species Impact Statement (Gunninah 1999c).

Table A.4 Summary of total effort (transects & nights/hours) and months, for each of the flora and fauna methods conducted along the proposed upgrade of the Pacific Highway at Karuah for: (A) Route Selection-Flora & Fauna Constraints report (Gunninah 1997a).

REPORT	SURVEY METHOD	EFFORT		MONTHS
		TRANSECTS	NIGHTS/HOURS	
A	**FLORA**	NA	40 hours	April 1997
	FAUNA			
	Trapping			
	Elliott:			
	Ground	6 (117) *	468 trap nights	April 1997
	Tree	6 (23) *	83 trap nights	April 1997
	Cage	6 (6) *	24 trap nights	April 1997
	Hair Tube	9 (27) *	119 trap nights	April 1997
	Microchiropteran Bat Surveys			
	Anabat	8	6 nights & 6.25 hours	April 1997
	Harp Traps	8	8 nights	April 1997
	Spotlighting	NA	13 hours	April 1997
	Herpetological Searches	Continuous & opportunistic	NA	April 1997
	Birds Surveys	Continuous & opportunistic	NA	April 1997
	Koala Surveys	4 (78 trees)	NA	April 1997
	General Habitat Searches	Continuous & opportunistic	NA	April 1997

* The number inside the brackets indicates the total number of traps deployed for that particular survey method.



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Gunninah Environmental Consulants

Phone: (02) 9906 5436 Fax: (02) 9906 7770

Appendix C Figure 1
1997a fauna survey locations within the study area.

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Part B Proposed Pacific Highway Upgrade Karuah, NSW, Proposed Horse Island Route-Flora & Fauna Assessment report (Gunninah 1999b). Details of the total flora and fauna effort (transects and trap nights/hours) invested into each survey method and months over which they were conducted are outlined in Table B.6 for Part B (Gunninah 1999b) and as a total for Parts A, B and C (Gunninah 1997a, 1999b & c) in Table C.12.

1 FLORA

Detailed botanical surveys of the study area were conducted from the 10th to 13th of November (inclusive) and on the 10th of December 1998. These surveys involved fourteen extensive random surveys (Cropper 1993) and thirty dedicated quadrats along the alignment (Table B.1). The vegetation quadrats were standard 20m x 20m (*ie* 400m^2), and were intensively surveyed, with all plant species present recorded (Appendix H).

All vegetation communities present were described, mapped (Chapter 4; Figure 4.1), and classified with reference to the structural and floristic characteristics described in Specht (1970). The conservation status of vegetation communities in the study area was established with reference to Benson (1989), Specht *et al* (1995) and Hager & Benson (1992).

An inventory of all plant species in random surveys and in the dedicated quadrats was obtained (Appendix H). Plant species identifications were made in accordance with the nomenclature of Harden (1990, 1991, 1992, 1993), and with recent classifications described in *Telopea* and *Cunninghamia*. The conservation status of plant species in the study area was established with reference to Briggs & Leigh (1996) in the national context, and to Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) in the state context.

Particular attention was paid to flora species of conservation significance which may be anticipated to occur in the study area. Relevant data (including threatened species records) were obtained from previous reports conducted in the immediate vicinity (Gunninah 1997a) and in the surrounding area (Ecotone 1995; Gunninah 1997b, c & d). Records of threatened flora species were also obtained from a search of records listed within 10km of the Horse Island Route on the NSW National Parks & Wildlife Service (NP&WS) Wildlife Atlas.

Targeted surveys were conducted in woodland/open forest communities in the study area for *Tetratheca juncea*, a threatened species which has been recorded recently in the surrounding area (Ecotone 1995; Gunninah 1997a, c & d). Broad-scale searches were conducted during the initial study area inspection (December 1997) within the known flowering period of this species (generally July to December - Harden 1993), given its cryptic nature when not in flower. Attention was also paid to the possible presence of *Gonocarpus salsoloides*, another threatened species known to occur in the general area (NP&WS Wildlife Atlas). More detailed and extensive surveys were conducted for *T juncea* in November 1998, and a number of other plant species of significance (including *G salsoloides*, *Eucalyptus robusta*, *Hakea bakeriana* and *Blandfordia grandiflora*) were also targeted.

2 FAUNA

Specific fauna survey methods and survey effort are detailed below, with survey locations indicated on Figure 2. Results of the fauna surveys are provided in Appendix I. Details of weather conditions throughout the survey are provided in Appendix D.

2.1 Trapping Transects

Trapping surveys for small and medium-sized mammals were conducted in areas of suitable habitat along the Horse Island route and in the surrounding area from the 17th of February to 3rd of March 1998. A combination of standard fauna trapping techniques were utilised at five survey transects at selected representative survey locations (Table B.2; Figure 2). Each trapping transect was sampled on each of four survey nights. Survey effort is outlined in Table B.3.

Table B.1 Location and date of each of the thirty dedicated flora quadrats conducted along the proposed Horse Island route.

Quadrat	Date	Location (AMG)	
1	10/11/98	398800	6387300
2	10/11/98	399600	6387800
3	10/11/98	399200	6387500
4	11/11/98	398700	6387800
5	11/11/98	399800	6388000
6	11/11/98	399800	6388400
7	11/11/98	400200	6388700
8	11/11/98	400400	6389000
9	11/11/98	400300	6388800
10	11/11/98	400500	6389100
11	11/11/98	400600	6389500
12	11/11/98	401400	6390000
13	11/11/98	401600	6389700
14	11/11/98	401900	6390000
15	11/11/98	401600	6390100
16	12/11/98	403800	6389800
17	12/11/98	404100	6389900
18	12/11/98	404000	6390300
19	12/11/98	404500	6388400
20	12/11/98	404300	6389900
21	12/11/98	404800	6390000
22	12/11/98	404600	6390200
23	13/11/98	405600	6389300
24	13/11/98	405700	6389000
25	13/11/98	405700	6388800
26	13/11/98	406400	6388600
27	10/12/98	405900	6388700
28	10/12/98	406600	6388800
29	13/11/98	403400	6389700
30	10/12/98	399800	6388800

Table B.2 Details of trapping transects, indicating the number of different trap types deployed at each transect.

Transects	Elliott traps (ground-based)	Elliott traps (tree-mounted)	Cage traps	Hair Tubes
1	20	5	1	-
2	19	5	1	6
3	20	5	1	5
4	15	-	1	-
5	19	5	1	5

Table B.3 Details of mammal trapping survey effort. Each trapping transect was sampled on each of four survey nights, with hair tubes deployed for thirteen nights.

Method	Trap-nights	Bait
Ground-based Elliott traps	372	Peanut butter/honey/rolled oats
Tree-mounted Elliott traps	80	Peanut butter/honey/rolled oats
Cage traps	54	Peanut butter/honey/rolled oats OR Chicken
Hair tubes	650	Peanut butter/honey/rolled oats OR Chicken

2.2 Microchiropteran Bat Surveys

Microchiropteran bat surveys were conducted using one direct method (harp trapping) and one indirect method (Anabat II ultrasonic call recording), in suitable habitat along the route and in the immediate vicinity.

2.2.1 Anabat II microchiropteran bat call detectors

- seven survey sites located in woodland/open forest communities (Table B.4; Figure 2);
- conducted over four nights (2nd-5th of March 1998 inclusive); and
- tapes sent to Mr Glenn Hoye for analysis.

Table B.4 Location of Anabat recording sites along the route and in the immediate vicinity (Figure 2).

Date	Anabat Survey Site No	Location (AMG)
2/3/98	1	400100 6388200
	2	399850 6387850
	3	400650 6389500
3/3/98	4	399740 6387580
4/3/98	5	403450 6389760
	6	403750 6389800
5/3/98	7	403950 6390050

2.2.2 Harp traps

- five trap locations, between two and four nights trapping at each location (Table B.5; Figure 2);
- conducted over four nights (3rd - 6th January): total of twelve trap-nights; and
- traps placed in likely fly-ways, such as roads, clearings and gullies (where appropriate).

Table B.5 Location of harp trap sites along the alignment and in the immediate vicinity, with details of survey effort (Figure 2).

Trap No	Location (AMG)		Survey Effort
1	399700	6387800	2 trap-nights
2	400150	6388850	2 trap-nights
3	400625	6389050	4 trap-nights
4	403300	6389700	2 trap-nights
5	404050	6390100	2 trap-nights

2.3 Spotlighting

Extensive spotlighting surveys, including both walked and driven surveys, were conducted along the route alignment and in the immediate vicinity (Figure 2).

- spotlighting over four nights (2nd-5th of March 1998 inclusive);
- total of approximately seventeen person-hours; and
- records maintained of all species observed or identified by calls.

2.4 Herpetological Surveys

- active diurnal searches were conducted throughout habitats along the alignment and in the immediate vicinity, particularly during and following rain over the period from the 27th of February to the 3rd of March 1998;
- searches involved turning logs, rocks and unnatural debris (such as building materials, tyres, rubble stock piles *etc*), searching decorticating and fallen bark, rock outcrops, leaf-litter and other suitable substrates;
- nocturnal surveys were conducted during spotlighting surveys and were concentrated around wet soaks in paddocks, along roads after rain, along the edge of the freshwater wetland and under vegetative debris (such as fallen logs) and refuse (*eg* plastic); and
- records maintained of all species observed or identified by call.

2.5 Bird Surveys

- general diurnal bird surveys conducted within all habitats along the proposed route, including estuarine wetlands (saltmarsh and mangroves), freshwater wetlands (sedgeland and swamp forest), woodland/open forest and agricultural and other disturbed areas;
- spotlighting surveys for nocturnal species (as for spotlighting details above);

- owl call playback at two locations in the general vicinity of the proposed Horse Island route (Figure 2); and
- records maintained of all species observed or identified by call.

2.6 Koala Surveys

- sixteen Koala survey transects selected in representative areas of potential habitat (Figure 2);
- a total of 193 trees were examined for signs of Koala scratches and for the presence of Koala scats located around their bases; and
- trees with a Diameter at Breast Height (DBH) of >30cm were selected where available and preferred Koala food trees targeted, including Tallow-wood *Eucalyptus microcorys*, Forest Red Gum *E tereticornis*, Grey Gums *E punctata* and *E propinqua*, *etc*. Where preferred food trees were not present, other healthy mature trees were selected for survey.

2.7 General Habitat Searches

- habitat searches to detect the presence or absence of tree-hollows and tree-hollow sizes and other features of relevance for native fauna along the proposed alignment and in the surrounding area;
- general habitat searches for indirect evidence of fauna, including diggings, scratchings, remains, scats, prints *etc*; and
- scats, bones or hair collected sent to Mr AB Rose for analysis.

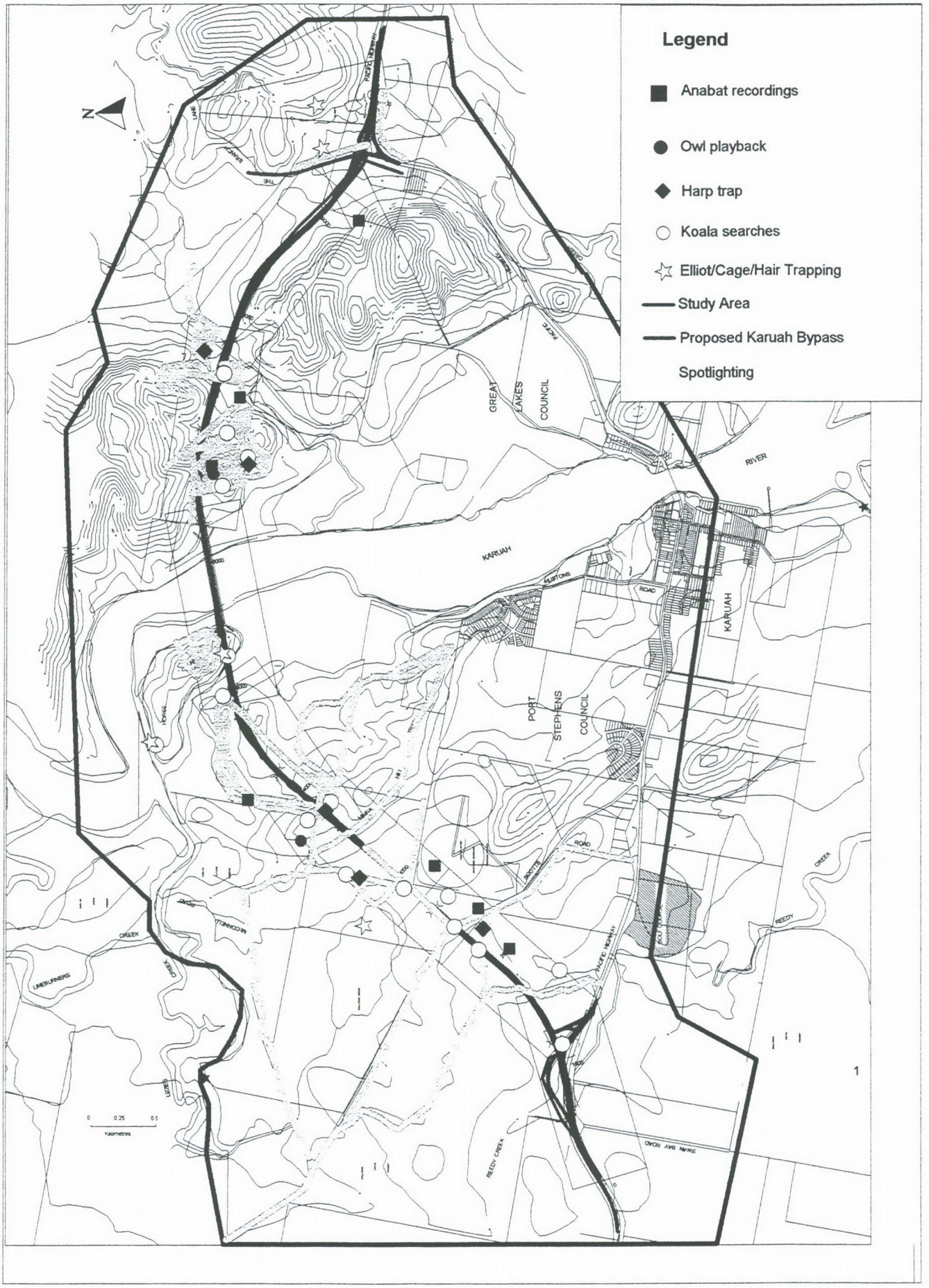
2.8 Opportunistic Observations

- records maintained of all species observed or identified from calls whilst conducting all survey work and travelling between survey sites.

Table B.6 Summary of total effort (transects & nights/hours) and months, for each of the flora and fauna methods conducted along the proposed upgrade of the Pacific Highway at Karuah for: (B) Proposed Horse Island Route-Flora & Fauna Assessment report (Gunninah 1999b).

REPORT	SURVEY METHOD	EFFORT		MONTHS
		TRANSECTS	NIGHTS/HOURS	
B	**FLORA**			
	Random	14	14 hours	Nov & Dec 1998
	Quadrats	30	15 hours	Nov & Dec 1998
	FAUNA			
	Trapping			
	Elliott: Ground	5 (93) *	372 trap nights	Feb & March 1998
	Tree	2 (20) *	80 trap nights	Feb & March 1998
	Cage Traps	5 (5) *	54 trap nights	Feb & March 1998
	Hair Tubes	3 (16) *	650 trap nights	Feb & March 1998
	Microchiropteran Bat Surveys			
	Anabat	7	7 nights	March 1998
	Harp Traps	5	12 nights	Jan 1998
	Spotlighting	NA	17.5 hours	March 1998
	Herpetological Searches	Continuous & opportunistic	NA	Jan - March 1998
	Bird Surveys	Continuous & opportunistic	NA	Jan - March 1998
	Koala Surveys	16 (193 trees)	NA	March 1998
	General Habitat Searches	Continuous & opportunistic	NA	Jan - March 1998

* The number inside the brackets indicates the total number of traps deployed for that particular survey method.



Karuah SIS
Project No. 98071

Gunninah Environmental Consulants

Phone: (02) 9906 5436 Fax: (02) 9906 7770

Appendix C Figure 2
FFA (1999b) fauna survey locations within the study area.

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APPENDIX C contd Details of flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah for the Route Selection - Flora & Fauna Constraints report (Gunninah 1997a), Proposed Horse Island Route - Flora & Fauna Assessment report (Gunninah 1999b), and Karuah Bypass - Species Impact Statement (Gunninah 1999c).

Part C Proposed Pacific Highway Upgrade Karuah, NSW, Proposed Horse Island Route-Species Impact Statement (Gunninah 1999c). Details of the total flora and fauna effort (transects and trap nights/hours) invested into each survey method and months over which they were conducted are outlined in Table C.11 for Part C (Gunninah 1999c) and as a total for Parts A, B and C (Gunninah 1997a, 1999b & c) in Table C.12.

1 FLORA

Detailed botanical surveys of the study area were conducted from the 10th to 13th of November (inclusive) and on the 10th of December 1998. These surveys involved 14 extensive random surveys (Cropper 1993) and thirty dedicated quadrats along the alignment (Table B.1 Part B), according to the survey requirements of the NP&WS Director-General (Appendix A). The vegetation quadrats were standard 20m x 20m (*ie* 400m^2), and were intensively surveyed, with all plant species present recorded, as detailed in Part B of this Appendix (Appendix H).

More detailed and extensive surveys were conducted for the '*subject species*', according to the requirements of the NP&WS Director-General (Appendix A). *Tetratheca juncea*, *Gonocarpus salsoloides*, *Eucalyptus robusta*, *Hakea bakeriana* and *Blandfordia grandiflora* as further detailed in Part B of this Appendix.

2 FAUNA

Specific fauna survey methods and survey effort are detailed below, with survey locations indicated on Figure 3a and b. Results of the fauna surveys are provided in Appendix I. Details of weather conditions throughout the survey are provided in Appendix D.

2.1 TRAPPING TRANSECTS

Trapping surveys for small and medium-sized mammals (and potentially reptiles) were conducted in areas of suitable habitat along the Horse Island Route option and in the surrounding area from the 26th to 29th of November 1998 and 16th to 19th January 1999 on the eastern side of the Karuah River, from the 16th to 19th of December 1998 on the western side of the River. A combination of trapping techniques were utilised along eight survey transects at selected representative survey locations (Table C.1; Figure 3b). Each trapping transect was sampled on each of four survey nights. Survey effort is outlined in Table 2.2.

Hair tubes were deployed between the 26th of November and the 5th of December, the 20th of December 1998 and the 2nd of January 1999, and the 30th of December 1998 and the 11th of January 1999. Transects 1 - 4 consisted of ten ground-based hair tubes, and transects 5 - 12 consisted of eight ground-based and three tree-based hair tubes, of which six were baited with meat and five were baited with a standard mixture of honey, oats and peanut butter. Hair tubes were deployed for between ten and thirteen nights, as detailed in Table C.2 and Table C.3.

Pitfall traps were utilised from the 26th to the 29th of November 1998, and the 6th to 9th of August 1999. Each transect consisted of ten pitfall traps which were sampled on each of four survey nights (Table C.2, C.4; Figure 3b).

2.2 MICROCHIROPTERAN BAT SURVEYS

Microchiropteran bat surveys were conducted using one direct method (harp trapping) and one indirect method (Anabat II ultrasonic call recording), in suitable habitat along the route option and in the immediate vicinity.

2.2.1 Anabat II microchiropteran bat call detectors

- eighteen survey sites located in woodland/open forest communities (Table C.5; Figure 3b);

- recordings conducted on the 27th of August, the 7th, 24th, 26th and 27th of November, 29th and 30th of December 1998, and 7th to 10th of August 1999, with transects 1 - 11 having recordings conducted overnight and transects 12 - 18 conducted for 30 minutes;
- tapes sent to Mr Glenn Hoye for analysis.

2.2.2 Harp traps

- nine trap locations; three nights trapping at each location (Table C.6; Figure 3b);
- traps 1 - 3 conducted from the 27th to 29th of November (nine trap nights), traps 4 to 7 conducted from the 22nd to 24th of December 1998 (twelve trap nights), and traps 8 and 9 conducted from the 16th to 18th of January 1999 (six trap nights); and
- traps placed in likely fly-ways, such as roads, clearings and gullies (where appropriate).

Table C.1 Date, location and number of different types of traps deployed at each transect (Figure 3b).

Transect	Date	Location (AMG)		Elliott traps (ground-based)	Elliott traps (tree-mounted)	Cage traps
1	26/11/98 - 05/12/98	403250 403300	6389900 6389150	25	10	1
2	20/12/98 - 02/01/99	405100 404900	6388900 6388775	25	10	1
3	20/12/98- 02/01/99	406250 406450	6389200 6389375	25	10	1
4	20/12/98- 02/01/99	406500 406650	6389300 6389500	25	10	1
5	20/12/98 - 02/01/99	401750 401825	6389900 6390150	25	10	1
6	20/12/98 - 02/01/99	400600 400750	6389200 6389350	25	10	1
7	30/12/98 - 11/01/99	400050 399800	6388650 6388650	25	10	1
8	30/12/98 - 11/01/99	399450 399700	6387225 6387225	25	10	1

Table C.2 Details of trapping survey effort.

Method	Trap-nights	Bait
Ground-based Elliott traps	800	Peanut butter/honey/rolled oats
Tree-mounted Elliott traps	320	Peanut butter/honey/rolled oats
Cage traps	32	Peanut butter/honey/rolled oats
Ground-based hair tubes	916	Peanut butter/honey/rolled oats OR Chicken
Tree-based hair tubes	306	Peanut butter/honey/rolled oats OR Chicken
Pitfall traps	80	No bait

Table C.3 Date, location, type and quantity of hair-tubes deployed at each transect (Figure 3b).

Transect	Date	Location (AMG)		Hair Tubes	
				Ground-based	Tree-based
1	26/11/98-05/12/98	403250	6389900	10	-
2	26/11/98-05/12/98	405100	6388900	10	-
3	26/11/98-05/12/98	406250	6389200	10	-
4	26/11/98-05/12/98	406500	6389300	10	-
5	20/12/98-02/01/99	399350	6387250	8	3
6	20/12/98-02/01/99	399800	6388200	8	3
7	20/12/98-02/01/99	399800	6387650	8	3
8	20/12/98-02/01/99	399500	6389800	8	3
9	20/12/98-02/01/99	401200	6388500	8	3
10	20/12/98-02/01/99	400950	6390000	8	3
11	31/12/98-11/01/99	403300	6390300	8	3
12	31/12/98-11/01/99	403980	6389900	8	3

Table C.4 Date, location and quantity of pitfall traps deployed at each transect (Figure 3b).

Transect	Date	Location (AMG)		Pitfall Traps
1	26-29/11/98	405200	6388800	10
2	06-09/08/99	399500	6387850	10

Table C.5 Date, location and survey effort of Anabat recording at each transect (Figure 3b).

Transect	Date	Location (AMG)		Survey Effort
1	28/08/98	404900	6388900	1 night
2	07/11/98	405200	6389900	1 night
3	24/11/98	406260	6389440	1 night
4	24/11/98	406470	6389300	1 night
5	26/11/98	403250	6389900	1 night
6	26/11/98	403800	6389800	1 night
7	27/11/98	404900	6388900	1 night
8	29/12/98	399250	6387000	1 night
9	29/12/98	399800	6387750	1 night
10	30/12/98	400050	6388650	1 night
11	30/12/98	400100	6389200	1 night
12	06/08/99	399900	6387700	30 mins
13	07/08/99	399900	6387600	30 mins
14	08/08/99	400000	6388450	30 mins
15	09/08/99	399200	6387200	30 mins
16	09/08/99	400550	6389200	30 mins
17	11/8/99	404900	6388950	30 mins
18	11/8/99	405100	6388975	30 mins

Table C.6 Date, location and survey effort of harp trap sites along the alignment and in the immediate vicinity (Figure 3b).

Transect	Date	Location (AMG)		Survey Effort
1	27-29/11/98	403750	6389200	3 trap-nights
2	27-29/11/98	403250	6390200	3 trap-nights
3	27-29/11/98	403750	6389750	3 trap-nights
4	22-24/12/98	399500	6389800	3 trap-nights
5	22-24/12/98	401000	6388500	3 trap-nights
6	22-24/12/98	399800	6387650	3 trap-nights
7	22-24/12/98	399500	6387500	3 trap-nights
8	16-18/1/99	406500	6388750	3 trap-nights
9	16-18/1/99	405200	6388850	3 trap-nights

2.3 SPOTLIGHTING

Extensive spotlighting surveys, including both walked and driven surveys, were conducted along the alignment and in the immediate vicinity (Figure 3a):

- spotlighting over 13 nights, from the 24th to 27th of November 1998, the 17th, 18th, 28th and 30th of December 1998, the 12th and 28th of January 1999, the 7th to 9th of August 1999 and the 11th of August 1999;
- total of approximately 43.5 person-hours (17.5 person hours driven surveys and 26 person-hours walked surveys); and
- records maintained of all species observed or identified by calls.

2.4 HERPETOLOGICAL SURVEYS

2.4.1 Reptiles

- active diurnal searches were conducted throughout habitats along the alignment and in the immediate vicinity, particularly during and following rain, throughout the entire period of faunal investigations;
- searches involved turning logs, rocks and unnatural debris (such as building materials, tyres, rubble stock piles *etc*), searching decorticating and fallen bark, rock outcrops, leaf-litter and other suitable substrates;
- opportunistic sightings of reptiles during other diurnal and nocturnal activities were recorded;
- specific diurnal and nocturnal surveys were conducted at three locations deemed suitable habitat for the Pale-headed Snake and Stephen's Banded Snake on the 24th and 25th of November 1998 (Table C.7);
- nocturnal surveys were conducted during spotlighting surveys and were concentrated around wet soaks in paddocks, along roads after rain, along the edge of the freshwater wetland and under vegetative debris (such as fallen logs) and refuse (*eg* plastic); and

- records maintained of all species observed or identified by call.

Table C.7 Location of searches for the Pale-headed Snake and Stephen's Banded Snake along the proposed route option and in the immediate vicinity.

Transect	Date	Location (AGM)		Approximate Size (hectares)
1	24th & 25th/11/98	406250	6389350	2
2	24th & 25th/11/98	404800	6388250	2
3	24th & 25th/11/98	403200	6390250	1

2.4.2 Amphibians

- active diurnal searches were conducted throughout habitats along the alignment and in the immediate vicinity, particularly during and following rain, throughout the entire period of faunal investigations;
- diurnal searches were conducted around suitable habitat such as creeklines, dams and wetlands and involved turning logs, rocks and unnatural debris (such as building materials, tyres, rubble stock piles etc), searching decorticating and fallen bark, rock outcrops, leaf-litter and other suitable substrates;
- opportunistic sightings of amphibians during other diurnal and nocturnal activities were recorded;
- nocturnal surveys were conducted during spotlighting surveys and were concentrated around wet soaks in paddocks, along roads after rain, along the edge of the freshwater wetland and under vegetative debris (such as fallen logs) and refuse (*eg* plastic);
- several permanent dams were deemed suitable habitat for the Green and Golden Bell Frog. Surveys were conducted after heavy rain for several days and nights for a minimum of 30 minutes, no dams were larger than 50^2m (Table C.8);
- specific searches for the Green-thighed Frog were conducted in areas of inundated grassland and at ponds or dams. Surveys conducted at dams were as for the Green and Golden Bell Frog. Areas of flooded grassland were limited along the route corridor to the area adjacent to Wallaroo Swamp and consist of a flooded grass understorey with Melaleuca overstorey. The area adjacent to Wallaroo Swamp was surveyed for several nights for a minimum of 2 hours (AGM - 399950/6388700). The search was conducted in a 2ha area surrounding the AGM location, call playback was used at this location;
- searches within suitable habitat were conducted along creeklines for the Stuttering Frog and the Great Barred Frog, particularly during and after rain; and
- records maintained of all species observed or identified by call.

Table C.8 Location of dams for searches for the Green and Golden Bell Frog and the Green-thighed Frog along the proposed route option and in the immediate vicinity.

Transect	Location (AGM)	
1	402800	6389900
2	403850	6389850
3	404450	6390000

2.5 BIRD SURVEYS

- general diurnal bird surveys were conducted within all habitats along the proposed route option, throughout the entire period of faunal investigations, including estuarine wetlands (saltmarsh and mangroves), freshwater wetlands (sedgeland and swamp forest), woodland/open forest and agricultural and other disturbed areas;

- more than twenty-five percent of wetlands located within 500m of the proposed route corridor were searched for aquatic birds;

- specific searches were conducted in habitat types known to be utilised by certain threatened species (*ie* aquatic wetlands and estuarine wetlands);

- a specific search of the estuarine wetland areas was conducted to search for individuals, roost or nest sights and habitat of threatened wading birds;

- observation of potential nest sights of threatened owls, the Glossy Black Cockatoo and threatened raptors were made during the hollow surveys conducted along the length and within 200m of the proposed route;

- specific searches for fruit doves and the Barred-Cuckoo Shrike were undertaken in locations of suitable habitat, with searches around fruiting trees conducted for a minimum of two hours in each location;

- areas within the route corridor were assessed for the presence of Glossy Black Cockatoos and/or chewed cones. Specific surveys for chewed cones were conducted in areas of high density of *Allocasuarina* or *Casuarina* adjacent to the proposed corridor;

- spotlighting surveys for nocturnal species (as for spotlighting details above);

- owl call playback for the Barking Owl, Masked Owl, Powerful Owl and Sooty Owl was conducted at seven locations in the general vicinity of the proposed Horse Island Route option (Table C.9; Figure 3a);

- call playback for the Bush-stone Curlew was conducted for two nights at two locations and for the Australasian Bittern and Black Bittern over two nights at the one location (Table C.9; Figure 3a);

- opportunistic sightings both inside and outside the corridor were recorded; and

- records maintained of all species observed or identified by call.

2.6 KOALA SURVEYS

- total of sixty-eight potential feeding trees, selected in representative areas of potential habitat were examined from the 7th to the 9th of August 1999, for signs of Koala scratches and for the presence of Koala scats located around their bases (Figure 3b); and

- trees with a Diameter at Breast Height (DBH) of >30cm were selected where available and preferred Koala food trees targeted, including Tallow-wood *Eucalyptus microcorys*, Forest Red Gum *Eucalyptus tereticornis*, Grey Gums *E punctata* and *E propinqua*, *etc*. Where preferred food trees were not present, other healthy mature trees were selected for survey.

Table C.9 Location of call playback sites for the Barking Owl, Masked Owl, Powerful Owl and Sooty Owl, the Bush-stone Curlew and the Australasian Bittern and Black Bittern, along the proposed route option and in the immediate vicinity (Figure 3a).

Species	Transect	Date	Location (AGM)	
Barking Owl, Masked Owl, Powerful Owl & Sooty Owl.	1	24/11/98 & 27/11/98	406450	6389500
	2	24/11/98 & 27/11/98	403200	6390000
	3	21/12/98 & 29/12/98	400350	6389250
	4	21/12/98 & 29/12/98	399900	6387600
	5	07/08/99	400000	6387500
	6	08/08/99	400000	6388450
	7	09/08/99	399200	6387200
Bush-stone Curlew	1	22/12/98 & 23/12/98	400350	6389250
	2	16/01/99 & 18/01/99	403200	6390000
Australasian Bittern & Black Bittern	1	09/08/99 & 11/08/99	401600	6389800

2.7 GENERAL HABITAT SEARCHES

- habitat searches to detect the presence or absence of tree-hollows and other features of relevance for native fauna along the proposed alignment and in the surrounding area (Appendix J; Figure 4.2);

- a survey of tree-hollows along the proposed route within the acquisition boundary was conducted on the 1st, 2nd, and 4th of July, and the 8th and 9th of August 1999, with the number and size of hollows being assessed for each tree, as discussed in detail in Appendix J (Figure 4.2); and

- stag watch involving three individuals watching hollow-bearing trees for ninety minutes, starting thirty minutes prior to sunset until sixty minutes after sunset, was conducted in four locations over four days (Table C.10).

- general habitat searches for indirect evidence of fauna, including diggings, scratchings, remains, scats, prints *etc*; and

- scats, bones or hair collected sent to M. Bowen[3] for analysis.

Table C.10 Location and date of stag watch conducted along the proposed Horse Island route option.

Location	Date	Location (AMG)	
		Easting	Northing
1	07/08/99	399893	6388257
2	08/08/99	400100	6388750
3	09/08/99	399250	6387150
4	11/08/99	405050	6389975

2.8 OPPORTUNISTIC OBSERVATIONS

- records maintained of all species observed or identified from calls whilst conducting all survey work and travelling between survey sites.

[3] Michiala Bowen B. App. Sc. (Hons)-Hair Tube, bone and predator scat identification and analysis, Rosebank NSW.

Table C.11 Summary of total effort (transects & nights/hours) and months, for each of the flora and fauna methods conducted along the proposed upgrade of the Pacific Highway at Karuah for (C) Karuah Bypass-Species Impact Statement (Gunninah 1999c).

REPORT	SURVEY METHOD	EFFORT		MONTHS
		TRANSECTS	NIGHTS/HOURS	
C	**FLORA**			
	Random	as for Table B.6	as for Table B.6	as for Table B.6
	Quadrats	as for Table B.6	as for Table B.6	as for Table B.6
	FAUNA			
	Trapping			
	Elliott:			
	Ground	8 (200) *	800 trap nights	Nov & Dec 1998
	Tree	8 (80) *	320 trap nights	Nov & Dec 1998
	Cage	8 (8) *	32	Nov & Dec 1998
	Hair Tubes:			
	Ground	12 (104) *	916	Nov & Dec 1998
	Tree	8 (24) *	306	Nov & Dec 1998
	Pitfall	2 (20) *	80	Nov 1998 & Aug 1999
	Microchiropteran Bat Surveys			
	Anabat	18	11 nights & 3.5 hours	Aug, Nov, Dec 1998 & Aug 1999
	Harp Traps	9	27 trap nights	Nov & Dec 1998 ; Jan & Aug 1999
	Spotlighting	NA	43.5 hours	Nov & Dec 1998; Jan & Aug 1999
	Herpetological Searches	Continuous & opportunistic	NA	Nov - Dec 1998; Jan & Aug 1999
	Call Playback (Green-thighed Frog)	1	1	Aug 1999
	Bird Surveys		NA	
	General	Continuous & opportunistic		Nov - Dec 1998; Jan & Aug 1999
	Call Playback:			
	Owl	8	9.5 hours	Nov & Dec 1998; Aug 1999
	Bittern	2	1.5 hours	Dec 1998 & Jan 1999
	Bush-stone Curlew	1	1.5 hours	Aug 1999
	Koala Surveys	68 trees	NA	March 1998 & Aug 1999
	Stag Watch	4	6 hours	Aug 1999
	General Habitat Searches	Continuous & opportunistic	NA	Nov - Dec 1998; Jan & Aug 1999

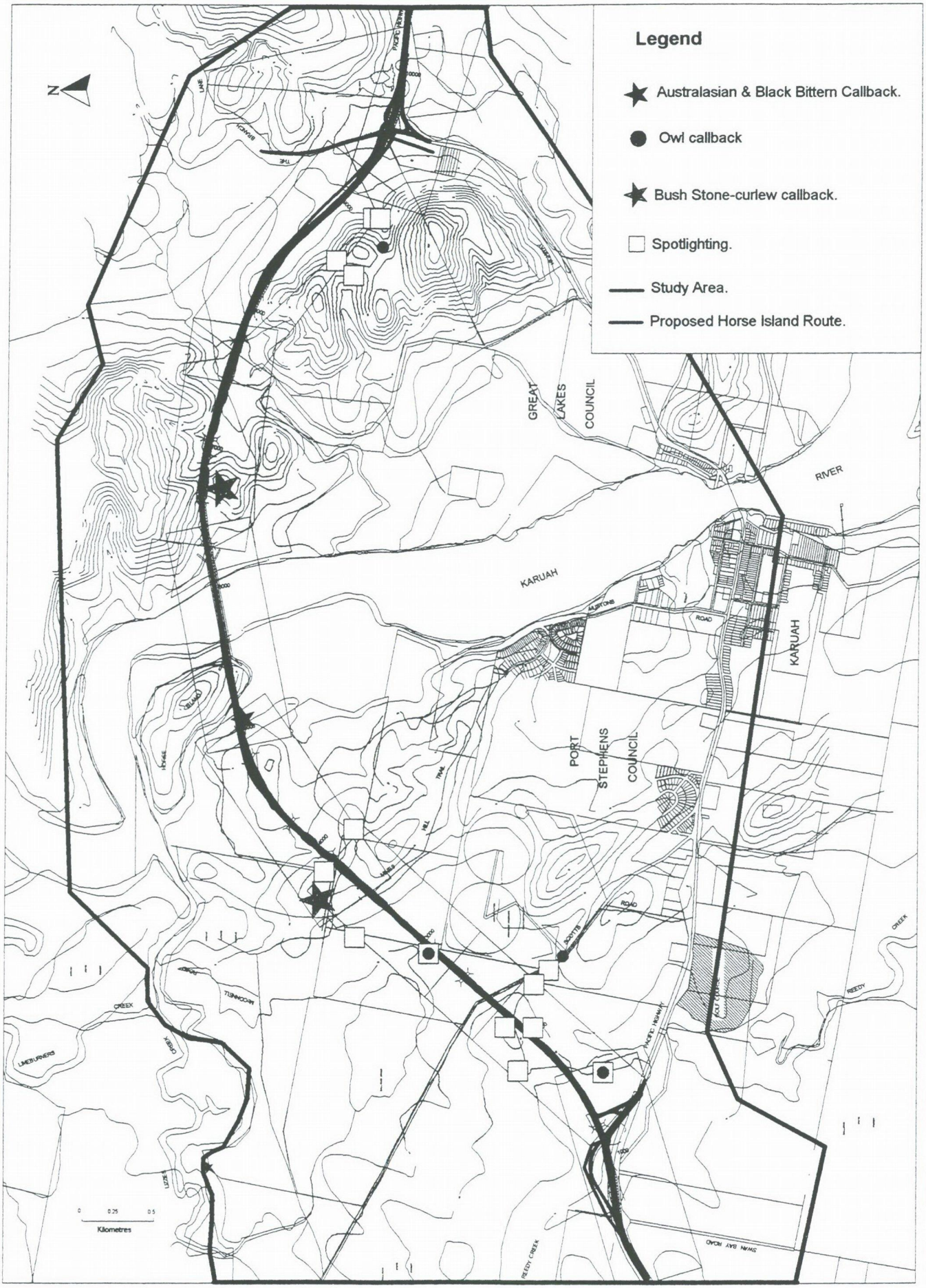
* The number inside the brackets indicates the total number of traps deployed for that particular survey method.

APPENDIX C contd Details of flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah for the Route Selection - Flora & Fauna Constraints report (Gunninah 1997a), Proposed Horse Island Route - Flora & Fauna Assessment report (Gunninah 1999b), and Karuah Bypass - Species Impact Statement (Gunninah 1999c).

Table C.12 Total effort (transects & nights/hours) and months, for each of the flora and fauna methods conducted along the proposed upgrade of the Pacific Highway at Karuah for: (A) Route Selection-Flora & Fauna Constraints report (Gunninah 1997a), (B) Proposed Horse Island Route-Flora & Fauna Assessment report (Gunninah 1999b), and (C) Karuah Bypass-Species Impact Statement (Gunninah 1999c).

SURVEY METHOD	EFFORT		MONTHS
	TRANSECTS	NIGHTS/HOURS	
FLORA	44 + A	69	April 1997; Nov & Dec 1998
FAUNA			
Trapping			
Elliott:			
Ground	19 (410) *	1640	April 1997; March, Nov & Dec 1998
Tree	18 (123) *	483	April 1997; March, Nov & Dec 1998
Cage	19 (19) *	110	April 1997; March, Nov & Dec 1998
Hair Tubes:			
Ground	24 (147) *	1685	April 1997; March, Nov & Dec 1998
Tree	8 (24) *	306	April 1997; March, Nov & Dec 1998
Pitfall	2 (20) *	80	Nov 1998 & Aug 1999
Microchiropteran Bat Surveys			
Anabat	33	24 nights & 9.75 hours	April 1997; March, Nov & Dec 1998
Harp Traps	18	47 nights	April 1997; Jan, Nov & Dec 1998; Jan 1999
Spotlighting	NA	74 hours	April 1997; Nov & Dec 1998; Jan & Aug 1999
Herpetological Searches	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999
Bird Surveys			
General	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999
Call Playback:			
Owl	8	9.5 hours	Nov & Dec 1998; Aug 1999
Bitterns	2	1.5 hours	Dec 1998 & Jan 1999
Bush-stone Curlew	1	1.5 hours	Aug 1999
Koala Surveys	339 trees	NA	April 1997; March 1998; August 1999
Stag Watch	4	6 hours	August 1999
General Habitat Searches	Continuous & opportunistic	NA	April 1997; Jan, March, Nov & Dec 1998; Jan & Aug 1999

* The number inside the brackets indicates the total number of traps deployed for that particular survey method.



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone (02) 99065436 Fax (02) 9906 7770

Appendix C Figure 3a
SIS (1999c) Fauna survey locations of spotlighing and call playback within the study area.

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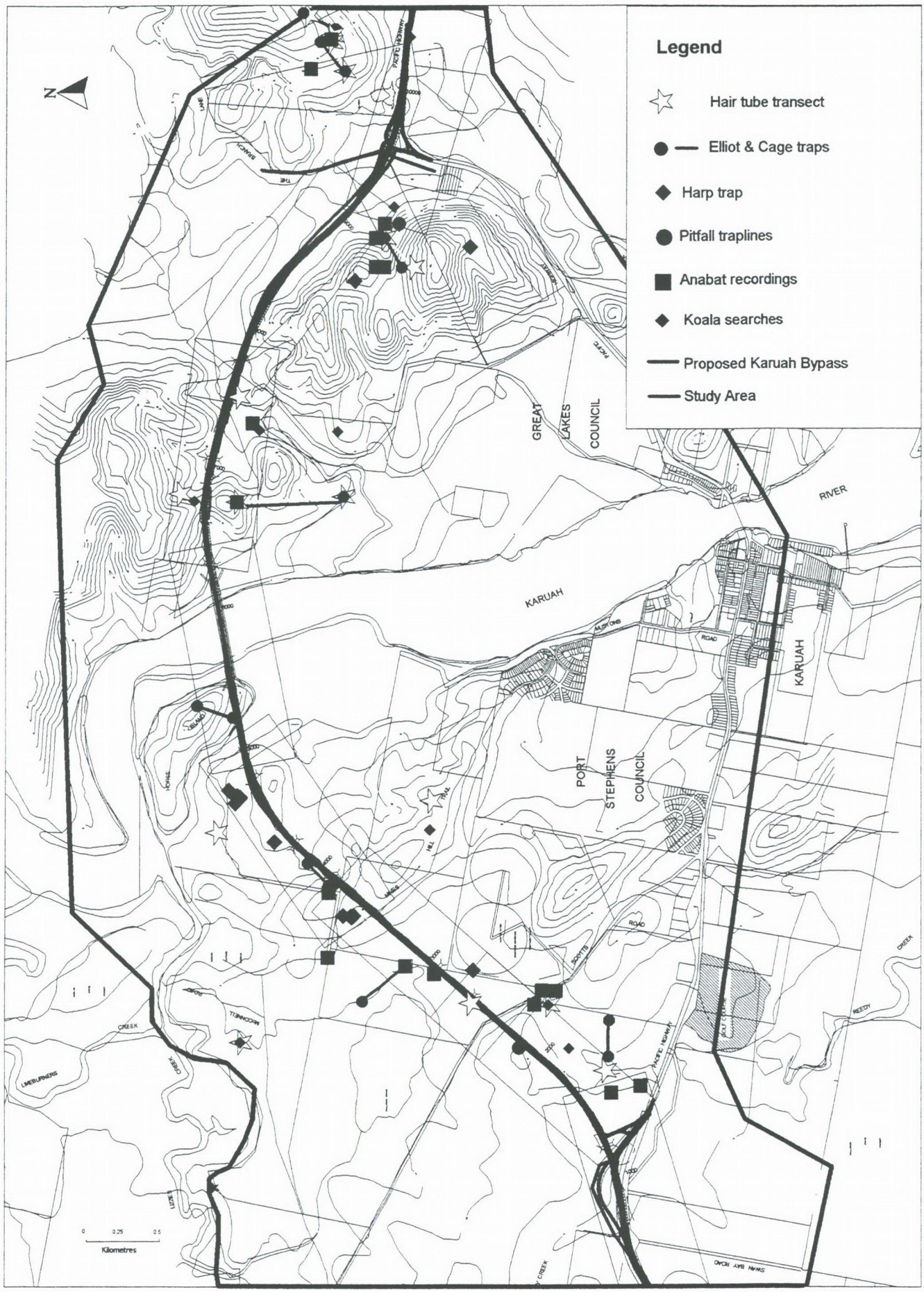

Karuah SIS
Project No. 98071

Gunninah Environmental Consulants

Phone: (02) 9906 5436 Fax: (02) 9906 7770

Appendix C Figure 3b
SIS 1999c fauna survey locations of Elliot, pitfall, cage and harp trapping, hair tube transects, Koala surveys and Anabat recordings within the study area.

Version: 5 11th October 1999

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX D

Weather Conditions Recorded During the Fauna Survey

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX D Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
21/04/97	Morning Afternoon Evening	- - -	- - nil	- - -	- - nil	- - light
22/04/97	Morning Afternoon Evening	24 - -	nil nil nil	- - -	nil moderate moderate	light moderate moderate
23/04/97	Morning Afternoon Evening	24 - 20	nil - nil	- - -	nil - nil	nil - moderate
24/04/97	Morning Afternoon Evening	- - -	nil nil nil	- - -	nil nil nil	nil moderate overcast
25/04/97	Morning Afternoon Evening	- - -	intermittent intermittent intermittent	- - -	- - -	overcast overcast overcast
26/04/97	Morning Afternoon Evening	- - -	nil nil -	- - -	nil moderate -	fog nil -
03/01/98 *	Morning Afternoon Evening	27.3 35.1 -	nil - -	- - -	light moderate -	light light -
04/01/98 *	Morning Afternoon Evening	21.2 24.6 -	intermittent - -	- - -	light-mod moderate -	overcast moderate -
05/01/98 *	Morning Afternoon Evening	24.8 24.7 -	nil - -	04/01/98	light mod-strong -	moderate moderate -
06/01/98 *	Morning Afternoon Evening	22.7 24.7 -	light - -	04/01/98	moderate moderate -	light moderate -
17/02/98 *	Morning Afternoon Evening	19.6 22.3 -	light - -	11/02/98	light-mod moderate -	light light -
18/02/98 *	Morning Afternoon Evening	18.2 25.0 -	nil - -	17/02/98	light moderate -	light nil -

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
19/02/98	Morning	21.4	nil	17/02/98	light	light
*	Afternoon	33.6	-		moderate	light
	Evening	-	-		-	-
20/02/98	Morning	26.6	nil	17/02/98	light	moderate
*	Afternoon	32.8	-		moderate	overcast
	Evening	-	-		-	-
21/02/98	Morning	23.3	nil	17/02/98	light	overcast
*	Afternoon	26.3	-		moderate	light
	Evening	--	-		-	-
22/02/98	Morning	21.8	nil	17/02/98	light-mod	nil
*	Afternoon	32.7	-		light-mod	nil
	Evening	-	-		-	-
23/02/98	Morning	23.0	nil	17/02/98	light	light
*	Afternoon	23.4	-		mod-strong	overcast
	Evening	-	-		-	-
24/02/98	Morning	20.6	nil	17/02/98	light	nil
*	Afternoon	25.0	-		moderate	nil
	Evening	-	-		-	-
25/02/98	Morning	20.9	nil	17/02/98	light	nil
*	Afternoon	33.1	-		light	light
	Evening	-	-		-	-
26/02/98	Morning	19-32	nil	-	light	nil
	Afternoon	32-36	nil	-	nil	nil
	Evening	20-25	nil	-	nil	nil
27/02/98	Morning	20-33	nil	-	nil	nil
	Afternoon	35-39	nil	-	nil	nil
	Evening	20-25	heavy	-	strong	overcast
28/02/98	Morning	18-23	light	-	light	overcast
	Afternoon	18-23	light	-	nil	overcast
	Evening	18-23	light	-	nil	overcast
01/03/98	Morning	18-23	light	-	nil	overcast
	Afternoon	18-23	light	-	nil	moderate
	Evening	18-23	nil	afternoon	light	light
02/03/98	Morning	19-24	nil	01/03/98	nil	light
	Afternoon	24-29	nil		nil	nil
	Evening	18-23	nil		nil	nil

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
03/03/98	Morning Afternoon Evening	19-25 24-29 20-25	nil nil nil	01/03/98	nil light nil	light nil light
04/03/98	Morning Afternoon Evening	19-26 23-29 18-23	nil nil nil	01/03/98	light light light	nil light light
05/03/98	Morning Afternoon Evening	19-24 21-26 20-25	nil nil light	01/03/98	light moderate moderate	light moderate overcast
06/03/98	Morning Afternoon Evening	17-22 19-24 -	nil nil -	05/03/98	moderate light -	light light -
24/11/98	Morning Afternoon Evening	20-25 20-25 16-21	nil nil nil	- - -	nil nil nil	nil nil nil
25/11/98	Morning Afternoon Evening	20-25 22-27 18-23	nil - light	- - -	nil light light	nil moderate overcast
26/11/98	Morning Afternoon Evening	20-25 23-28 18-23	nil nil light	25/11/98	nil nil nil	light nil overcast
27/11/98	Morning Afternoon Evening	16-21 19-24 16-21	nil nil nil	26/11/98	light nil light	overcast light light
28/11/98	Morning Afternoon Evening	18-23 23-25 18-23	nil nil nil	26/11/98	nil nil nil	moderate nil moderate
29/11/98	Morning Afternoon Evening	20-25 20-25 -	nil nil -	26/11/98	light nil -	light light -
30/11/98 *	Morning Afternoon Evening	17.6 21.7 -	light - -	29/11/98	light mod-strong -	moderate light -
01/12/98 *	Morning Afternoon Evening	16.8 20.2 -	light - -	30/11/98	light moderate -	overcast moderate -

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
02/12/98 *	Morning Afternoon Evening	18.4 22.7 -	light - -	01/12/98	light moderate -	light light -
03/12/98 *	Morning Afternoon Evening	19.8 27.8 -	nil - -	02/11/98	moderate light -	overcast overcast -
04/12/98 *	Morning Afternoon Evening	17.7 23.1 -	nil - -	02/11/98	light mod-strong -	overcast moderate
05/12/98	Morning Afternoon Evening	20-24 25-30 20-25	nil nil nil	-	nil light nil	nil nil nil
12/12/98	Morning Afternoon Evening	20-24 25-30 20-25	nil nil nil	-	nil light nil	nil nil nil
13/12/98	Morning Afternoon Evening	19-24 24-29 20-24	nil nil nil	-	light light light	moderate overcast overcast
14/12/98	Morning Afternoon Evening	17-23 23-28 18-27	steady intermittent light drizzle	-	light light light	overcast overcast overcast
15/12/98	Morning Afternoon Evening	17-22 24-29 21-23	intermittent nil nil	heavy morning morning	light light nil	overcast overcast overcast
16/12/98	Morning Afternoon Evening	20-25 29-34 17-22	nil nil nil	15/12/98	nil light light-mod	moderate light nil
17/12/98	Morning Afternoon Evening	22-27 30-35 18-24	nil nil nil	15/12/98	nil light light-mod	nil nil moderate
18/12/98	Morning Afternoon	18-22 20-25	nil nil	15/12/98	light light	moderate overcast
19/12/98	Morning Afternoon Evening	20-25 28-35 18-23	nil nil nil	15/12/98	light light light-mod	light moderate moderate

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
20/12/98	Morning Afternoon Evening	20-25 28-33 20-25	nil nil nil	15/12/98	light nil light	nil nil nil
21/12/98	Morning Afternoon Evening	22-27 29-34 23-25	nil nil nil	15/12/98	nil nil nil	nil nil nil
22/12/98	Morning Afternoon Evening	20-24 28-33 20-24	nil nil nil	15/12/98	nil nil light	nil nil nil
23/12/98	Morning Afternoon Evening	20-24 28-33 19-24	nil nil nil	15/12/98	nil light light	moderate nil moderate
24/12/98	Morning Afternoon Evening	22-27 29-34 20-25	nil nil nil	15/12/98	light light light	light moderate moderate
25/12/98 *	Morning Afternoon Evening	23.8 25.2 -	nil - -	22/12/98	light moderate -	light light -
26/12/98 *	Morning Afternoon Evening	23.2 26.3 -	nil - -	22/12/98	light moderate -	moderate light -
27/12/98 *	Morning Afternoon Evening	21.2 26.2 -	nil - -	22/12/98	moderate mod-strong -	light nil -
28/12/98	Morning Afternoon Evening	20-25 30-35 20-23	nil nil nil	15/12/98	nil nil nil	nil nil nil
29/12/98	Morning Afternoon Evening	23-28 29-34 22-24	nil nil nil	15/12/98	nil light nil	light light moderate
30/12/98 *	Morning Afternoon Evening	21 - 25 26 - 27 24 - 26	nil nil nil	22/12/98	light moderate moderate	moderate light light
31/12/98	Morning Afternoon Evening	20-25 24-29 19-24	nil nil nil	22/12/98	nil light moderate	nil nil nil

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
01/01/99	Morning Afternoon Evening	20-25 25-30 19-24	nil nil nil	22/12/98	light light light	nil nil nil
02/01/99	Morning Afternoon Evening	21-25 28-32 17-22	nil nil nil	22/12/98	nil nil nil	nil nil moderate
03/01/99	Morning Afternoon Evening	21-27 28-32 19-24	nil nil nil	22/12/98	light nil light	nil nil nil
04/01/99 *	Morning Afternoon Evening	21.8 31.8 -	nil - -	03/01/99	light light-mod -	overcast light -
05/01/99 *	Morning Afternoon Evening	26.3 31.0 -	nil - -	03/01/99	light mod- -	light light -
06/01/99 *	Morning Afternoon Evening	25.5 31.7 -	nil - -	03/01/99	light moderate -	light light -
07/01/99 *	Morning Afternoon Evening	24.2 31.8 -	nil - -	03/01/99	light moderate -	light light -
08/01/99 *	Morning Afternoon Evening	23.6 31.3 -	nil - -	03/01/99	light moderate -	light moderate -
09/01/99 *	Morning Afternoon Evening	21.8 22.1 -	light - -	03/01/99	moderate light -	overcast moderate -
10/01/99 *	Morning Afternoon Evening	23.3 25.3 -	light - -	09/01/99	light moderate - light	light light -
11/01/99 *	Morning Afternoon Evening	22.2 35.4 -	nil - -	10/01/99	light -	light light -
12/01/99 *	Morning Afternoon Evening	23 - 25 27 - 29 24 - 25	nil nil nil	10/01/99	light moderate moderate	moderate light light
16/01/99 *	Morning Afternoon Evening	14 - 24 27 - 29 25 - 27	nil nil nil	14/01/99	light light moderate	nil nil light

APPENDIX D contd Weather conditions experienced during fauna investigations conducted in the study area (Gunninah 1997a, 1999b, c).*

Date	Time	Temp°C	Rain	Last Rain	Wind	Cloud Cover
17/01/99 *	Morning Afternoon Evening	15 - 24 27 - 30 25 - 27	nil nil nil	14/01/99	light light moderate	light light moderate
18/01/99 *	Morning Afternoon Evening	28 - 24 28 - 33 27 - 29	nil nil nil	14/01/99	light light moderate	moderate nil nil
19/01/99 *	Morning Afternoon Evening	19 - 25 30 - 33 28 - 31	nil nil nil	14/01/99	light light moderate	nil nil nil
28/01/99 *	Morning Afternoon Evening	22 - 24 23 - 25 22 - 23	light drizzle intermittent light drizzle	27/01/99	nil moderate light	moderate moderate moderate
06/08/99	Morning Afternoon Evening	10 - 15 15 - 20 13 - 15	nil nil light drizzle	-	light light moderate	light moderate heavy
07/08/99	Morning Afternoon Evening	14 - 20 17 - 22 14 - 17	nil nil nil	06/08/99	nil nil nil	light nil nil
08/08/99	Morning Afternoon Evening	16 - 21 16 - 21 13 - 14	nil nil intermittent	06/08/99	light nil nil	moderate heavy heavy
09/08/99	Morning Afternoon Evening	16 - 21 21 - 26 14 - 17	nil nil nil	08/08/99	moderate moderate moderate	nil nil nil
10/08/99 *	Morning Afternoon Evening	14 - 20 17 - 23 14 - 17	nil nil nil	08/08/99	light nil nil	nil nil nil
11/08/99 *	Morning Afternoon Evening	15 - 20 16 - 23 14 - 18	nil nil nil	08/08/99	light nil nil	light nil nil

* The weather details for these days were generated from meteorological observations at Williamtown RAAF Weather Station; information supplied by the Bureau of Meteorology.

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX E

Compliance of Field Survey Methods with the Requirements of the NP&WS Director-General

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX E Compliance of field surveys with the NP&WS Director-General's requirements.

SPECIES	ACTIVITIES	COMPLIANCE
Mammals		
Koala *Phascolarctos cinereus*	Information Review; Habitat Assessment; diurnal scat, scratch and sighting surveys; spotlighting; tree inspection; searches at base of trees.	yes yes yes yes yes yes
Squirrel Glider *Petaurus norfolcensis*	Call playback; spotlighting dusk stag watch & nest location; tree-mounted Elliott traps (B);	no (Table 3.4) yes yes partly, A size Elliott Traps (Section 3.5.3)
Yellow-bellied Glider *Petaurus australis*	Call playback; spotlighting; dusk stag watch; location of nests and sap incisions.	no (Table 3.4) yes yes yes
Brush-tailed Phascogale *Phascogale tadpoatafa*	tree-mounted hair tubes; tree-mounted Elliott Traps (B); spotlighting; scat collection; location of nests.	yes partly, A size Elliott Traps (Section 3.5.3) yes yes yes
Tiger Quoll *Dasyurus maculatus*	hair tubes (ground); spotlighting; scat collection; cage traps; location of dens and latrines.	yes yes yes yes yes
Parma Wallaby *Macropus parma*	spotlight surveys in forest and along forest/pasture edges; scat collection.	yes yes
Red-legged Pademelon *Thylogale stigmatica*	spotlight surveys in forest and along forest/pasture edges; scat collection.	yes yes
Black-striped Wallaby *Macropus dorsalis*	spotlight surveys in forest and along forest/pasture edges; scat collection.	yes yes

SPECIES	ACTIVITIES	COMPLIANCE
Mammals contd		
Long-nosed Potoroo *Potorous tridactylus*	spotlight surveys in forest; scat collection; hair tubes (ground); cage traps.	yes yes yes yes
Rufous Bettong *Aepyprymnus rufescens*	spotlight surveys in forest; scat collection; hair tubes (ground).	yes yes yes
New Holland Mouse *Pseudomys novaehollandiae*	Elliott trapping (A).	yes
Eastern Chestnut Mouse *Pseudomys gracilicaudatus*	Elliott trapping (A), ground.	yes
Common Planigale *Planigale maculata*	pitfall trapping.	yes
Common Wombat *Vombatus ursinus*	scat, burrow and digging search and ID.	yes
Common Bent-wing Bat *Minopterus schreibersii*	Anabats; Harp traps; identification of potential roosts.	yes yes yes
Little Bent-wing Bat *Minopterus australis*	Anabats; Harp traps; identification of potential roosts.	yes yes yes
Large-footed Myotis *Myotis adversus*	Harp traps; identification of potential roosts.	yes yes
Greater Broad-nosed Bat *Scoteanax rueppellii*	Anabats; Harp traps; identification of potential roosts.	yes yes yes
Yellow-bellied Sheathtail Bat *Taphozous flaviventris*	Anabats; Harp traps; identification of potential roosts.	yes yes yes
Hoary Bat *Chalinolobus nigrogriseus*	Anabats; Harp traps.	yes yes

APPENDIX E contd Compliance of field surveys with the NP&WS Director-General's requirements.

SPECIES	ACTIVITIES	COMPLIANCE
Mammals contd		
Large Pied Bat *Chalinolobus dwyeri*	Anabats; Harp traps; identification of potential roosts.	yes yes yes
Eastern Freetail Bat *Mormopterus norfolkensis*	Anabats; Harp traps; identification of potential roosts.	partly, stationary only yes yes
Beccarii's Freetail Bat *Mormopterus beccarii*	Anabats; identification of potential roosts.	yes yes
Golden-tipped Bat *Kerivoula papuensis*	Harp traps; identification of potential roosts.	yes yes
Northern Long-eared Bat *Nyctophilus bifax*	Harp traps; identification of potential roosts.	yes yes
Eastern Cave Bat *Vespadelus troughtoni*	Harp traps; identification of potential roosts.	yes yes
Queensland Blossom Bat *Syconycteris australis*	Mist nets; harp traps.	no (Section 3.5.5) yes
Black Flying Fox *Pteropus alecto*	Spotlighting for colonies.	no (Table 3.3)
Birds	General bird census.	yes
Bush Stone-curlew *Burhinus grallarius*	Call playback.	yes
Glossy Black Cockatoo *Calyptorhynchus lathami*	searches for chewed cones; listening at dusk; surveys for nests.	yes yes yes
Powerful Owl *Nixos strenua*	Call playback; dusk stag watch; scat and pellet collection; location of nest and roost sites & whitewash.	yes yes yes yes
Masked Owl *Tyto novaehollandiae*	Call playback; dusk stag watch; scat and pellet collection; location of nest and roost sites & whitewash.	yes yes yes yes

SPECIES	ACTIVITIES	COMPLIANCE
Birds contd		
Sooty Owl *Tyto tenebricosa*	Call playback; dusk stag watch; scat and pellet collection; location of nest and roost sites & whitewash.	yes yes yes yes
Barking Owl *Nixox connivens*	Call playback; dusk stag watch; scat and pellet collection; location of nest and roost sites & whitewash.	yes yes yes yes
Grass Owl *Tyto capensis*	Call playback.	no (Table 3.3 & 3.4)
Black-necked Stork *Ephippiorhynchus asiaticus*	searches of wetland and riparian areas.	yes
Brolga *Grus rubicunda*	searches of wetland and riparian areas.	yes
Wompoo Fruit-dove *Ptilinopus magnificus*	searches of fruiting trees in rainforest; call playback in suitable habitat.	yes no (Table 3.4)
Superb Fruit-dove *Ptilinopus superbus*	searches of fruiting trees in rainforest; call playback in suitable habitat.	yes no (Table 3.4)
Rose-crowned Fruit-dove *Ptilinopus regina*	searches of fruiting trees in rainforest; call playback in suitable habitat.	yes no (Table 3.4)
Double-eyed Fig Parrot *Cyclopsitta diophthalma coxeni*	searches in rainforest.	yes
Black Bittern *Ixobrychus flavicollis*	searches of wetland and riparian areas; call playback.	yes yes
Australasian Bittern *Botaurus poiciloptilus*	searches of wetland and riparian areas; call playback.	yes yes
Bush Hen *Amaurornis olivaceus*	surveys in dense vegetation close to water.	no (Table 3.3)
Black-breasted Button Quail *Turnix melanogaster*	searches for evidence of presence; call playback if evidence found.	no (Table 3.3 & 3.4)

APPENDIX E contd Compliance of field surveys with the NP&WS Director-General's requirements.

SPECIES	ACTIVITIES	COMPLIANCE
Birds contd		
White-eared Monarch *Monarcha levcotis*	morning search in rainforest and along forest edges.	yes
Barred Cuckoo Shrike *Coracina lineata*	searches for fruiting trees	yes
Comb-crested Jacana *Irediparra gallinacea*	searches of wetland and riparian areas.	yes
Ground Parrot *Pezoporus wallicus*	searches within suitable habitat (low heath); listening at dusk; call playback.	no (Table 3.3) no (Table 3.3) no (Table 3.4)
Swift Parrot *Lathamus discolor*	diurnal searches; habitat assessment.	yes yes
Turquoise Parrot *Neophema pulchella*	diurnal searches; habitat assessment.	yes yes
Regent Honeyeater *Xanthomyza phrygia*	diurnal searches; habitat assessment.	yes yes
Osprey *Pandion haliaetus*	searches for and identification of raptor nests.	yes
Square-tailed Kite *Lophoictinia isura*	searches for and identification of raptor nests.	yes
Red Goshawk *Erythrotriochis radiatus*	searches for and identification of raptor nests.	yes
Lesser Sand Plover *Charadrius mongolus*	diurnal searches; habitat assessment.	yes yes
Pied Oystercatcher *Haematopus longirostris*	diurnal searches; habitat assessment.	yes yes
Sooty Oystercatcher *Haematoptus fuliginosus*	diurnal searches; habitat assessment.	yes yes
Little Tern *Sterna albifrons*	diurnal searches; habitat assessment.	yes yes
Chestnut-rumped Heathwren *Sericornis pyrrhopygius*	diurnal searches; habitat assessment.	yes yes

SPECIES	ACTIVITIES	COMPLIANCE
Amphibians		
Green-thighed Frog *Litoria brevipalmata*	listening for calls; spotlighting; call playback; tadpole collection.	yes yes yes no (Section 2.5.6)
Green & Golden Bell Frog *Litoria aurea*	diurnal and nocturnal surveys; during or after good rain; call playback; tadpole collection.	yes yes no (Table 3.4) no (Section 3.5.6)
Wallum Sedgefrog *Litoria olongburensis*	listening for calls; spotlighting; call playback.	yes yes no (Table 3.4)
Wallum Froglet *Crinia tinnula*	listening for calls; spotlighting; call playback.	yes yes no (Table 3.4)
Great Barred Frog *Mixophyes iteratus*	listening for calls; spotlighting; call playback; tadpole collection.	yes yes no (Table 3.4) no (Section 3.5.6).
Mixophyes balbus	listening for calls; spotlighting; call playback; tadpole collection.	yes yes no (Table 3.4) no (Section 3.5.6)
Mixophyes fleayi	listening for calls; spotlighting; call playback; tadpole collection.	yes yes no (Table 3.4) no (Section 3.5.6)
Reptiles		
Pale-headed Snake *Hoplocephalus bitorquatus*	nocturnal surveys; diurnal surveys; habitat assessment.	yes yes yes
Stephen's Banded Snake *Hoplocephalus stephensii*	nocturnal surveys; diurnal surveys; habitat assessment.	yes yes yes

SPECIES	ACTIVITIES	COMPLIANCE
Reptiles contd		
White-crowned Snake *Cacophis harriettae*	pitfall trapping; dropboard surveys; diurnal surveys; habitat assessment.	no (Table 3.3) no (Table 3.3) no (Table 3.3) yes
Three-toed Snake-toothed Skink *Coeranoscincus reticulatus*	pitfall trapping; diurnal surveys; habitat assessment.	no (Table 3.3) no (Table 3.3) yes

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX F

Habitat Requirements and Relevance of Subject Species

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
BIRDS			
Ardeidae			
Australasian Bittern *Botaurus poiciloptilus*	Inhabits mainly temperate southeast and southwest Australia; occurs in terrestrial wetlands and occasionally estuarine habitats.	Limited potential habitat present along the Karuah River and Horse Island; more extensive potential habitat associated with Wallaroo Swamp and freshwater wetlands near existing Highway. Not recorded in recent surveys in the study area or locality; not recently spotted in the area (HBOC 1997 Records). Likelihood of occurrence - low to moderate.	No significant impact. Some (limited) loss of potential habitat along banks of Karuah River and edges of Horse Island. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality.
Black Bittern *Ixobrychus flavicollis*	Inhabits terrestrial wetlands with thick vegetation; preferred habitat is estuarine mangroves and rainforest adjacent to freshwater; forages along water's edge for fish and crayfish; roosts on ground or in dense foliage; present on the warmer mesic coastal plains.	Potential mangrove habitat along the Karuah River, around Horse Island and freshwater wetland habitat associated with Wallaroo swamp. Not recorded along the alignment, but recently spotted near study area (HBOC 1997 Records). Likelihood of occurrence - low to moderate.	No significant impact. Some loss of potential habitat along banks of Karuah River and edges of Horse Island. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of potential habitat to be affected, and the extent of suitable habitat in the locality.
Charadriidae			
Lesser Sand Plover *Charadrius mongolus*	Inhabits littoral and estuarine environments; migrates to Australia during northern winter; feeds on crustaceans, crabs and insects on exposed intertidal mudflats or sandflats.	Potential mudflat and estuarine habitats along the Karuah River and around Horse Island. No records from the study area or the locality; recorded in Hunter region to the south of study area (HBOC 1997 Records). Likelihood of occurrence - low.	No impact. Some Limited loss of potential estuarine foraging habitat at the site proposed for the Karuah River crossing. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of potential habitat to be affected, and the extent of suitable habitat in the locality.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Ciconiidae			
Black-necked Stork *Ephippiorhynchus asiaticus*	Occurs in tropical and subtropical terrestrial wetlands to 0.5m in depth; feeds on crustaceans and insects; nests in the fork of tall trees; roosts on the ground at the edge of wetlands. Principal distribution being is located further north, with records in the locality and subregion being rare.	Potential habitat present, associated with Wallaroo Swamp and freshwater wetlands near the existing Highway, west of the Karuah River, No records from study area or the locality; recorded in the lower Myall Lakes district (HBOC 1997 Records). Study area south of usual distributional range. Likelihood of occurrence - low.	No impact. Some loss of potential habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of potential habitat to be affected, and the lack of direct impacts on 'potential' habitat.
Accipitridae			
Osprey *Pandion haliaetus*	Inhabits littoral environments and terrestrial wetlands; requires large bodies of fresh, brackish or salt water for fishing; nests often constructed in tall dead trees, on cliffs or on artificial structures.	Potential foraging habitat provided by Karuah River, and potential nesting trees widely scattered. Recorded in flight over the Karuah River; no current or past evidence of breeding or nesting observed in the study area.	No significant impact. No adverse impacts on Karuah River given the incorporation of strict environmental management protocols (such as sediment and water quality control) in the project. No "*significant effect*" given its high mobility, the small area of potential habitat to be affected, and extent of suitable foraging and nesting habitat in the locality and region.
Red Goshawk *Erythrotriorchis radiatus*	Inhabits fertile coastal and subcoastal forest and woodland, especially floodplains; feeds on other birds, mammals, reptiles and insects; nests and roosts in tall trees within 1km of water.	Stands of potential open forest habitat present throughout the study area, locality and region. No records from the study area or locality. Likelihood of occurrence - low.	No significant impact. Some loss of potential open forest habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of potential habitat to be affected, and the extent of suitable habitat in the locality and region.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Accipitridae			
Square-tailed Kite *Lophoictinia isura*	Occurs in open forest, woodland or shrubland; absent from cleared areas; higher likelihood of occurrence on flatter terrain such as coastal flats; hunts within the forest canopy for passerine birds; nests adjacent to extensive areas of forest or woodland.	Stands of open forest (potential habitat) present throughout the study area, locality and region. No records from the study area or locality. Likelihood of occurrence - low to moderate.	No significant impact. Some loss of open forest (potential habitat). No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.
Gruidae			
Brolga *Grus rubicundus*	Occurs in terrestrial wetlands, grasslands and woodland of tropical and temperate Australia, where it feeds on large invertebrates, small vertebrates, seeds, grassy shoots and bulbs.	Potential habitat scattered throughout study area and locality. No records from the study area or locality. Study area outside of distributional range. Likelihood of occurrence - very low.	No impact. Not considered relevant to the proposal, given that the study area is outside the usual distributional range, and given the absence of records for the study area and locality, and, the small area of 'potential' habitat to be affected,
Turnicidae			
Black-breasted Button Quail *Turnix melanogaster*	Little known species; occurs in southeast Qld and northeast NSW; inhabits dry rainforest, particularly where canopy, groundcover and vines are dense; Clarence River Valley is southern distributional limit.	No suitable habitat present in study area. No records from study area or locality. Study area outside of distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range, and given the absence of suitable habitat and the lack of records for the study area and locality.
Rallidae			
Bush-hen *Amaurornis olivaceus*	Inhabits dense vegetation surrounding swamps, flooded grassland and rainforest fringes in tropical and subtropical regions; southern limit appears to be Bundjalung NP; high rainfall and warm to hot climates are favoured; forages on the ground for insects, worms, seeds and soft young leaves; found in close proximity to freshwater.	Theoretically potential habitat present. No records from study area or locality; Study area is outside of distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside the special distributional range and given the absence of records for the study area and locality.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Jacanidae			
Comb-crested Jacana *Irediparra gallinacea*	Inhabits freshwater wetlands with abundant floating vegetation; forages on surface of water for seeds and aquatic invertebrates; nests in water on floating or emergent vegetation; builds temporary nests for nocturnal roosting.	Potential habitat present in scattered freshwater wetlands near the existing Highway. No records from the study area or locality, but is thought to be a resident in the Hunter Region (HBOC 1998). Likelihood of occurrence - very low to low.	No impact. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*" and the immediate locality.
Burhinidae			
Bush Stone-curlew *Burhinus grallarius*	Inhabits lightly timbered open forest and woodland, or partly cleared farmland with remnants of woodland; preys on invertebrates (such as insects molluscs, crustaceans and spiders), small vertebrates (such a frogs, lizards and snakes), and also some vegetation and seeds.	Potential open forest and grassland habitat present throughout study area and locality. Recorded in very open woodland on the both sides of the Karuah River within the study area; recorded regularly in locality, but at apparently low densities.	Potential for adverse impact on individuals. Bypass will remove some potential habitat. A "*significant effect*" could be imposed upon individuals of the Bush Stone-curlew, but is not likely to be imposed on a local population.
Columbidae			
Wompoo Fruit-Dove *Ptilinopus magnificus*	Generally inhabits large undisturbed patches of tall mesic tropical or subtropical rainforest; prefers fleshy-fruited trees and vines; nests and roosts in dense trees or bushes; occurs from northern Qld to the NSW south coast, and is resident in Hunter Region (HBOC 1998 Records); greatest likelihood of occurrence in warm mesic forests at lower latitude and altitude.	No present rainforest habitat present along the alignment. Not recorded in the study area or locality. Likelihood of occurrence - very low.	No impact. Not considered relevant to the proposal given the lack of records of the species and the absence of suitable habitat in the areas "*to be affected by the action*".
Rose-crowned Fruit-Dove *Ptilinopus regina*	Generally inhabits tall tropical and subtropical rainforest, especially with thick vine growth; prefers large expanses of dry rainforest in warm low latitude and altitude regions; forages in tree canopy for fruits; roosts in dense canopy; occurs from Kimberly to central NSW.	No rainforest habitat present along the alignment. Not recorded in the study area or locality. Likelihood of occurrence - very low.	No impact. Not considered relevant to the proposal given the lack of records of the species and the absence of suitable habitat in the areas "*to be affected by the action*".

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Columbidae contd			
Superb Fruit-Dove *Ptilinopus superbus*	Generally inhabits rainforest canopies, preferring dry subtropical rainforests and low elevation subtropical or littoral rainforest remnants; feeds in canopy on fruits; roosts and nests in foliage 1-7m above the ground; occurs from northern Qld to Northern Rivers in NSW; rare in the Hunter region.	No potential rainforest habitat present along the alignment. Not recorded in the study area or locality? Rare in the Hunter Region to the south of the study area (HBOC 1998 Records). Likelihood of occurrence - very low.	No impact. Not considered relevant to the proposal given the lack of records of the species and the absence of suitable habitat in the areas "*to be affected by the action*".
Cacatuidae			
Glossy Black Cockatoo *Calyptorhynchus lathami*	Inhabits dry sclerophyll forest and woodland; in northeast NSW, feeds exclusively on the cones of *Allocasuarina torulosa* and *A littoralis*; requires large tree-hollows for nesting; distributed along the east coast of Australia in cool regions mainly in the foothills of the ranges and on the coast; moderate probability of occurrence in cooler, dry forest regions of NSW.	Suitable foraging habitat present particularly west of the Karuah River; large tree-hollows for nesting generally scarce throughout study area due to selective logging practices and previous clearing. Recorded where in the study area. Substantial population known to occur in Wallaroo SF. Present.	Limited impact. Removal of potential and known foraging habitat west of the Karuah River; loss of some potential nest trees (not a 'limiting factor'). A "*significant effect*" is not likely, given the relatively small area of habitat to be removed, the extent of habitat in the study area and locality, and the mobility of the species and distribution of relevant resources.
Psittacidae			
Double-eyed Fig-Parrot *Cyclopsitta diophthalma*	Lives in drier dense lowland rainforests; forages on fruit, especially figs; distributed from southern Qld to northeast NSW, north from Kempsey.	No suitable habitat present along the alignment. Not recorded in the study area or locality. Study area outside of usual distribution range. Likelihood of occurrence - extremely low.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range, and given the absence of suitable habitat and the lack of records for the study area and locality.
Ground Parrot *Pezoporus wallicus*	Restricted to floristically diverse dense coastal heathlands; highly dependent on specific fire regime of infrequent fire occurrence; may forage for seeds and grains in adjacent montane regions; nests on the ground underneath very dense vegetation; found along entire eastern seaboard, particularly in cooler climatic regions.	No suitable habitat present. Not recorded in study area or locality. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given the absence of suitable habitat and the lack of records for the study area and locality.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Psittacidae contd			
Swift Parrot *Lathamus discolor*	Inhabits dry eucalypt forest and woodland; forages on winter-flowering eucalypts (*eg* Blue gum *Eucalyptus nitida*); breeds only in Tasmania and migrates as far as southeast Qld in winter.	Potential foraging habitat present in open forest stands, in the subject study area and throughout the locality and region. Not recorded in the study area, and habitat is marginal and widespread Recorded in the locality and known from the Hunter Region to the south (HBOC 1998 Records); Likelihood of occurrence - low (occasional).	No significant impact. Some loss of open forest (potential foraging habitat) particularly west of the Karuah River. No "*significant effect*" anticipated even if this species does occur on occasion, given the small area "*likely to be affected by the action*" in comparison to the extent of potential habitat in the locality and region.
Turquoise Parrot *Neophema pulchella*	Inhabits woodland, open forest and timbered grasslands; occurs in patches from southeast Qld to northeast Victoria; more common west of the escarpment on the tablelands and along dry forest corridors towards the sea; nests in eucalypt woodland adjacent to clearing, ridgelines and near creeks in farmland.	Potential habitat present in the study area and throughout the locality. Not recorded in the study area or the locality, but known to occur in the Hunter region to the south (HBOC 1997 Records). Likelihood of occurrence - low to moderate (occasional).	No significant impact. Some loss of potential open forest and grassland habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.
Strigidae			
Barking Owl *Ninox connivens*	Inhabits dry open eucalypt woodlands, savanna woodland and riverine forest, but has been found in denser forests; prefers warmer climates; nests in roomy tree-cavities; prey includes birds, mammals (including rabbits) and nocturnal insects.	Potential habitat present in the study area and throughout the locality. Not recorded in the study area or the locality, but known to occur in the Hunter region to the south (HBOC 1997 Records). Likelihood of occurrence - low to moderate.	No significant impact. Some loss of potential open forest habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat.
Powerful Owl *Ninox strenua*	Widely distributed in open and tall open productive forest in southeastern Australia, and occasionally inhabits woodland and riparian habitat; prefers cool to moderate temperatures and low to medium rainfall on flatter terrain; feeds on arboreal mammals; nests in very large tree-hollows.	Potential habitat present in the study area and throughout the locality. Not recorded in the study area, but is known to occur in the Hunter region to the south (HBOC 1997 Records). Likelihood of occurrence - moderate.	No significant impact. Some loss of open forest (potential habitat). No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

SPECIES	HABITAT REQUIREMENTS	LIKELIHOOD OF OCCURRENCE	POTENTIAL IMPACT OF PROPOSAL
Tytonidae			
Eastern Grass Owl *Tyto capensis longimembris*	Inhabits coastal marshy Wallum heaths and swampy tussock grasslands; primary distribution along northern coastline of QLD, NT and WA, but has been known to disperse as far south as Murray-Darling during plentiful years; feeds predominantly on terrestrial nocturnal rodents, particularly the Dusky Field Rat and Long-haired Rat; nests and roosts in a scraped depression or platform of trampled plant stems under dense tussocks, entered by tunnels through undergrowth.	No potential habitat present. Not recorded in the study area or the locality, but recorded during previous surveys (HBOC 1997 Records). Likelihood of occurrence - none.	No impact. No potential habitat present. Not regarded as relevant to the proposal or to this SIS.
Masked Owl *Tyto novaehollandiae*	Inhabits coastal and subcoastal forests and woodlands where rainfall is low; a predator of small terrestrial and arboreal mammals which are hunted in areas of open understorey, with adjacent denser understorey preferred to sustain favoured food supply; nests and roosts in tree-hollows (in live eucalypts) or in caves.	Suitable foraging habitat and resources in the study area and throughout the locality; large tree-hollows for nesting throughout study area and locality, although uncommon due to selective logging practices, clearing and bushfires. Recorded nesting in a hollow-bearing tree along alignment. Intermediate to high probability of occurrence in Wallaroo, Karuah and Medowie SFs (NP&WS 1994). Present.	Adverse impact on one pair of the Masked Owl. The loss of a known nest tree and potential other nest trees along the alignment; the loss of open forest (foraging habitat). A "*significant effect*" may be imposed upon the pair of Masked Owls along the alignment, although no "*significant effect*" is considered likely on the species. Specific impact amelioration measures are to be implemented.
Sooty Owl *Tyto tenebricosa*	Specialised inhabitant of rainforest and tall open forest which supports tree-hollows for roosting and nesting (Debus 1994); possible need for sclerophyll forest component; preferred habitat is in gullies or sheltered valleys where rainfall is high and temperatures warm; widespread throughout moderately rugged terrain along coastal NSW; intolerant of disturbance.	No preferred habitat present. Not recorded in the study area or the locality. Likelihood of occurrence - extremely low.	No impact. Not considered relevant to the proposal given the lack of records of the species in the vicinity and absence of suitable habitat in the areas "*likely to be affected by the action*".

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Podargidae Marbled Frogmouth *Podargus ocellatus*	Lives only in lowland subtropical rainforests in southeastern QLD and northeastern NSW, often along flowing creeks; usually roosts in thick vegetation; prefers areas of deep soil profile and high annual mean temperature.	No suitable habitat present in the study area. Not recorded in the study area or the locality. Likelihood of occurrence - extremely low.	No impact. Not considered relevant to the proposal given the lack of records of the species in the vicinity and absence of suitable habitat in the areas "*likely to be affected by the action*".
Meliphagidae Regent Honeyeater *Xanthomyza phrygia*	Lives in eucalypt forest and woodland and dry sclerophyll forests with large mature trees supplying high nectar flows; found at low and high altitudes; regularly appears when banksias (eg *B ericifolia* and *B spinulosa*) and eucalypts (eg *E robusta*) are flowering.	Potential habitat present small patches in open forest stands in the study area and throughout the locality and region; No records in the study area, but recorded throughout the Hunter region to the south (HBOC 1997 Records), Likelihood of occurrence - low (occasional or vagrant).	No significant impact. Some loss of open forest (potential foraging habitat) particularly west of the River. No "*significant effect*" anticipated given the absence of records in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.
Dicruridae White-eared Monarch *Monarcha leucotis*	Inhabits eucalypt forest at the edge of tropical and subtropical rainforest, along creeks and occasionally in mangroves; prefers warm to very warm mean temperatures and moderate to high rainfall; forages below the canopy and on the ground for insects; nests and roosts in trees; southern range limit is at Iluka Nature Reserve.	No suitable habitat present. Not recorded in the study area or locality and not known in the Hunter region to the south (HBOC 1997 Records), The study area is outside usual distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside the White-eared Monarch's distributional range, and given the absence of suitable habitat and the lack of records for the study area and locality.
Campephagidae Barred Cuckoo-shrike *Coracina lineata*	Favours lowlands in northern NSW foraging for fruit and insects in remnant subtropical, dry and littoral rainforests including margins and regrowth; not common in dry sclerophyll forests; migrates into NSW during winter, favouring warm to very warm temperatures.	No suitable habitat present. Not recorded in the study area or the locality. Likelihood of occurrence - extremely low to none.	No impact. Not considered relevant to the proposal given the lack of records of the species and absence of suitable habitat in the areas "*likely to be affected by the action*".

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Haematopodidae			
Pied Oystercatcher *Haematopus longirostris*	Coastal; nests on mudflats or sand above high-tide mark or in dunes; forage on mud or sandflats, may forage in adjacent inland regions during high tide; feeds on molluscs, worms, crabs, small fish.	Potential foraging and nesting habitat along Karuah River and around Horse Island. Not recorded in the study area, but known from the locality and recently spotted near study area (HBOC 1997 Records). Likelihood of occurrence - high (occasional).	No significant impact. Some loss of "*potential*" estuarine mudflat habitat at the site proposed for the River crossing. No "*significant effect*" anticipated given the limited area of potential habitat for this species in areas "*likely to be affected by the action*" and the extent of suitable habitat.
Sooty Oystercatcher *Haematopus fuliginosus*	Inhabits rocky shores, within 50m of shoreline; opportunistic feeder of molluscs and crustaceans in muddy and rocky substrates; breeds on offshore islands, nesting commonly on rocky or gravel shores above high-tide mark; may nest in shoreline vegetation or beachcast seaweed.	Potential mudflat foraging habitat present along Karuah River and around Horse Island. Recorded in locality, but not in study area (HBOC 1997 Records). Likelihood of occurrence - moderate (occasional).	No significant impact. Some loss of "*potential*" estuarine mudflat habitat at the site of the River crossing. No "*significant effect*" anticipated given the limited area of potential habitat for this species in areas "*likely to be affected by the action*" and the extent of suitable habitat.
Laridae			
Little Tern *Sterna albifrons*	Found along sheltered coastal environments, such as estuaries, lakes and harbours; may be found 1km inland along rivers or harbours; breeds on sand-spits, banks or other unvegetated sandy areas, may nest up to 5m above high tide mark on newly disturbed cleared habitats; forages in shallow waters of estuaries, coastal lakes or up to 50m offshore.	Potential foraging habitat along the Karuah River, but no preferred sandy nesting habitat present. Not recorded in the study area, but occurs in the locality and in the Hunter region to the south (HBOC 1997 Records). Likelihood of occurrence - very low. moderate.	No significant impact. Some (extremely limited) loss of potential estuarine foraging habitat at the site proposed for the River crossing. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*" and the extent of suitable foraging habitat.
Pardalotidae			
Chestnut-rumped Heathwren *Hylacola pyrrhopygia*	Inhabits heathlands and heathy woodlands; prefers cooler climates and is found up to 1500m above sea level; may be found both along coastal regions or inland from the Qld/NSW border through to SA; in northern NSW, found at higher altitudes; forages in thick undergrowth; eggs laid on or near the ground.	Potential habitat in areas of open forest with a reasonably dense understorey in study area. Recorded in the study area and previously recorded in Wallaroo SF (HBOC 1997. Present.	Limited Impact. Loss of (limited) area of currently suitable habitat, and areas of forested woodland which may become suitable habitat under appropriate management regimes. A "*significant effect*" may be imposed upon small numbers of the species, but the species in general is not likely to be significantly affected by the proposal.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
REPTILES			
Elapidae			
Pale-headed Snake *Hoplocephalus bitorquatus*	Partly arboreal; occurs in a wide range of habitats, including wet and dry sclerophyll forest and rainforest; shelters under decorticating bark; occurs from northern Queensland to the NSW Central Coast, on both sides of the Great Dividing Range; restricted to lower, warmer elevations.	Potentially suitable habitat provided by open forest stands in the study area and throughout the locality. Not recorded in the study area or the locality. Likelihood of occurrence - low.	No significant impact. Some loss of potential open forest habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.
Stephen's Banded Snake *Hoplocephalus stephensii*	Nocturnal and partly arboreal; shelters under decorticating bark; occurs in wet and dry sclerophyll forest, dry subtropical rainforests and rock outcrops; close proximity to mesic and xeric forest formations; distributed along the coast and in adjacent ranges from southeast Queensland to Gosford.	Potentially suitable habitat provided by open forest stands in the study area and throughout the locality. Not recorded in the study area or the locality. Likelihood of occurrence - extremely low to low.	No significant impact. Some loss of potential open forest habitat. No "*significant effect*" anticipated given the absence of records for this species in the areas "*likely to be affected by the action*", the small area of 'potential' habitat to be affected, and the extent of suitable habitat in the locality and region.
White-crowned Snake *Cacophis harriettae*	Inhabits coastal and near coastal areas between the tropic of Capricorn and Coffs Harbour; prefers wet sclerophyll forests and heathlands; nocturnal; feeds on lizards; shelters under leaf-litter, fallen timber *etc*.	Little suitable habitat in study area. The study area is outside of normal distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal, given that the study area is outside this species' distributional range, the absence of suitable habitat and the lack of records for the study area and locality.
Scincidae			
Three-toed Snake-toothed Skink *Coeranoscincus reticulatus*	Restricted to littoral and subtropical rainforest and adjacent wet sclerophyll forest with rainforest species dominating understorey; burrows into rotting logs or soil under logs; occurs from southeastern Qld to northeastern NSW, with its southern distributional limit upslope of Grafton.	No suitable habitat present in study area. The study area is outside of normal distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range, the absence of suitable habitat and the lack of records for the study area and locality.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
AMPHIBIANS			
Hylidae			
Green & Golden Bell Frog *Litoria aurea*	Highly terrestrial species found near and amongst vegetation at the edges of permanent or ephemeral water; active by day and night; an active terrestrial predator; cannibalistic; shelters under debris on low, often flooded river flats, or around semi-permanent water bodies.	Potential habitat (theoretically) associated with farm dams and freshwater wetlands in the study area. Not recorded in the study area or the locality; closest known site at Raymond Terrace has been destroyed (White 1996). Likelihood of occurrence - extremely low.	No significant impact. Some loss of potential or theoretical habitat, but no loss of 'known' habitat. No "*significant effect*" anticipated given the lack of evidence for this species in the areas "*likely to be affected by the action*".
Green-thighed Frog *Litoria brevipalmata*	Poorly known; found in wet sclerophyll forests from Ourimbah to southeast Qld; breeding occurs in late spring and summer around grassy semi-permanent ponds immediately after heavy rainfall; appears to prefer still standing water.	Potential habitat present through forest/grassland areas in the study area. Not recorded in study area nor the locality, but is known from State Forests to the south and north; Likelihood of occurrence - unknown, but probably low.	No significant impact likely. Very limited loss of potential 'known' breeding habitat; culverts at all drainage lines no special or unique habitat or resources along alignments. No "*significant effect*" anticipated given the lack of evidence for this species in the areas "*likely to be affected by the action*".
Wallum Tree Frog *Litoria olongburensis*	Inhabits creeks and marshy or swampy lowland habitats; lowland wetlands with acidic waters on Pleistocene coastal sand deposits are preferred, amongst emergent vegetation and reeds; found in the sandy heathlands of southeastern Qld/northeastern NSW; warm annual mean temperatures preferred.	No potential habitat present. Not recorded in the study area or in the locality. Likelihood of occurrence - none.	No impact. No suitable habitat will be lost. Not considered relevant to the proposal given the lack of evidence or records of the species, and the absence of preferred habitat in the areas "*likely to be affected by the action*".
Wallum Froglet *Crinia tinnula*	Inhabits sedgelands and paperbark swamps, particularly with acidic waters; feeds on invertebrates; shelters amongst sedges and emergent vegetation.	No potential habitat present. Not recorded in the study area or in the locality. Likelihood of occurrence - none.	No impact. No suitable habitat will be lost. Not considered relevant to the proposal given the lack of evidence or records of the species, and the absence of preferred habitat in the areas "*likely to be affected by the action*".

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Myobatrachidae			
Stuttering Barred Frog *Mixophyes balbus*	Subtropical distribution; found in riparian zone in warm and cool high altitude temperate rainforest and wet sclerophyll forest at any altitude; potentially widespread habitat throughout eastern NSW in cool to mild temperature ranges where large tracts of forest remain intact; deep leaf litter or thick understorey cover required; species found along graded banks with undercuts and steep edges; eggs laid on rocks or gravel.	Preferred habitat not present in the study area. Not recorded in the study area or the locality. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given the lack of evidence or records of the species, and the absence of preferred habitat in the areas "*likely to be affected by the action*".
Blue-eyed Barred Frog *Mixophyes fleayi*	Inhabits riparian vegetation in mid to high altitude subtropical and cool temperate rainforest where water is flowing; highly restricted to far northeastern NSW/southeastern Qld; requires deep leaf litter or thick understorey growth; takes refuge in adjacent rainforests in disturbed areas.	No suitable habitat present in the study area. Not recorded in the study area or the locality. Study area outside distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range, the absence of suitable habitat and the lack of records for the study area and locality.
Gold-eyed Barred Frog *Mixophyes iteratus*	Inhabits subtropical and warm temperate rainforests and rainforests with sclerophyll emergents; mainly at higher elevations, and in foothills and coastal forests; requires dense litter and/or understorey, including cover provided by invasive weeds; requires narrow and rapidly descending streams; distribution is widespread between Narooma and the Bunya Mountains in southeastern Qld.	No suitable habitat present in the study area. Not recorded in the study area or in the locality. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given the absence of suitable habitat and the lack of records for or evidence of the species in the study area and locality.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
MAMMALS			
Dasyuridae			
Brush-tailed Phascogale *Phascogale tapoatafa*	Inhabits dry sclerophyll forest and woodland, as well as open forest with sparse groundcover; feeds on invertebrates and nectar; nests in large tree-hollows, rotting stumps or bird nests; home ranges are up to 60ha for females and up to 100ha for males; rarely feeds on ground.	Potential open forest habitat present in the study area and locality; tree-hollows relatively uncommon but widely distributed. Not recorded in the study area but known from previous surveys in the locality (Gunninah 1997b, c; NP&WS Atlas). Likelihood of occurrence - moderate to high (under appropriate circumstances).	No significant impact currently, but the possibility of long-term effects. Removal of potential habitat (although no evidence of current use), and relevant resources (such as hollow-bearing trees); possible constraints on movement and increases in road mortality. A "*significant effect*" on the individuals along or near the alignment is likely, although a "*significant effect*" on the species is likely to occur.
Common Planigale *Planigale maculata*	Inhabits rainforest, dry sclerophyll forest, grassland and marshland; feeds on invertebrates and small vertebrates; constructs a nest on the ground with grass and bark in a sheltered position; often found under discarded sheets of iron and other such waste. Most southern record north of Forster (NP&WS 1994a).	Potential habitat present in the study area. Not recorded in the study area or the locality. Study area is outside usual distributional range. Likelihood of occurrence - extremely low to none.	No impact. Not considered relevant to the proposal, given that the study area is outside the species' distributional range and given the lack of records for or evidence of the study area and locality, and the lack of special or unique habitat.
Tiger Quoll *Dasyurus maculata*	Occurs in a range of habitats, including rainforest, open forest, woodland, coastal heathland and inland riparian forest; dens have been located in caves, rock crevices and hollow logs.	Potential open forest habitat present in the study area and throughout the locality. Not recorded in the study area but known from the locality (Clarke *pers comm*; NP&WS Atlas). Marginal to intermediate probability of occurrence in Karuah and Wallaroo SFs (NP&WS 1994). Likelihood of occurrence in moderate (but restricted to a few sites).	No significant impact. Loss of some ares of potential habitat in forested lands along the alignment, although areas of significance are few and not unique. No "*significant effect*" likely, given few records and the limited loss of potential or relevant habitats.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Phascolarctidae			
Koala *Phascolarctos cinereus*	Inhabits open eucalypt forest and woodland; preferred food species in the area include *Eucalyptus tereticornis*, *E microcorys*, *E punctata* and *E robusta*.	Suitable open forest habitat present in study area and throughout locality. Recorded in low numbers in the study area and considered common but with a patchy distribution in the locality and wider region. Present.	Adverse impact anticipated for individuals although not likely for species as a whole. Bypass will remove food resources and habit movement of animals through the landscape. Possibility of a "*significant effect*" on individuals and the local sub-population of the Koala.
Vombatidae			
Common Wombat *Vombatus ursinus*	Inhabits forested areas, including woodland, forest and heathland, particularly near open grassy areas; nests and shelters in extensive burrows; forages on native grasses and roots.	Possible habitat throughout study area and locality. Not recorded in study area. Likelihood of occurrence - extremely low.	No impact. No records or evidence in study area. No "*significant effect*".
Petauridae			
Squirrel Glider *Petaurus norfolcensis*	Inhabits dry sclerophyll forest and woodland; feeds on invertebrates, gum and nectar in trees; nests communally in tree-hollows.	Suitable open forest habitat is present in the study area and throughout the locality; relevant tree-hollows are relatively uncommon and widely distributed. Recorded in the study area and along the alignment, and widely through the region. Present.	Adverse impact on individuals likely. Bypass will remove foraging and shelter habitat (hollow-bearing Trees), and will present a barrier to movement through the landscapes. A "*significant effect*" maybe imposed upon elements of the local population of Squirrel Gliders, not with standing the implementation of appropriate impact amelioration measures.
Yellow-bellied Glider *Petaurus australis*	Inhabits tall, dry to moist forest with a diverse range of canopy species; feeds on sap, nectar and invertebrates; nests in tree-hollows; home range is approximately 35ha.	Potential (theoretically) open forest habitat in the study area and locality. No evidence of this species in the study area and not known from the locality. Likelihood of occurrence - extremely low to none.	No impact. No recognised habitat or resources; no evidence of presence in the locality. Not considered relevant to the proposal given the lack of evidence or records of the species, and the absence of preferred habitat in the areas "*likely to be affected by the action*".

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Potoroidae			
Rufous Bettong *Aepyprymnus rufescens*	Occurs in dry sclerophyll forest and woodland, wet sclerophyll forest and coastal forest where the understorey is open and grassy; nests in shallow depressions; forages nocturnally on herbs, grasses and roots.	Theoretical habitat and resources present in the study area and locality. No evidence in the study area and no records for the locality. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given the lack of evidence or records of the species, and the absence of preferred habitat in the areas "*likely to be affected by the action*".
Long-nosed Potoroo *Potorous tridactylus*	Occurs in sclerophyll forests with thick groundcover, and coastal heaths; feeds on roots, tubers, fungi, insects on ground; nests at the base of grass tussocks.	Suitable open forest habitat present in the study area and the locality but patchily distributed. Recorded (tentatively) in the study area at the eastern and of the alignment.	Possible adverse impact on individuals, although not likely on the species. Limited loss of habitat and resources and some potential restrictions on movements; possible increases in road mortality.
Macropodidae			
Parma Wallaby *Macropus parma*	Inhabits wet and dry sclerophyll forest and rainforest, particularly where the understorey ranges from dense and scrubby to open and grassy; forages nocturnally on grasses and herbs.	Potentially suitable habitat present in the study area and locality. No evidence of presence in the study area and no records from the locality. Likelihood of occurrence - extremely low.	No significant impact. Some loss of potential open forest habitat. No "*significant effect*" anticipated given the absence of any evidence in the areas "*likely to be affected by the action*" or in the locality, and the extent of suitable habitat in the locality and region.
Black-striped Wallaby *Macropus dorsalis*	Occurs in closed forest and scrub; shelters in large groups amongst dense understorey, including weed thickets; forages nocturnally in open pasture with some cover; occurs north from approximately Grafton to northern QLD.	Marginal potential habitat present in the study area, but not recorded in the study area or the locality. The study area is outside of normal distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside the Black-striped Wallaby's distributional range and given the absence of records for the study area and locality.
Red-legged Pademelon *Thylogale stigmatica*	Inhabits rainforest and wet sclerophyll forest; forages on leaves and fruit of rainforest plants; rarely leaves the cover of dense vegetation.	Preferred habitat not present in the study area. No evidence of this species in the study area and no records from the locality. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area does not support preferred habitat and given the absence of any records for the study area and locality.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Pteropodidae			
Queensland Blossom Bat *Syconycteris australis*	Inhabits sub-tropical rainforest, coastal eucalypt forest, heathland and Melaleuca swamps; feeds on nectar and pollen; *Banksia integrifolia* is especially important in winter; roosts in the sub-canopy of rainforest adjacent to heaths; known as far south as Forster.	No specific or relevant resources present within the study area and no preferred rainforest roosting habitat present along the alignment. Not recorded in the study area. Likelihood of occurrence - extremely low to none.	No impact. No "*significant effect*" given the absence of records in areas "*likely to be affected by the action*" and in the locality, the species' high mobility, the lack of relevant resources in the study area and the extent of suitable habitat in the locality and region.
Black Flying Fox *Pteropus alecto*	Roosts in mangrove swamps (especially those on islands in estuaries), and forages in rainforest; feeds on fruits and occasionally on blossoms; high roosting in dense leaf cover; southern distributional limit is Ballina.	Limited potential (theoretical) roosting habitat present along the Karuah River and around Horse Island, but no rainforest foraging habitat present along the alignment. Not recorded in the locality. Study area is outside of distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range and given the lack of records for the study area and locality.
Emballonuridae			
Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*	Poorly known species; inhabits eucalypt forest; forages above the tree canopy; requires tree-hollows for roosting.	Potential foraging habitat present in study area and widely distributed throughout the surrounding landscape; tree-hollows generally uncommon in the study area, Not recorded in the study area or locality?; Likelihood of occurrence - low to moderate.	No significant impact. Some loss of potential foraging and roosting habitat. No "*significant effect*" given the absence of records in areas "*likely to be affected by the action*" and in the locality, the species' high mobility, and the extent of suitable habitat in the locality and region.
Beccari's Freetail Bat *Mormopterus beccarii*	Occurs in a range of habitats, from rainforest to desert, where it forages above the canopy and along rivers; roosts in tree-hollows, but has been found in man-made structures; occurs across northern Australia, from approximately Shark Bay to Brisbane.	Potential habitat present within the study area and in the locality. Not recorded in the study area or locality. Study area is outside of distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range and given the absence of records for the study area and locality.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Emballonuridae contd			
Eastern Freetail Bat *Mormopterus norfolkensis*	Little known species; inhabits dry eucalypt forest and woodland; roosts in trees.	Suitable foraging habitat present in study area and widely distributed throughout the surrounding landscape; tree-hollows generally uncommon in the study area. Identified from calls recorded in forest communities within the study area. Present.	No significant impact. Some loss of open forest habitat (foraging and roosting resources). No "*significant effect*" anticipated given the absence of records of the species in the areas "*likely to be affected by the action*" and in the locality, the species' high mobility, and the extent of suitable habitat in the locality and region.
Vespertilionidae			
Golden-tipped Bat *Kerivoula papuensis*	Inhabits closed lowland forests especially rainforest; often located in coastal forests amongst dense vegetation near creeks; feeds on spiders in canopy; roosts in dense foliage and roofs.	Limited potential habitat available in the study area. Not recorded in the study area or locality. Likelihood of occurrence - extremely low to low.	No impact. Not considered relevant to the proposal given the absence of records for the study area and locality, and the limited potential habitat available in the areas "*likely to be affected by the action*".
Little Bent-wing Bat *Miniopterus australis*	Inhabits well-timbered areas including rainforest, Melaleuca swamps and dry sclerophyll forest; forages beneath the canopy for small insects; roosts in caves and tunnels; occurs from Cape York to the NSW central coast.	Suitable foraging habitat present in study area and widely distributed throughout the surrounding landscape; no roosting sites or nursery caves present in the study area. Identified from calls within the study area. Present.	No significant impact. Some loss of potential open forest foraging habitat, but no roosting resources. No "*significant effect*" anticipated given the species' high mobility, the lack of roosting resources in the study area and the extent of suitable habitat in the locality and region.
Common Bent-wing Bat *Miniopterus schreibersii*	Forages for insects above the canopy in well-timbered valleys; roosts in caves, old mines, stormwater channels and buildings; occurs in two disjunct populations, one from Cape York to the Mount Lofy Ranges in South Australia, and the other in the northern corner of WA, extending to Darwin,	Suitable foraging habitat present in study area and widely distributed throughout the surrounding landscape; no roosting sites or nursery caves present in the study area. Recorded in the study area and in the locality. Present.	No significant impact. Some loss of potential open forest foraging habitat, but no roosting resources. No "*significant effect*" anticipated given the species' high mobility, the lack of roosting resources in the study area and the extent of suitable habitat in the locality and region.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Vespertilionidae contd			
Eastern Long-eared Bat *Nyctophilus bifax*	Occurs primarily in rainforest; roosts in tree hollows and amongst foliage in dense vegetation, particularly rainforest; in NSW, restricted to the northeastern corner to approximately Iluka.	No suitable habitat present along alignment. Not recorded in the study area or the locality. The study area is outside of distributional range. Likelihood of occurrence - none.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range, the absence of suitable habitat and the lack of records for the study area and locality.
Large Pied Bat *Chalinolobus dwyeri*	Occurs in dry sclerophyll forest and woodland from central Queensland to southern NSW; roosts in caves, tunnels and other artificial structures.	Suitable foraging habitat present in study area and widely distributed throughout the surrounding landscape; no roosting sites present in the study area. Not recorded in the study area but known from the locality. Likelihood of occurrence - low to moderate.	No significant impact. Some loss of open forest foraging habitat, but no roosting resources. No "*significant effect*" given the absence of records in areas "*likely to be affected by the action*", the species' high mobility, the lack of roosting resources and the extent of suitable habitat in the locality and region.
Hoary Bat *Chalinolobus nigrogriseus*	Inhabits wet sclerophyll forest, open woodland, scrub and sand dunes; forages for insects on surfaces as well as in flight; roosts in rock crevices and tree-hollows; occurs from the Kimberly across northern Australia to approximately Grafton.	Potential foraging and roosting habitat present in study area and widely distributed throughout the surrounding landscape. Not recorded in the study area. Study area is outside usual distributional range. Likelihood of occurrence - low.	No impact. Not considered relevant to the proposal given that the study area is outside this species' distributional range and the absence of records for the study area and locality.
Large-footed Myotis *Myotis adversus*	Roosts in caves, mines or tunnels, under bridges and in buildings; always occurs near bodies of water, ranging from rainforest streams to large lakes and reservoirs; forages over water for aquatic invertebrates.	Suitable open water foraging habitat provided by the Karuah River and nearby freshwater wetlands and farm dams; no roosting sites present in the study area. Not recorded in the study area, but known from the locality. Likelihood of occurrence - low to moderate (occasional).	No impact. No "*significant effect*" anticipated given that the proposal will not adversely affect foraging resources for this species, the absence of roost sites in the areas "*likely to be affected by the action*", and the extent of suitable foraging habitat in the locality.

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Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Vespertilionidae contd			
Greater Broad-nosed Bat *Scoteanax rueppellii*	Occurs in various habitats, particularly forested gullies and along river systems; prefers drier areas; feeds on slow-flying insects and possibly on other bats (in captivity); nests in tree-hollows.	Foraging and roosting habitat present in study area and widely distributed throughout the surrounding landscape. Recorded in the study area, and known from the locality. Present.	No significant impact. Some loss of open forest habitat (foraging and roosting resources). No "*significant effect*" anticipated given the absence of records of the species in the areas "*likely to be affected by the action*" and in the locality, the species' high mobility, and the extent of suitable habitat in the locality and region.
Eastern Cave Bat *Vespadelus troughtoni*	Very poorly known species; roosts and nests in caves; occurs from Cape York to central NSW, on both sides of the Great Dividing Range; inhabits dry and wet forest.	Potential foraging habitat present in the study area, but no roosting caves. Not recorded in the study area or the locality. Likelihood of occurrence - extremely low to low.	No impact. Some loss of potential open forest foraging habitat. No "*significant effect*" anticipated given the absence of records of the species in the areas "*likely to be affected by the action*" and in the locality, the species' high mobility, the lack of roosting resources in the study area and the extent of suitable habitat in the locality and region.
Muridae			
Eastern Chestnut Mouse *Pseudomys gracilicaudatus*	Inhabits dense wet heath and swampy areas; appears to be a colonising species, occurring in high numbers in recently burnt areas; nocturnal; forages on seeds, leaves, fungi and insects.	Not suitable habitat present. Not recorded in the study area. Likelihood of occurrence - extremely low to none.	No impact. Not considered relevant to the proposal given that the study area does not support preferred habitat and given the absence of any records for the study area.
New Holland Mouse *Pseudomys novaehollandiae*	Occurs in dry heath and open forest; prefers sandy soils with sparse groundcover and litter layers; appears to be a colonising species, occurring in high numbers in recently disturbed areas; forages on seeds, invertebrates, flowers and fungi; nocturnal; burrows in sandy soil.	No suitable habitat present. Not recorded in the study area. Likelihood of occurrence - extremely low.	No impact. Not considered relevant to the proposal given that the study area does not support preferred habitat and given the absence of any records for the study area.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
FLORA			
Blandfordiaceae			
Christmas Bells *Blandfordia grandiflora*	Occurs from the Hawkesbury River to Glen Innes, on the coast and tablelands. Grows on damp sandy and peaty soils (Harden 1993).	Suitable habitat present (through patchy) in open forest stands in the study area and locality. Recorded in Smooth-barked Apple/Sydney Peppermint open forest in the study area. Present.	Localised impact. Loss of some habitat for the species along alignment, but suitable habitat is widespread in the locality and region. No "*significant effect*" anticipated given the small area quite "*likely to be effected by the action*" and the extent of suitable habitat.
Haloragaceae			
Gonocarpus salsoloides	Grows in swampy areas on sandy substrates in coastal areas from Port Macquarie to Royal NP (Harden 1991).	Could potentially occur in swampy areas of the study area, particularly around Wallaroo Swamp and other natural swamps. Not recorded in the study area. Likelihood of occurrence - low.	No impact. Suitable habitat extremely rare or not present, and no record of the species.
Myrtaceae			
Eucalyptus fergusonii	Occurs in wet sclerophyll forest or woodland on sandy soils from Bulahdelah to Morisset (Harden 1991).	Suitable habitat present in open forest stands in the study area and locality. Recorded in Spotted Gum open forest in the study area and also likely to occur in other communities. Present.	Localised impact. Loss of some habitat for the species along alignment, but suitable habitat is widespread in the locality and region. No "*significant effect*" anticipated given the small area quite "*likely to be effected by the action*" and the extent of suitable habitat.
Swamp Mahogany *Eucalyptus robusta*	Occurs in heath or swampy sites on sandy soils north from Moruya (Harden 1991).	Suitable habitat present in open forest stands in the study area and locality. Recorded in Cabbage Gum/White Stringybark/Rough-barked Apple open forest in the study area and as remnant trees or amongst small stands in cleared pasture or highly modified land. Present.	Localised impact. Loss of some habitat for the species along alignment, but suitable habitat is widespread in the locality and region. No "*significant effect*" anticipated given the small area quite "*likely to be effected by the action*" and the extent of suitable habitat.

APPENDIX F Habitat requirements, likelihood of occurrence on the subject site, and potential impacts on subject species along the Karuah Bypass.

Species	Habitat Requirements	Likelihood of Occurrence	Potential Impact of Proposal
Myrtaceae contd			
Syzygium paniculatum	Occurs in subtropical and littoral rainforest in coastal areas in disjunct populations from Bulahdelah to Jervis Bay (Harden 1991). Prefers sandy soils.	No preferred habitat present in the study area. Not recorded in the study area. Likelihood of occurrence - extremely low.	No impact. Suitable habitat extremely rare or not present, and no record of the species.
Proteaceae			
Grevillea guthrieana (obtusiflora)	Occurs in dry sclerophyll forests or woodland on acid soils (Harden 1991).	Possible habitat present in open forest stands in the study area and locality, although no evidence of acid soils. Not recorded in the study area, but has been recorded in the Great Lakes District. Likelihood of occurrence - low to moderate.	No significant impact. No evidence for species in the study area, and even if present is not likely to be subjected to a "*significant effect*", given the extent of similar habitat in the locality and region.
Hakea bakeriana	Occurs in dry sclerophyll forest on the coast and adjacent ranges from the mid-north coast of NSW to the Glenorie district (Harden 1991).	Potential habitat present in open forest stands in the study area and locality. Not recorded in the study area, but potentially present in open forest communities in the study area. Likelihood of occurrence - low to moderate.	No significant impact. No evidence for species in the study area, and even if present is not likely to be subjected to a "*significant effect*", given the extent of similar habitat in the locality and region.
Tremandraceae			
Black-eyed Susan *Tetratheca juncea*	Occurs in dry sclerophyll forest on coastal sandstone from Bulahdelah to Lake Macquarie; also found in swampy heath.	Suitable habitat present in open forest stands in the study area and locality. Recorded at two locations in Smooth-barked Apple/Brown Stringybark/Bastard Mahogany open forest in the study area, and may also potentially occur in Smooth-barked Apple/Sydney Peppermint communities. Present.	Adverse impacts on individuals and possibly on sub-populations. Occasional plants maybe lost along the whole alignment. Partial loss of population on Horse Island is inevitable. A "*significant effect*" will be imposed upon the Horse Island population, but the significance of impacts upon the species as a whole are not clear.

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX G

Inventory of Fauna Species Recorded

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX G Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

KEY

Conservation Status

- * Introduced species.
- E Endangered - listed on Schedule 1 of the NSW *Threatened Species Conservation Act* 1995 (TSC Act).
- V Vulnerable - listed on Schedule 2 of the TSC Act.
- R Rare in the locality or in the North Coast Region (NP&WS)

Sources of Information

- A Species recorded in the study area during investigations conducted for the Species Impact Statement (Gunninah 1999c)
- B Species recorded in the study area during investigations conducted for the Fauna and Flora Assessment (Gunninah 1999b).
- C Species recorded in the general vicinity of the subject site during surveys conducted for previous reports (Ecotone 1995; Gunninah 1997a, 1997b, 1997c, 1997d).
- D Species listed on databases for the locality
  - a NSW NP&WS Wildlife Atlas Port Stephens (9332) and Newcastle (9732) 1:100000 map-sheets. Species recorded within 10km of the general study area (amgs 6376000 - 6400000 and 388000 - 416000). Accessed November 1998.
  - b Species listed on the Birds Australia Atlas in the general vicinity of the study area (between latitudes 32°30'S and 32°50'S and longitudes 151°50'E and 152°00'E).

Microchiropteran bat call identification reliability estimates

C Confident P Probable Po Possible

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	BIRDS					
	Casuariidae					
	Emu	*Dromaius novaehollandiae*				a
	Phasianidae					
	Brown Quail	*Coturnix ypsilophora*				b
	Anatidae					
	Musk Duck	*Biziura lobata*			×	b
	Black Swan	*Cygnus atratus*		×	×	b
	Australian Wood Duck	*Chenonetta jubata*	×	×	×	a,b
	Pacific Black Duck	*Anas superciliosa*	×	×	×	b
	Australasian Shoveler	*Anas rhynchotis*			×	
	Grey Teal	*Anas gracilis*				b
	Chestnut Teal	*Anas castanea*				b
	Hardhead	*Aythya australis*			×	b
	Podicipedidae					
	Australasian Grebe	*Tachybaptus novaehollandiae*	×	×	×	b
	Hoary-headed Grebe	*Poliocephalus poliocephalus*				b
	Great Crested Grebe	*Podiceps cristatus*				b
	Anhingidae					
	Darter	*Anhinga melanogaster*			×	b
	Phalacrocoracidae					
	Little Pied Cormorant	*Phalacrocorax melanoleucos*		×	×	b
	Pied Cormorant	*Phalacrocorax varius*				b
	Little Black Cormorant	*Phalacrocorax sulcirostris*		×	×	b
	Great Cormorant	*Phalacrocorax carbo*		×	×	b
	Pelecanidae					
	Australian Pelican	*Pelecanus conspicillatus*			×	b
	Ardeidae					
	White-faced Heron	*Egretta novaehollandiae*	×	×	×	b
	White-necked Heron	*Ardea pacifica*		×		b
	Great Egret	*Ardea alba*				b

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Ardeidae cont					
	Intermediate Egret	*Ardea intermedia*		×	×	
	Cattle Egret	*Ardea ibis*		×	×	b
	Striated Heron	*Butorides striatus*			×	b
	Nankeen Night Heron	*Nycticorax caledonicus*				b
	Threskiornithidae					
	Glossy Ibis	*Plegadis falcinellus*				b
	Australian White Ibis	*Threskiornis molucca*		×	×	b
	Straw-necked Ibis	*Threskiornis spinicollis*		×	×	b
	Royal Spoonbill	*Platalea regia*		×	×	b
	Yellow-billed Spoonbill	*Platalea flavipes*				b
	Ciconiidae					
V	Black-necked Stork	*Ephippiorhynchus asiaticus*				b
	Accipitridae					
V	Osprey	*Pandion haliaetus*		×		
	Pacific Baza	*Aviceda subcristata*				a
	Black-shouldered Kite	*Elanus axillaris*	×	×	×	b
	Whistling Kite	*Haliastur sphenurus*		×	×	a,b
	Brahminy Kite	*Haliastur indus*				a
	White-bellied Sea-Eagle	*Haliaetus leucogaster*		×	×	a,b
	Brown Goshawk	*Accipiter fasciatus*	×		×	b
	Grey Goshawk	*Accipiter novaehollandiae*			×	
	Wedge-tailed Eagle	*Aquila audax*	×	×		a
	Little Eagle	*Hieraaetus morphnoides*			×	
	Falconidae					
	Brown Falcon	*Falco berigora*	×	×		b
	Australian Hobby	*Falco longipennis*				b
	Peregrine Falcon	*Falco peregrinus*				a
	Nankeen Kestrel	*Falco cenchroides*				a,b
	Rallidae					
	Lewin's Rail	*Gallirallus pectoralis*				b
	Purple Swamphen	*Porphyrio porphyrio*			×	b
	Dusky Moorhen	*Gallinula tenebrosa*			×	
	Eurasian Coot	*Fulica atra*			×	b
	Scolopacidae					
	Latham's Snipe	*Gallinago hardwickii*	×			b
	Bar-tailed Godwit	*Limosa lapponica*				b
	Whimbrel	*Numenius phaeopus*				a,b
	Eastern Curlew	*Numenius madagascariensis*		×		b
	Marsh Sandpiper	*Tringa stagnatilis*				b
	Common Greenshank	*Tringa nebularia*				b
	Common Sandpiper	*Actitis hypoleucos*				b
	Grey-tailed Tattler	*Heteroscelus brevipes*				b
	Red-necked Stint	*Calidris ruficollis*				b
	Sharp-tailed Sandpiper	*Calidris acuminata*				b
	Curlew Sandpiper	*Calidris ferruginea*				b
	Burhinidae					
E	Bush Stone-curlew	*Burhinus grallarius*	× (t)			a,b
	Recurvirostridae					
	Black-winged Stilt	*Himantopus himantopus*				b
	Charadriidae					
	Pacific Golden Plover	*Pluvialis fulva*				a
	Red-capped Plover	*Charadrius ruficapillus*				b
	Double-banded Plover	*Charadrius bicinctus*				a
V	Lesser Sand Plover	*Charadrius mongolus*				b

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Charadriidae contd					
	Black-fronted Plover	*Elseyornis melanops*				b
	Masked Lapwing	*Vanellus miles*	×	×	×	a,b
	Laridae					
	Silver Gull	*Larus novaehollandiae*		×		b
	Gull-billed Tern	*Sterna nilotica*				b
	Caspian Tern	*Sterna caspia*				a
	Common Tern	*Sterna hirundo*				b
E	Little Tern	*Sterna albifrons*				b
	Crested Tern	*Sterna bergii*		×		b
	Columbidae					
*	Rock Dove	*Columba livia*				b
*	Spotted Turtle-Dove	*Streptopelia chinensis*	×	×	×	a,b
	Common Bronzewing	*Phaps chalcoptera*			×	
	Brush Bronzewing	*Phaps elegans*				a
	Crested Pigeon	*Ocyphaps lophotes*	×	×	×	a,b
	Peaceful Dove	*Geopelia placida*	×	×	×	b
	Bar-shouldered Dove	*Geopelia humeralis*	×	×		b
	Wonga Pigeon	*Leucosarcia melanoleuca*	×		×	a
V	Wompoo Fruit-Dove	*Ptilinopus magnificus*				a
	Topknot Pigeon	*Lopholaimus antarcticus*				b
	Cacatuidae					
V	Glossy Black-Cockatoo	*Calyptorhynchus lathami*	×		×	a,b
	Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*		×	×	a,b
	Galah	*Cacatua roseicapilla*	×	×	×	a,b
	Little Corella	*Cacatua sanguinea*			×	
	Sulphur-crested Cockatoo	*Cacatua galerita*		×	×	a
	Psittacidae					
	Rainbow Lorikeet	*Trichoglossus haematodus*		×		a,b
	Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*			×	b
	Little Lorikeet	*Glossopsitta pusilla*				a,b
	Australian King-Parrot	*Alisterus scapularis*	×		×	a,b
	Eastern Rosella	*Platycercus eximius*	×	×	×	a,b
	Red-rumped Parrot	*Psephotus haematonotus*	×	×		b
	Cuculidae					
	Pallid Cuckoo	*Cuculus pallidus*				a,b
	Brush Cuckoo	*Cuculus variolosus*	×			b
	Fan-tailed Cuckoo	*Cacomantis flabelliformis*	×		×	a,b
	Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*				b
	Shining Bronze-Cuckoo	*Chrysococcyx lucidus*				a,b
	Common Koel	*Eudynamis scolopacea*	×			a,b
	Channel-billed Cuckoo	*Scythrops novaehollandiae*	×			a,b
	Centropodidae					
	Pheasant Coucal	*Centropus phasianinus*	×			a,b
	Strigidae					
V	Powerful Owl	*Ninox strenua*				a
	Southern Boobook	*Ninox novaeseelandiae*	×		×	a
	Tytonidae					
V	Masked Owl	*Tyto novaehollandiae*	×		×	a
	Podargidae					
	Tawny Frogmouth	*Podargus strigoides*	×	×	×	a
	Caprimulgidae					
	White-throated Nightjar	*Eurostopodus mystacalis*	×	×		a
	Aegothelidae					
	Australian Owlet-nightjar	*Aegotheles cristatus*	×	×	×	a

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Apodidae					
	White-throated Needletail	*Hirundapus caudacutus*	×	×	×	b
	Alcedinidae					
	Azure Kingfisher	*Alcedo azurea*	×		×	a
	Halcyonidae					
	Laughing Kookaburra	*Dacelo novaeguineae*	×	×	×	a,b
	Forest Kingfisher	*Todiramphus macleayii*			×	
	Sacred Kingfisher	*Todiramphus sanctus*	×	×	×	a,b
	Meropidae					
	Rainbow Bee-eater	*Merops ornatus*		×		a
	Coraciidae					
	Dollarbird	*Eurystomus orientalis*		×	×	a,b
	Climacteridae					
	White-throated Treecreeper	*Cormobates leucophaeus*	×	×	×	a,b
	Brown Treecreeper	*Climacteris picumnus*				b
	Maluridae					
	Superb Fairy-wren	*Malurus cyaneus*	×	×	×	a,b
	Variegated Fairy-wren	*Malurus lamberti*	×	×	×	a,b
	Southern Emu-wren	*Stipiturus malachurus*			×	a,b
	Pardalotidae					
	Spotted Pardalote	*Pardalotus punctatus*	×	×	×	a,b
	Striated Pardalote	*Pardalotus striatus*	×		×	b
	Yellow-throated Scrubwren	*Sericornis citreogularis*	×			b
	White-browed Scrubwren	*Sericornis frontalis*	×	×	×	a,b
R	Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	×			a
	Weebill	*Smicrornis brevirostris*	×		×	
	Brown Gerygone	*Gerygone mouki*	×			a,b
	White-throated Gerygone	*Gerygone olivacea*	×	×	×	a,b
	Brown Thornbill	*Acanthiza pusilla*	×	×	×	a,b
	Buff-rumped Thornbill	*Acanthiza reguloides*		×		a,b
	Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*				b
	Yellow Thornbill	*Acanthiza nana*			×	a,b
	Striated Thornbill	*Acanthiza lineata*	×	×	×	a,b
	Meliphagidae					
	Red Wattlebird	*Anthochaera carunculata*	×		×	a,b
	Little Wattlebird	*Anthochaera chrysoptera*				a,b
	Noisy Friarbird	*Philemon corniculatus*	×		×	a,b
	Blue-faced Honeyeater	*Entomyzon cyanotis*				a
	Noisy Miner	*Manorina melanocephala*	×	×	×	a,b
	Lewin's Honeyeater	*Meliphaga lewinii*	×		×	a,b
	Yellow-faced Honeyeater	*Lichenostomus chrysops*	×	×	×	a,b
	Fuscous Honeyeater	*Lichenostomus fuscus*				a,b
	Brown-headed Honeyeater	*Melithreptus brevirostris*		×		a,b
	White-naped Honeyeater	*Melithreptus lunatus*	×		×	a
	Brown Honeyeater	*Lichmera indistincta*			×	a,b
	White-cheeked Honeyeater	*Phylidonyris nigra*		×	×	a,b
	Tawny-crowned Honeyeater	*Phylidonyris melanops*				b
	Eastern Spinebill	*Acanthorhynchus tenuirostris*	×		×	a,b
	Scarlet Honeyeater	*Myzomela sanguinolenta*	×			a,b
	White-fronted Chat	*Epthianura albifrons*				a,b
	Petroicidae					
	Scarlet Robin	*Petroica multicolor*			×	a
	Hooded Robin	*Melanodryas cucullata*				b
	Eastern Yellow Robin	*Eopsaltria australis*	×	×	×	a,b
	Jacky Winter	*Microeca fascinans*		×		b

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Pomatostomidae					
	Grey-crowned Babbler	*Pomatostomus temporalis*				b
	Cinclosomatidae					
	Eastern Whipbird	*Psophodes olivaceus*	×		×	a,b
	Neosittidae					
	Varied Sittella	*Daphoenositta chrysoptera*				b
	Pachycephalidae					
	Crested Shrike-tit	*Falcunculus frontatus*	×			b
	Golden Whistler	*Pachycephala pectoralis*	×		×	a,b
	Rufous Whistler	*Pachycephala rufiventris*	×	×	×	a,b
	Grey Shrike-thrush	*Colluricincla harmonica*	×	×	×	a,b
	Dicruridae					
	Black-faced Monarch	*Monarcha melanopsis*			×	a,b
	Leaden Flycatcher	*Myiagra rubecula*	×		×	a,b
	Restless Flycatcher	*Myiagra inquieta*				b
	Magpie-lark	*Grallina cyanoleuca*	×	×	×	a,b
	Rufous Fantail	*Rhipidura rufifrons*	×		×	a,b
	Grey Fantail	*Rhipidura fuliginosa*	×	×	×	a,b
	Willie Wagtail	*Rhipidura leucophrys*	×	×	×	a,b
	Spangled Drongo	*Dicrurus bracteatus*		×	×	
	Campephagidae					
	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	×	×	×	a,b
	White-bellied Cuckoo-shrike	*Coracina papuensis*				a
	Cicadabird	*Coracina tenuirostris*	×	×	×	a,b
	White-winged Triller	*Lalage sueurii*				b
	Oriolidae					
	Olive-backed Oriole	*Oriolus sagittatus*	×		×	a,b
	Figbird	*Sphecotheres viridis*			×	a
	Artamidae					
	White-breasted Woodswallow	*Artamus leucorhynchus*				a,b
	Dusky Woodswallow	*Artamus cyanopterus*				a,b
	Grey Butcherbird	*Cracticus torquatus*	×	×	×	a,b
	Pied Butcherbird	*Cracticus nigrogularis*	×	×		a,b
	Australian Magpie	*Gymnorhina tibicen*	×	×	×	a,b
	Pied Currawong	*Strepera graculina*	×	×	×	a,b
	Corvidae					
	Australian Raven	*Corvus coronoides*	×	×	×	a,b
	Forest Raven	*Corvus tasmanicus*				a
	Corcoracidae					
	White-winged Chough	*Corcorax melanorhamphos*	×	×	×	a,b
	Ptilonorhynchidae					
	Satin Bowerbird	*Ptilonorhynchus violaceus*	×		×	a,b
	Green Catbird	*Ailuroedus crassirostris*	×			
	Motacillidae					
	Richard's Pipit	*Anthus novaeseelandiae*	×	×	×	b
	Passeridae					
*	House Sparrow	*Passer domesticus*				b
	Zebra Finch	*Taeniopygia guttata*				b
	Double-barred Finch	*Taeniopygia bichenovii*				b
	Red-browed Finch	*Neochmia temporalis*	×	×	×	a,b
	Diamond Firetail	*Stagonopleura guttata*				b
	Chestnut-breasted Mannikin	*Lonchura castaneothorax*				b
	Dicaeidae					
	Mistletoebird	*Dicaeum hirundinaceum*		×	×	a,b

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Hirundinidae					
	Welcome Swallow	*Hirundo neoxena*	×	×	×	a,b
	Tree Martin	*Hirundo nigricans*				a,b
	Fairy Martin	*Hirundo ariel*	×			b
	Sylviidae					
	Clamorous Reed-Warbler	*Acrocephalus stentoreus*				b
	Little Grassbird	*Megalurus gramineus*				b
	Golden-headed Cisticola	*Cisticola exilis*			×	b
	Rufous Songlark	*Cincloramphus mathewsi*				b
	Brown Songlark	*Cincloramphus cruralis*				b
	Zosteropidae					
	Silvereye	*Zosterops lateralis*			×	a,b
	Muscicapidae					
	Bassian Thrush	*Zoothera lunulata*				b
	Sturnidae					
*	Common Starling	*Sturnus vulgaris*		×	×	b
*	Common Mynah	*Acridotheres tristis*		×	×	b
	AMPHIBIANS					
	Myobatrachidae					
	Tusked Frog	*Adelotus brevis*				a
	Common Eastern Froglet	*Crinia signifera*	×		×	a
	Eastern Banjo Frog	*Limnodynastes dumerilii*		×		a
	Ornate Burrowing Frog	*Limnodynastes ornatus*				a
	Brown-striped Frog	*Limnodynastes peronii*	×		×	a
	Spotted Grass Frog	*Limnodynastes tasmaniensis*	×		×	a
	Brown Toadlet	*Pseudophryne bibroni*		×		a
	Red-backed Toadlet	*Pseudophryne coriacea*			×	a
	Smooth Toadlet	*Uperoleia laevigata*	×		×	a
	Hylidae					
	Green Tree Frog	*Litoria caerulea*	×			
	Bleating Tree Frog	*Litoria dentata*	×			a
	Eastern Dwarf Tree Frog	*Litoria fallax*	×	×	×	a
	Frecinet's Frog	*Litoria freycineti*	×			a
	Günther's Frog	*Litoria latopalmata*	×	×	×	a
	Peron's Tree Frog	*Litoria peronii*	×	×	×	a
	Leaf Green Tree Frog	*Litoria phyllochroa*				a
	Tyler's Tree Frog	*Litoria tylerii*	×			
	Verreaux's Tree Frog	*Litoria verreauxii*	×		×	
	REPTILES					
	Chelidae					
	Long-necked Tortoise	*Chelodina longicollis*		×		
	Agamidae					
	Jacky Lizard	*Amphibolurus muricatus*	×	×	×	a
	Bearded Dragon	*Pogona barbata*	×	×	×	a
	Eastern Water Dragon	*Physignathus leseurii*	×		×	
	Varanidae					
	Lace Monitor	*Varanus varius*	×	×	×	a
	Gekkonidae					
	Southern Leaf-tailed Gecko	*Phyllurus cornatus*			×	
	Broad-tailed Gecko	*Phyllurus platurus*	×			
	Lesueur's Velvet Gecko	*Oedura lesueurii*	×			
	Robust Velvet Gecko	*Oedura robusta*			×	
	Scincidae					
	Striped Skink	*Ctenotus robustus*	×		×	a

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Scincidae contd					
	Land Mullet	*Egernia major*				a
	Eastern Water Skink	*Eulamprus quoyii*		×	×	a
	Pink-tongued Lizard	*Hemisphaeriodon gerrardii*			×	
	Friendly Sunskink	*Lampropholis amicula*				a
	Garden Skink	*Lampropholis delicata*	×	×	×	a
	Grass Skink	*Lampropholis guichenoti*	×	×	×	
	Eastern Blue-tongued Lizard	*Tiliqua scincoides*			×	a
	Shingleback	*Trachydosaurus rugosus*				a
	Bandy Bandy	*Vermicella multifasciata*	×			
	Boidae					
	Diamond Python	*Morelia spilota* ssp *spilota*			×	
	Elapidae					
	Golden-crowned Snake	*Cacophis squamulosus*				a
	Small-eyed Snake	*Cryptophis nigrescens*	×			
	Yellow-faced Whip Snake	*Demansia psammophis*			×	
	Black-bellied Swamp Snake	*Hemiaspis signata*		×	×	
	Red-bellied Black Snake	*Pseudechis porphyriacus*	×	×	×	a
	Eastern Brown Snake	*Pseudonaja textilis*		×		a
	MAMMALS					
	Ornithorhynchidae					
	Platypus	*Ornithorhynchus anatinus*				a
	Tachyglossidae					
	Short-beaked Echidna	*Tachyglossus aculeatus*	×		×	a
	Dasyuridae					
	Brown Antechinus	*Antechinus stuartii*	×	×	×	a
V	Tiger Quoll	*Dasyurus maculatus*				a
V	Brush-tailed Phascogale	*Phascogale tapoatafa*			×	a
	Common Dunnart	*Sminthopsis murina*			×	
	Peramelidae					
	Long-nosed Bandicoot	*Perameles nasuta*	×			a
	Northern Brown Bandicoot	*Isoodon macrourus*	×		×	a
	Phascolarctidae					
V	Koala	*Phascolarctos cinereus*	×	×	×	a
	Vombatidae					
R	Common Wombat	*Vombatus ursinus*				a
	Petaurdiae					
	Sugar Glider	*Petaurus breviceps*	×		×	a
V	Squirrel Glider	*Petaurus norfolcensis*		×	×	a
	Pseudocheiridae					
	Common Ringtail Possum	*Pseudocheirus peregrinus*	×	×	×	a
	Acrobatidae					
	Feathertail Glider	*Acrobates pygmaeus*	×	×	×	a
	Phalangeridae					
	Mountain Brushtail Possum	*Trichosurus caninus*			×	
	Common Brushtail Possum	*Trichosurus vulpecula*	×	×	×	a
	Potoridae					
V	Long-nosed Potoroo	*Potorous tridactylus*	×			
	Macropodidae					
	Kangaroo	*Macropus* sp				a
	Red-necked Wallaby	*Macropus rufogriseus*	×	×	×	a
	Eastern Grey Kangaroo	*Macropus giganteus*		×	×	a

APPENDIX G contd Fauna species recorded along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah, NSW.

Status	COMMON NAME	SCIENTIFIC NAME	A	B	C	D
	Macropodidae contd					
	Common Wallaroo	*Macropus robusta*			×	a
	Swamp Wallaby	*Wallabia bicolor*	×	×	×	a
	Pteropidae					
	Grey-headed Flying-fox	*Pteropus poliocephalus*				a
	Rhinolophidae					
	Eastern Horseshoe-bat	*Rhinolophus megaphyllus*	×		×	
	Molossidae					
	Little Freetail Bat	*Mormopterus* sp1		C	×	
V	Eastern Free-tail Bat	*Mormopterus norfolkensis*	C	C	×	
	White-striped Mastiff Bat	*Nyctinomus australis*		×	×	a
	Vespertilionidae					
	Gould's Wattled Bat	*Chalinolobus gouldii*		×	×	a
	Chocloate Wattled Bat	*Chalinolobus morio*		×	×	a
	Long-eared Bat	*Nyctophilus* sp		C	×	
	Lesser Long-eared Bat	*Nyctophilus geoffroyi*		×		a
	Gould's Long-eared Bat	*Nyctophilus gouldi*	×			a
V	Large Bent-wing Bat	*Miniopterus schreibersii*	P		×	
V	Little Bent-wing Bat	*Miniopterus australis*	C	×	×	
	Eastern Broad-nosed Bat	*Scotorepens orion*		P	×	
V	Greater Broad-nosed Bat	*Scoteanax rueppellii*	Po	P		
	Eastern Forest Bat	*Vespadelus pumilus*		Po		
	Little Forest Bat	*Vespadelus vulturnus*	×	×	×	a
	Muridae					
	Bush Rat	*Rattus fuscipes*	×	×	×	a
	Swamp Rat	*Rattus lutreolus*		×	×	a
R	New Holland Mouse	*Pseudomys novaehollandiae*				a
	Introduced Mammals					
*	Black Rat	*Rattus rattus*			×	
*	Dingo/Dog	*Canis familiaris*		×		a
*	Goat	*Capra hircus*				a
*	Cattle	*Bos taurus*		×		
*	Horse	*Equus caballus*		×	×	a
*	Cat	*Felis catus*		×		a
*	Rabbit	*Oryctolagus cuniculus*		×		
*	Brown Hare	*Lepus capensis*		×	×	a
*	House Mouse	*Mus musculus*				a
*	Sheep	*Ovis aries*				a
*	Fox	*Vulpes vulpes*	×			a

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX H

Inventory of Flora Species Recorded

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX H Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

KEY

Conservation Status

* Exotic/non-endemic species

N Noxious weed listed on the *NSW Noxious Weeds Act 1993*

R Rare or Threatened Australian Plant - ROTAP (Briggs & Leigh 1996)

E Threatened species listed on Schedule 1 (Endangered) of the *NSW Threatened Species Conservation Act 1995* (TSC Act)

V Threatened species listed on Schedule 2 - Vulnerable of the TSC Act

r Species of regional conservation significance

K Species specified in Schedule 2 of the State Environmental Planning Policy 44 - Koala Habitat Protection

Sources of Information

A Species recorded along the Horse Island route and in the surrounding area (Gunninah 1999b & c)

B Species recorded previously in the 'main study area' for the proposed upgrade of the Pacific Highway at Karuah (Gunninah 1997a) - immediately north of Karuah and south of the Horse Island route option.

Status	BOTANICAL NAME	COMMON NAME	A	B
	FILOCOPSIDA			
	Adiantaceae			
	Adiantum aethiopicum	Maiden-hair Fern	×	×
	Cheilanthes sieberi	Mulga Fern	×	×
	Cheilanthestenifolia	Rock Fern	×	
	Azollaceae			
	Azolla pinnata	-	×	×
	Blechnaceae			
	Blechnum cartilagineum	Gristle Fern		×
	Blechnum indicum	Swamp Water Fern	×	×
	Dennstaedtiaceae			
	Pteridium esculentum	Bracken	×	×
	Dicksoniaceae			
	Calochlaena dubia	Common Ground Fern	×	
	Gleicheniaceae			
	Gleichenia dicarpa	Pouched Coral Fern	×	×
	Lindsaeaceae			
	Lindsaea linearis	Screw Fern		×
	Lindsaea microphylla	Lacy Wedge Fern	×	×
	Pteridaceae			
	Pteris tremula	Tender Brake	×	
	Scrophulariaceae			
	Gratiola pedunculata	-	×	
	Veronica plebeia	Trailing Speedwell	×	
	Selaginellaceae			
	Selaginella uliginosa	-	×	×
	CONIFEROPSIDA			
	Pinaceae			
*	*Pinus radiata*	Radiata Pine	×	×
	MAGNOLIOPSIDA: DICOTYLEDONS			
	Acanthaceae			
	Brunoniella australis	Blue Trumpet	×	×
	Pseuderanthemum variabile	Pastel Flower	×	
	Amaranthaceae			
	Alternanthera denticulata	Lesser Joyweed	×	×

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Apiaceae			
	Actinotus helianthi	Flannel Flower		×
	Burchardia umbellata	Milkmaids	×	
	Centella asiatica	Pennywort	×	×
	Hydrocotyle peduncularis	-	×	
	Platysace linearifolia	-	×	
	Trachymene incisa	-	×	×
	Xanthosia pilosa	-	×	×
	Xanthosia tridendata	-	×	×
	Apocynaceae			
	Parsonsia straminea	Common Silkpod	×	×
	Araliaceae			
	Astrotricha longifolia	Star-hair	×	×
	Polyscias sambucifolia ssp A	Elderberry Panax	×	×
	Asclepiadaceae			
*	*Araujia sericifolia*	Moth Vine	×	×
*	*Gomphocarpus fruticosus*	Narrow-leaved Cotton Bush	×	×
	Marsdenia rostrata	Common Milk Vine	×	
	Asteraceae			
*	*Ageratina adenophora*	Crofton Weed	×	×
*	*Ageratum houstonianum*	-	×	
*	*Bidens pilosa*	Cobbler's Pegs	×	×
	Brachycome angustifolia var *angustifolia*	-	×	×
	Calotis dentex	-	×	
	Calotis hispidula	Bogan Flea	×	×
*	*Carduus nutans* ssp *nutans*	Nodding Thistle	×	×
*	*Carthamus lanatus*	Saffron Thistle	×	
	Cassinia aculeata	Dolly Bush	×	
	Cassinia uncata	Sticky Cassinia	×	×
	Centipeda minima	Spreading Sneezeweed	×	
	Chrysocephalum apiculatum	Common Everlasting	×	×
*	*Cirsium vulgare*	Spear Thistle	×	×
*	*Conyza albida*	Tall Fleabane	×	×
*	*Conyza bonariensis*	Flaxleaf Fleabane	×	×
*	*Conyza canadensis*	Canadian Fleabane	×	×
	Cotula coronopifolia	Water Buttons	×	
	Epaltes australis	Spreading Nut-heads	×	×
	Euchiton sphaericus	-	×	
	Glossogyne tannensis	Cobbler's Tack	×	×
	Gnaphalium involucratum	Star Cudweed	×	×
	Gnaphalium sphaerocarpum	-	×	×
	Helichrysm rutidolepis	Pale Everlasting	×	×
	Helichrysm scorpioides	Button Everlasting	×	
*	*Hypochaeris radicata*	Flatweed	×	×
*	*Lactuca serriola*	Prickly Lettuce	×	
	Lagenifera stipitata	Blue Bottle-daisy	×	×
	Ozothamnus diosmifolius	White Dogwood	×	×
	Pseudognaphalium luteo-album	Jersey Cudweed	×	×
	Senecio diaschides	-	×	×
*	*Senecio madagascariensis*	Fireweed	×	×
	Senecio hispidulus var *hispidulus*	Hill Fireweed	×	×
	Sigesbeckia orientalis	Indian Weed	×	
*	*Silybum marianum*	Variegated Thistle	×	×
*	*Sonchus asper* ssp *glaucescens*	Prickly Sowthistle	×	
*	*Sonchus oleraceus*	Common Sowthistle	×	×
*	*Tagetes minuta*	Stinking Roger	×	×
	Vernonia cinerea	-	×	×
	Vittadinia hispidula	-	×	
	Vittadinia muelleri	-	×	
	Avicenniaceae			
	Avicennia marina ssp *australiasica*	Grey Mangrove	×	×
	Bignoniaceae			
	Pandorea pandorana	Wonga Wonga Vine	×	
	Brassicaceae			
*	*Capsella bursa-pastoris*	Shepherd's Purse	×	×
*	*Coronopus didymus*	Lesser Swinecress	×	

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Brassicaceae contd			
*	*Raphanus raphanistrum*	Wild Radish	×	×
	Campanulaceae			
	Wahlenbergia communis	Tufted Bluebell	×	×
	Wahlenbergia gracilis	Australian Bluebell	×	×
	Wahlenbergia stricta var *stricta*	Tall Bluebell	×	×
	Caprifoliaceae			
*	*Lonicera japonica*	Japanese Honeysuckle	×	×
	Cassythaceae			
	Cassytha glabella	Devil's Twine	×	×
	Cassytha pubescens	Devil's Twine	×	×
	Casuarinaceae			
	Allocasuarina littoralis	Black Sheoak	×	×
	Allocasuarina torulosa	Forest Oak	×	×
	Casuarina glauca	Swamp Oak	×	×
	Chenopodiaceae			
	Atriplex australasica		×	
	Atriplex semibaccata	Creeping Saltbush	×	×
*	*Chenopodium album*	Fat Hen	×	×
	Einadia hastata	Berry Saltbush	×	×
	Sarcocornia quinqueflora	-	×	×
	Suaeda australis	-	×	×
	Convolvulaceae			
	Dichondra repens	Kidney Weed	×	×
	Polymeria calycina	-	×	×
	Cunoniaceae			
	Callicoma serratifolia	Black Wattle		×
	Ceratopetalum gummiferum	Christmas Bush		×
	Dilleniaceae			
	Hibbertia acicularis	-	×	
	Hibbertia aspera	Guinea-flower	×	×
	Hibbertia diffusa	Guinea-flower	×	×
	Hibbertia empetrifolia	Guinea-flower	×	
	Hibbertia linearis	Guinea-flower	×	
	Hibbertia obtusifolia	Guinea-flower	×	×
	Hibbertia scandens	Climbing Guinea-flower	×	×
	Droseraceae			
	Drosera auriculata	-	×	
	Epacridaceae			
	Epacris pulchella	-	×	×
	Epacridaceae contd			
	Leucopogon appressus	Beard-heath	×	×
	Leucopogon juniperinus	Beard-heath	×	×
	Leucopogon virgatus	Beard-heath	×	×
	Monotoca elipticaa	-	×	
	Monotoca scoparia	-	×	
	Euphorbiaceae			
	Breynia oblongifolia	Coffee Bush	×	×
	Euphorbia peplus	Petty Spurge		×
	Glochidion ferdinandi ssp *ferdinandi*	Cheese Tree	×	×
	Phyllanthus gasstroemii	-	×	×
	Phyllanthus hirtellus	-	×	×
	Phyllanthus virgatus	-	×	×
	Poranthera microphylla	-	×	×
	Fabaceae: Caesalpinoideae			
*	*Senna pendula* var *glabrata*	Cassia	×	×
	Fabaceae: Faboideae			
	Chorizema parviflorum	Eastern Flame Pea	×	×

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Fabaceae: Faboideae cont			
	Bossiaea heterophylla	-	×	
	Bossiaea obcordata	-	×	
	Bossiaea rhombifolia sp rhombifolia	-	×	
	Daviesia corymbosa	-	×	
	Daviesia genistifolia	Broom Bitter Pea	×	×
	Daviesia ulicifolia	Gorse Bitter Pea	×	×
	Desmodium varians	Slender Tick-trefoil	×	×
	Dillwynia floribunda	Egg and Bacon Pea	×	
	Dillwynia retorta sp *complex*	Egg and Bacon Pea	×	×
	Dillwynia phylicoides sp complex	Egg and Bacon Pea	×	×
	Dillwynia ramosissima	Egg and Bacon Pea	×	
	Glycine clandestina	Glycine	×	×
	Glycine microphylla	Glycine	×	×
	Glycine tabacina	Glycine	×	×
	Gompholobium glabratum	Dainty Wedge Pea		×
	Gompholobium latifolium	Golden Glory Pea	×	×
	Gompholobium pinnatum	Pinnate Wedge Pea	×	×
	Gompholobium virgatum	Leafy Wedge Pea	×	×
	Hardenbergia violacea	False Sarsaparilla	×	×
	Kennedia rubicunda	Red Kennedy Pea	×	×
*	*Medicagoarabica*	Spotted Burr Medic	×	
*	*Medicago polymorpha*	Burr Medic	×	
	Mirbelia rubiifolia	Egg and Bacon Pea	×	×
	Pultenaea elliptica	Egg and Bacon Pea	×	×
	Pultenaea palacea var *palacea*	Egg and Bacon Pea	×	×
	Pultenaea retusa	Egg and Bacon Pea	×	×
	Pultenaea rosmarinifolia	Egg and Bacon Pea	×	
	Pultenaea villosa	Egg and Bacon Pea	×	×
*	*Robinia pseudoacacia*	Black Locust	×	
*	*Trifolium repens*	White Clover	×	
*	*Trifolium pratense*	Red Clover	×	
*	*Vicia sativa*	-	×	×
*	*Vicia tetrasperma*	Slender Vetch	×	×
	Vigna vexilata var *angustifolia*	Wild Cow Pea	×	×
*	*Wisteria floribunda*	Wisteria	×	
	Fabaceae: Mimosoideae			
*	*Acacia baileyana*	Cootamundra Wattle	×	
*	*Acacia binervata*	Two-veined Hickory	×	
	Acacia brownii	-	×	×
	Acacia falcata	-	×	×
	Acacia floribunda	White Sally	×	×
	Acacia implexa	Hickory Wattle	×	×
	Acacia irrorata ssp *irrorata*	Green Wattle	×	×
	Acacia longifolia	Sydney Golden Wattle	×	×
	Acacia longissima	-	×	×
	Acacia maidenii	Maiden's Wattle	×	×
	Acacia myrtifolia	Red-stemmed Wattle	×	×
*	*Acacia podalyriifolia*	Queensland Silver Wattle	×	
	Acacia suaveolens	Sweet Wattle	×	
	Acacia terminalis	Sunshine Wattle	×	×
	Acacia ulicifolia	Prickly Moses	×	×
	Gentianaceae			
*	*Centaurium erythraea*	Common Centaury	×	
*	*Centaurium tenuiflorum*	-	×	
	Goodeniaceae			
	Dampiera stricta	-	×	×
	Goodenia bellidifolia ssp *bellidifolia*	-	×	×
	Goodenia dimorpha var *dimorpha*	-	×	×
	Goodenia hederacea var *hederacea*	-	×	×
	Goodenia heterophylla ssp heterophylla	-	×	
	Goodeniaovata	-	×	
	Goodenia paniculata	-	×	×
	Selliera radicans	-		×
	Haloraginaceae			
	Gonocarpus micranthus	-	×	
	Gonocarpus tetragynus	-		×
	Gonocarpus teucrioides	-	×	×
	Myriophyllum variifolium	Water-milfoil		×

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Hypericaceae			
	Hypericum gramineum	Small St John's Wort	×	×
	Lauraceae			
*	*Cinnamomun camphora*	Camphor Laurel	×	×
	Lentibulariaceae			
	Utricularia laterifolia	Small Bladderwort	×	×
	Lobeliaceae			
	Lobelia alata	Anged Lobelia	×	
	Lobelia dentata	-	×	
	Pratia purpurascens	Whiteroot	×	×
	Loganiaceae			
	Logania albiflora	-	×	
	Mitrasacme polymorpha	-	×	
	Loranthaceae			
	Ameyema pendulum	Mistletoe	×	×
	Dendrophthoe vittelina	Mistletoe		×
	Muellerina celastroides	Mistletoe		×
	Muellerina eucalyptoides	Mistletoe		×
	Malvaceae			
*	*Pavonia hastata*	-	×	×
*	*Sida rhombifolia.*	Paddy's Lucerne	×	×
	Menispermaceae			
	Stephania japonica var sicolor	Snake Vine	×	
	Myoporaceae			
	Eremophila debilis	Winter Apple	×	×
	Myrsinaceae			
	Aegicerus corniculatum	River Mangrove	×	×
	Myrtaceae			
	Acmena smithii	Lilly Pilly	×	
	Angophora costata	Smooth-barked Apple	×	×
	Angophora floribunda	Rough-barked Apple	×	×
	Callistemon linearis	Narrow-leaved Bottlebrush	×	×
	Callistemon rigidus	Stiff Bottlebrush	×	×
	Callistemonsalignus	Willow Bottlebrush	×	
	Corymbia gummifera	Red Bloodwood	×	×
	Corymbia maculata	Spotted Gum	×	×
	Eucalyptus acmenoides	White Mahogany	×	×
	Eucalyptus amplifolia ssp *amplifolia*	Cabbage Gum	×	×
	Eucalyptus capitellata	Brown Stringybark	×	
	Eucalyptus eugenioides	Thin-leaved Stringybark	×	×
R	*Eucalyptus fergusonii spp fergusonii*	-	×	
	Eucalyptus fibrosa ssp fibrosa	Broad-leaved Ironbark	×	×
	Eucalyptus globoidea	White Stringybark	×	×
K	*Eucalyptus microcorys*	Tallow-wood	×	×
	Eucalyptus paniculata spp paniculata	Grey Ironbark	×	
	Eucalyptus piperita	Sydney Peppermint	×	×
	Eucalyptus propinqua	Grey Gum	×	×
K	*Eucalyptus punctata*	-	×	
	Eucalyptus resinifera ssp *resinifera*	Red Mahogany	×	×
Kr	*Eucalyptus robusta*	Swamp Mahogany	×	
	Eucalyptus siderophloia	Grey Ironbark	×	×
K	*Eucalyptus tereticornis*	Forest Red Gum	×	×
	Eucalyptus umbra	Bastard White Mahogany	×	×
	Kunzea ambigua	Tick Bush	×	×
	Kunzea capitata	-	×	
	Leptospermum arachnoides	Tea-tree		×
	Leptospermum juniperinum	Tea-tree	×	×
	Leptospermum laevigatum	Coast Tea-tree	×	×
	Leptospermum liversidgei	-	×	×
	Leptospermum polygalifolium ssp *cismontanum*	-	×	×
	Leptospermum polygalifolium ssp *polygalifolium*	-	×	×

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Myrtaceae cont			
	Leptospermum trinervium	-	×	×
	Melaleuca decora	Paperbark	×	×
	Melaleucaericifolia	-	×	
	Melaleuca linariifolia	Paperbark	×	×
	Melaleuca nodosa	Paperbark	×	×
	Melaleuca sieberi	-	×	
	Melaleuca styphelioides	Prickly-leaved Tea-tree	×	×
	Melaleuca squarrosa	Paperbark	×	×
	Melaleuca quinquenervia	Paperbark	×	×
	Syncarpia glomulifera	Turpentine	×	×
	Nymphaeceae			
*	*Nymphaea capensis*	Cape Waterlily	×	×
	Oleaceae			
*	*Ligustrum lucidum*	Large-leaved Privet	×	×
*	*Ligustrum sinense*	Small-leaved Privet	×	×
	Olea europaea ssp africana	African Olive	×	×
	Notolaea longifolia forma longifolia	Large Mock-olive	×	×
	Notolaea ovata	-	×	×
	Notolaea venosa	Veined Mock-olive	×	×
	Onagraceae			
	Ludwigia peploides ssp *montevidensis*	Water Primrose	×	×
	Oxalidaceae			
*	*Oxalis corniculata*	Creeping Oxalis	×	×
*	*Oxalis pes-caprae*	Soursob	×	×
	Papaveraceae			
*	*Argemone ochroleuca*	Mexican Poppy	×	
	Passifloraceae			
*	*Passiflora edulis*	Passionfruit	×	×
	Pittosporaceae			
	Billardiera scandens	Appleberry	×	×
	Bursaria spinosa var *spinosa*	Blackthorn	×	×
	Pittosporum undulatum	Sweet Pittosporum	×	×
	Plantaginaceae			
*	*Plantago lanceolata*	Lamb's Tongues	×	×
*	*Plantago varia*	Plantain	×	×
	Polygalaceae			
	Comesperma ericinum	-	×	×
	Polygonaceae			
	Persicaria decipiens	Slender Knotweed	×	×
	Persicaria lapathifolia	Pale Knotweed	×	×
*	*Polygonum aviculare*	Wireweed	×	×
*	*Rumex crispus*	Curled Dock	×	×
	Primulaceae			
*	*Angallis arvensis*	Scarlet/Blue Pimpernel	×	
	Samulos repens	Creeping Brookweed	×	
	Proteaceae			
	Banksia cumminghamii ssp cunninghamii	-	×	
	Banksia oblongifolia	-	×	
	Banksia serrata	Old Man Banksia	×	×
	Banksia spinulosa var collina	Hairpin Banksia	×	×
	Banksia spinulosa var *spinosa*	Hairpin Banksia	×	×
	Grevillea buxifolia sp buxifolia	Grey Spider Flower		×
	Grevillea linearifolia	-		×
	Grevillea sericea	-	×	
	Grevillea speciosa	Red Spider Flower	×	×
r	*Hakea bakeriana*	-	×	
	Hakea dactyloides	-	×	×
	Hakea gibbosa	-	×	×
	Hakea sericea	-	×	×
	Hakea teretifolia	-	×	

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Proteaceae cont			
	Lambertia formosa	Mountain Devil	×	×
	Lomatia silaifolia	Crinkle Bush	×	×
	Persoonia levis	Broad-leaved Geebung	×	×
	Persoonia linearis	Narrow-leaved Geebung	×	×
	Xylomelum pyriforme	Woody Pear		×
	Ranunculaceae			
	Clematis aristata	-	×	
	Ranunculus inundatus	Buttercup	×	×
*	*Ranunculus repens*	Creeping Buttercup	×	×
	Rosaceae			
*	*Rubus fruticosus* species aggregate	Blackberry	×	×
	Rubus hillii	Molucca Bramble		×
	Rubiaceae			
	Opercularia diphylla	Stinkweed	×	×
	Opercularia hispida	Hairy Stinkweed	×	
	Opercularia varia	Variable Stinkweed	×	×
	Pomax umbellata	-	×	×
	Rutaceae			
	Boronia ledifolia	Sydney Boronia, Ledum Boronia	×	
	Boronia pinnata	Pinnate Boronia		×
	Boronia polygalifolia	-	×	
	Phebalium squamulosum	Scaly Phebalium		×
	Zieria pilosa		×	
	Zieria smithii ssp A	Sandfly Zieria	×	
	Salicaceae			
*	*Salix fragilis*	Crack Wattle	×	
	Santalaceae			
	Exocarpus cuppressiformis	Blueberry Ash	×	×
	Sapindaceae			
	Dodonaea triquetra	Common Hop Bush	×	×
	Solanaceae			
*	*Solanum mauritianum*	Wild Tobacco	×	×
*	*Solanum nigrum*	Blackberry Nightshade	×	×
*	*Solanum pseudocapsicum*	Madeira Winter Cherry	×	×
*	*Solanum seaforthianum*	Brazilian Nightshade	×	×
	Stylidiaceae			
	Stylidium graminifolium	Grass Triggerplant	×	
	Thymeleaceae			
	Pimelea linifolia		×	
	Pimelea linifolia ssp *linifolia*	Rice-flower	×	×
	Tremandraceae			
RV	*Tetratheca juncea*	Black-eyed Susan	×	×
	Tetratheca thymifolia	Black-eyed Susan		×
	Urticaceae			
	Urtica incisa	Stinging Nettle	×	
	Verbenaceae			
*	*Lantana camara*	Lantana	×	×
*	*Verbena bonariensis*	Purpletop	×	×
*	*Verbena rigida*	Veined Verbena	×	×
	Violaceae			
	Hybanthus monopetalus	Slender Violet-Bush	×	
	Viola betonicifolia	-	×	
	Viola hederacea forma B	Ivy-leaved Violet	×	×
	Vitaceae			
	Cayratia Clematidea	Slender Grape	×	
	Cissus hypoglauca	Giant Water Vine	×	

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	MAGNOLOPSIDA: MONOCOTYLEDONS			
	Anthericaceae			
	Caesia parviflora var *parviflora*	Pale Grass Lily	×	×
	Laxmania gracilis	-	×	
	Sowerbaea juncea	Vanilla Plant, Lady Rush	×	
	Tricoryne elatior	Yellow Autumn Lily	×	×
	Tricoryne simplex	-	×	
	Arthropodiaceae			
	Arthropodium milleflorum	Vanilla Lilly	×	
	Arthropodium minus	Small Vanilla Lily	×	×
	Asparagaceae			
*	*Protosparagus densiflorus*	Asparagus fern	×	×
	Blandfordiaceae			
r	*Blandfordia grandiflora*	Christmas Bell	×	
	Commelinaceae			
	Commelina cyanea	Scurvey Weed	×	×
	Polia crispata	-	×	
*	*Tradescantia albiflora*	Wandering Jew	×	×
	Cyperaceae			
	Baumea articulata	Jointed Twig-rush	×	×
	Baumea juncea	-	×	
	Baumea nuda	-	×	×
	Baumea rubiginosa	-	×	×
	Baumea teretifolia	-	×	
	Bolboschoenus caldwellii	-	×	×
	Carex appressa	-	×	
	Carex fascicularis	Tassel Sedge	×	
	Carex longebrachiata	Bergalia Tussock	×	
	Caustis pentandra	-	×	×
	Cyathocheta diandra	-	×	×
	Cyperus difformis	Dirty Dora	×	×
*	*Cyperus eragrostis*	Umbrella Sedge	×	×
	Cyperus polystachyos	-	×	×
*	*Cyperus rotundus*	Nutgrass	×	×
*	*Cyperustenellus*	-	×	
	Eleocharis acuta	-	×	×
	Eleocharis cylindrostachys	-	×	×
	Eleocharis sphacelata	Tall Spikerush	×	×
	Fimbristylis dichotoma	-	×	×
	Gahnia aspera	Saw-sedge	×	
	Gahnia clarkei	Saw-sedge	×	×
	Gahnia melanocarpa	Saw-sedge	×	×
	Gahnia sieberiana	Saw-sedge	×	×
	Isolepis nodosa	Knobby Club-rush	×	
	Lepidosperma filiforme	-	×	
	Lepidosperma flexuosum	-	×	×
	Lepidospermagunni	-	×	
	Lepidosperma laterale	-	×	×
	Lepidosperma lineare	-	×	×
	Lepidosperma longitudinale	-	×	×
	Lepidosperma lumicola	-	×	×
	Lepidospermaurophorum	-	×	
	Ptilothrix deustra	-	×	
	Schoenoplectus mucronatus	-	×	×
	Schoenoplectus validus	-	×	×
	Schoenus brevifolius	-	×	×
	Schoenus imberbis	-	×	
	Schoenus paludosus	-	×	
	Doryanthaceae			
	Doryanthes excelsa	Gymea Lily		×
	Hydrocharitaceae			
*	*Elodea canadensis*	Canadian Pondweed	×	

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Hypoxidaceae			
	Hypoxis hygrometrica var *hygrometrica*	Golden Weather-grass	×	×
	Iridaceae			
*	*Crocosmia crocosmiiflora*	Montbretia	×	×
	Patersonia glabrata	Native Iris	×	×
	Patersonia sericea	Native Iris	×	×
*	*Romulea rosea* var *australis*	Onion Grass	×	×
	Juncaceae			
*	*Juncus acutus ssp acutus*	Sharp Rush	×	
*	*Juncus articulatus*	-	×	
*	*Juncusbufonius*	Toad Rush	×	
	Juncuscontinuus	-	×	
	Juncus krausii ssp *australiensis*	Sea Rush	×	×
	Juncus mollis	-	×	×
	Juncus planifolius	-	×	×
	Juncus polyanthemus	-	×	
	Juncus prismatocarpus	-	×	×
	Juncus subsecundus	-	×	
	Juncus usitatus	-	×	×
	Luzula flaccida	Woodrush	×	×
	Juncaginaceae			
	Triglochin microtuberosum	Water Ribbons	×	
	Lemnaceae			
	Spirodela punctata	-	×	
	Liliaceae			
	Thysanotus microtuberosum	Fringe-lily		×
	Thysanotus tuberosus	Common Fringe-lily	×	×
	Lomandraceae			
	Lomandra cylindrica	-	×	
	Lomandra filiformis ssp *filiformis*	Wattle Mat-rush	×	×
	Lomandra glauca	Pale mat-rush	×	×
	Lomandra longifolia	Spiny-headed Mat-rush	×	×
	Lomandra multiflora	Many-flowered Mat-rush	×	
	Lomandra obliqua	Mat-rush	×	×
	Orchidaceae			
	Caladenia catenata	White Caladenia		×
	Caladenia major	-		×
	Calochilus sp	-	×	
	Cymbidium suave	Snake Orchid		×
	Dendrobium aemulum	White Feather Orchid		×
	Dipodium punctatum	Hyacinth Orchid		×
	Thelymitra sp	-	×	
	Philydraceae			
	Philydrum lanuginosum	Frogsmouth	×	×
	Phormiaceae			
	Dianella caerula var *producta*	Blue Flax Lily	×	×
	Dianella crinoides	Blue Flax Lily	×	×
	Dianella longifolia var longifolia	Blue Flax Lily	×	
	Dianella prunina	Blue Flax Lily	×	×
	Poaceae			
	Agrostis avenacea	Blowngrass	×	×
*	*Andropogon virginicus*	Whiskey Grass	×	×
	Anisopogon avenaceus	Oat Speargrass	×	
	Aristida ramosa var ramosa	Threeawn Grass	×	×
	Aristida vagans	Threeawn Speargrass	×	×
*	*Arundo donax*	Giant Reed	×	×
*	*Avena fatua*	Wild Oats	×	×
*	*Axonopus affinis*	Narrow-leaved Carpet Grass	×	×
	Bothriochloa biloba	-	×	×
	Bothriochloa decipiens	Pitted Bluegrass	×	×
	Bothriochloa macra	Red Grass	×	×
*	*Briza maxima*	Quaking Grass	×	

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Poaceae cont			
*	*Briza minor*	Shivery Grass	×	×
*	*Bromus catharticus*	Prairie Grass	×	
	Capillipedium parviflorum	Scented-top Grass	×	×
	Chionochloa pallida	Silvertop Wallaby Grass		×
*	*Chloris gayana*	Rhodes Grass	×	×
	Cymbopogon refractus	Barbed Wire Grass	×	×
	Cynodon dactylon	Couch Grass	×	×
	Danthonia linkii var *fulva*	Wallaby Grass	×	×
	Danthonia pilosa	Smooth-flowered Wallaby Grass	×	×
	Danthonia racemosa var *racemosa*	Wallaby Grass	×	×
	Danthonia tenuior	Wallaby Grass	×	×
	Deyeuxia quadriseta	-	×	
	Dichantheum sericeum ssp *sericeum*	Queensland Bluegrass	×	×
	Dichelachne crinita	Longhair Plumegrass	×	
	Digitaria parviflora	Small-flowered Finger Grass		×
*	*Digitaria sanguinalis*	Crab Grass	×	×
*	*Echinochloa crus-galli*	Barnyard Grass	×	×
	Echinopogon caespitosus var *caespitosus*	Hedgehog Grass	×	×
	Entolasia marginata	Bordered Panic	×	×
	Entolasia stricta	Wiry Panic	×	×
	Eragrostis brownii	Brown's Lovegrass	×	×
	Eragrostiscurvula	African Lovegrass	×	
*	*Holcus lanatus*	Yorkshire Fog	×	
*	*Hordeum leporinum*	Barley Grass	×	
	Imperata cylindrica var *major*	Blady Grass	×	×
*	*Lolium perenne*	Perennial Ryegrass	×	
*	*Melinis repens*	Red Natal Grass	×	
	Microlaena stipoides var *stipoides*	-	×	×
	Oplismenus aemulus	Basket Grass	×	×
	Oplismenus imbecillis	-	×	
*	*Ottochloa gracillima*	-	×	
*	*Paspalum dilatatum*	Paspalum	×	×
*	*Paspalum urvillei*	Vasey Grass	×	
*	*Phalaris aquatica*	Phalaris	×	
*	*Phleum pratense*	Tomothy	×	
	Phragmites australis	Common Reed	×	×
*	*Poa annua*	Winter Grass	×	×
	Poa sieberiana	-	×	
*	*Rostraria cristata*	Annual Cat's Tail	×	
*	*Setaria pumila*	Pale Pigeon Grass	×	×
*	*Sporobolus capensis*	-	×	×
*	*Sporobolus indicus* var *capensis*	Parramatta Grass	×	×
*	*Sporobolus virginicus* var *capensis*	-	×	×
	Stipa pubescens	Speargrass	×	×
	Stipaverticillata	Speargrass	×	
	Tetrarrhena juncea	Wiry Ricegrass	×	
	Themeda australis	Kangaroo Grass	×	×
*	*Urochloa panicoides*	Liverseed Grass	×	×
*	*Vulpia bromoides*	Squirrel Tail Fescue	×	×
*	*Vulpia myuros*	Rat's Tail Fescue	×	
	Zoysia macrantha	Prickly Couch	×	×
	Potamogetonaceae			
	Potamogeton tricarinatus	Floating Pondweed	×	×
	Restionaceae			
	Lepyrodia interrupta	-	×	×
	Lepyrodia muelleri	-	×	×
	Lepyrodia scariosa	-	×	
	Leptocarpus tenax	-	×	×
	Restio pallens	-	×	×
	Restio tetraphyllus ssp meiostachyus	-	×	
	Ripogonaceae			
	Geitonoplesium cymosum	Scrambling Lily	×	×
	Eustrephus latifolius	Wombat Berry	×	×
	Typhaceae			
	Typha orientalis	Cumbungi	×	×
	Xanthorrhoeaceae			
	Xanthorrhoea fulva	Grass Tree	×	×

APPENDIX H contd Flora species recorded during field investigations conducted along the proposed Horse Island route option for the Pacific Highway upgrade at Karuah.

Status	BOTANICAL NAME	COMMON NAME	A	B
	Xanthorrhoeaceae contd			
	Xanthorrhoea latifolia ssp *latifolia*	Grass Tree	×	×
	Xanthorrhoea media ssp media	Grass Tree	×	

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX I

Subject Species Recorded During Field Surveys

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX I Details of Subject Species recorded during flora and fauna investigations conducted along the proposed upgrade of the Pacific Highway at Karuah.

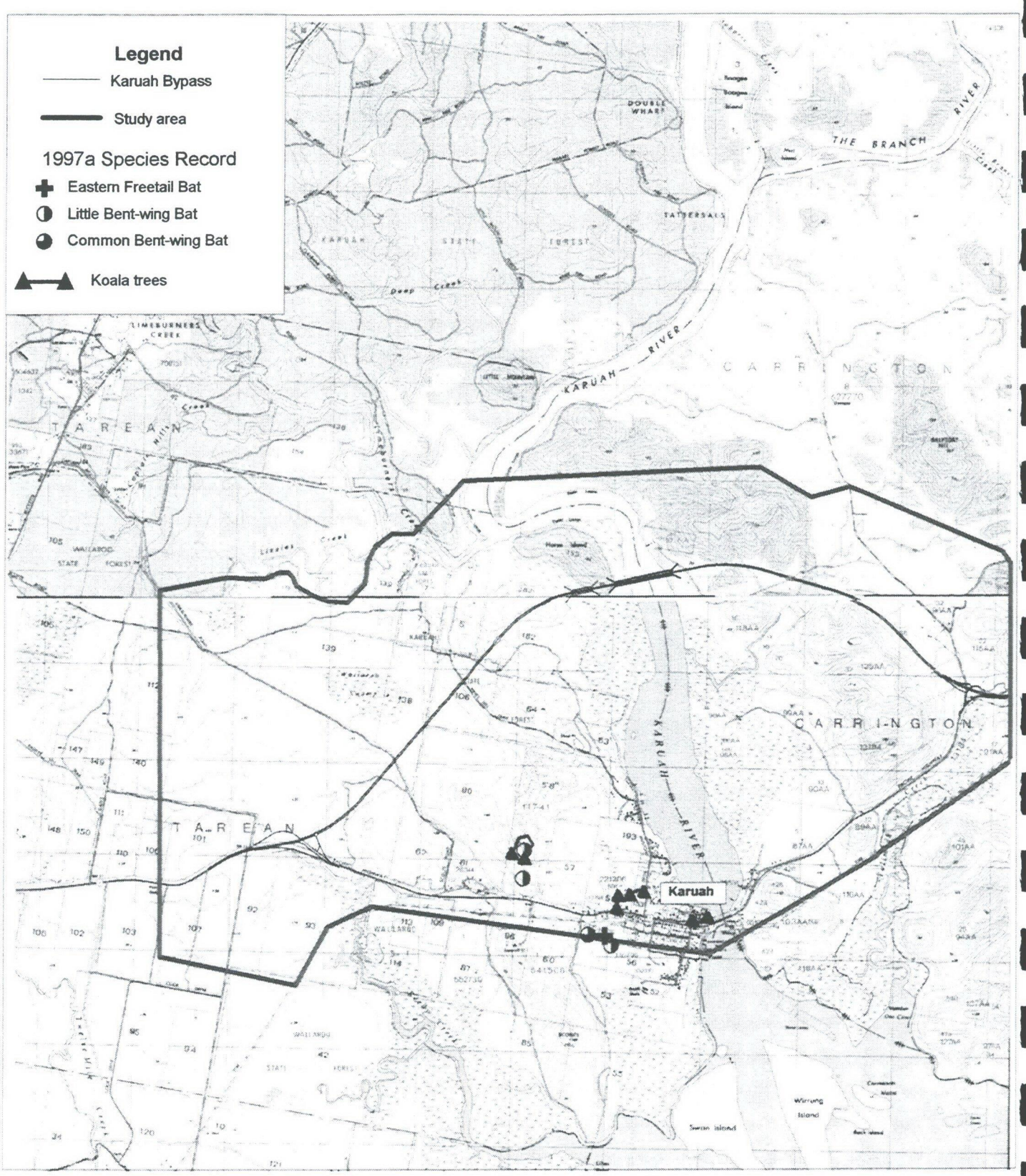
Part A

Proposed Pacific Highway Upgrade Karuah, NSW. Route Selection - Flora & Fauna Constraints report (Gunninah 1997a).

Details of the species, number of individuals, location (transect number and AMG) and date on which they were identified during flora and fauna investigations (Table 1). Flora species records are represented on Figure 5.1 (Chapter 5 of SIS) and fauna records on Figure 5.2 (Chapter 5 of SIS) and Figure 1 (this Appendix).

Table 1 The number of individuals, date and location (transect number and AMG) of all Subject Species recorded during the initial flora and fauna investigations in 1997.

Survey Method	Species	Number of Individuals	Observation Type	Transect Number	Date	Location (AMG)	
Flora							
	Tetratheca juncea	-	Observed	Random	24/04/97	402500	6386700
Fauna							
Anabat recording	Little Bent-wing Bat	-	Definite	2	22/04/97	401100 401300	6386800 6387150
		-	Probable	3	23/04/97	401100 401800	6387100 6386250
		-	Probable	4	24/04/97	402040 402010	6386110 6386500
	Common Bent-wing Bat	-	Probable	3	23/04/97	401100 401800	6387100 6386250
	Eastern Freetail Bat	-	Possible	4	24/04/97	402040 402010	6386110 6386500
Koala Search	Koala tree	-	Scratchings & scats	K1	21/04/97	400900 401100	6387100 6387000
		-	Scratchings	K2	22/04/97	402100 402100	6386500 6386600
		-	Scratchings	K3	23/04/97	402200 402400	6386700 6386700
		-	Scratchings	K4	24/04/97	402900 403000	6386400 6386400



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

Appendix I Figure 1
Location of subject fauna species recorded during the 1997a fauna survey in the study area.

Version: 4 8th October 1999

Part B

Proposed Pacific Highway Upgrade Karuah, NSW. Proposed Horse Island Route - Flora & Fauna Assessment report (Gunninah 1999b).

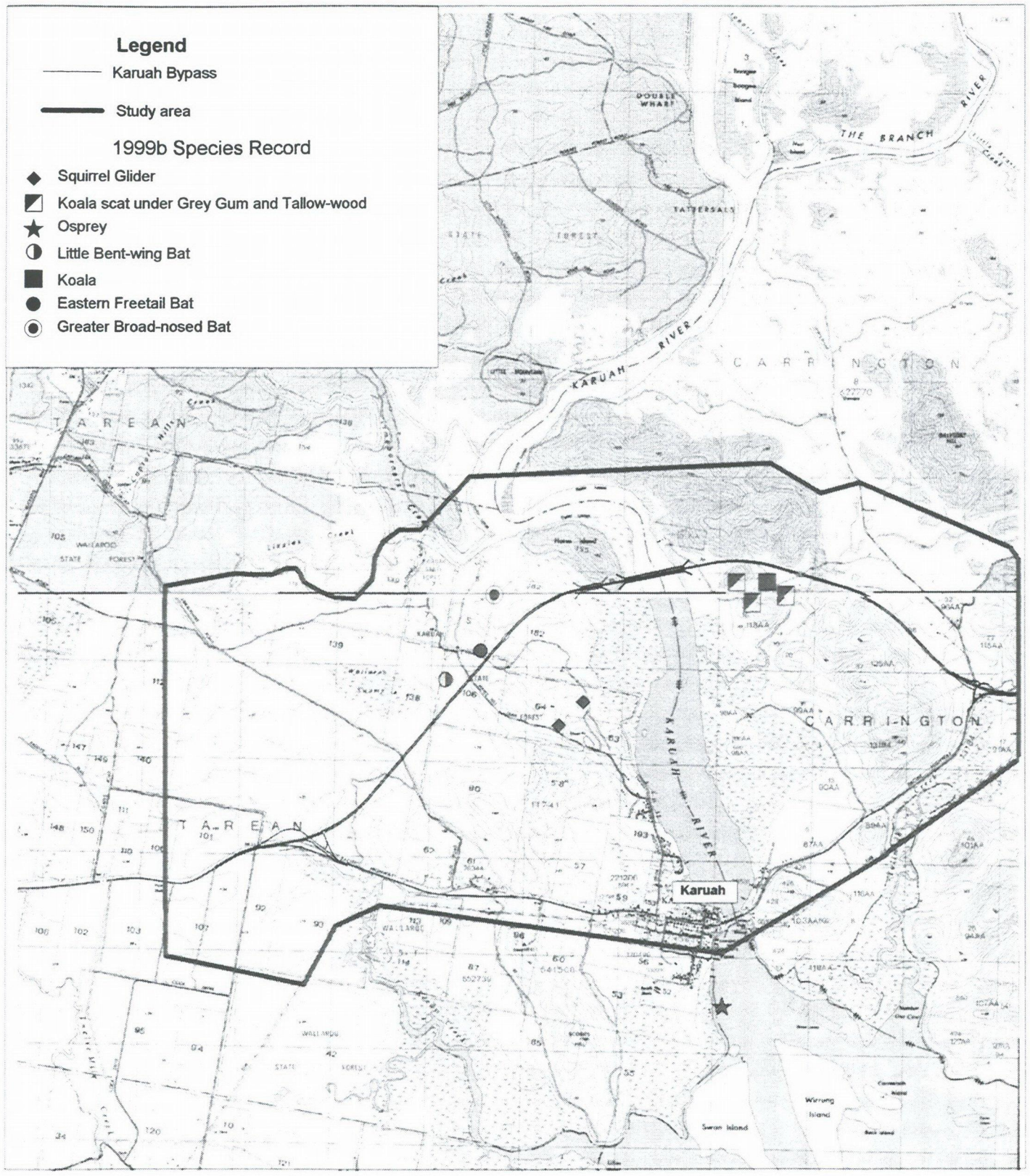
Details of the species, number of individuals, location (transect number and AMG) and date on which they were identified during flora and fauna investigations (Table 2). Flora species records are represented on Figure 5.1 (Chapter 5 of SIS) and fauna records on Figure 5.2 (Chapter 5 of SIS) and Figure 2 (this Appendix). *Tetratheca juncea* was the only threatened flora species (as listed under Schedules 2 of the *Threatened Species Act 1995*) identified at two locations, the first being approximately 150 - 200m long by 50m wide on the east and south east slopes of Horse Island, and the second being approximately 70m in diameter and found south of the existing Pacific Highway. Both of the populations were in flower at the time of survey, and some possible latent fruit set was observed in a few individuals on Horse Island.

Table 2 The number of individuals, date and location (transect number and AMG) of all Subject Species recorded during flora and fauna investigations for the Horse Island Route Assessment report (Gunninah 1999b).

Survey Method	Species	Number of Individuals	Observation Type	Transect Number	Date	Location (AMG)	
Flora							
	Tetratheca juncea	70 - 90 clumps	Observed	Q 14	12/11/98	401900	6390000
		40 clumps	Observed	Q 26	13/11/98	406400	6388600
	Eucalyptus fergusonii	-	Observed	Random	13/11/98	-	-
		-	Observed	Random	11/11/98	-	-
		-	Observed	Q 15	12/11/98	401600	6390100
	Eucalyptus robusta	-	Observed	Random	10/12/98	-	-
		-	Observed	Random	10/12/98	-	-
		-	Observed	Random	13/11/98	-	-
		-	Observed	Random	11/11/98	-	-
		-	Observed	Q 24	13/11/98	405700	6389000
		-	Observed	Q 25	13/11/98	405700	6389000
		-	Observed	Q 27	10/12/98	405900	6388700
		-	Observed	Q 28	10/12/98	406600	6388800
		-	Observed	Q 30	10/12/98	399800	6388800
	Blandifordia grandiflora	-	Observed	Q 1	10/11/98	398800	6387300
	Hakea bakeriana	-	Observed	Random	13/11/98	-	-
Fauna							
Spotlight	Squirrel Glider	1	Observed	-	02/02/98	399700	6398750
		1	Observed	-	03/03/98	401600	6388650
	Koala	1	Observed	-	05/03/98	400110	6390450
Opportunistic	Osprey	1	Observed	-	05/03/98	403100	6385500
Harp Trap	Little Bent-wing Bat	4	Observed	Trap 2	03/03/98	400150	6388850

Table 2 cont The number of individuals, date and location (transect number and AMG) of all Subject Species recorded during flora and fauna investigations for the Horse Island Route Assessment report (Gunninah 1999b).

Survey Method	Species	Number of Individuals	Observation Type	Transect Number	Date	Location (AMG)	
Fauna contd							
Anabat recordings	Eastern Freetail Bat	-	Definite	3	02/03/98	400650	6389500
	Greater Broad-nosed Bat	-	Probable	3	02/03/98	400650	6389500
Targeted Koala Search	Koala tree	3 Tallow-wood trees	Scats	-	04/03/98	403180	6389900
		1 Tallow-wood tree	Scats	-	04/03/98	403500	6389900
		6 Grey Gum trees	Scratches & scats	-	04/03/98	403500	6389900
		Grey Gums	Scratches	-	04/03/98	401800	6389900


Legend
Karuah Bypass
Study area
1999b Species Record
Squirrel Glider
Koala scat under Grey Gum and Tallow-wood
Osprey
Little Bent-wing Bat
Koala
Eastern Freetail Bat
Greater Broad-nosed Bat
KARUAH RIVER
THE BRANCH
DOUBLE WHARF
TATTERSALLS
CARRINGTON
TAREAN
Karuah
Karuah SIS
Project No. 98071
Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770
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Appendix I Figure 2
Location of subject fauna species recorded during the FFA (1999b) survey .
Version: 5 8th October 1999

Part C

Proposed Pacific Highway Upgrade Karuah, NSW. Proposed Horse Island Route - Species Impact Statement (Gunninah 1999c).

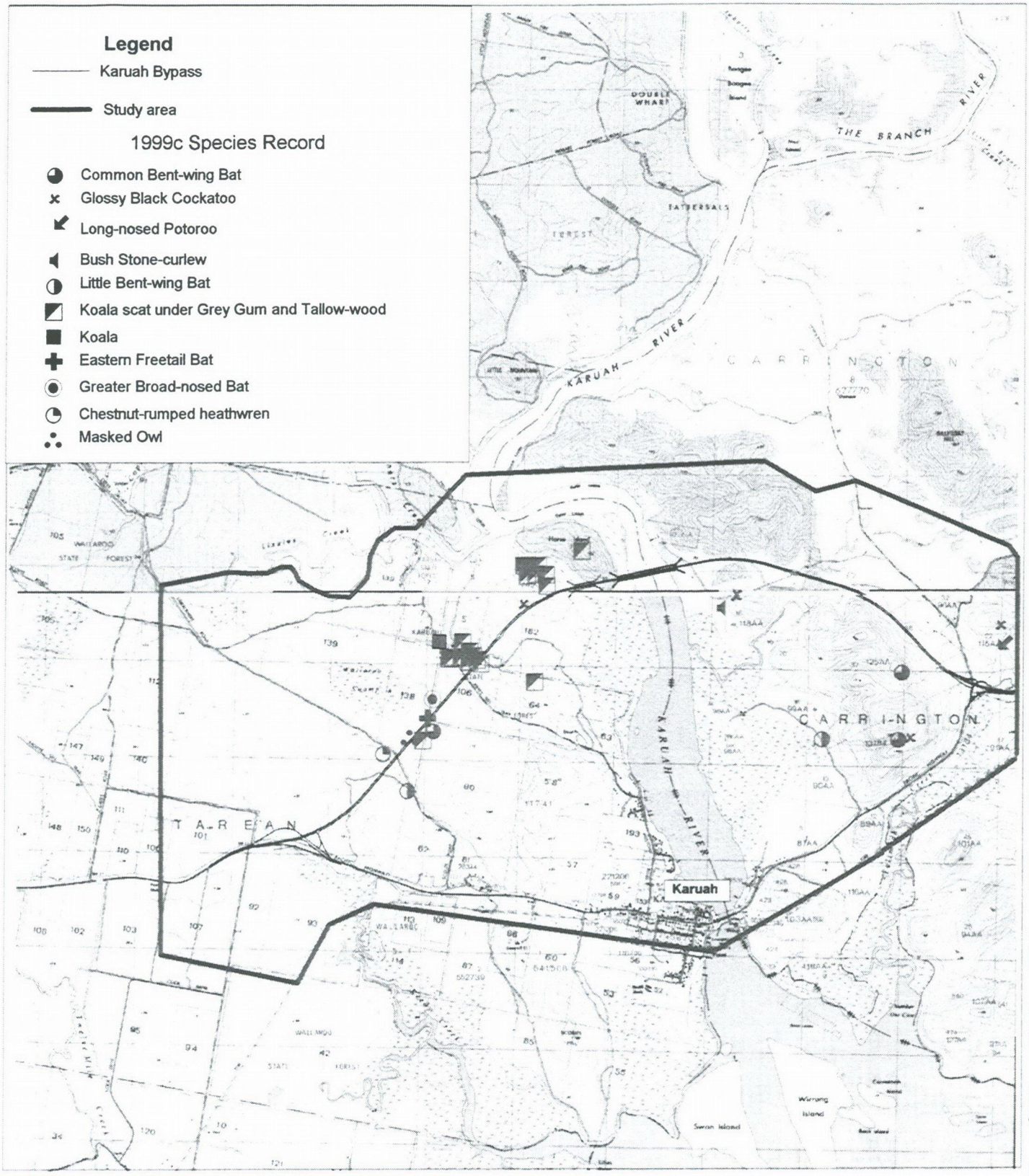
Details of the species, number of individuals, location (transect number and AMG) and date on which they were identified during flora and fauna investigations (Table 2). Flora species records are represented on Figure 5.1 (Chapter 5 of SIS) and fauna records on Figure 5.2 (Chapter 5 of SIS) and Figure 3 (this Appendix).

Table 3 The number of individuals, date and location (transect number and AMG) of all Subject Species recorded during supplementary flora and fauna investigations specifically for the SIS (Gunninah1999c).

Survey Method	Species	Number of Individuals	Observation Type	Transect Number	Date	Location (AMG)	
Flora	as for Table 2						
Fauna							
Spotlight	Long-nosed Potoroo	1	Observed	-	24/11/98	406400	6389300
	Bush-stone Curlew	1	Observed	-	26/11/98	403050	6389700
	Glossy Black Cockatoo	-	Crushed cones	-	26/11/98	403300	6389750
	Koala	1	Observed	-	28/01/99	400150	6389200
	Koala tree	-	Scats	-	28/01/99	404800	6388250
	Masked Owl	1	Observed	-	07/08/99	399853	6388278
		-	Nest tree	-	07/08/99	399853	6388278
Diurnal Bird Survey	Chestnut-rumped Heathwren	1	Observed	-	07/08/99	399524	6388080
Anabat recording	Greater Broad-nosed Bat	-	Possible	3	29/12/98	400050	6388650
	Little Bent-wing Bat	-	Definite	2B	26/11/98	403800	6389800
		-	Definite	1B	07/08/99	399800	6387700
		-	Definite	2A	09/08/99	400000	6388450
	Common Bent-wing Bat	-	Probable	2A	09/08/99	400000	6388450
		-	Probable	2B	10/08/99	405100	6388975
		-	Possible	4B	10/08/99	404900	6388975
	Eastern Freetail Bat	-	Definite	2B	10/08/99	405100	6388975
Targeted Search	Glossy Black Cockatoo	-	Crushed cones	-	28/11/98	406200	6389450
	Glossy Black Cockatoo	-	Crushed cones	-	17/01/99	401000	6389650
	Glossy Black Cockatoo	-	Crushed cones	-	08/08/99	400893	6389586

Table 3 contd The number of individuals, date and location (transect number and AMG) of all Subject Species recorded during supplementary flora and fauna investigations specifically for the SIS (Gunninah 1999c).

Survey Method	Species	Number of Individuals	Observation Type	Transect Number	Date	Location (AMG)	
Fauna contd							
Koala Search	Koala trees	6 Tallow-wood & Grey Gums trees	Scats	-	06/03/98	405050	6388300
		8 Grey Gums	Scats	-	06/03/98	405050	6388300
		2	Scats	-	08/08/99	400382	6389097
		1	Scratchings & scats	-	08/08/99	401157	6389868
		1	Scratchings & scats	-	08/08/99	401188	6388850
		Tallow-wood	Scratchings	-	08/08/99	401189	6399838
		Tallow-wood	Scratchings	-	08/08/99	401157	6389968
		Tallow-wood	Scratchings	-	08/08/99	401178	6389858
		Tallow-wood	Scratchings	-	08/08/99	401200	6389846
		Tallow-wood	Scratchings	-	08/08/99	401198	6389936
		Tallow-wood	Scratchings	-	08/08/99	401198	6389837
		Tallow-wood	Scratchings	-	08/08/99	401204	6389847
		Tallow-wood	Scratchings	-	08/08/99	401206	6389852
		Tallow-wood	Scratchings	-	08/08/99	401206	6389852
		Tallow-wood	Scratchings	-	09/08/99	401246	6389916
		Tallow-wood	Scratchings	-	09/08/99	401245	6389916
		Tallow-wood	Scratchings	-	09/08/99	401245	6389915
		Tallow-wood	Scratchings	-	09/08/99	401245	6389914
		Grey Gums	Scats	-	09/08/99	400602	6389171
		Tallow-wood	Scats	-	09/08/99	400623	6389158
		Grey Gums	Scats	-	09/08/99	400567	6389170
		Tallow-wood	Scats	-	09/08/99	400030	6388181



Karuah SIS
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

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Kilometre

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Appendix I Figure 3
Location of subject fauna species recorded during the SIS (1999c) survey in the study area.

Version: 4 8th October 1999

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX J

Hollow-bearing Tree Survey

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

APPENDIX J Details of tree hollow investigations conducted along the proposed upgrade of the Pacific Highway at Karuah, Flora and Fauna Assessment (1999b) and Species Impact Statement (1999c).

1 INTRODUCTION

The Roads & Traffic Authority (RTA) is proposing to upgrade the Pacific Highway at Karuah, on the mid-north coast of NSW. A route which bypasses the town of Karuah to the north (the 'Horse Island' route) has been selected as the 'preferred option' and a Species Impact Statement (SIS) has been prepared for the project. This SIS addressees the matters contained in Sections 109, 110, 111 of the *NSW Threatened Species Conservation Act* 1995 (TCA Act), and the matters contained in the requirements of the Director-General of National Parks & Wildlife Service (NP&WS), pursuant to Section 111 of the TCA Act. Section 1.8 of the Director-Generals requirements outlines that "A description of fauna habitat components such as the frequency and size of tree-hollows and stags...".

This investigation and report have been conducted to detail the location of hollow-bearing trees and stags within the study area. The significance of hollow-bearing trees, their removal, any potential impact upon threatened fauna and impact amelioration measures are dealt with in Chapters 10 and 12 of the SIS.

The aims of this investigation and report are:

- to locate hollow-bearing trees within the study area, and determine the number of hollows; and
- to document the numbers and types of tree-hollows which will be removed by the works.

2 SURVEY METHODS

A survey of tree-hollows along the proposed route within the acquisition boundary was conducted on the 1st, 2nd and 4th of July and the 8th and 9th of August 1999. The number and size of trunk and limb hollows was assessed for each hollow-bearing tree and stag. The location of hollow-bearing trees and stags are illustrated in Figure 4.2, and details are provided in Table 1.

Table 1 Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
1 *	Stringybark	32	12	one medium	
2	*E umbra*	67	23	several small & medium	one large
3	*E umbra*	45	18	several small & one medium	one medium
4	Stag	60	13	several small & medium	one large
5	*Angophora floribunda*	28	14	one medium	one small
6	*A floribunda*	18	8		one small
7	Stag	21	11		one medium
8	Stag	53	17	two small & medium	
9	Stag	60	15	two large & medium	one large & medium
10	Stag	58	12	two medium	
11	Stag	55	16	several medium	one large
12	*Corymbia gummifera*	65	22	two medium, one small & large	several medium
13 *	Stringybark	45	15		one large
14	Stag	40	13	one medium	one medium
15 *	Stringybark	38	14	two medium	
16	Stag	35	10		one medium
17	*A costata*	48	25	one medium	
18	*A costata*	65	22		one very large
19	Stag	50	16		one medium
20	*C gummifera*	80	20	four small	
21	Stag	60	18	four medium	
22	*A costata*	65	24	two medium	
23	*C gummifera*	65	20	one medium & small	
24	*A costata*	120	26	two medium	
25	*A costata*	70	25	two medium & small	
26	*A costata*	80	26	one medium	
27	*E tereticornis*	25	15	two medium	
28	*E tereticornis*	40	14	several small	
29	*E tereticornis*	30	10	one small	

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
30	Stag	32	14	one medium & small	
31	*E tereticornis*	40	17		one small
32	Stag	31	12	one medium	
33	*E tereticornis*	130	20	several medium	one large
34	*E tereticornis*	105	18	several medium	
35	Stag	60	20	several medium	
36	Stag	50	11		two medium
37	Stag	60	14	several medium	
38	*E resinifera*	100	15	two medium	one large
39	*E resinifera*	95	18		one large
40	*A costata*	90	26	two medium	one large
41	Stag	65	20	two medium & several small	one medium
42	*A costata*	90	27	several medium	
43	*E resinifera*	55	14	one medium	
44	*A costata*	100	30	two medium & one small	
45	*A costata*	80		several medium & small	
46	*A costata*	70	22	two medium & small	one medium
47	Stag	25	10	one medium & two small	
48	*Stag*	30	12	one medium & two small	
49	*E resinifera*	50	17	two medium & one small	one medium
50	*E resinifera*	45	20	one small	two medium
51	*E resinifera*	50	18	one large & medium	
52	Stag	45	14	one large & small, several medium	
53	*E resinifera*	40	20	two medium	
54	Stag	35	15	one medium	
55	Stag	20	12		one small
56	*E paniculata* subsp paniculata	35	18		one medium & small
57	Stag	30	10		one small

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
58	*A costata*	45	22	several medium	one medium
59	*C maculata*	40	22	one small	one large
60	*E umbra*	40	23	one small	
61	Stag	45	20	one medium & small	
62	*C gummifera*	50	25	two medium	
63	*E punctata*	45	15	two small	
64	*E umbra*	100	25	two medium & one small	
65	*E maculata*	65	25	one large	
66	Stag	50	10	one medium & two small	
67	Stag	105	20	several small & medium, one large	
68	Stag	45	15	one medium & small	
69	Stag	55	17	several small & medium	
70	Stag	50	18	one small	
71	Stag	45	18	two small	
72	*E microcorys*	115	32	several medium & small	one large
73	Stag	75	17	two small & one medium	
74	Stag	35	10	two small	
75	*E maculata*	85	25	two small	
76	Stag	85	10	one medium & small	
77	Stag	65	13	several small	
78	*E maculata*	85	25	one medium	one small
79	*E punctata*	70	27	two medium	
80	*E umbra*	65	24	two small	
81	*E microcorys*	130	25	one small	
82	Stag	65	25	two small	
83	Stag	75	15	one small	one medium
84	Stag	60	15	one medium & small	
85	*A costata*	115	25		one medium
86	*E microcorys*	110	28	one small	one medium

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
87 ♦	Ironbark	75	22	one small	
88	*C gummifera*	50	18	two small	
89	Stag	90	20	two small	
90	Stag	65	16	several small	
91	*E resinifera*	100	20		one medium
92	*C gummifera*	115	23	two small	
93	Stag	65	12	one small	
94	Stag	55	16	two small	
95	Stag	45	17	two small	
96	Stag	60	18	two small	
97	Stag	40	10	one small	
98	*A costata*	90		one medium	
99	Stag	100		two medium	
100	*E resinifera*	100			one medium
101	Stag	100		two medium	one medium
102	Stag	110		one medium	two large
103	Stag	75		one medium	one medium
104	*E resinifera*	85		one medium & two small	
105	Stag	65		one medium	
106	Stag	115			one large
107	Stag	40			one medium
108	*E umbra*	65		several medium & two small	
109 *	Stringybark	60		one medium	
110	*C gummifera*	60		one medium	
111	*C gummifera*	50		two medium	
112	Stag	75		one medium	one large
113	Stag	70		two medium	
114	*C gummifera*	110		two medium	
115	*A floribunda*	35		two small	
116	*C gummifera*	45			one small
117	Stag	45			one small
118	Stag	45		two medium	
119 *	Stringybark	45		one medium	one medium

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
120	Stag	35		one small	
121	Stag	70		two small	two medium & one small
122	*A floribunda*	40		one medium & one small	
123	Stag	35		two small	
124	Stringybark	80		one medium & several small	
125	*C gummifera*	85		one medium & several small	
126 *	Stringybark	65			one medium
127 *	Stringybark	85			three medium
128 *	Stringybark	80		two medium	
129 *	Stringybark	100		two medium	one large
130	*E umbra*	105		several medium & several small	
131	Stag	55		one small	
132	*C gummifera*	45			one medium
133	Stag	80			one large
134 *	Stringybark	45		one medium	
135	Stag	40			one medium
136 *	Stringybark	120		several medium & several small	
137 *	Stringybark	100		two medium & two small	
138	Stag	110		one medium	
139	*A floribunda*	40		two medium	
140	*A floribunda*	45		one small	
141	*A floribunda*	100		three small	
142	*A floribunda*	100		one medium	
143	Stag	45		one medium	
144	*C gummifera*	100			one large
145	Stag	80		one medium & two small	
146	*C gummifera*	90		two medium & two small	
147	*C gummifera*	100		one medium	one small
148	Stag	90		two small	

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
149	*C gummifera*	100		one large & two medium	
150	*A costata*	100		one medium	one medium
151	*A costata*	100		one medium	
152	Stag	60		one medium	
153	Stag	110		two medium & several small	
154	*A costata*	65			one medium
155	*C gummifera*	80		three small	
156	*A costata*	110			one medium
157	*E tereticornis*	130		three medium	one medium
158	*E tereticornis*	70			one medium & one small
159	Stag	120		several medium & two small	one medium
160	Stag	90		one medium	
161 *	Stringybark	100		one medium	
162	*A costata*	100		one medium	
163	*E umbra*	140		three medium	
164	*E maculata*	100		one medium	
165	*E punctata*	40			one small
166	*C gummifera*	110		two medium	
167 ♦	Ironbark	180		one medium & two small	
168	Stag	35			one medium
169	*E maculata*	45		two small	one medium
170	*E maculata*	60		one small	
171	Stag	45		one medium	
172	*E maculata*	110		two medium & several small	two medium
173	Stag	60		one small	
174	Stag	60		two medium & two small	
175	Stag	65		pipe	
176	*C gummifera*	130		one large, two medium & one small	
177 ♦	Ironbark	70		one medium	

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
178 ♦	Ironbark	70		one small	
179	Stag	40		six small	
180	Stag	25		two small	
181	Stag	35		three small	
182	Stag	25		one small	
183	Stag	25		one medium	
184 ♦	Ironbark	45		one medium	
185	*E maculata*	45		one medium	
186	Stag	45		one large	one medium
187	Stag	25		one small	
188	Stag	25		one small	
189	*E maculata*	100			
190 *	Stringybark	50		one small	
191	Stag	50		one medium	
192	*E maculata*	140		several medium	
193	Stag	40		several small	
194	Stag	35		one medium & one small	
195	Stag	70		one medium	
196	Stag	35		one medium	
197	Stag	35		one medium	
198	*E resinifera*	80		one medium	one medium
199 ♦	Ironbark	80		several small	
200	Stag	60		one medium & one small	
201	Stag	40		several small	
202	*E maculata*	80			one large
203	*E maculata*	90			one medium
204	*E umbra*	90		one medium	
205	*E umbra*	40		one small	
206	Stag	45		two medium & several small	two medium
207	Stag	45			one large & one medium
208	Stag	15		several small	
209	*E umbra*	110			one large

Table 1 contd Hollow-bearing trees located in the subject site, with their Depth at Breast Height (DBH) (cm), Height (m), and number of limb and trunk hollows.

Tree	Species	DBH (cm)	Height (metres)	Tree-Hollows	
				Limb	Trunk
210	*A costata*				one medium
211	*E resinifera*	100		one medium	one medium
212	*E resinifera*	40			one medium
213	*E resinifera*	80		several small	
214	*E tereticornis*	40		several small	
215	*E tereticornis*	40		two small	
216	*E tereticornis*	70		two small	
217	*E maculata*	60			one medium

* Stringybark refers to either *Eucalyptus eugenioides* or *E globoidea*; and

♦ Ironbark refers to either *E paniculata* subsp *paniculata* or *E siderophloia* with the burnt nature of these trees making them too difficult to identify correctly.

Pacific Highway Upgrade at Karuah

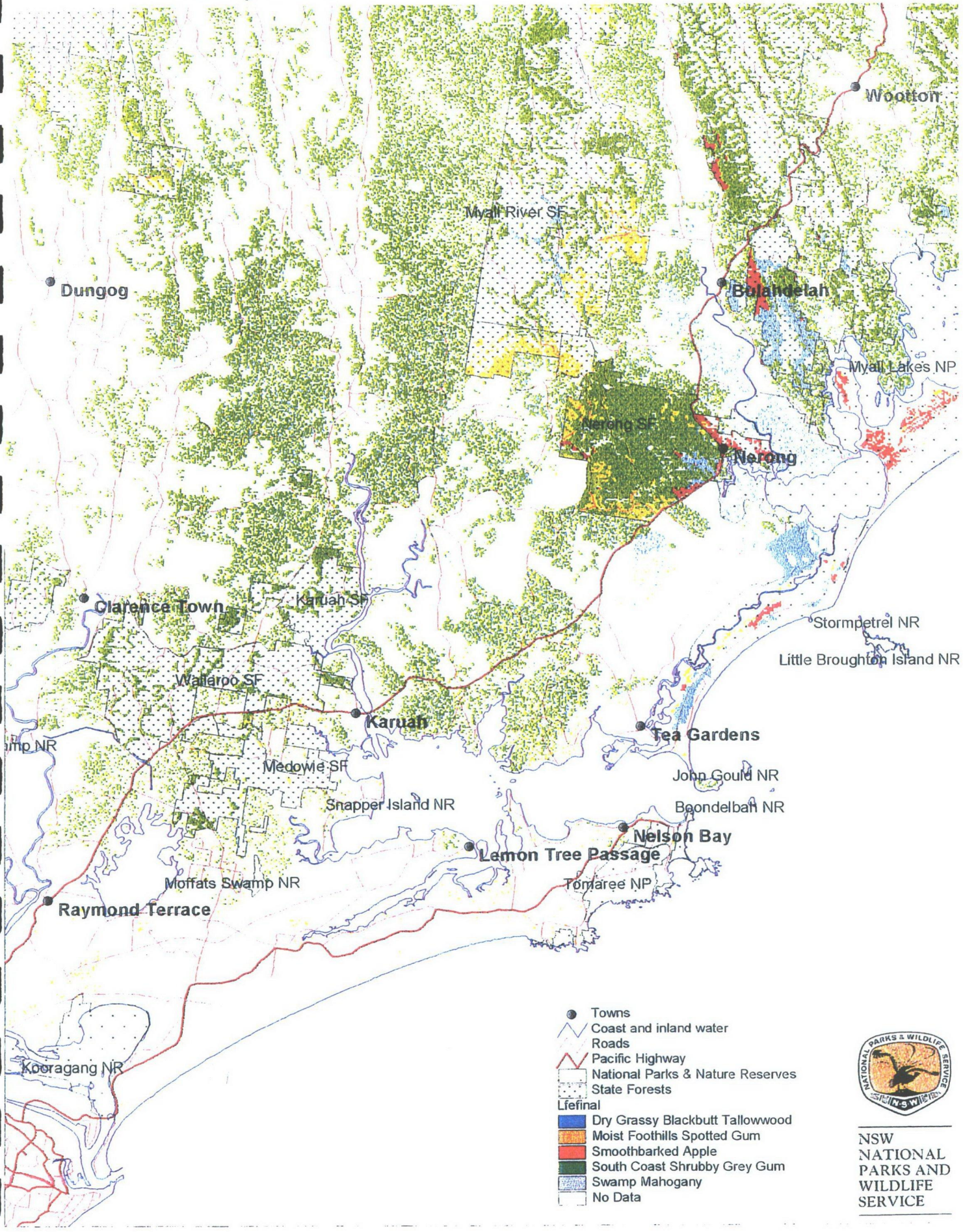
Species Impact Statement

APPENDIX K

NP&WS Habitat Prediction Maps

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

Quality Habitat Model - Forest Ecosystems (CRA)



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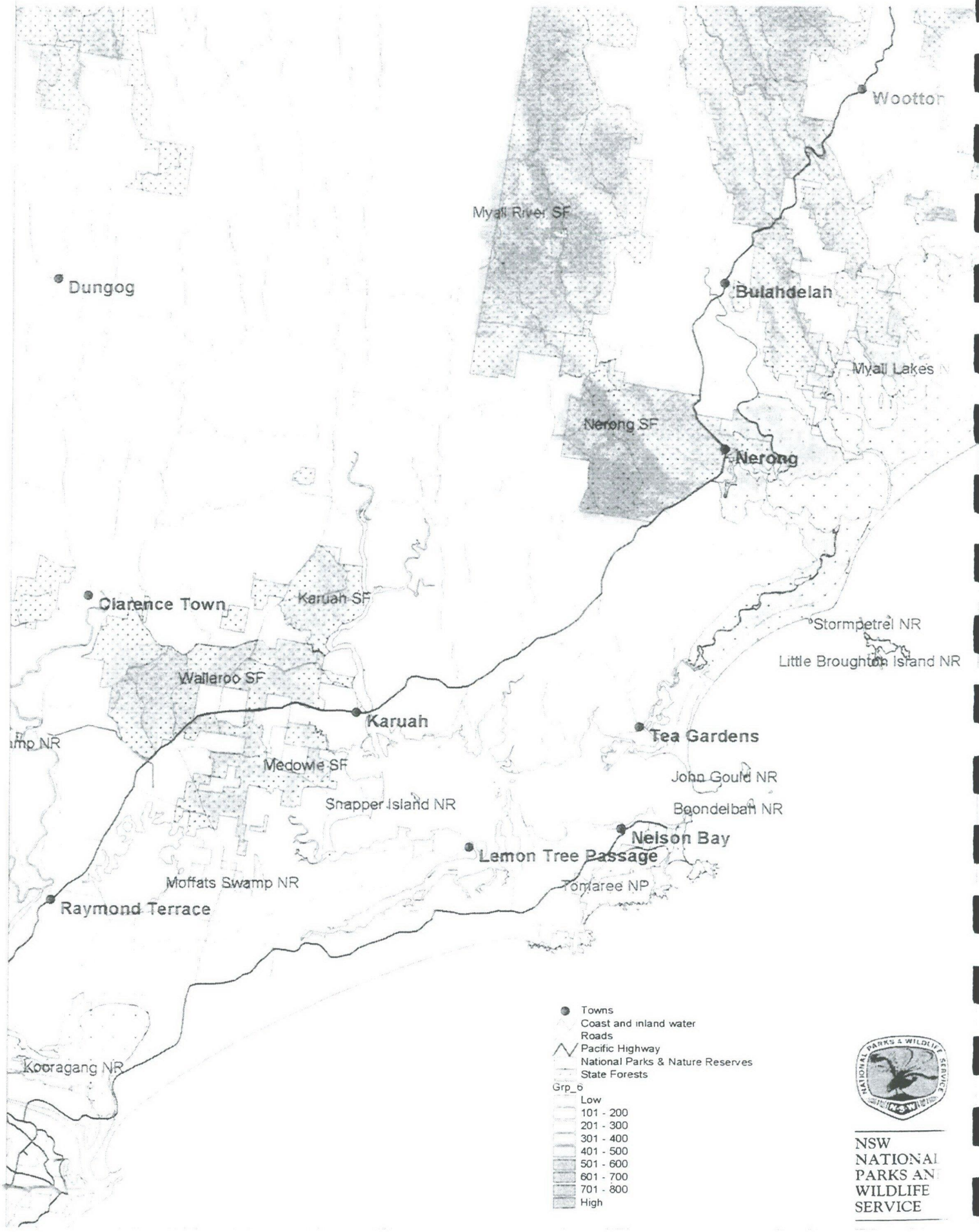
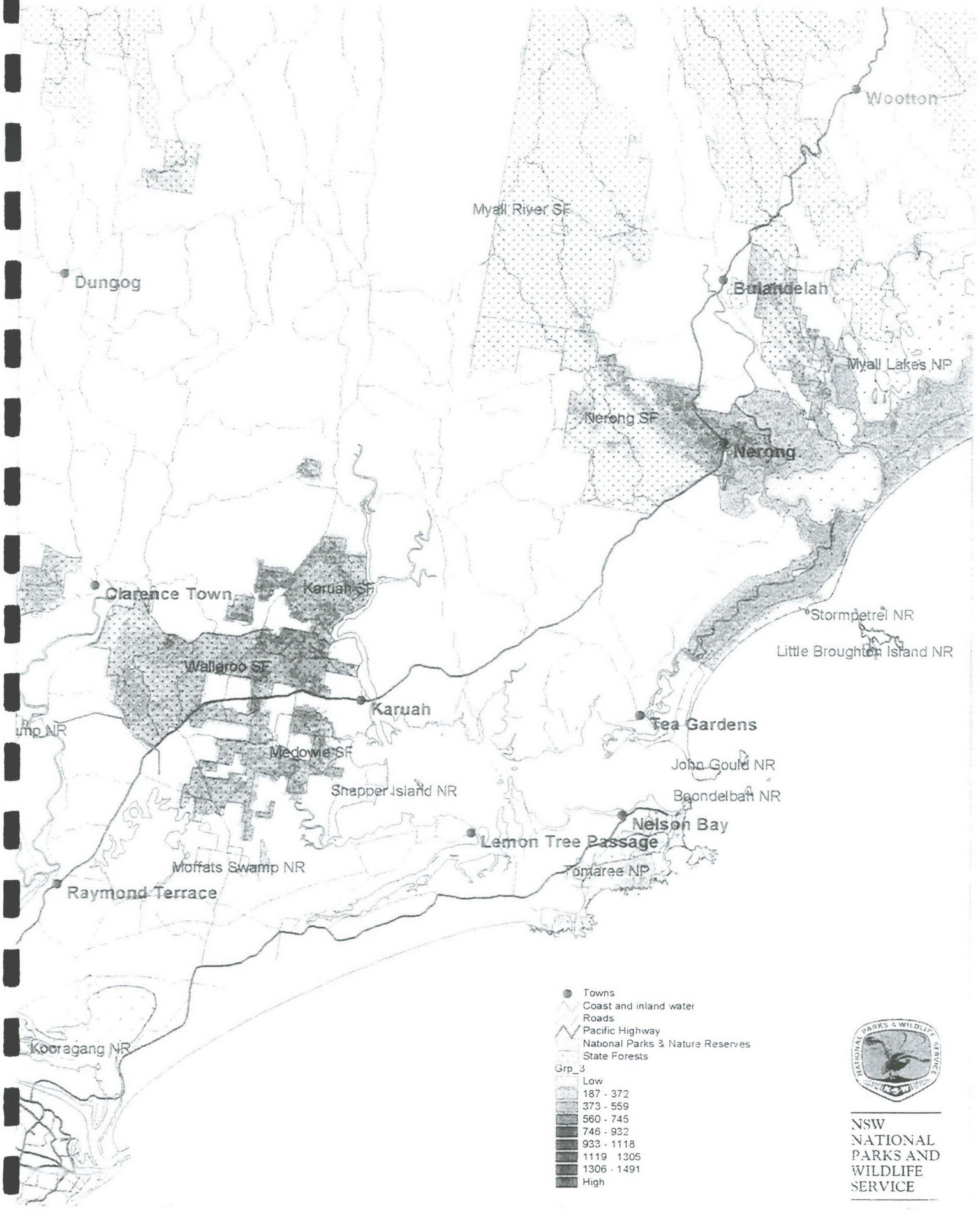
Quality Habitat Model - Coast and Ranges faunal assemblage (CRA) PLO



Quality Habitat Model - Dry Forest faunal assemblage (CRA) PLO



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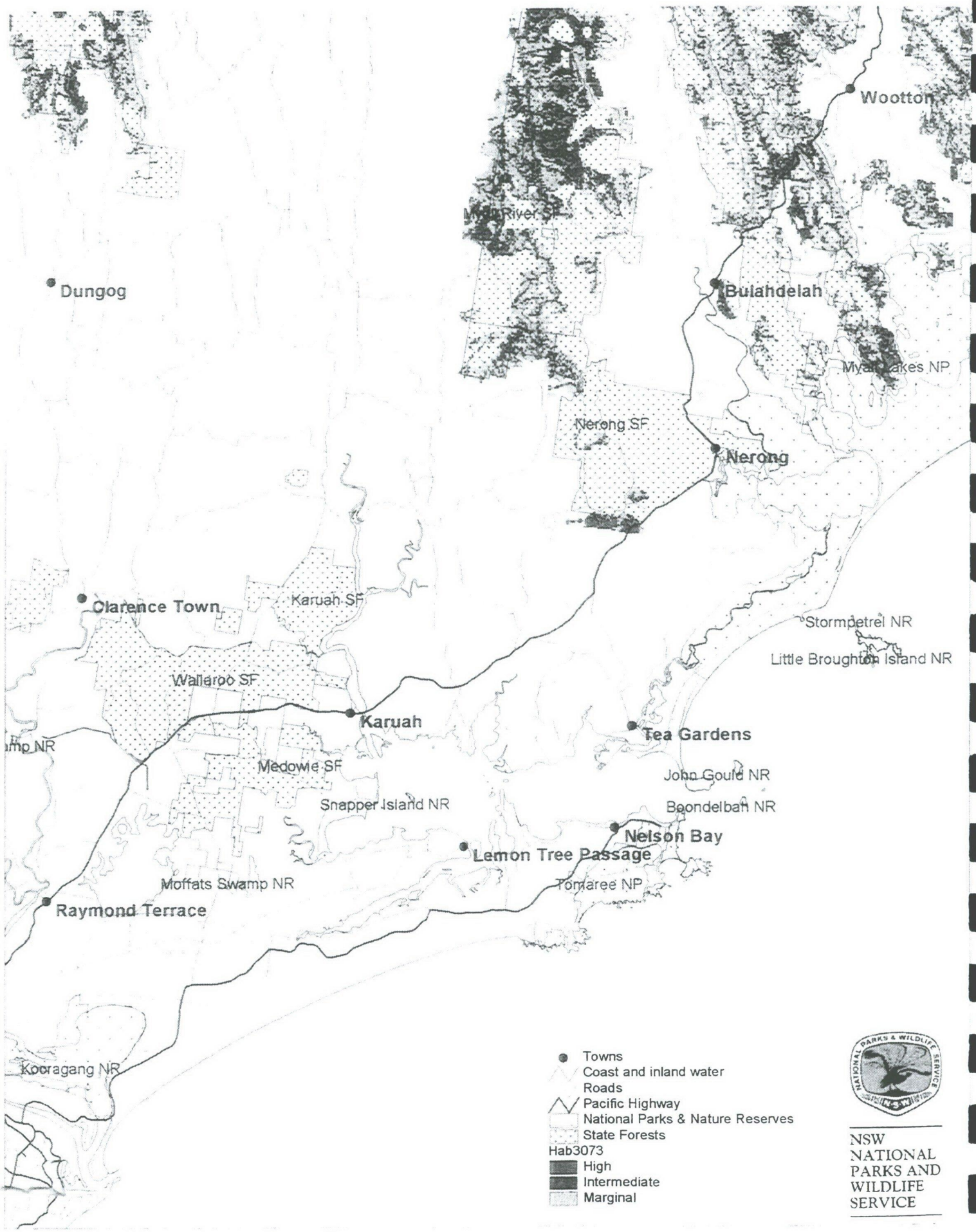
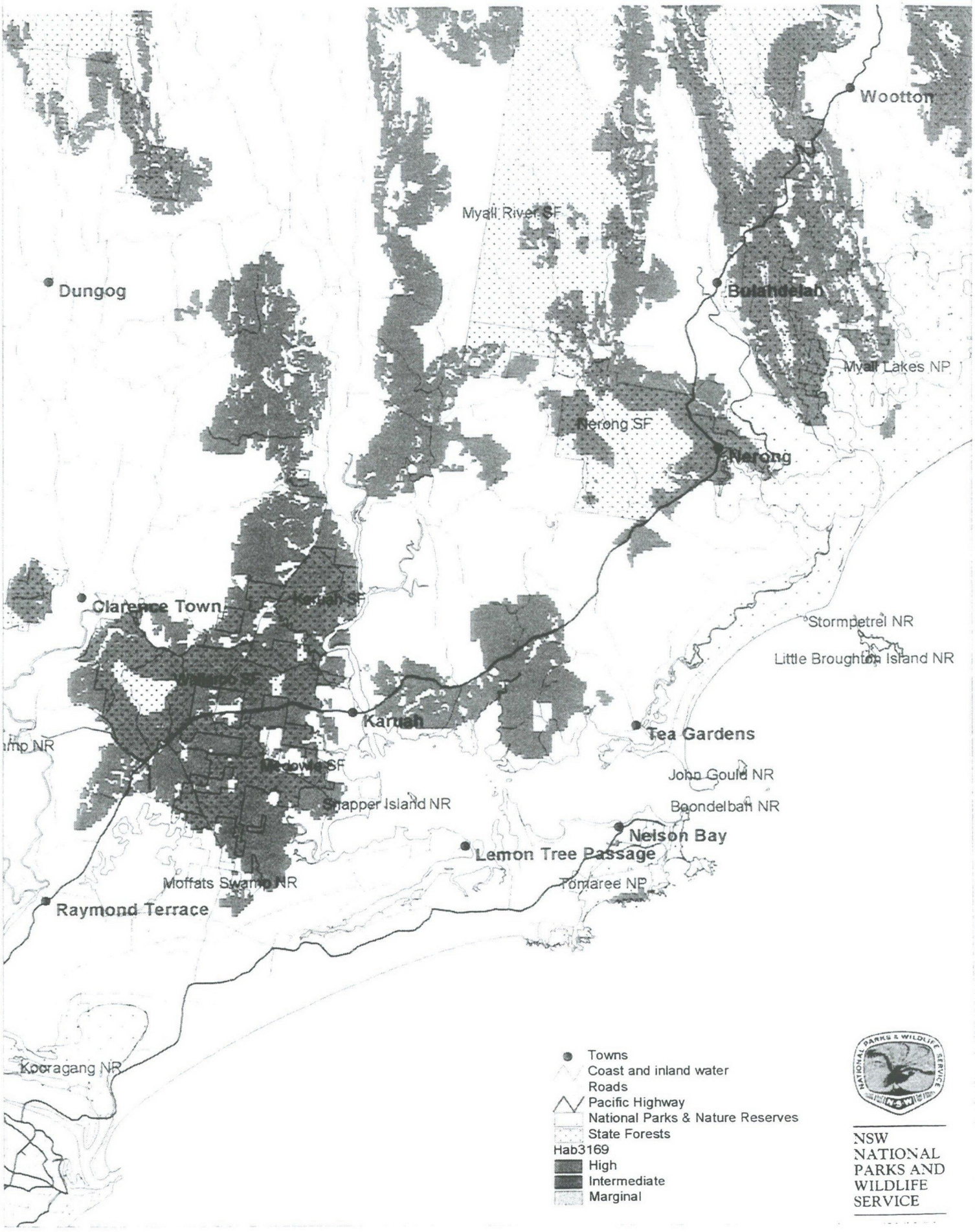
Quality Habitat Model - Mixophes balbus (CRA)



Quality Habitat Model - Littoria brevipalmata (CRA)



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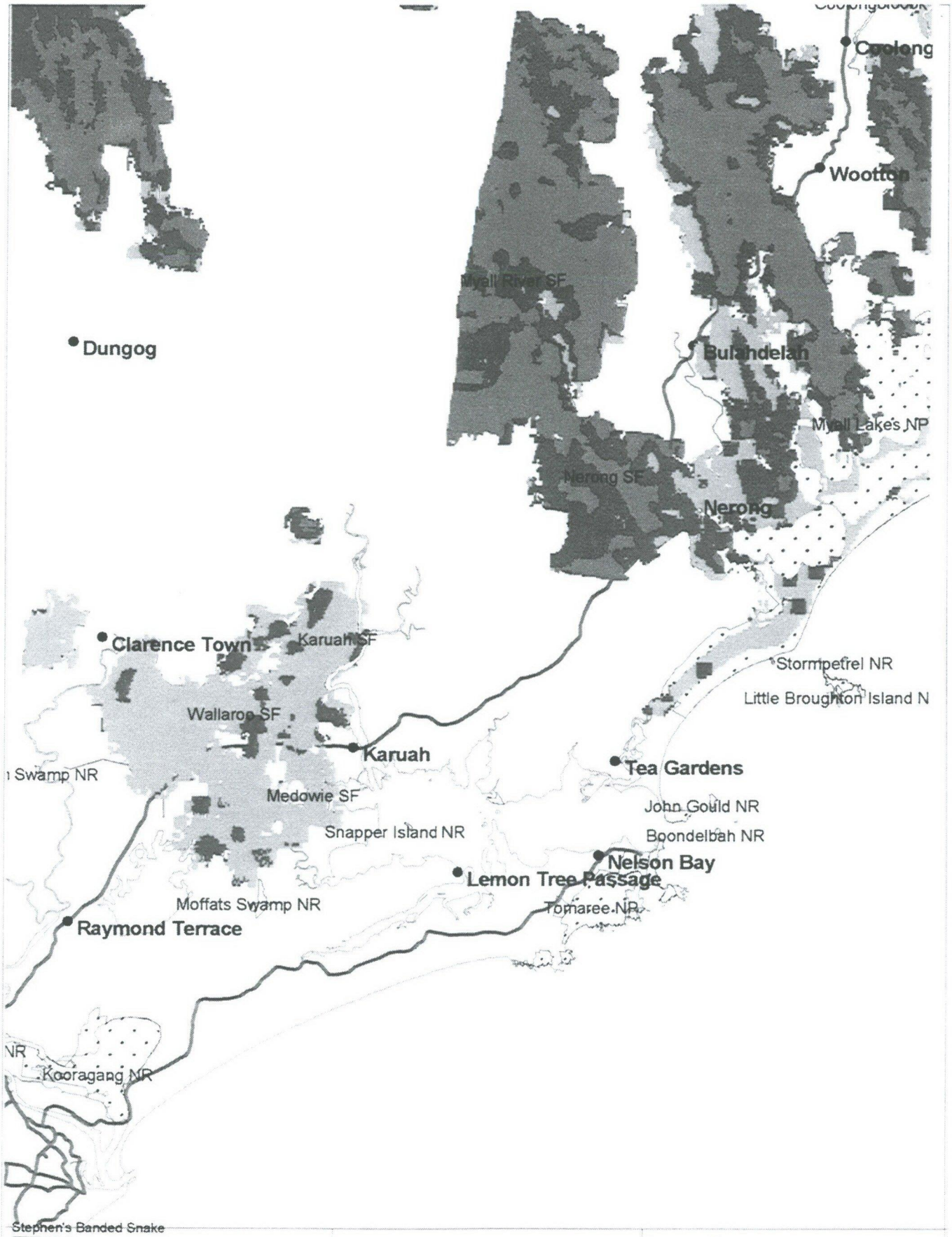
Dungog
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Bulahdelah
Myall Lakes NP
Merong SF
Nerong
Clarence Town
Karuah SF
Wallarop SF
Karuah
Swamp NR
Medowie SF
Snapper Island NR
Tea Gardens
Stormpetrel NR
Little Broughton Island N
John Gould NR
Boondelbah NR
Nelson Bay
Lemon Tree Passage
Tomaree NR
Moffats Swamp NR
Raymond Terrace
Kooragang NR
Stephen's Banded Snake
High
Intermediate
Marginal
Towns
Coast and inland water
Pacific Highway
National Parks & Nature Reserves
State Forests
Stephen's Banded Snake habitat model (PLO)
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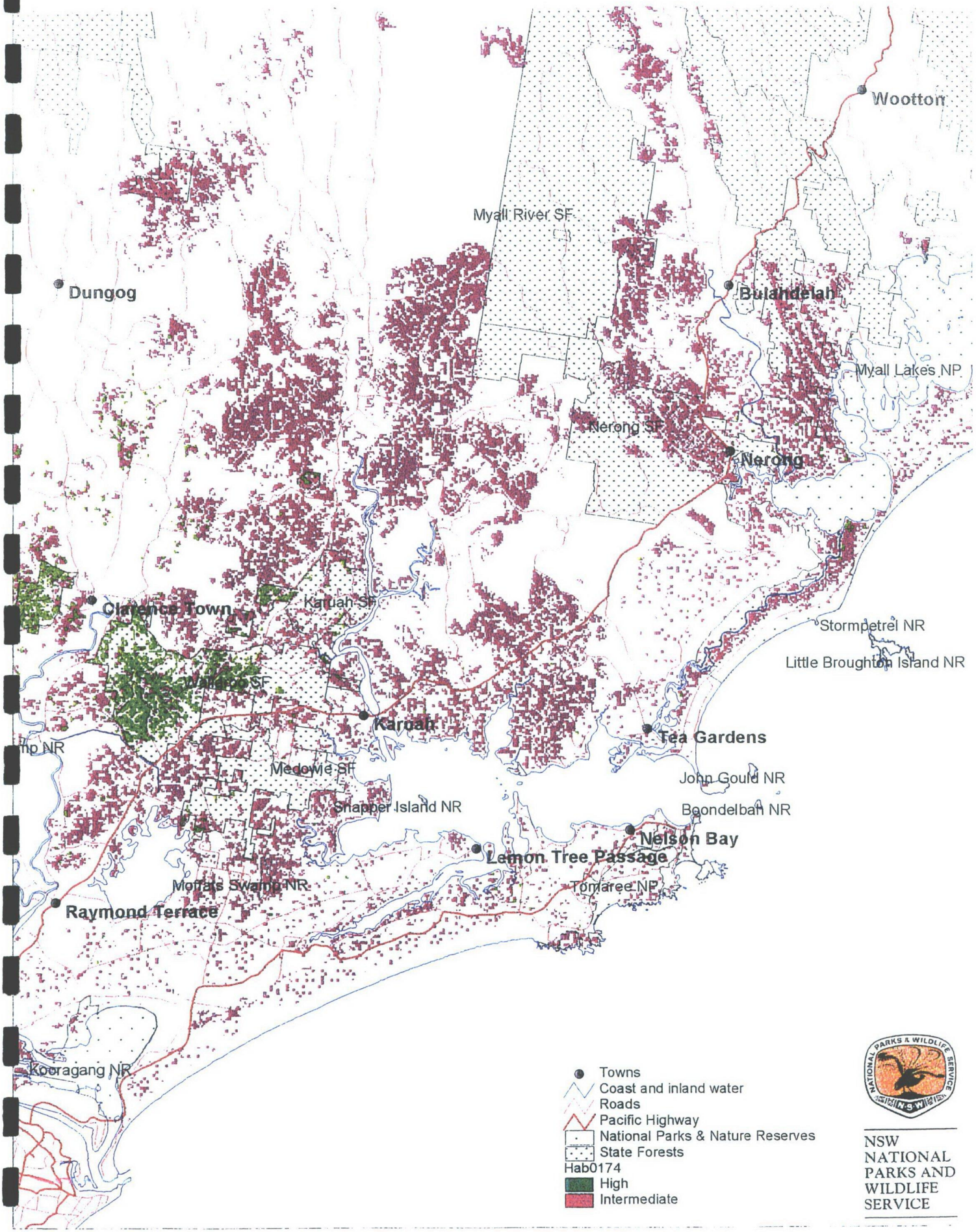
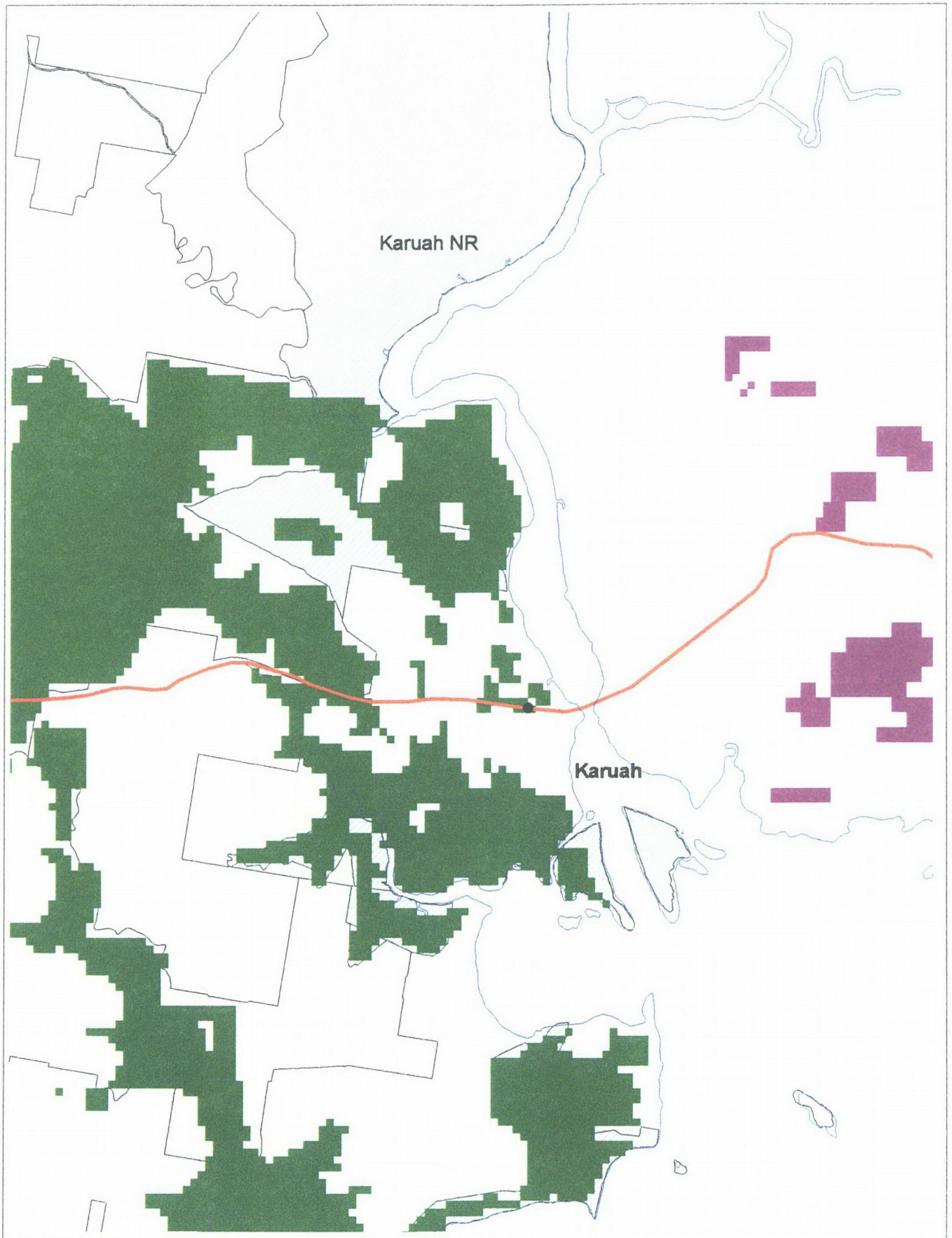
Quality Habitat Model - Bush stone curlew (CRA)



NSW NATIONAL PARKS AND WILDLIFE SERVICE



Towns
Coast and inland water
Pacific Highway
Chestnut-rumped Heathwren (0498)
High
Intermediate
Marginal
Npestate.shp
State Forest

Chestnut-rumped Heathwren

Quality Habitat Model

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PROJECTION : RTA Karuah Bypass Project

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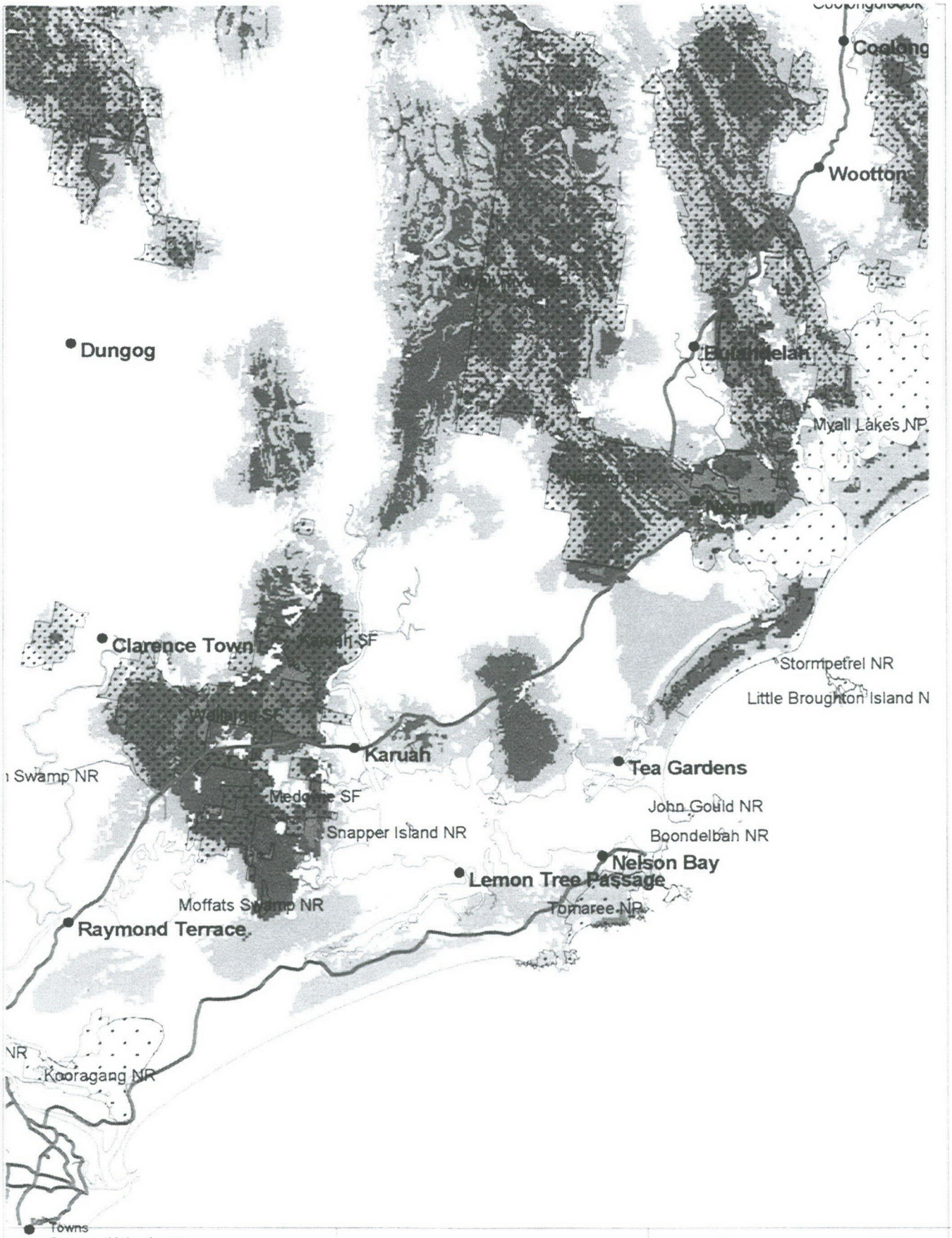
Lynn Baker
18 August 1999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Coolongo
Wootton
Dungog
Myall Lakes NP
Clarence Town
Stormpetrel NR
Little Broughton Island N
Karuah
Tea Gardens
Swamp NR
John Gould NR
Boondelbah NR
Snapper Island NR
Nelson Bay
Lemon Tree Passage
Moffats Swamp NR
Tomaree NR
Raymond Terrace
Kooragang NR
Towns
Coast and inland water
Pacific Highway
National Parks & Nature Reserves
State Forests
Glossy Black Cockatoo
High
Intermediate
Marginal
Glossy Black Cockatoo habitat model
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0 4 8 Kilometers
PROJECTION : AMG Zone 56
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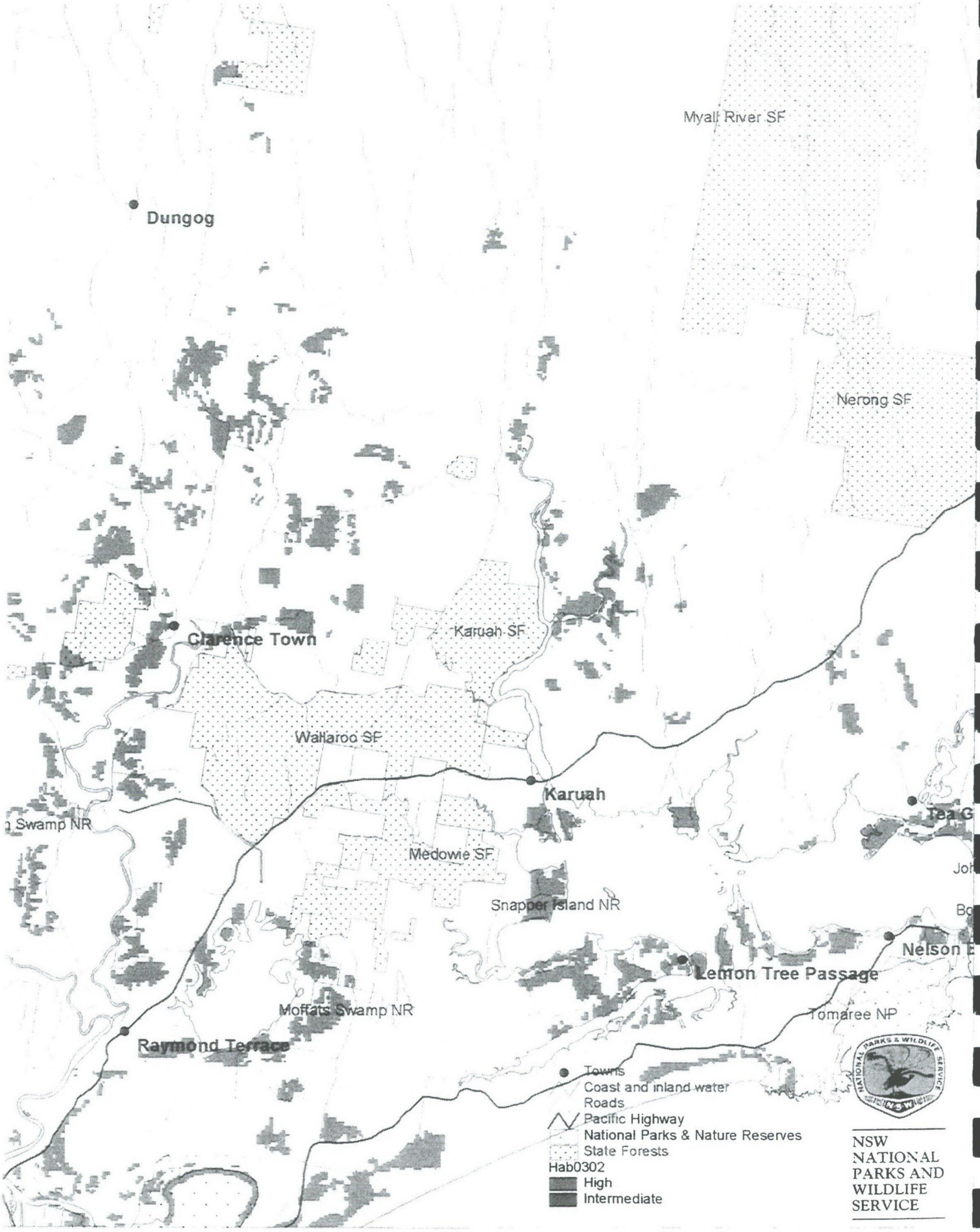
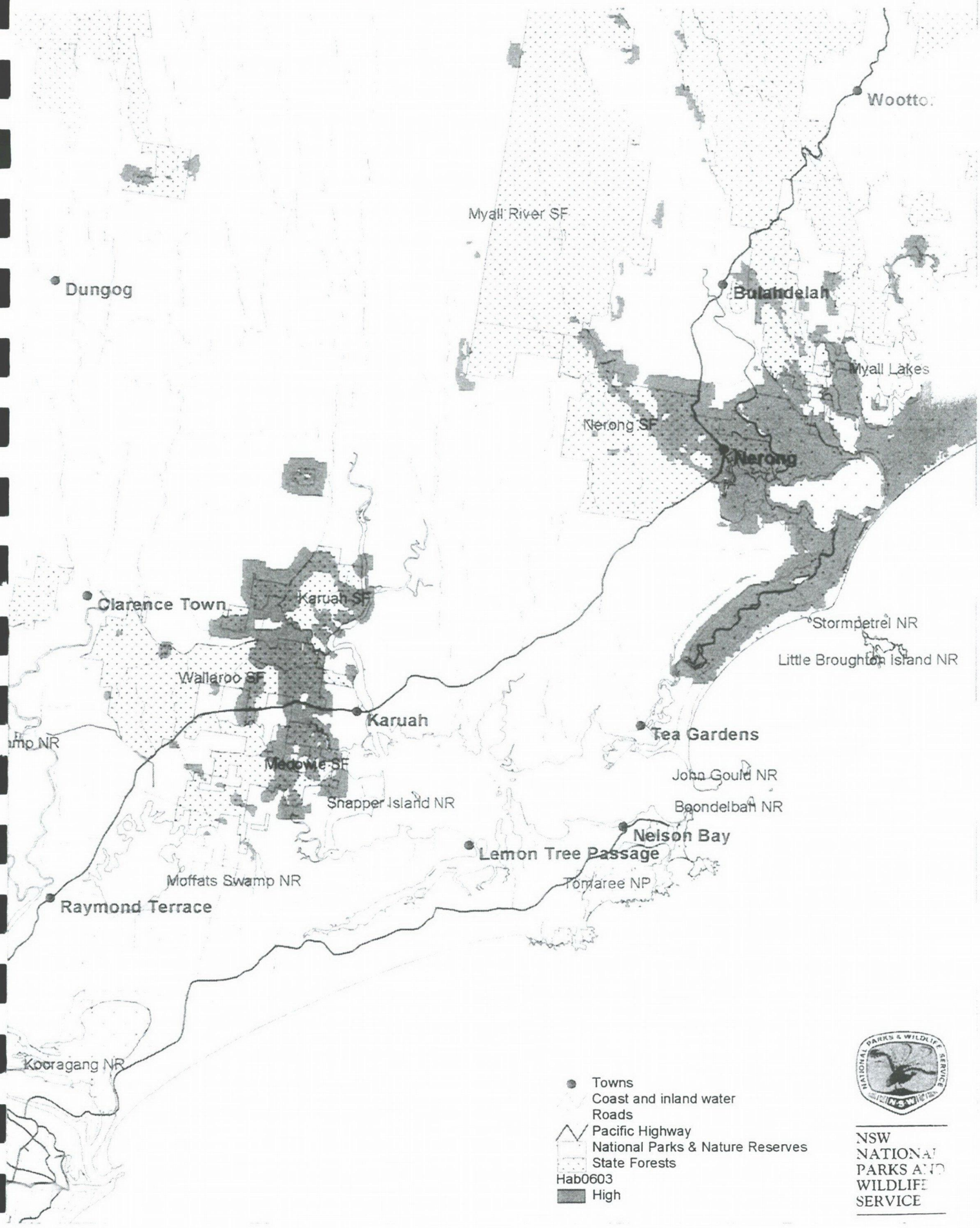
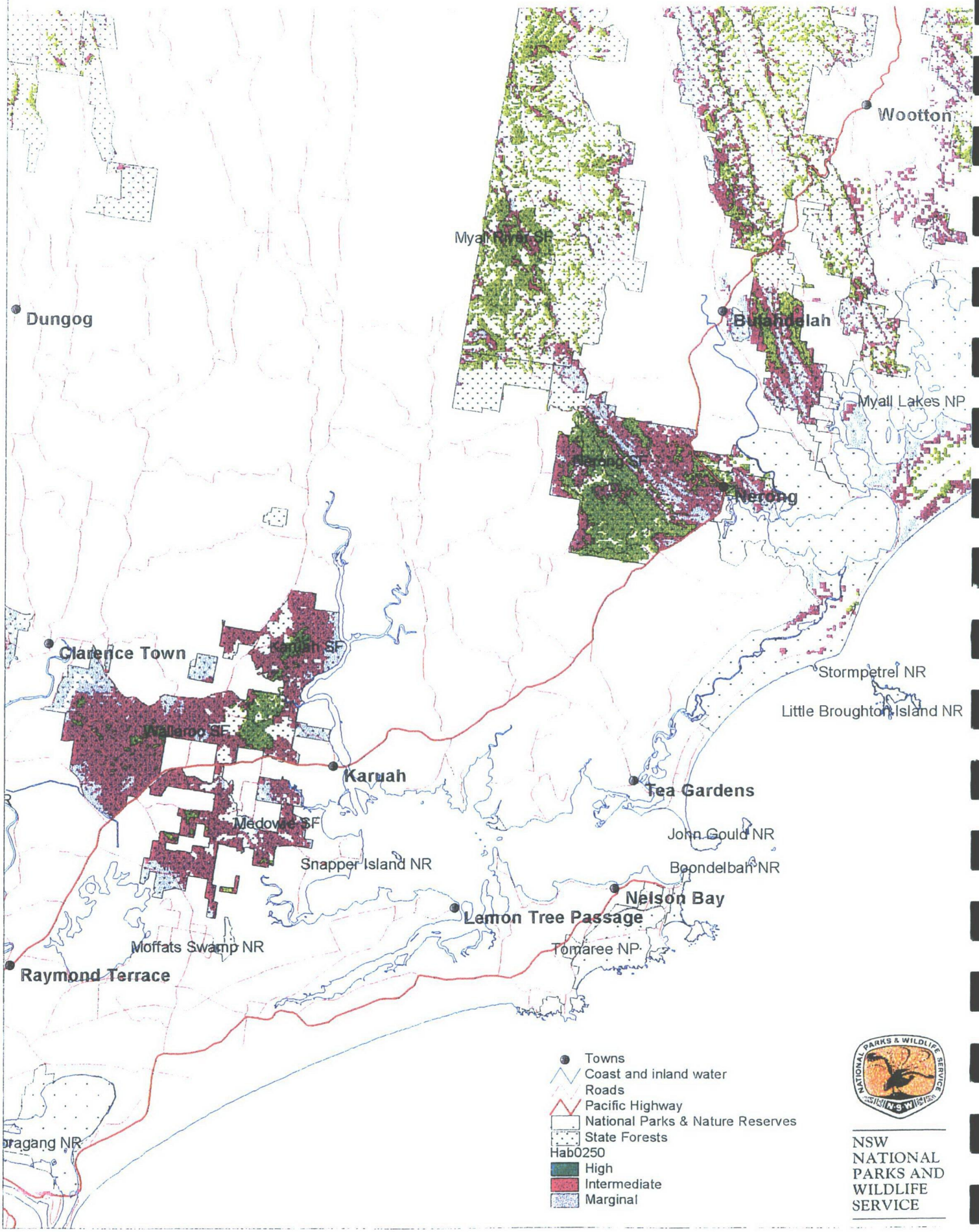
Quality Habitat Model - Turquoise Parrot (CRA)



Quality Habitat Model - Regent honeyeater (CRA) PLO

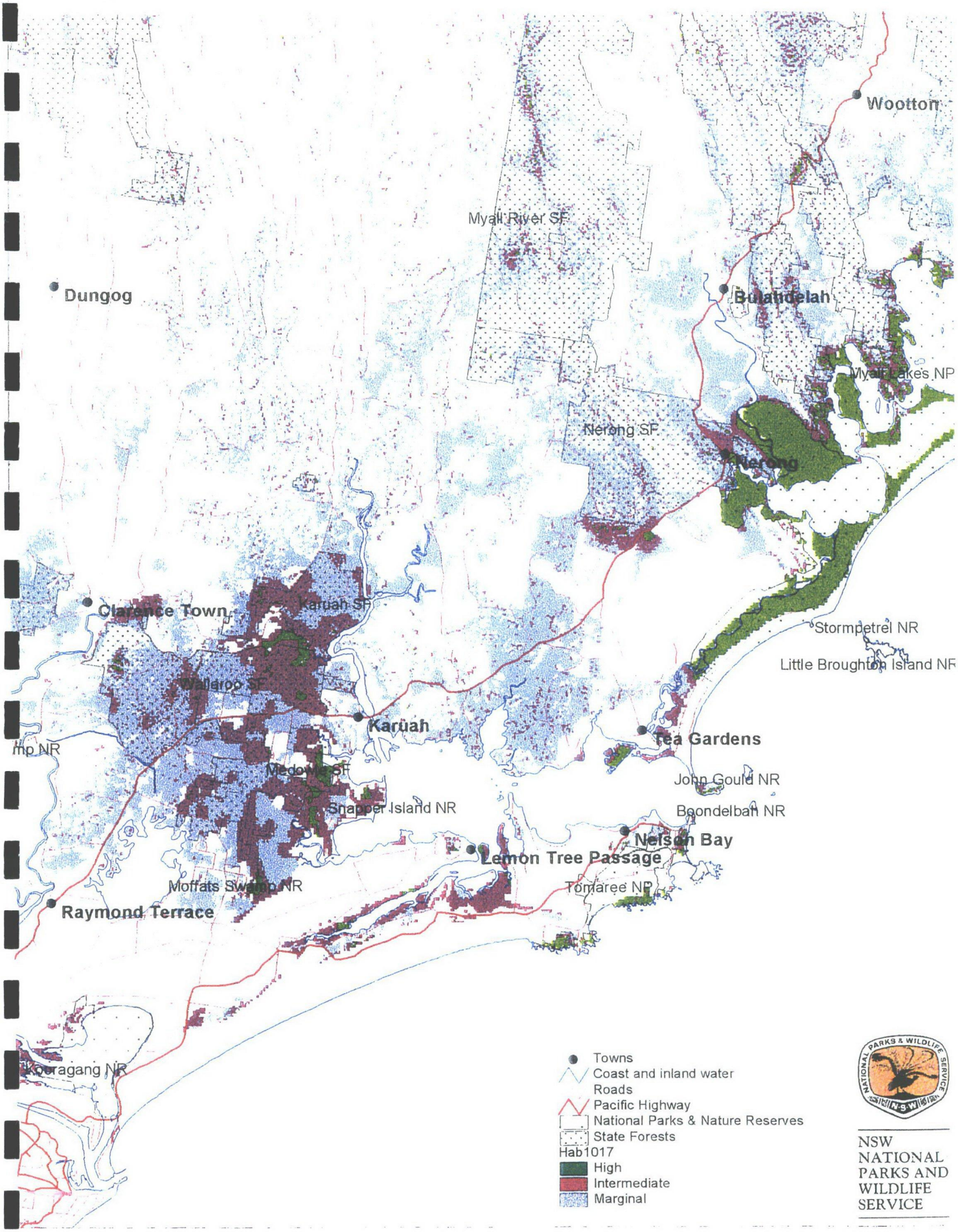


Quality Habitat Model - Masked Owl (CRA)

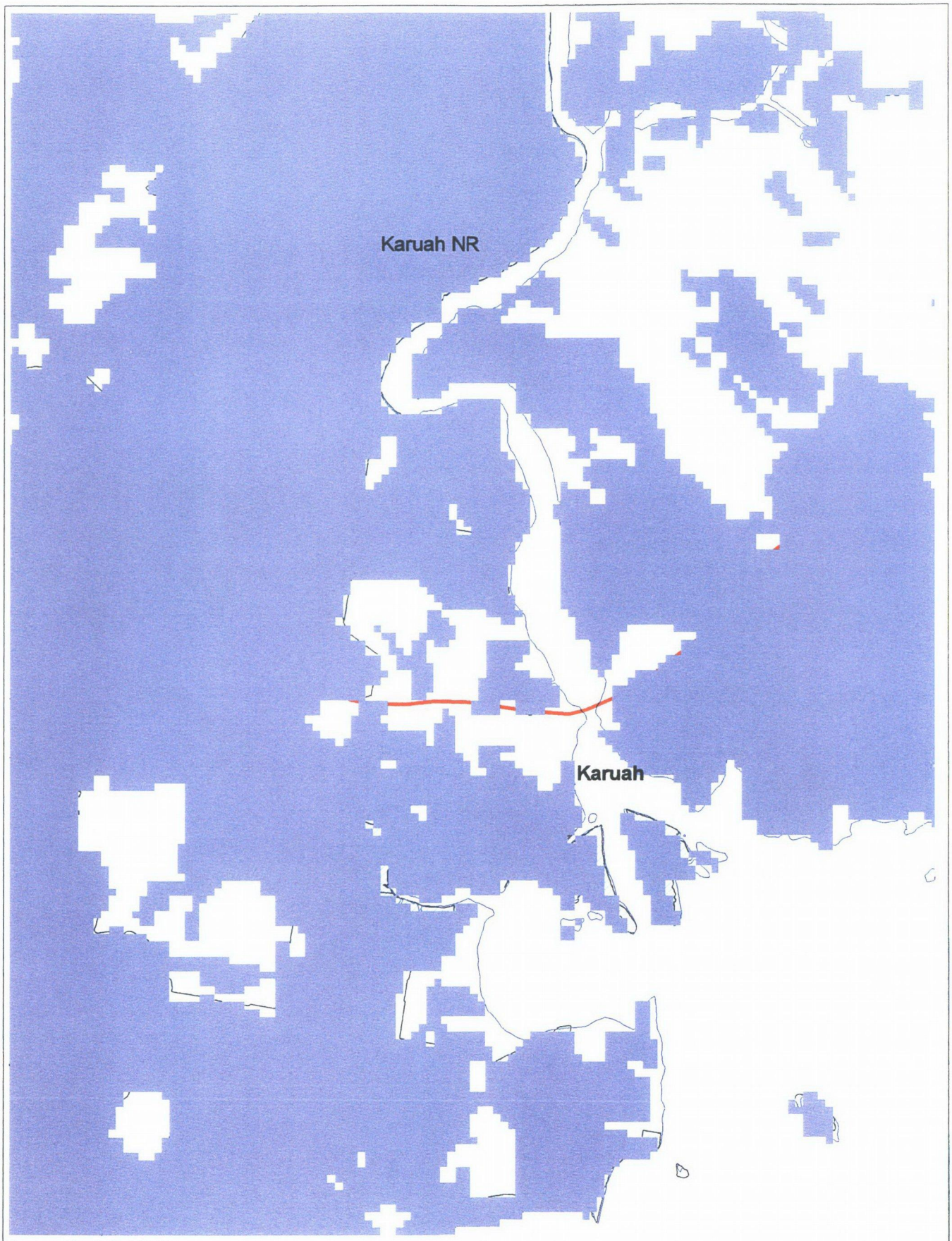


NSW NATIONAL PARKS AND WILDLIFE SERVICE

Quality Habitat Model - Brush-tailed phascogale (CRA)



NSW NATIONAL PARKS AND WILDLIFE SERVICE



~~Common Planigale (1045)~~
High
Intermediate
Marginal
Towns
Coast and inland water
Pacific Highway
Npestate.shp
State Forest

Common Planigale

Quality Habitat Model

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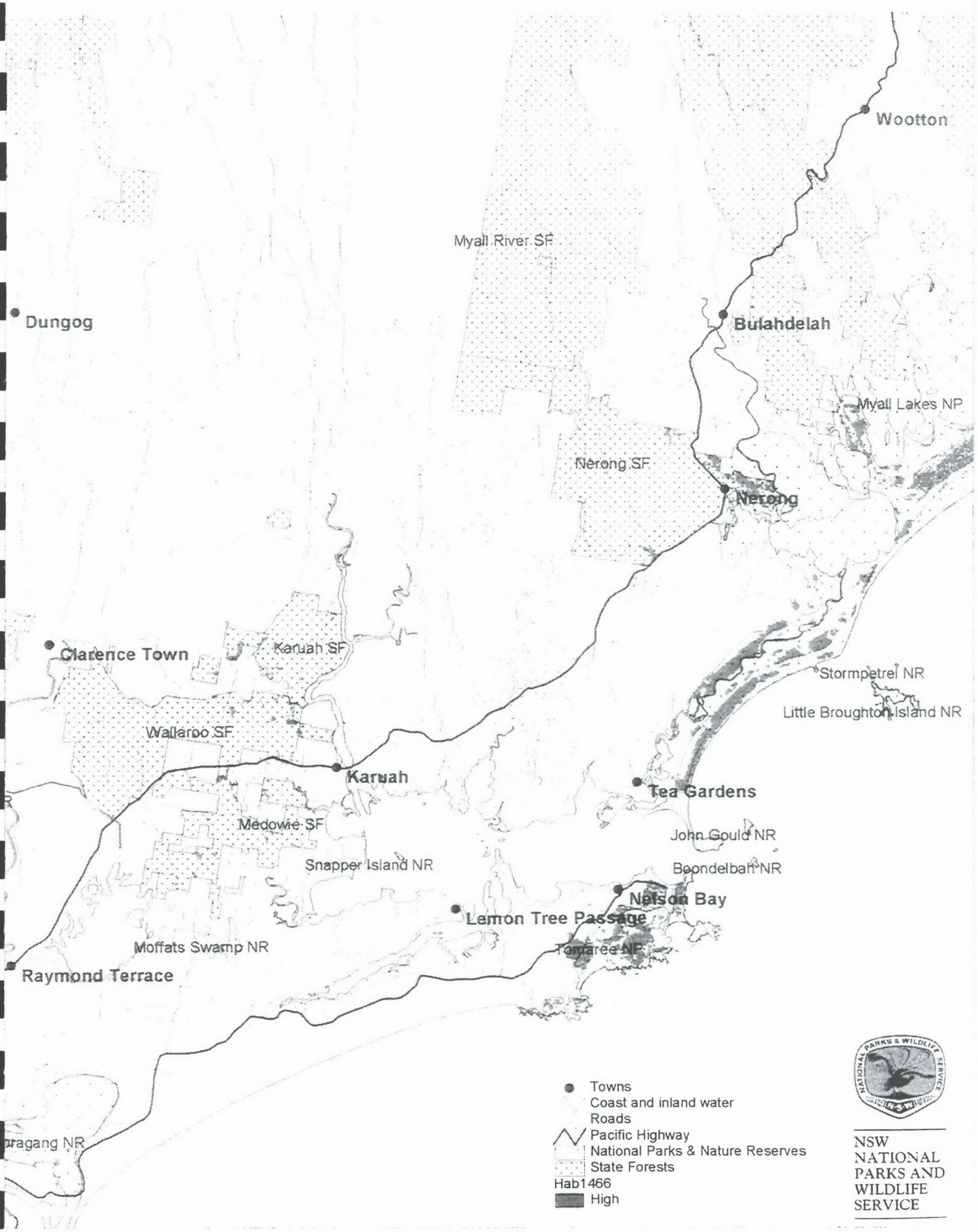
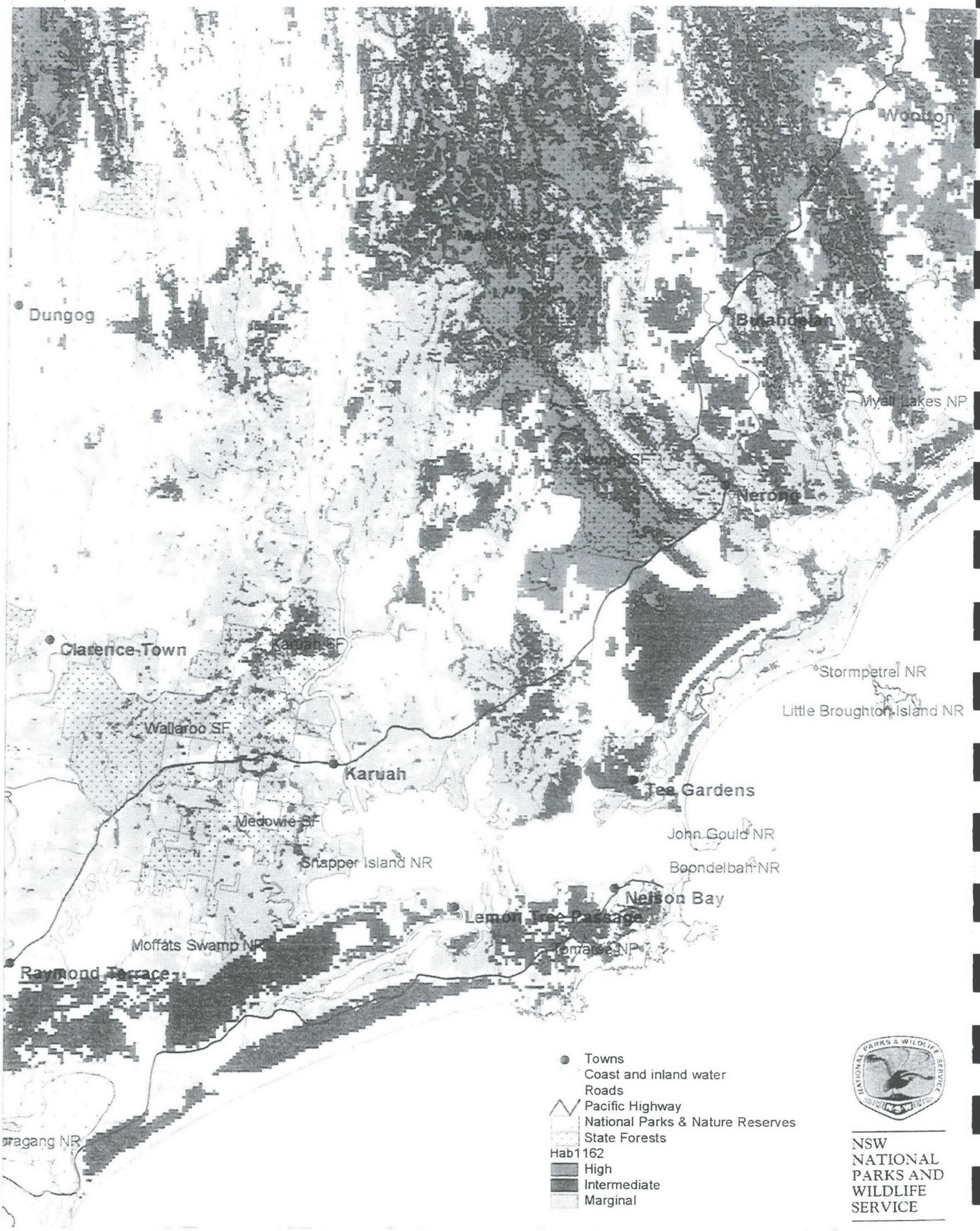
Quality Habitat Model - Eastern Chestnut Mouse (CRA)



Quality Habitat Model - Koala (CRA)



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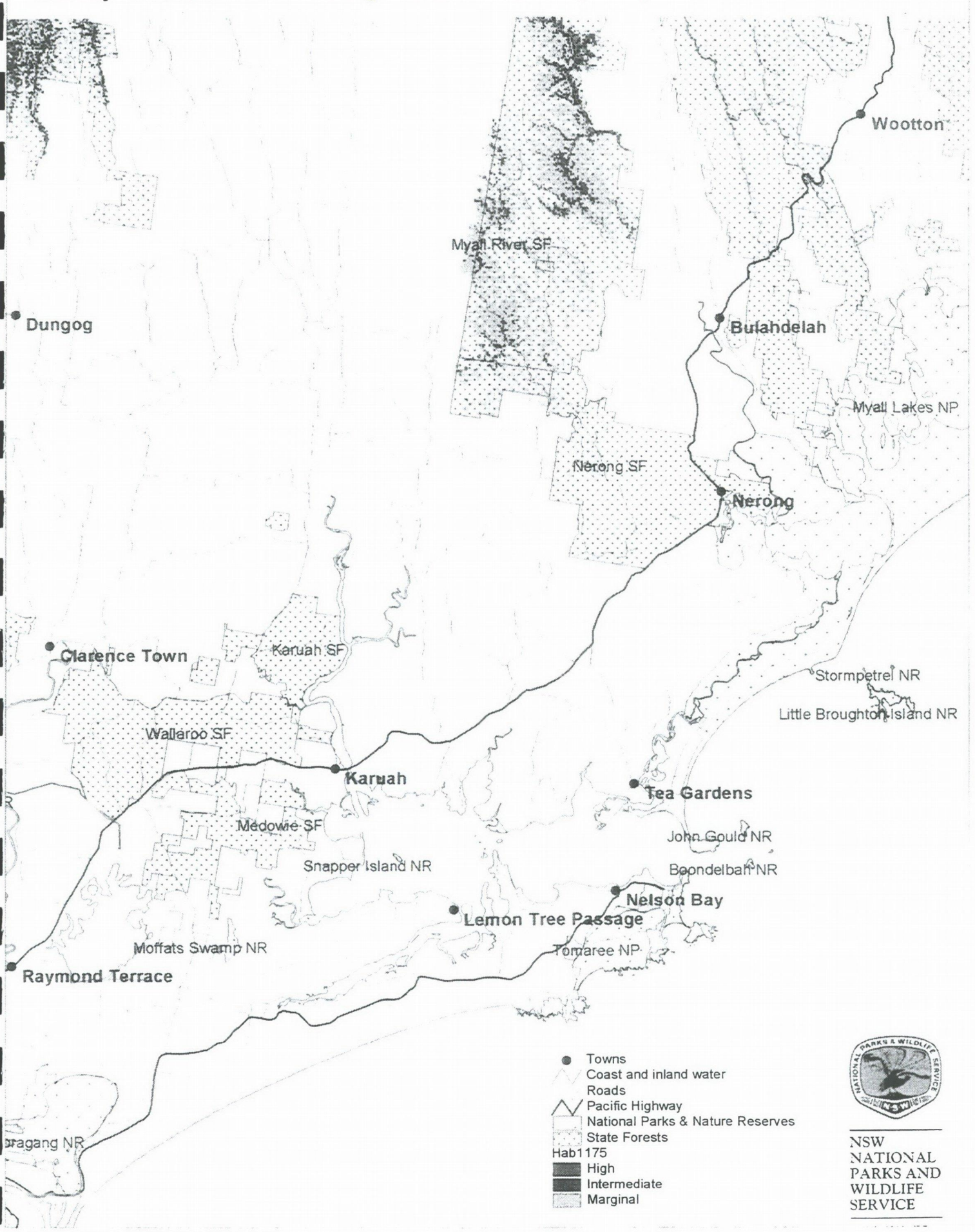
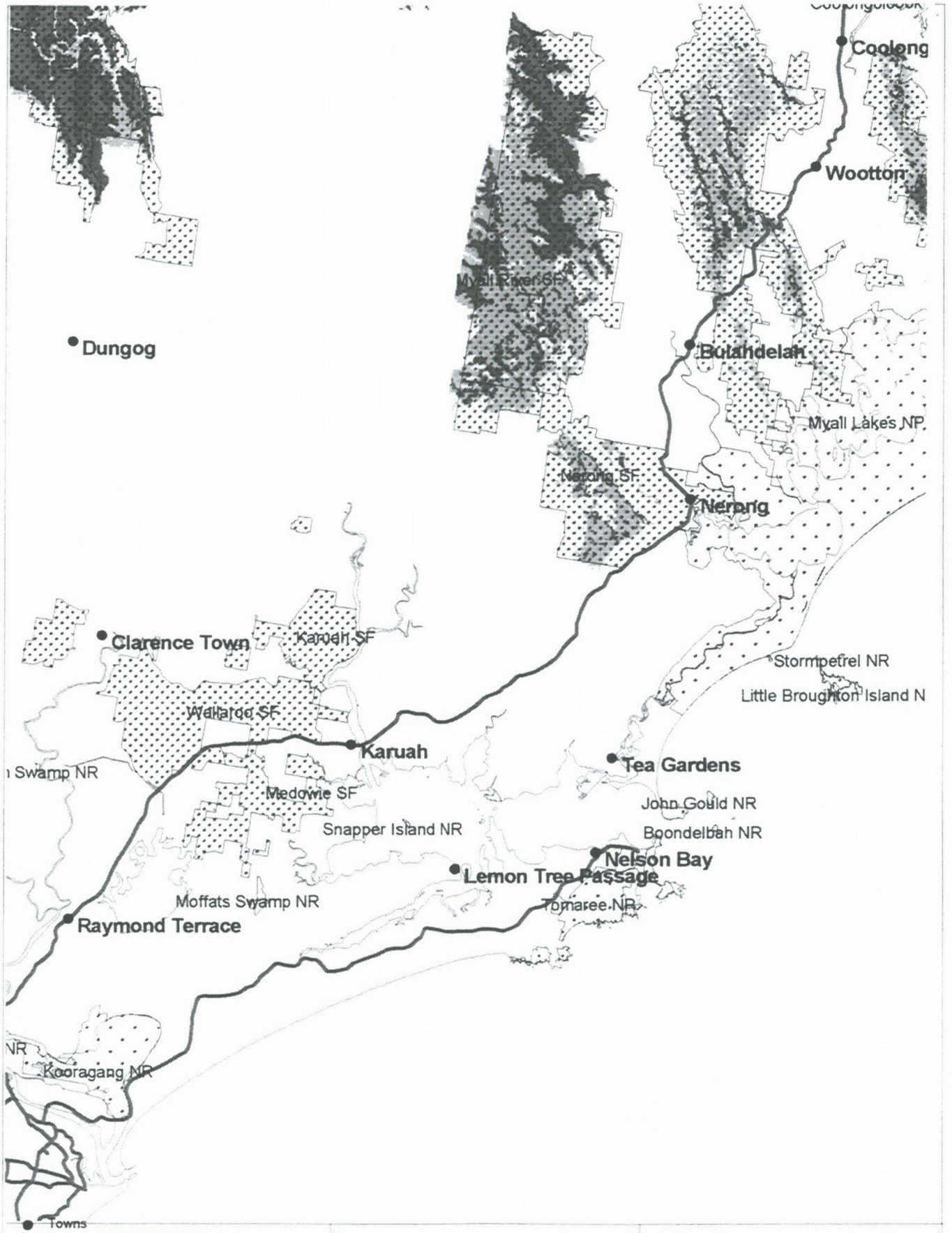
Quality Habitat Model - Long-nosed Potoroo (CRA)





Parma Wallaby habitat model (PLO)

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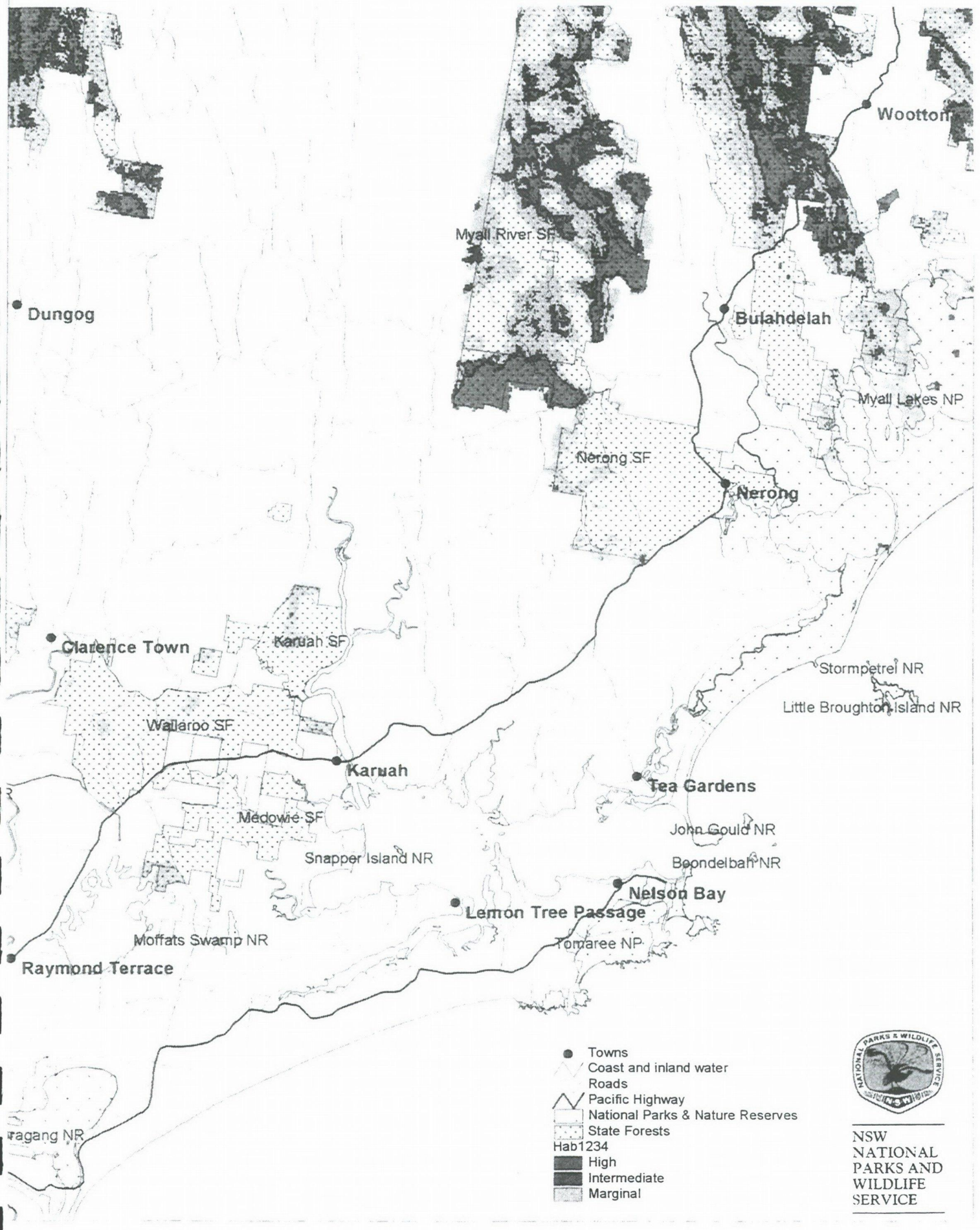
Quality Habitat Model - Red-legged Pademelon (CRA) PLO



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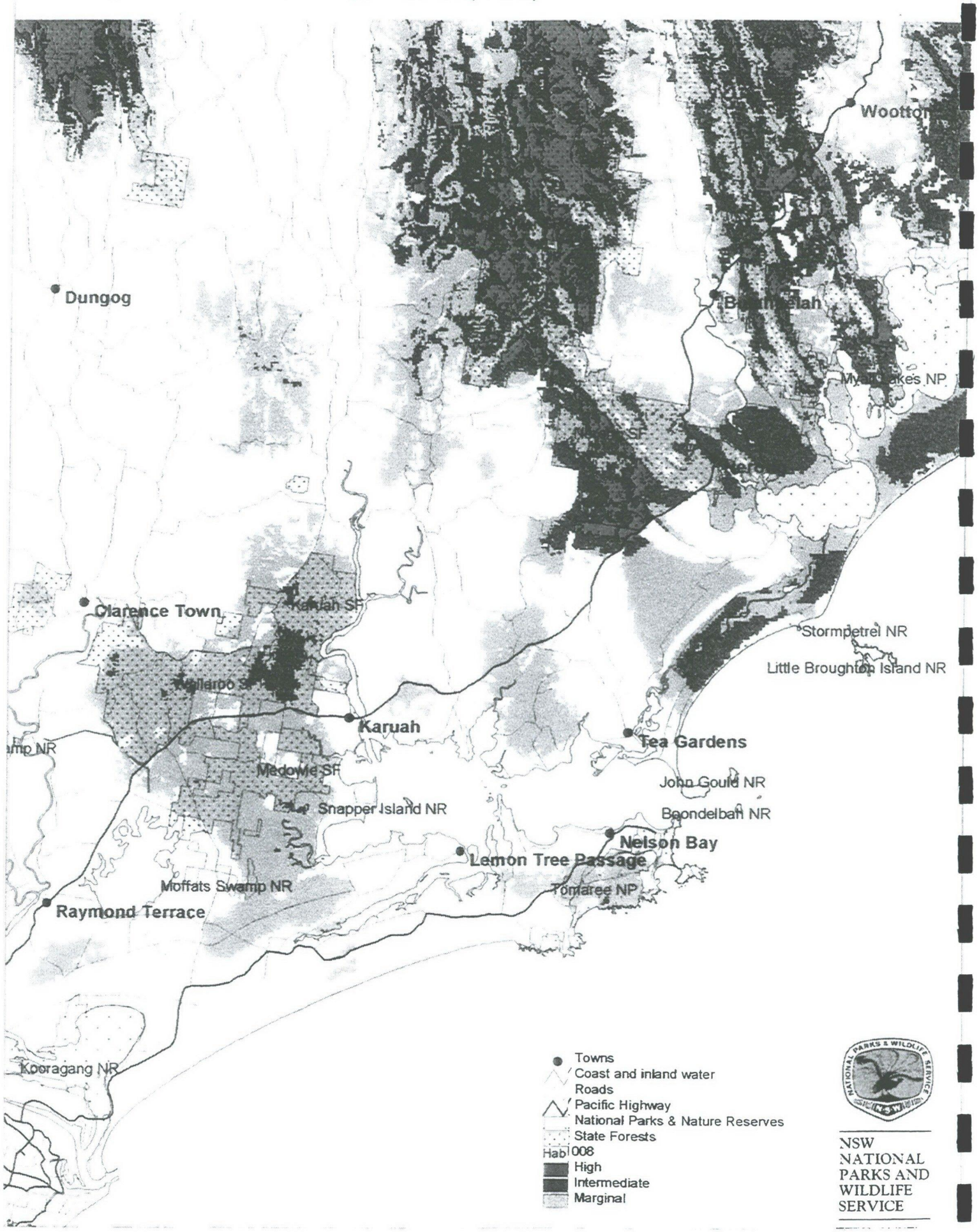
Quality Habitat Model - Tiger Quoll (CRA)



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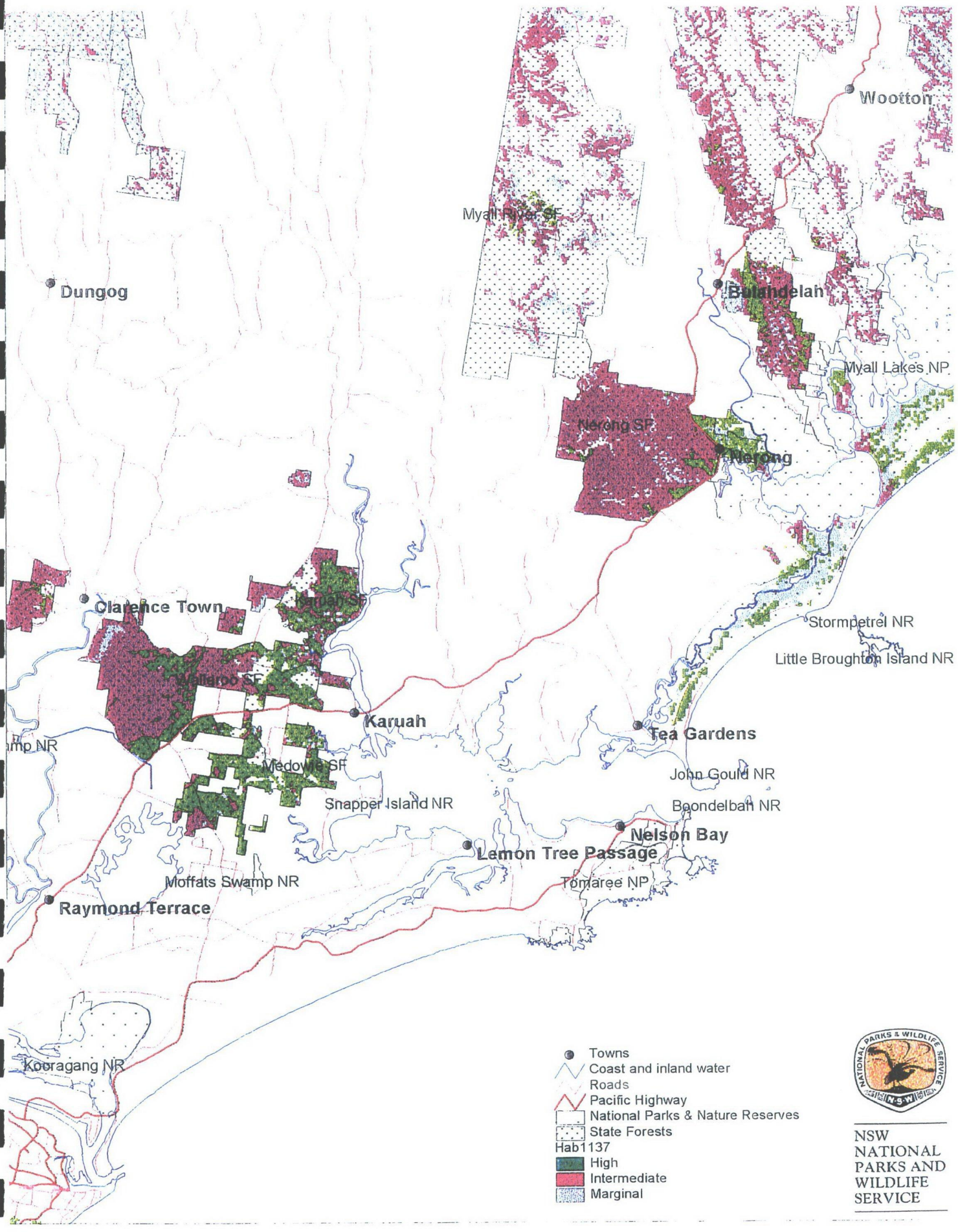
Quality Habitat Model - Squirrel glider (CRA) PLO



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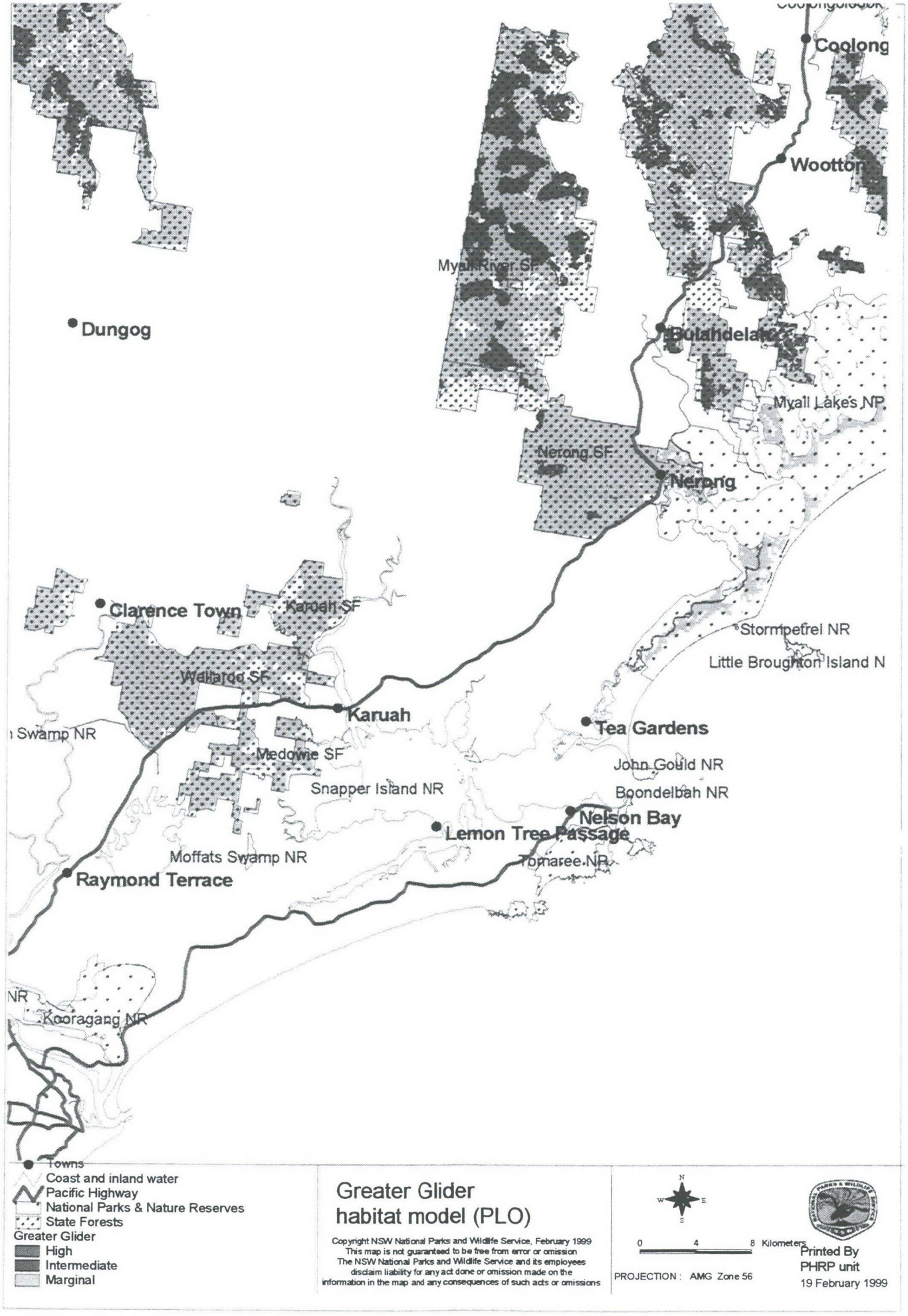
Coolongolook
Coolong
Wootton
Myall River SF
Dungog
Bulahdelah
Myall Lakes NP
Nerong SF
Nerong
Clarence Town
Karuah SF
Stormpetrel NR
Little Broughton Island N
Wallaroo SF
Karuah
Swamp NR
Tea Gardens
Medowie SF
John Gould NR
Snapper Island NR
Boondelbah NR
Nelson Bay
Lemon Tree Passage
Moffats Swamp NR
Tomaree NR
Raymond Terrace
NR
Kooragang NR
Towns
Coast and inland water
Pacific Highway
National Parks & Nature Reserves
State Forests
Greater Glider
High
Intermediate
Marginal
Greater Glider
habitat model (PLO)
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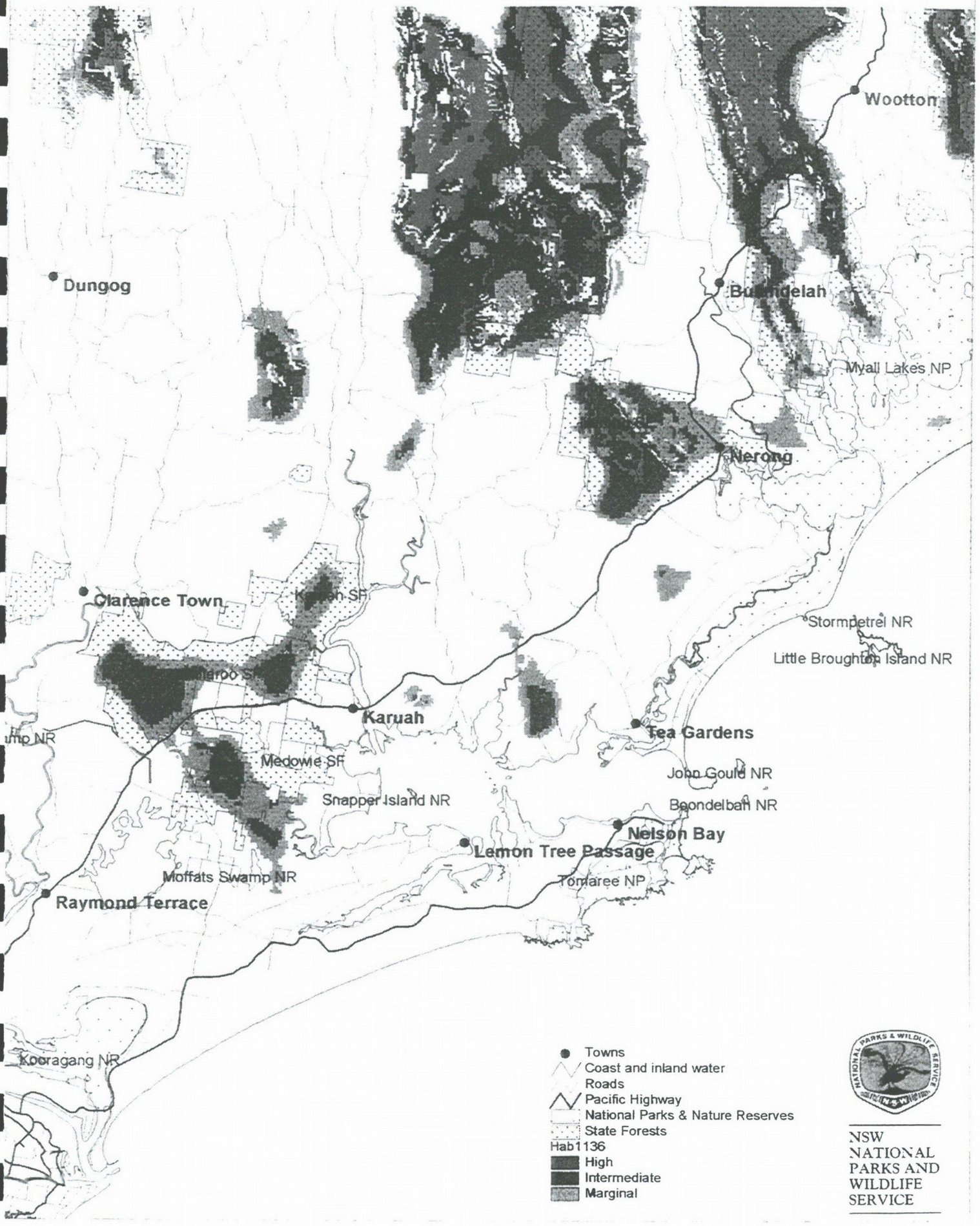
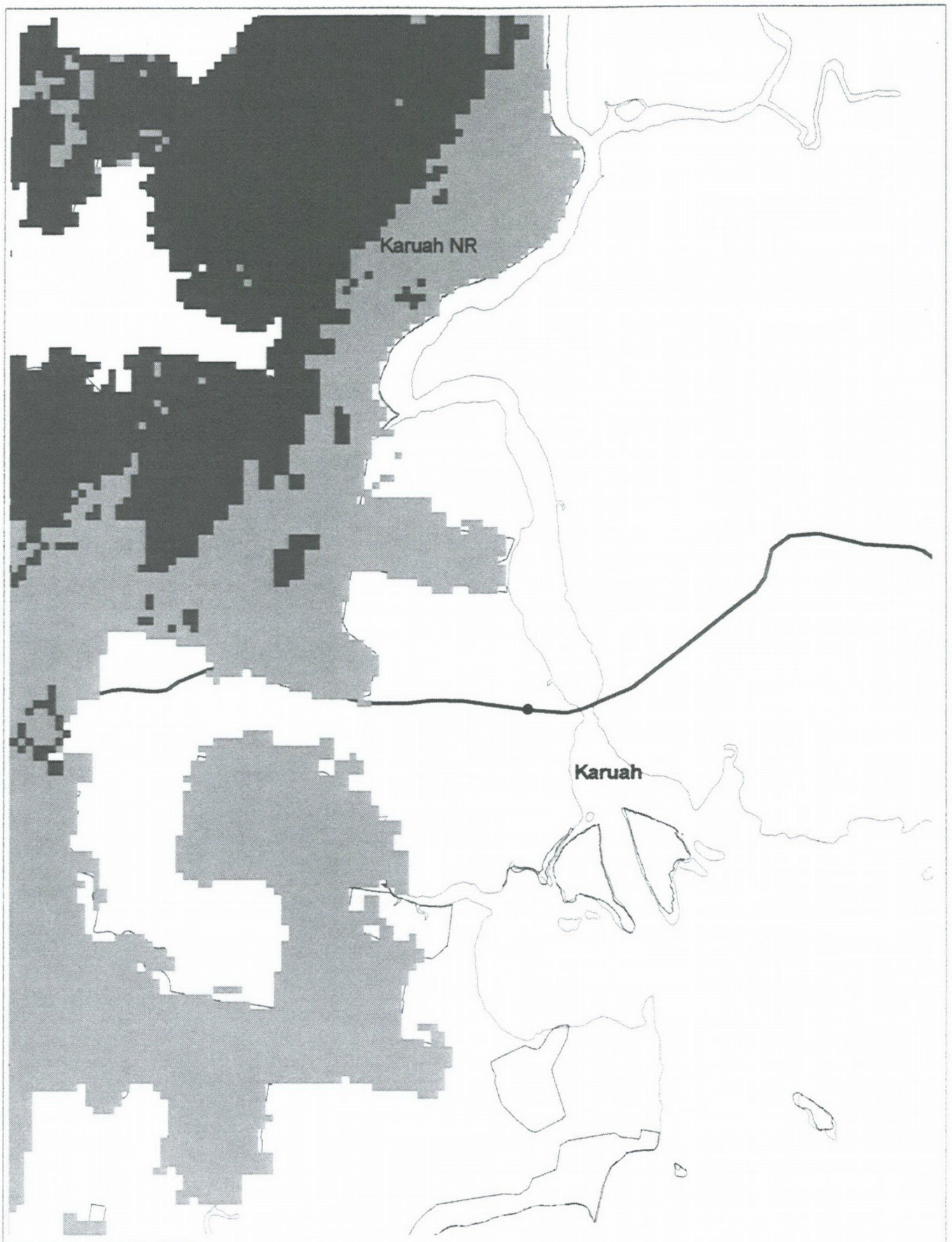
Quality Habitat Model - Yelllow-belllied glider (CRA)





Common Bent-wing Bat (1341)
- High
- Intermediate
- Marginal
- Towns
- Coast and inland water
- Pacific Highway
- Npestate.shp
- State Forest

Common Bent-wing Bat

Quality Habitat Model, PLO

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Little Bent-wing Bat (1346)
High
Marginal
Intermediate
Towns
Coast and inland water
Pacific Highway
Npestate.shp
State Forest

Little Bent-wing Bat

Quality Habitat Model, PLO

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PROJECTION : RTA Karuah Bypass Project

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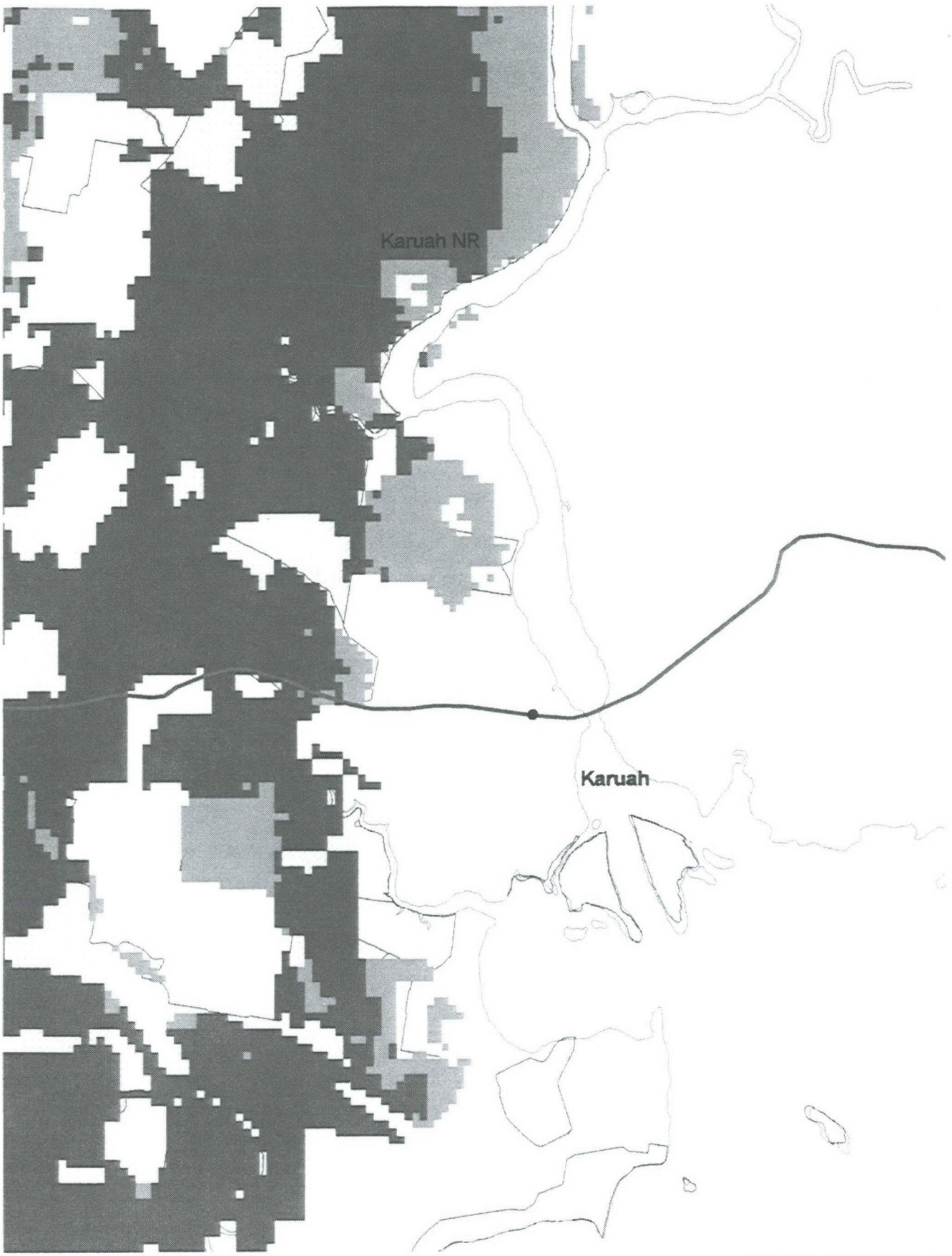

Towns
Coast and inland water
Pacific Highway
Greater Broad-nosed Bat (1361)
High
Intermediate
Marginal
Npestate.shp
State Forest

Greater Broad-nosed Bat Quality Habitat Model, all tenures

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Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX L

Project Description and Construction Issues

(Chapters 6 & 7 from the EIS)

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

6. Project description

This chapter initially presents the design criteria on which the concept design for the proposed Pacific Highway bypass at Karuah is based. An overview of the proposal is then presented followed by discussion of key elements of the proposal including bridges, junctions, and the provision for fauna movement. A comprehensive landscape strategy for the proposal is presented. An economic evaluation of the proposal concludes this chapter.

6.1 Design criteria

The concept design for the proposed Pacific Highway bypass at Karuah along the Horse Island corridor is based on the road design standards that have been adopted for the Pacific Highway Upgrading Program and the accommodation of other influences including environmental issues, land management requirements, and service provision. The overall objective of the concept design is the development of a 'value for money' project from a broad community perspective.

Further details on the material in this chapter can be found in Working Paper No 2 - Concept Design (Arup, 1999b).

6.1.1 Road design standards

The road design standards applicable for the proposed upgrading of the Pacific Highway at Karuah are those that are being used throughout the Pacific Highway Upgrading Program. These standards are:

- four lane divided road;
- minimum design speed of 110 km/h;
- 30 year traffic capacity design standards including intersections;
- desirable flood protection of 1% Annual Exceedance Probabilities (AEP) and minimum AEP of 5%;
- on road provision for cyclists;
- ability to meet the standard cross-sections developed for the Pacific Highway Upgrading Program; and
- lighting where safety standards require such as at junctions.

6.1.2 Other design influences

The concept design also incorporates responses to a range of other influences that are not necessarily reflected in specific design standards or criteria, including:

- input into design criteria from a multi-disciplinary approach involving NPWS, DUAP and NSW Fisheries from the project outset;
- continued provision of access for local landowners or managers, especially where landholdings are severed by the proposed bypass;
- provision for safe movement of terrestrial and arboreal fauna across the corridor consistent with biodiversity principles;

- alignment consideration to mitigate effects on the approved Karuah Sewerage Scheme, cultural heritage sites, visual impacts and property boundaries where possible;
- geotechnical considerations;
- soil erosion considerations;
- provision for emergency service vehicles to access land adjoining the highway via locked gates using a 'left in, left out' movements to and from the highway; and
- reducing the direct impact on and thus permanent loss of SEPP 14 wetlands by bridging these areas rather than using embankments.

6.2 Overview of the proposal

The proposed bypass extends 9.8 km from a point on the existing Pacific Highway 48.3 km north of Newcastle to a point 57.9 km north where it rejoins the highway north of Karuah. The existing two lane highway between these two points would remain to provide drive-through access to Karuah with a travel distance slightly less than the bypass. The location of the preferred route relative to Karuah is shown in Figure 6.1. The proposed bypass is shown in Figures 6.2A to 6.2H in plan and longitudinal section. Typical cross sections are shown in Figure 6.3. The main features of the proposed bypass are described below. Extensive provision for fauna movement across the bypass has been integrated into the design through fauna underpasses, drainage culverts, bridges, and modifications to the carriageway cross section - these provisions are described in Section 6.11.

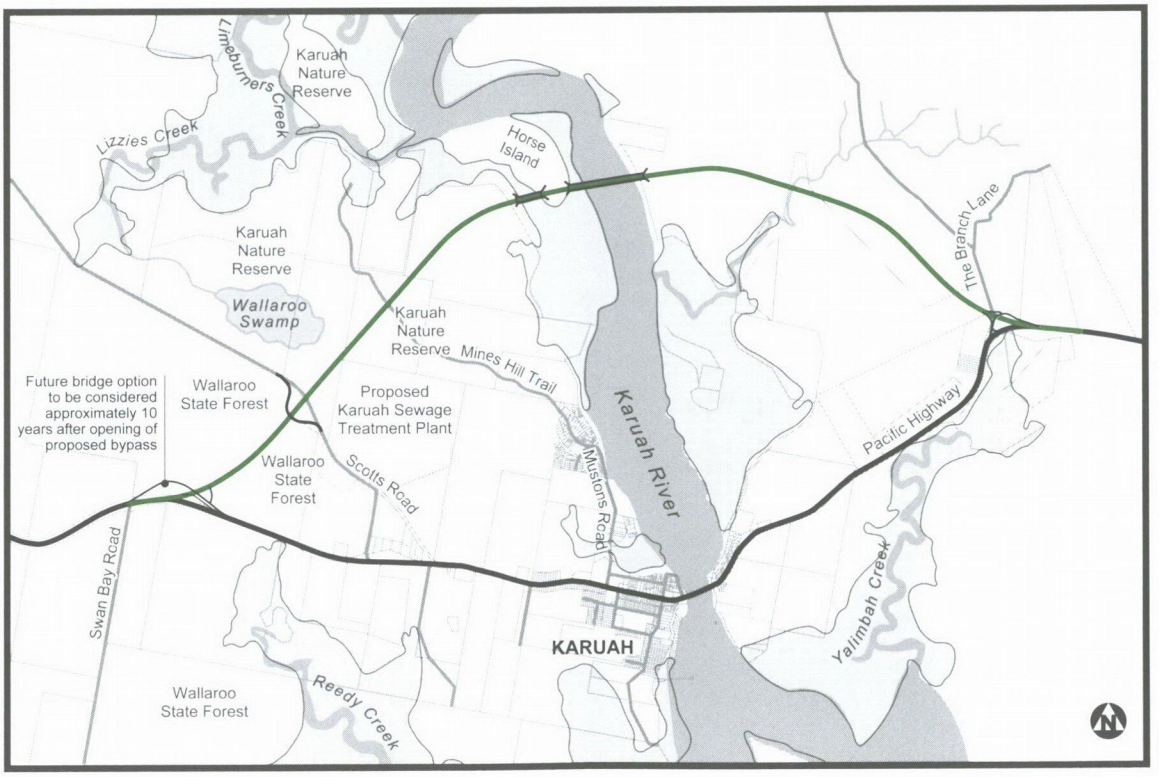


Figure 6.1
The preferred route

Raymond Terrace to Karuah duplication (under construction)

Karuah Bypass

access track

Future bridge option (stage 2) to be considered approximately 10 years after opening of proposed bypass

100.0 200.0 300.0 400.0 500.0 800.0 900.0 1000.0 1300.0 1400.0 1500.0 1600.0

Swan Bay Road

fauna underpass/ drainage

Western Interchange

Stage 2 only

Stage 1 only

Karuah

0 50 100 150 200 250 m

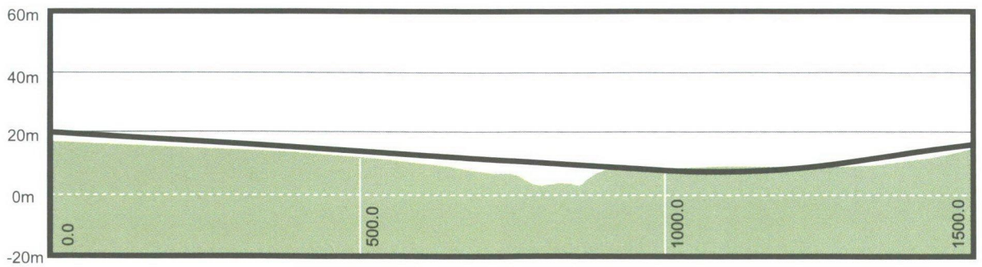
Figure 6.2A

Proposed route alignment

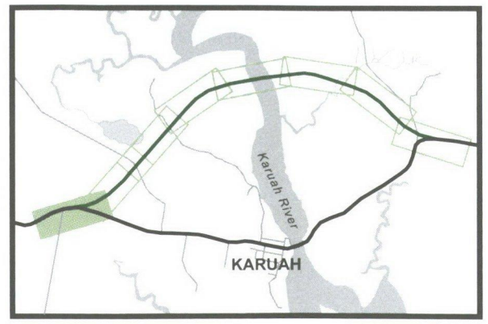
sedimentation basins

proposed land acquisition boundary

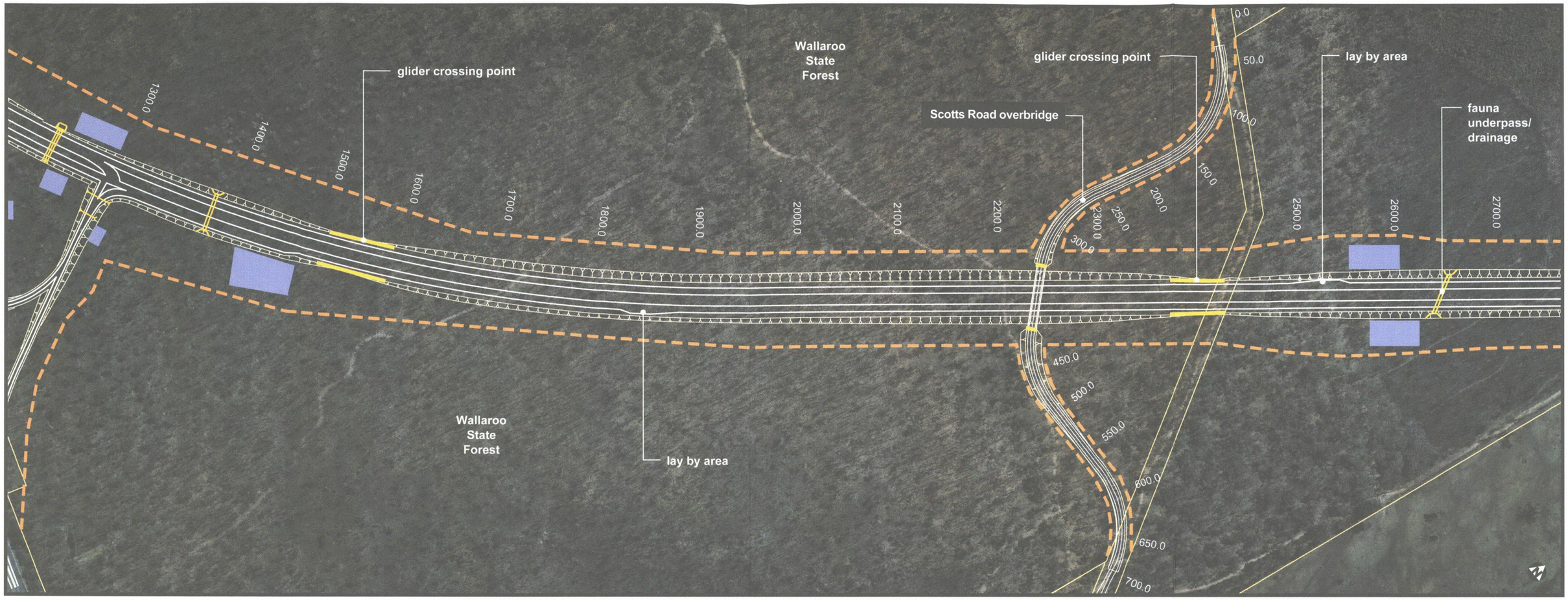
property boundary



Longitudinal Section



Key Map



0 50 100 150 200 250 m

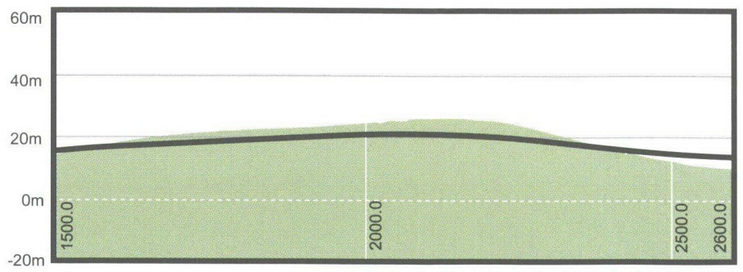
Figure 6.2B

Proposed route alignment

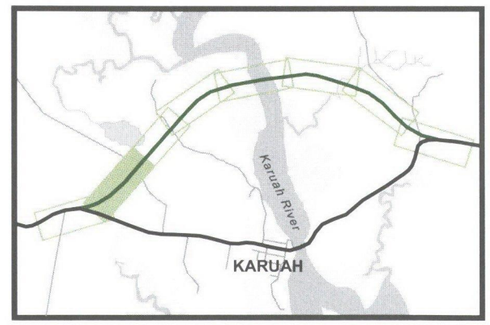
sedimentation basins

proposed land acquisition boundary

property boundary



Longitudinal Section



Key Map

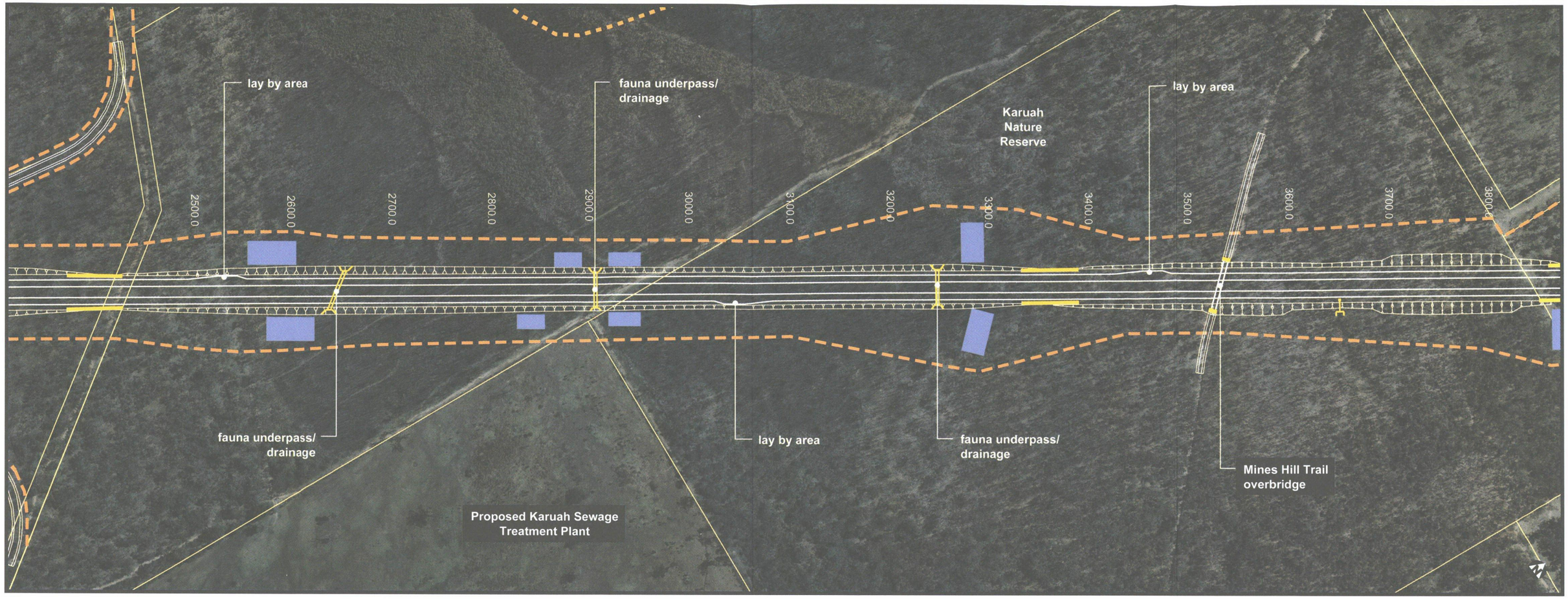
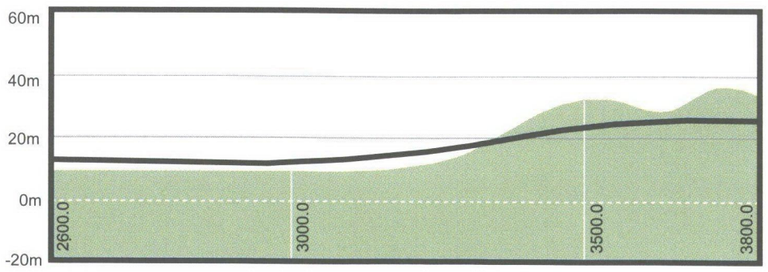
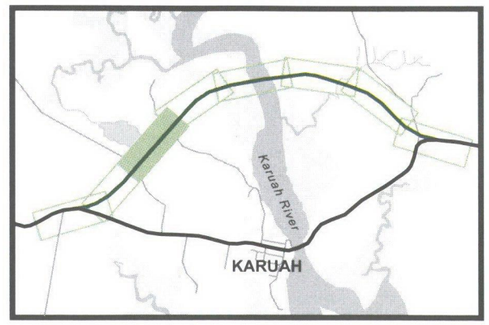


Figure 6.2C
Proposed route alignment

sedimentation basins
proposed land acquisition boundary
property boundary



Longitudinal Section



Key Map

median crossover facility
and lay by area combined

fauna underpass/
drainage

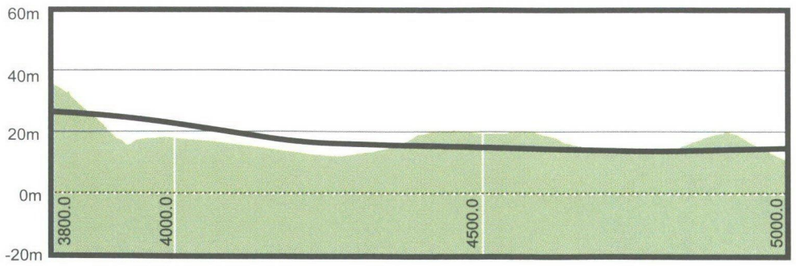
fauna underpass/
drainage

3600.0
3700.0
3800.0
3900.0
4000.0
4100.0
4200.0
4300.0
4400.0
4500.0
4600.0
4700.0
4800.0
4900.0
5000.0
5100.0

0 50 100 150 200 250 m

Figure 6.2D
Proposed route alignment

sedimentation basins
proposed land acquisition boundary
property boundary



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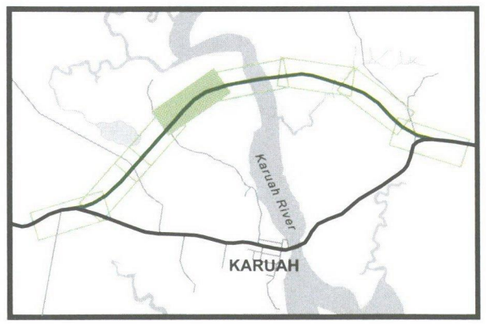


Key Map

Horse Island

wetlands

Eastern abutment of Horse Island (wetlands) bridge

Karuah River

Eastern abutment of Karuah River bridge

5000.0 5100.0 5200.0 5300.0 5400.0 5500.0 5600.0 5700.0 5800.0 5900.0 6000.0 6100.0 6200.0 6300.0 6400.0

bridge over wetlands

Western abutment of Karuah River bridge

bridge over Karuah River

Midden site, KA10

Horse Island lay by/ bridge maintenance areas

Western abutment of Horse Island (wetlands) bridge

wetlands

Underpass for local access

SEPP 14 boundary

0 50 100 150 200 250 m

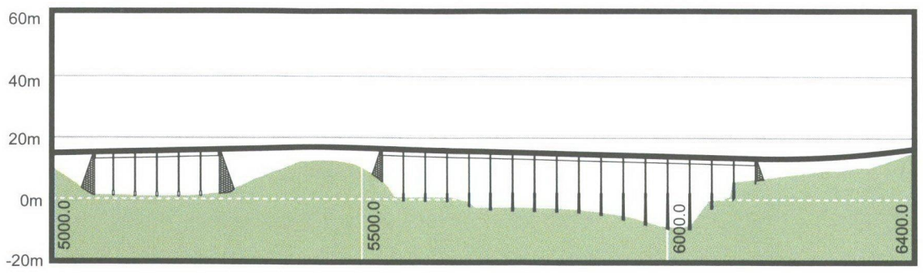
Figure 6.2E

Proposed route alignment

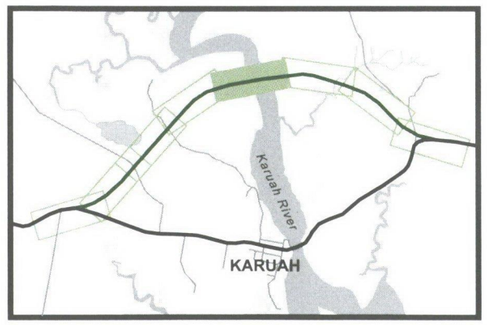
sedimentation basins

proposed land acquisition boundary

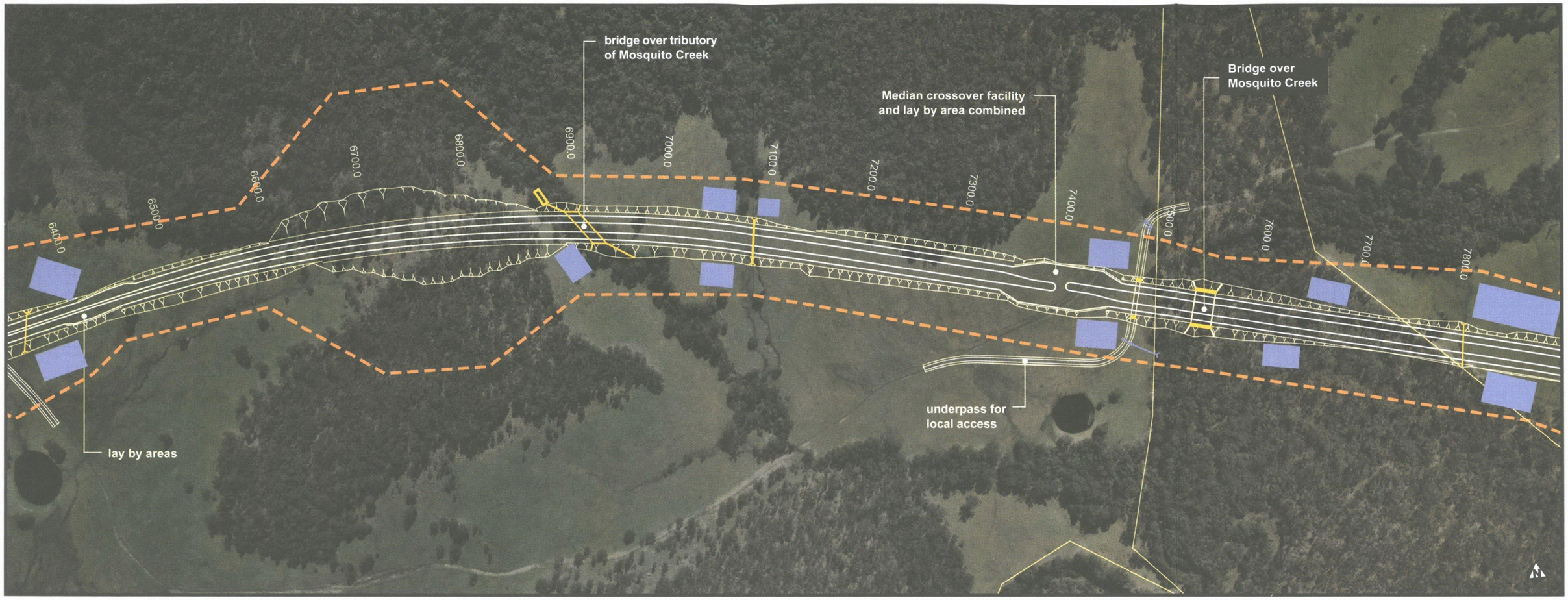
property boundary



Longitudinal Section



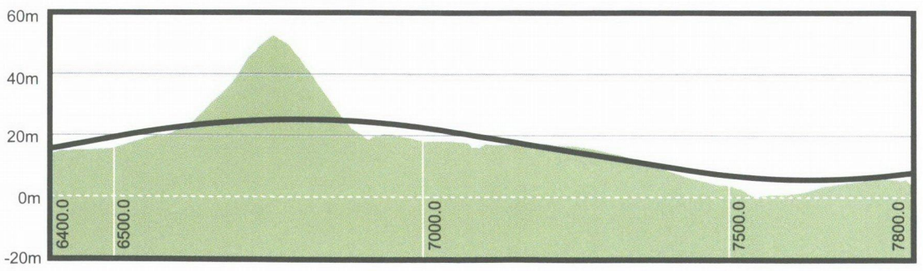
Key Map



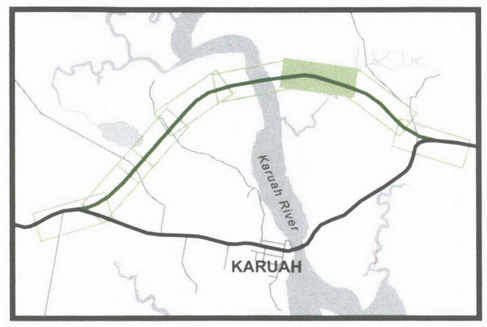
0 50 100 150 200 250 m

Figure 6.2F
Proposed route alignment

sedimentation basins
proposed land acquisition boundary
property boundary



Longitudinal Section



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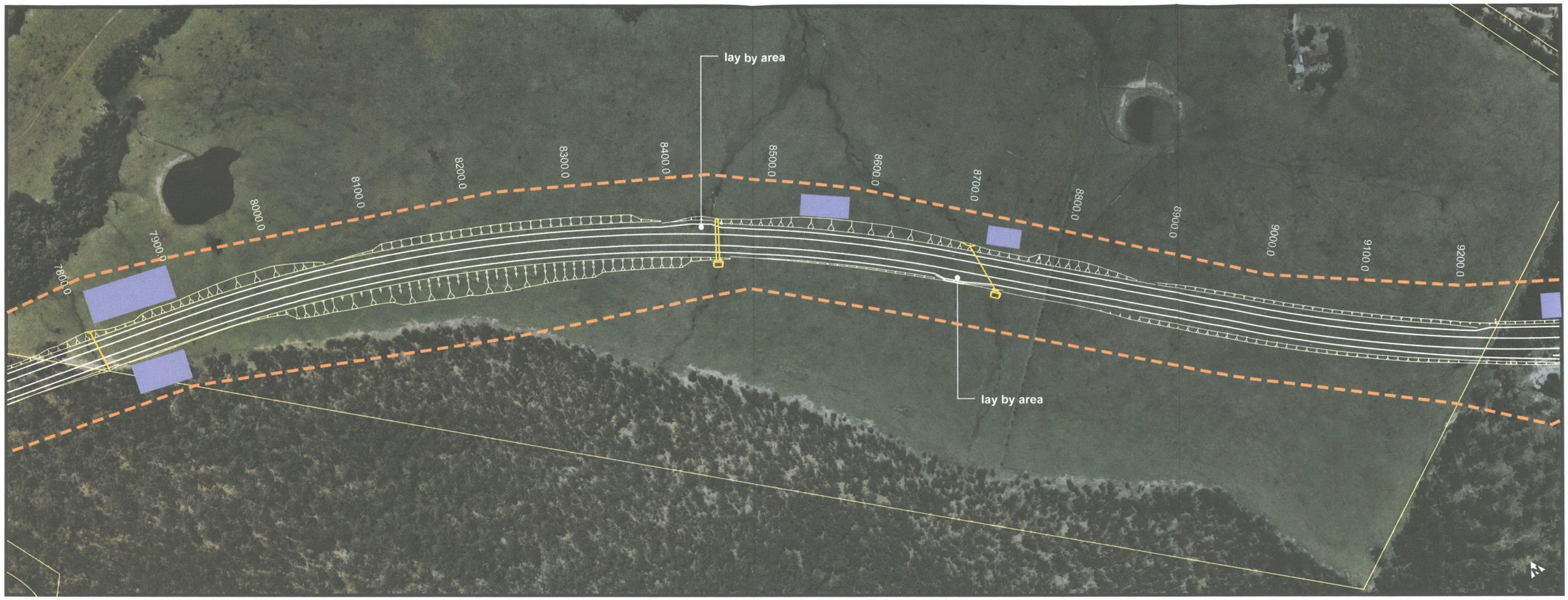
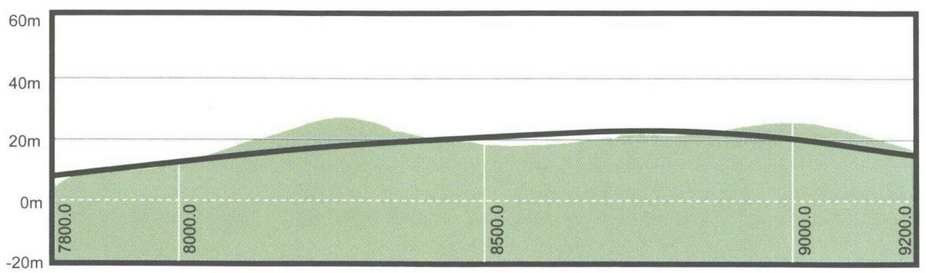


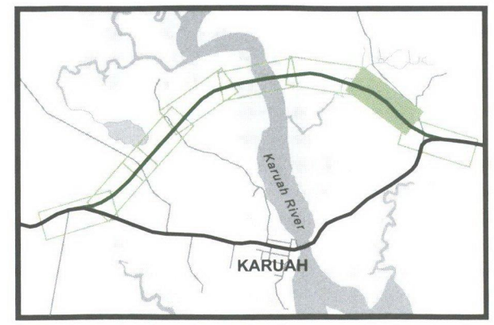
0 50 100 150 200 250 m

Figure 6.2G
Proposed route alignment

sedimentation basins
proposed land acquisition boundary
property boundary



Longitudinal Section



Key Map

Eastern Interchange overbridge

The Branch Lane

Quarry access

Quarry

Existing Quarry access to be closed

Karuah Bypass

Karuah to Bulahdelah Upgrade (seperate project)

9200.0

9300.0

9400.0

9500.0

9600.0

9700.0

9800.0

9900.0

10000.0

10200.0

10300.0

10400.0

Eastern Interchange

fauna crossing/ drainage

Karuah

0 50 100 150 200 250 m

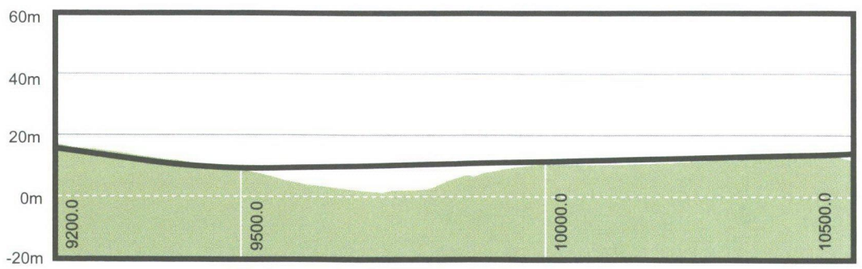
Figure 6.2H

Proposed route alignment

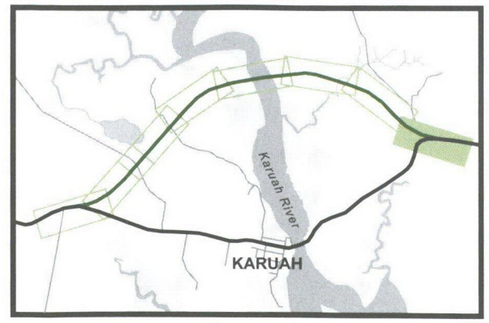
sedimentation basins

proposed land acquisition boundary

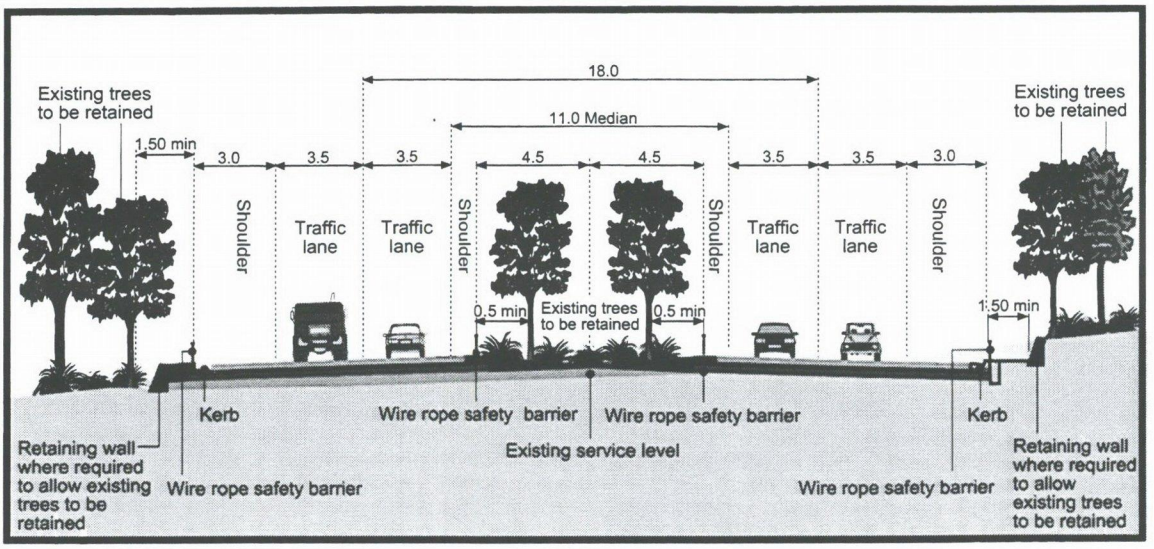
property boundary



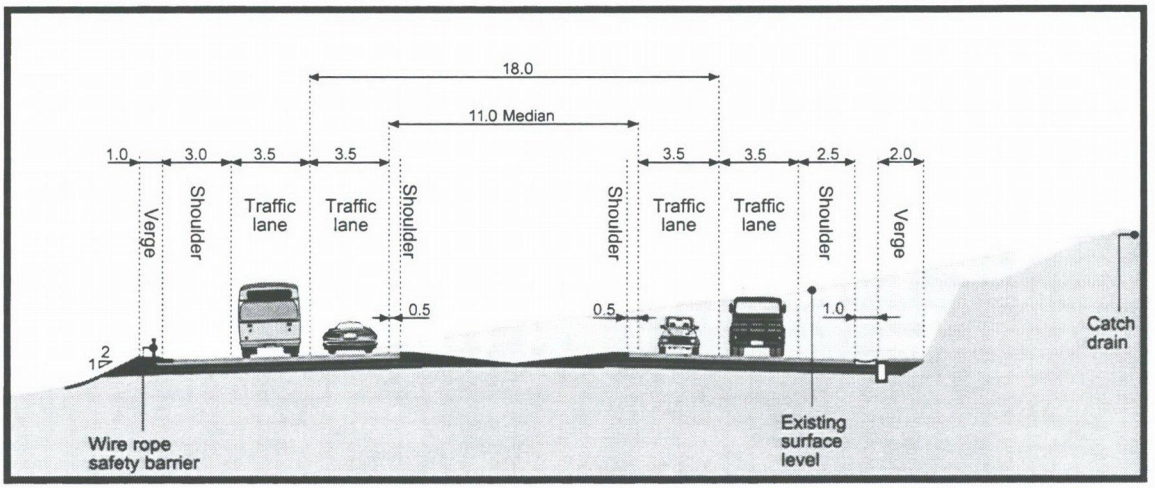
Longitudinal Section



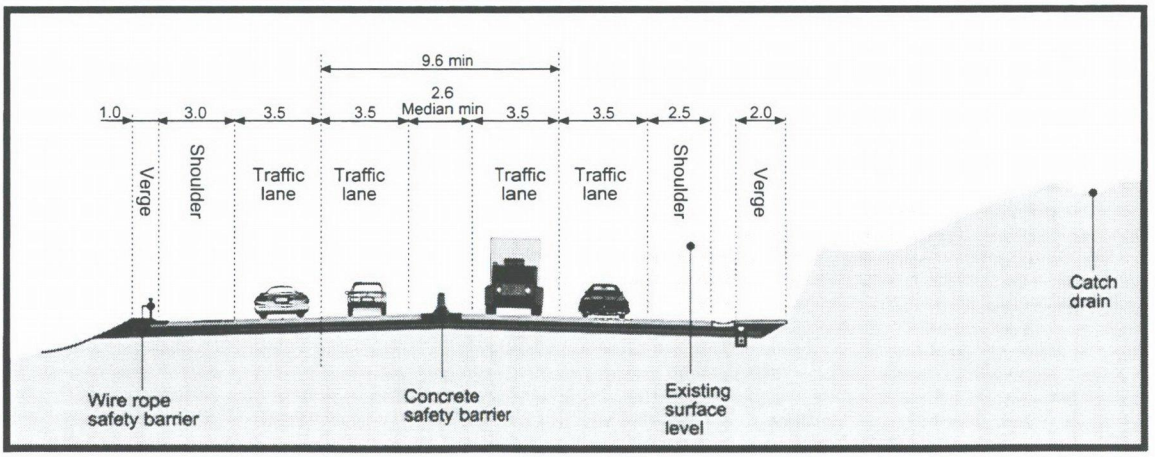
Key Map



Typical cross section in glider crossing zones



Typical cross section 11m depressed median



Typical cross section narrow median treatment

Figure 6.3

Typical cross sections

6.2.1 Existing highway to Horse Island

Just east of Swan Bay Road, the proposed bypass would deviate from the existing highway alignment (which marks the end of the dual carriageway currently under construction between Raymond Terrace and Karuah). Initially, an at-grade intersection on the proposed bypass would provide for access to and from Karuah for most northbound and southbound traffic movements (see Section 6.6). The road design allows traffic from Swan Bay Road to access Karuah via this at-grade intersection. Southbound traffic leaving Karuah would have an acceleration lane allowing traffic to enter the dual carriageway safely.

A bridge at this intersection to cater for northbound traffic into Karuah is not warranted, at this stage, on the basis of traffic volumes or accident data, but it is likely to be required within ten to fifteen years after opening the bypass to traffic. An overbridge design has therefore been included in the concept design assessed in this EIS but would be implemented in the future when traffic or accident demands warrant it.

From the western junction, the proposed bypass heads northeastwards through gently rolling sections of the Wallaroo State Forest. Immediately northeast of the junction, the road would be in cutting up to 5 m deep. Scotts Road would be deviated slightly to the south of its current alignment to cross the bypass on an overbridge where the proposed bypass is in cutting. This bridge would provide for continued local access and possibly fauna movement because of the low volume of local traffic and the integration of the bridge with the existing land form.

North of Scotts Road, the proposed bypass moves into the Karuah Nature Reserve. It would be on embankment between 2.5 m to 4 m above the surrounding land near Walleroo Swamp with a road grade of 0.5% and would pass on embankment close to the northwest corner of the cleared site of the approved Karuah Sewage Treatment Plant. The proposed bypass would not affect the operation of these works although some minor land acquisition would be required (see Section 7.8). From this point, the proposed bypass continues to traverse Karuah Nature Reserve for approximately 800 m moving from embankment to cutting. To provide for access by the NPWS in the management of the Nature Reserve and for the other nearby land owner, an overbridge would be provided at Mines Hill Trail where the bypass would be in a 7 m cutting.

Northeast of the Nature Reserve, the proposed bypass traverses privately-owned land through a series of cuttings up to 5 m deep and embankments through partially forested, undulating terrain, before reaching SEPP 14 Wetland No 773 on the west side of Horse Island. A 200 m long bridge, with a narrow median, would cross this section of wetland to Horse Island with a clearance of 12-13 m between the wetlands and the underside of the bridge.

6.2.2 Horse Island and the Karuah River

The proposed bypass would then traverse the very southern section of Horse Island for a distance of approximately 250 m on fill between 4 to 14 m deep. Embankments with 2:1 slopes would support the bypass between the two bridges on either side of Horse Island. The narrow median would reduce the footprint of the road on Horse Island. Consistent with the requirement for lay-by areas on each side of the highway at spacings of 1 km, localised widening of the bypass on Horse Island for a distance of approximately 50 m on each side would serve as breakdown bays and bridge service areas. Drainage on this section of the road would flow from Horse Island westwards, and be treated in appropriately placed sedimentation and water quality treatment basins in cleared areas near Chainage 4800 (see Section 6.7).

The 612 m bridge across the Karuah River is the most significant structure on the proposed bypass (see Section 6.5). It would maintain at least a 10 m clearance above the navigable section of water on the east side of the river. Drainage on this bridge would flow eastwards where runoff would be treated through water quality ponds located on flat, cleared land on the eastern bank of the Karuah River to ensure that water quality objectives are met and that oyster leases in the river are protected from direct road runoff.

6.2.3 East of the river to The Branch Lane

East of the river the proposed bypass would be on a short section of fill up to 7 m deep, and would start to gradually revert to an 11 m wide median while climbing at a 3.8% grade towards the saddle. To provide for vehicular access on the privately-owned land on both sides of the proposed bypass, a 4 m by 4 m box culvert is proposed at Chainage 6300 (see Figure 6.2E).

The saddle has a high point of RL 53.5 and the resulting cutting would be up to 27 m deep. Immediately east of the saddle, the proposed bypass would include a 15 m bridge over a minor creek and then a 20 m bridge over Mosquito Creek. Both of these bridges would allow for fauna movement under the bypass along the creek lines. East of Mosquito Creek, the proposed bypass moves through shallow cuts and fills designed to reduce the extent of earthworks in the cleared land.

The eastern junction would have full grade separation to cater for all turning movements, local access from The Branch Lane to Karuah, and vehicle movements to and from the existing quarry. East of this junction the proposed bypass joins the proposed duplication of the Pacific Highway from this point northwards to Bulahdelah.

6.3 Carriageway design

The design of the proposed bypass would comply with all relevant RTA design requirements.

The bypass cross section consists of two carriageways, each with two 3.5 m wide traffic lanes and a 2.5 m wide left shoulder, generally separated by an 11 m wide median without a central barrier. A 3 m wide shoulder would be provided where guard fencing is located. The 11 m wide median would generally be depressed for drainage reasons and landscaped to reduce headlight glare. Typical cross sections for various parts of the bypass are presented in Figure 6.3.

To facilitate the safe movement of arboreal fauna such as Squirrel Gliders across the proposed bypass, special provision would be made at four locations within Wallaroo State Forest and Karuah Nature Reserve areas on the west side of the river. This would involve the installation of guardrails at the edge of the shoulders and retention of mature trees behind the guardrails in the median strip and at either side of the carriageway. In this way, the 'tree-to-tree' glide distances for the Squirrel Gliders can be reduced to approximately 20 m across each carriageway. Given the short lengths of this treatment (up to 80 m at cut to fill transition points), consideration can be given to reducing the impact of drainage requirements along the centre of the median strip.

The normal median width of 11 m would be reduced in the vicinity of Horse Island and the Karuah River to reduce both the impacts on the SEPP 14 wetlands and the bridge costs. West of Horse Island, the median would reduce from 11 m wide through a transition zone approximately 500 m long to a narrow median 2.6 m wide (including the inner shoulders). This narrow median would apply for approximately 1,400 m on the two bridges and the intervening section of road across Horse Island. A central concrete (New Jersey, RTA Type F) barrier would be used across the bridges to maximise savings in construction costs. East of the river the median would gradually widen out again over a distance of approximately 600 m to an 11 m wide median. A wire rope guard fence would be used once the median width is sufficient to provide the deflection offsets required.

Full strength pavement would be used for the highway travel lanes and the inner and outer shoulders.

6.4 Cut and fill requirements

The concept design for the proposed bypass achieves a cut and fill balance on both sections of the roadway east and west of the river.

Based on data from geophysical surveys, in general, cut and fill batters of 2:1 (vertical:horizontal) can be used in the weathered and fractured zones and 4:1 (vertical:horizontal) in the medium to high strength rock. The cuts have been battered according to slope height and to the material type present. Terraces are provided at 7 m intervals and the base of the slopes would have dish drains and verge widths related to the materials within the slope. It is anticipated that spot bolting would be required in rock cuttings to stabilise isolated wedges. The location of these seams of rock would be confirmed during excavation.

6.5 Bridges

The proposed 612 m bridge across the Karuah River is a major feature of this proposal in both design and cost terms. This bridge would have a minimum clearance of 10 m from the estimated mean high water spring tide level at Karuah (RL 0.7 AHD). The proposal also includes the 200 m bridge across the protected SEPP 14 wetlands with a clearance of 12-13 m and three other smaller bridges to carry the proposed bypass over creeks or local roads. A consistent design approach has been taken to all these bridges.

'Super tee' girders with piers at 35-36 m spacing would be used for both the Karuah River bridge and the SEPP 14 wetlands bridge. Both bridges would have one deck approximately 22.6 m wide (outside to outside) to accommodate the dual carriageways separated by a narrow median to meet the minimum 110 km/h design requirements.

The bridges to cater for local access across the proposed bypass would be 8 m wide at Scotts Road with a sealed two lane roadway and 4.2 m wide at Mines Hill Trial.

6.6 Junctions and local access arrangements

6.6.1 Junctions

Two junctions are included in the proposal to provide access to and from Karuah at points 48.5 km north of Newcastle and west of Karuah and 57.9 km north of Newcastle and east of Karuah. These junctions would provide for most turning movements from the opening of the bypass. There are no other junctions or access points on or off the proposed bypass for general traffic between these two junctions.

At the western junction, a two-stage development is proposed (see Figure 6.2A). Stage 1 involves an at-grade intersection with a median right-turn lane for access to Karuah. It would provide for all turning movements except for right turns onto the bypass for traffic leaving Karuah from the southwest. The design of the Stage 1 at-grade intersection allows the future addition in Stage 2 of a grade-separated ramp to provide direct access into Karuah for vehicles travelling from Raymond Terrace. It is anticipated that the Stage 2 ramp would be required ten to fifteen years after opening of the bypass. The at-grade seagull intersection between Swan Bay Road and the Pacific Highway would be retained in Stage 1 and in Stage 2.

A junction is proposed at the eastern end of the bypass, providing for all movements to and from Karuah. The proposed junction rationalises the existing roads in order to maintain local movements for the trucks (including B-doubles) accessing the quarry, traffic along The Branch Lane, local property access and the connection via the existing highway between the bypass and Karuah. The design of the junction at the eastern end of the bypass is relatively complex and is confined by SEPP 14 Wetland No 777 south of the highway and the operating quarry north of the highway. The endangered

plant *Tetratheca juncea* also exists in this confined area (see Section 10.2). The proposed bypass would cross the local road system on twin bridges with reinforced earth walls to reduce the footprint through this area. On and off ramps also provide access to the existing local road system.

6.6.2 Local access

In some areas, the proposed bypass would sever existing at-grade public roads or private access routes. All existing access would be reinstated or maintained as part of the proposed works. Two bridges would be provided to maintain continuity of access along existing public roads or tracks through Wallaroo State Forest and Karuah Nature Reserve west of the Karuah River.

Several adjustments would be made to existing access tracks to private property to ensure continuity of access for present and future rural activities and existing dwellings. The design of the eastern interchange integrates continued access for trucks (including B-doubles) to and from the operating quarry adjacent to The Branch Lane.

The existing Pacific Highway through the Karuah township is expected to serve as a local road after the opening of the proposed bypass. Under this scenario, ownership of the existing highway and bridge would be transferred from the RTA to Great Lakes and Port Stephens Councils.

6.7 Drainage and water quality treatment

As the proposed bypass crosses the Karuah River and traverses or passes close to several SEPP 14 or other wetlands, particular attention has been given in the concept design to environmental measures that would be implemented to meet EPA guidelines for runoff discharge.

The most sensitive points for control of runoff are:

- the major bridges over the Karuah River and SEPP 14 Wetland No 743 west of Horse Island;
- Mosquito Creek and other drainage lines that flow into SEPP 14 Wetland No 776 on the east side of the Karuah River, south of the proposed bypass route;
- the roadway east of Wallaroo Swamp;
- the eastern junction which traverses a non-protected wetland and is immediately north of SEPP 14 Wetland No 777; and
- the western junction that is located just north of SEPP 14 Wetland No 786 on the south side of the existing highway.

Surface runoff from the road upstream of these areas would undergo sufficient treatment using water quality ponds and chemical traps to contain spills of hazardous materials to ensure that it meets relevant guidelines for discharge into wetlands or water courses. The location of sedimentation basins was selected taking into account geotechnical, hydrologic, hydraulic, soil conservation and other environmental issues such as avoiding mature trees wherever possible (see Figures 6.2A to 6.2H).

6.8 Lighting, fencing and signposting

The proposed bypass would only be lit at the two junctions that provide access to Karuah. Lighting would be provided in accordance with the *Roadway Lighting Guide* (AUSTROADS,1988b).

The road reserve would be fenced on both sides in a manner consistent with adjoining land uses to prevent unauthorised pedestrian access and inadvertent intrusion by wildlife or stock. This fencing would generally be of the fauna exclusion ('floppy top') variety to ensure that Koalas and other climbing animals are not able to wander onto the roadway. In some areas, post and wire fencing may be used where fauna activity is unlikely.

Road signage would be determined during the detail design stage and would conform to prevailing RTA practice. Discussions would be held with Port Stephens and Great Lakes Councils during this stage of the project in relation to any particular signage requirements prior to the two junctions. An objective of any such signage would be to alert motorists to the facilities and attractions available in Karuah.

6.9 Noise attenuation measures

The predicted impact of road traffic noise from the proposed bypass is described in Chapter 19. In order to meet the relevant criteria for road traffic noise for residential and other sensitive land uses, noise attenuation measures would need to be implemented along certain sections of the bypass to assist in reducing traffic noise levels. These measures are discussed in Chapter 19.

6.10 Pedestrian and cyclist facilities

Pedestrians would generally not be permitted within the road reserve along this section of the Pacific Highway. Provision for pedestrian movements across the highway are incorporated with the provision for local vehicle access.

Long distance cyclists would be able to use this section of the Pacific Highway. Continuous sealed shoulders with a minimum width of 2.5 m (which would also function as breakdown lanes) would be provided for all roadway sections of the proposed bypass. On the major bridge structures, the shoulders would be 2 m wide.

Cyclists would have an alternative route along the existing Pacific Highway through Karuah. This route is generally suitable for cyclists although there is not a continuous sealed shoulder. However, the forecast traffic volumes on this route after the opening of the bypass would be consistent with safe, on-road cycling conditions.

6.11 Provision for fauna movement

A summary of the provisions that have been made in the concept design to allow for the safe movement of fauna across the highway corridor, together with the rationale for each measure, is presented in Table 6.1. The location of these measures is shown on Figures 6.2A to 6.2H.

As noted above, the proposed highway reservation would be fenced on both sides with fauna and stock proof fencing in all relevant locations. This fencing would generally be of the 'floppy top' variety to ensure that Koalas and other climbing animals are not able to wander onto the roadway, and thus reducing fauna mortality.

Further consideration of the need for design features to facilitate safe fauna movement across the bypass is given in Chapter 10.

Table 6.1 Location and type of fauna crossings

Location (chainage)	Purpose	Features and size (mm)	Relationship to fauna habitat
869	Drainage	Existing drainage culvert across the Pacific Highway - 2 x 3000w x 1500h	Likely to be used only by amphibians, reptiles and possibly small mammals. Larger terrestrial fauna can cross the existing highway at grade.
877	Fauna crossing	Dedicated fauna underpass - 3000w x 3000h	Sufficient in size for all native fauna.
1230	Drainage	Drainage culvert – 2 x 2400w x 600h	Can be used by reptiles, amphibians and small mammals. Leads into a small island of land surrounded by roads (not particularly suitable location for fauna).
1400	Fauna crossing	Small fauna culvert 3000w x 1800h	Suitable for small to medium terrestrial mammals. Leads to small island of land surrounded by roads (not particularly suitable location for fauna).
1500-1580	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in 11 m wide median.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
2338	Bridge over bypass for Scotts Road	8 m wide bridge	Low traffic volumes on Scotts Road would enable road to be used by fauna, to some extent at least. Of potential relevance for macropods, Echidnas, other medium to large terrestrial mammals and larger reptiles.
2370-2430	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in 11 m wide median	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
2645	Fauna crossing and drainage	Combined fauna crossing and drainage culvert - 3000w x 2400h	Oversized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for most terrestrial fauna, including smaller macropods, Koalas, small to medium terrestrial mammals, reptiles and amphibians.
2901	Fauna crossing and drainage	Combined fauna crossing and drainage culvert - 3000w x 1200h	Oversized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for Koalas, small to medium terrestrial mammals, reptiles and amphibians.
3244	Fauna crossing	Small fauna culvert - 3000w x 1800h	Suitable for small to medium terrestrial mammals, reptiles and amphibians. Not likely to be used by large kangaroos or wallabies.
3340-3400	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in 11 m wide median.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
3530	Bridge over bypass for Mines Hill Trail	4.2 m wide bridge	Low traffic volumes on Mines Hill Trail would enable road to be used by fauna, to some extent at least. Of potential relevance for macropods, Echidnas, other medium to large terrestrial mammals and larger reptiles.

Location (chainage)	Purpose	Features and size (mm)	Relationship to fauna habitat
3647	Drainage	Drainage culvert- 600 diameter	Can be used by reptiles, amphibians and possibly small mammals.
3850 - 3890	Glider crossing	Retention of large trees adjacent to the road (on each side) and retention of trees or placement of 'glider poles' and young trees in 11 m wide median.	Primarily for Squirrel Gliders, but likely to be utilised also by Sugar Gliders and Feathertail Gliders (if present).
3907	Fauna crossing	Dedicated fauna underpass – 3000w x 3000h.	Sufficient in size for all native fauna.
3945	Drainage	Drainage culvert – 900 diameter.	Can be used by reptiles, amphibians and possibly small mammals.
4268	Fauna crossing and drainage	Combined drainage culvert and fauna underpass - 3000w x 1500h.	Suitable for small to medium terrestrial mammals, reptiles and amphibians. Not likely to be used by large kangaroos or wallabies.
4799	Drainage	Drainage culvert - 600 diameter.	Can be used by reptiles, amphibians and possibly small mammals.
5067	Western abutment of Horse Island bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation).	Bridge abutment is located 10 to 15 m back from the edge of the SEPP 14 wetland, providing a strip of land for fauna movement. This area can be landscaped and rehabilitated if necessary using native vegetation to provide safe and secure fauna crossings at the edge of the wetland. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitats.
5267	Eastern abutment of Horse Island bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation).	As above.
5530	Western abutment of Karuah River bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation)	Bridge abutment is located 20 m back from the edge of the SEPP 14 wetlands, providing a strip of land for fauna movement. This area can be rehabilitated if necessary using native vegetation to provide safe and secure fauna crossings at the edge of the wetland. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitats.
6142	Eastern abutment of Karuah River bridge	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation).	Bridge abutment is located 35 m back from the top of the river bank, providing a strip of land for fauna movement. This area can be landscaped and rehabilitated if necessary using native vegetation to provide safe and secure fauna crossings both above and below the east river bank. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitats.
6295	Underpass for local access	Low traffic volumes on the local access underpass will enable its use by fauna on occasions.	Most likely used by Koalas (if present), kangaroos and wallabies, Echidnas, goannas, and other large terrestrial fauna which utilise open landscapes.
6345	Drainage	Drainage culvert - 1050 diameter.	Can be used by reptiles, amphibians and possibly small mammals.

Location (chainage)	Purpose	Features and size (mm)	Relationship to fauna habitat
6911	Bridge over Mosquito tributary	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation).	Bridge abutments are to be constructed so as to retain a strip of bank that will need rehabilitation. These areas can be landscaped and rehabilitated using native vegetation to provide safe and secure fauna crossings at the edge of the wetland. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
7088	Fauna crossing and drainage	Drainage culvert - 1200w x 1200h	Likely to be used only by amphibians, reptiles, and possibly small mammals. Larger terrestrial fauna can cross the existing highway at grade.
7476	Underpass for local access	Low traffic volumes on the local access underpass will enable its use by fauna on occasions. (4000w x 4000h)	Most likely used by Koalas, kangaroos and wallabies, Echidnas, goannas, and other large terrestrial fauna which utilise open landscapes.
7545	Bridge over Mosquito Creek	Riparian vegetation and natural ground surfaces; cover and shelter materials (logs, rocks, and groundcover vegetation). (20m span 7535-7555)	Bridge abutments are to be constructed so as to retain a strip of bank that will need rehabilitation. These areas can be landscaped and rehabilitated using native vegetation to provide safe and secure fauna crossings at the edge of the wetland. Bridge abutments are likely to be used by all terrestrial fauna, as well as some birds associated with riparian habitat.
7807	Drainage culvert	Drainage culvert - 1050 diameter.	Can be used by reptiles, amphibians and possibly small mammals.
8446	Fauna crossing and drainage	Drainage culvert - 3000w x 600h	Likely to be used only by amphibians, reptiles, and possibly small mammals.
8710	Fauna crossing and drainage	Drainage culvert - 900w x 900h	Likely to be used only by amphibians, reptiles, and possibly small mammals.
9651	Bridge over The Branch Lane	Span of approximately 25 m	Potential for use by larger native fauna during the evenings or other periods of low traffic flow.
10129	Fauna crossing and drainage	Combined fauna crossing and drainage culvert - 3000w x 1800h	Oversized for drainage requirements, to provide fauna underpass capability. Reinforced concrete box culvert with partially raised floor or tilted for drainage control. Of potential value for most terrestrial fauna, including smaller macropods, Koalas, small to medium terrestrial mammals, reptiles and amphibians.

6.12 Landscape and urban design concept plan

The landscape and urban design concept plan for the proposed bypass is shown on Figures 6.4A to 6.4G. Artist's impressions of the proposed bypass and photomontages are shown on Figures 6.5A to 6.5B and Figures 6.6A to 6.6D respectively. Each of the strategy plans identifies:

- extent of existing vegetation cover;
- extent of cut and fill earthworks embankments; and
- extent and type of landscape revegetation.

The design principles underlying this concept plan are:

- revegetation of cleared construction areas to integrate with adjoining woodland and open forest vegetation communities;
- revegetation of earthworks embankments to integrate with adjoining woodland and open forest vegetation communities, and stabilise earthworks zones;
- enhancement of the visual and environmental experience of travelling along the road corridor for users, for example, through provision of opportunities for extended views beyond the road reserve;
- through the provision of guard rails in limited sections for safety reasons, the tree canopy vegetation may be brought closer to the edge of the roadway and to earthworks batters of over 1:3 (vertical:horizontal) grade or flatter;
- reinforcement of visual buffer provided by native vegetation to the limited local viewing points of the proposed highway from the Karuah River and rural residences;
- provision of headlight glare reduction and visual emphasis of directional separation of road carriageways through appropriate median strip planting;
- the road alignment responds to existing topographical and drainage characteristics to enable the road construction to 'fit in' to the adjoining landform;
- landscape treatments to reflect the varied landscape unit settings through which the route passes; and
- road alignment and structures to provide a visually pleasing composition for both road users and viewers of the corridor.

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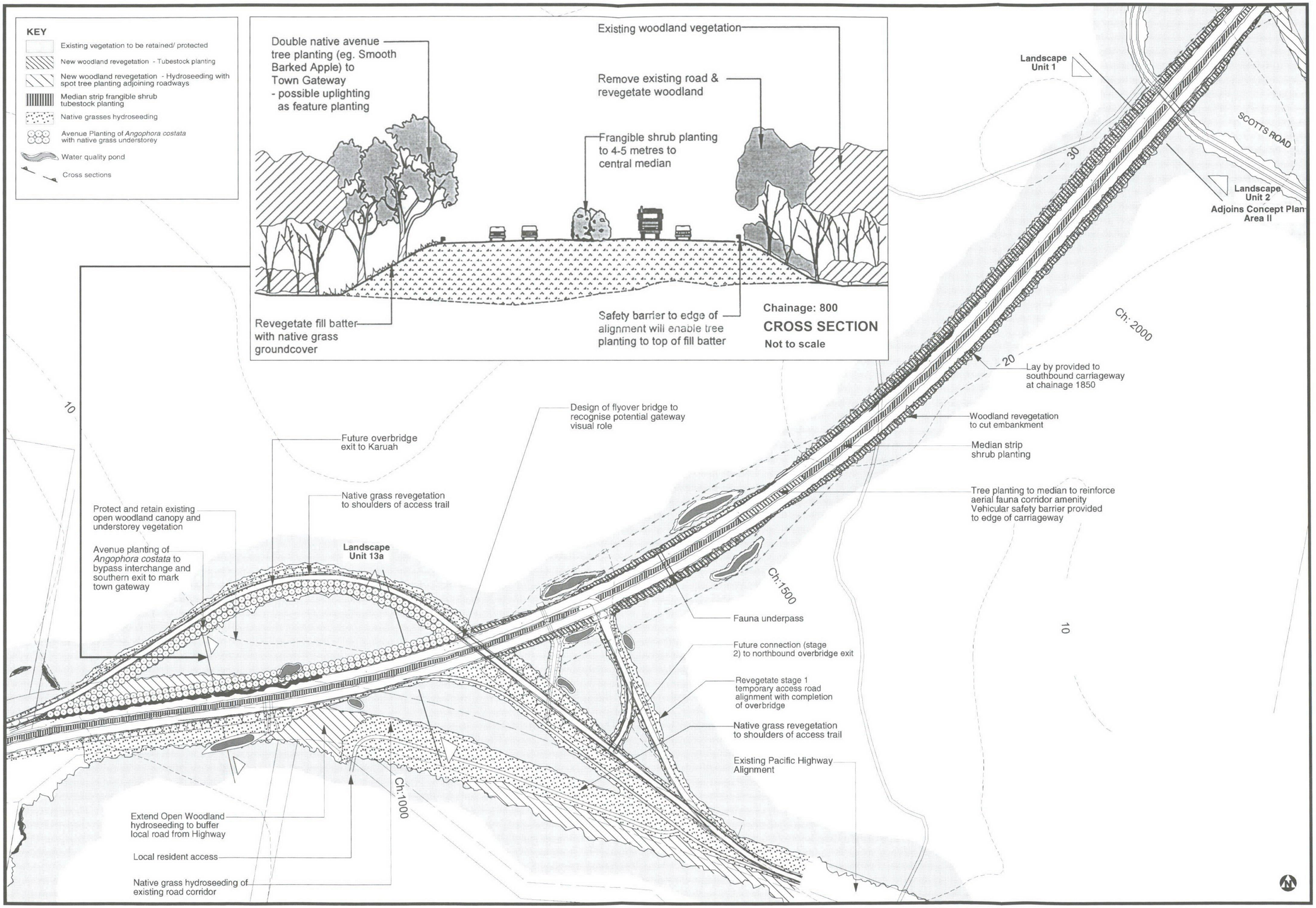


Figure 6.4A

Landscape and urban design strategy

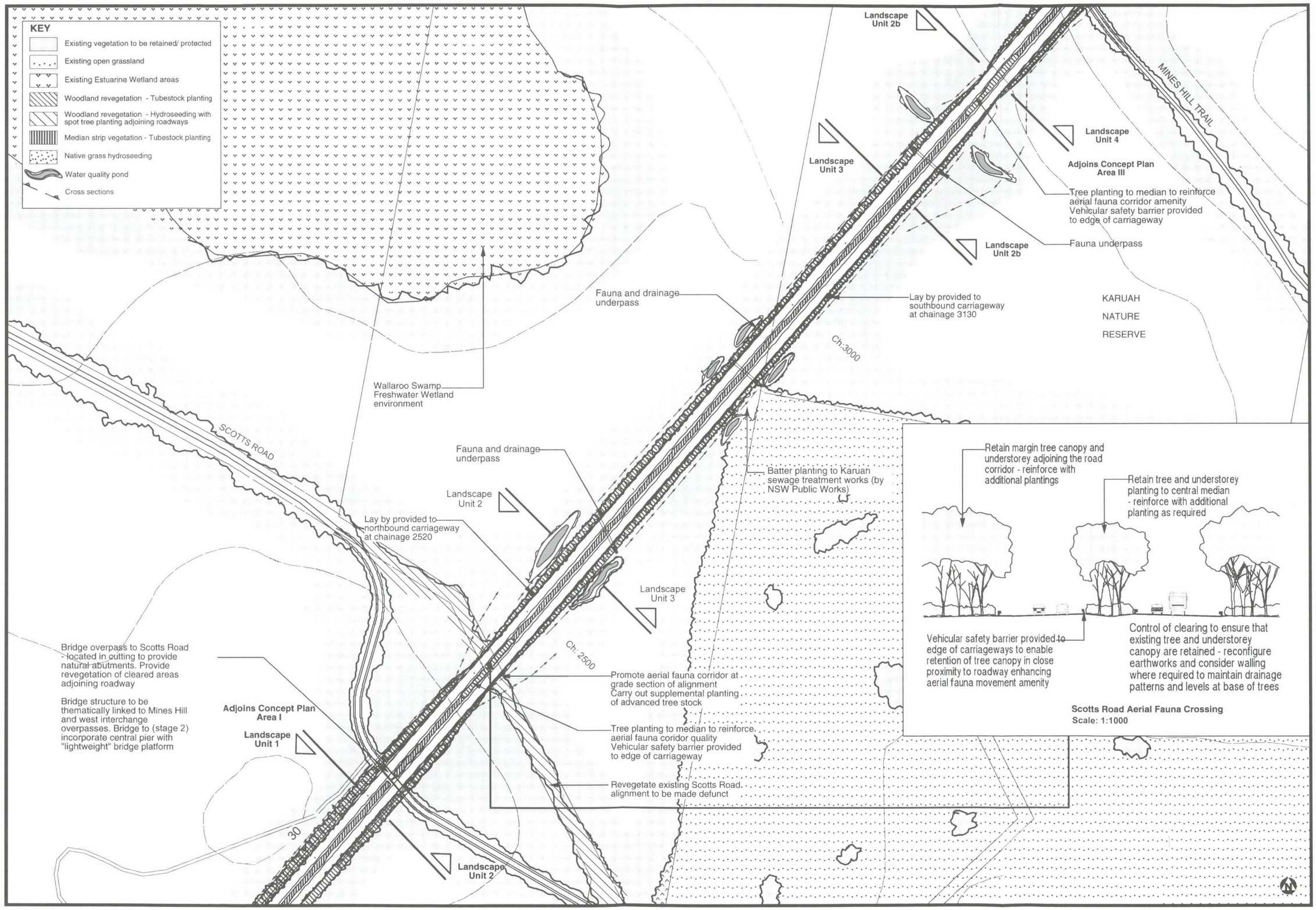


Figure 6.4B

Landscape and urban design strategy

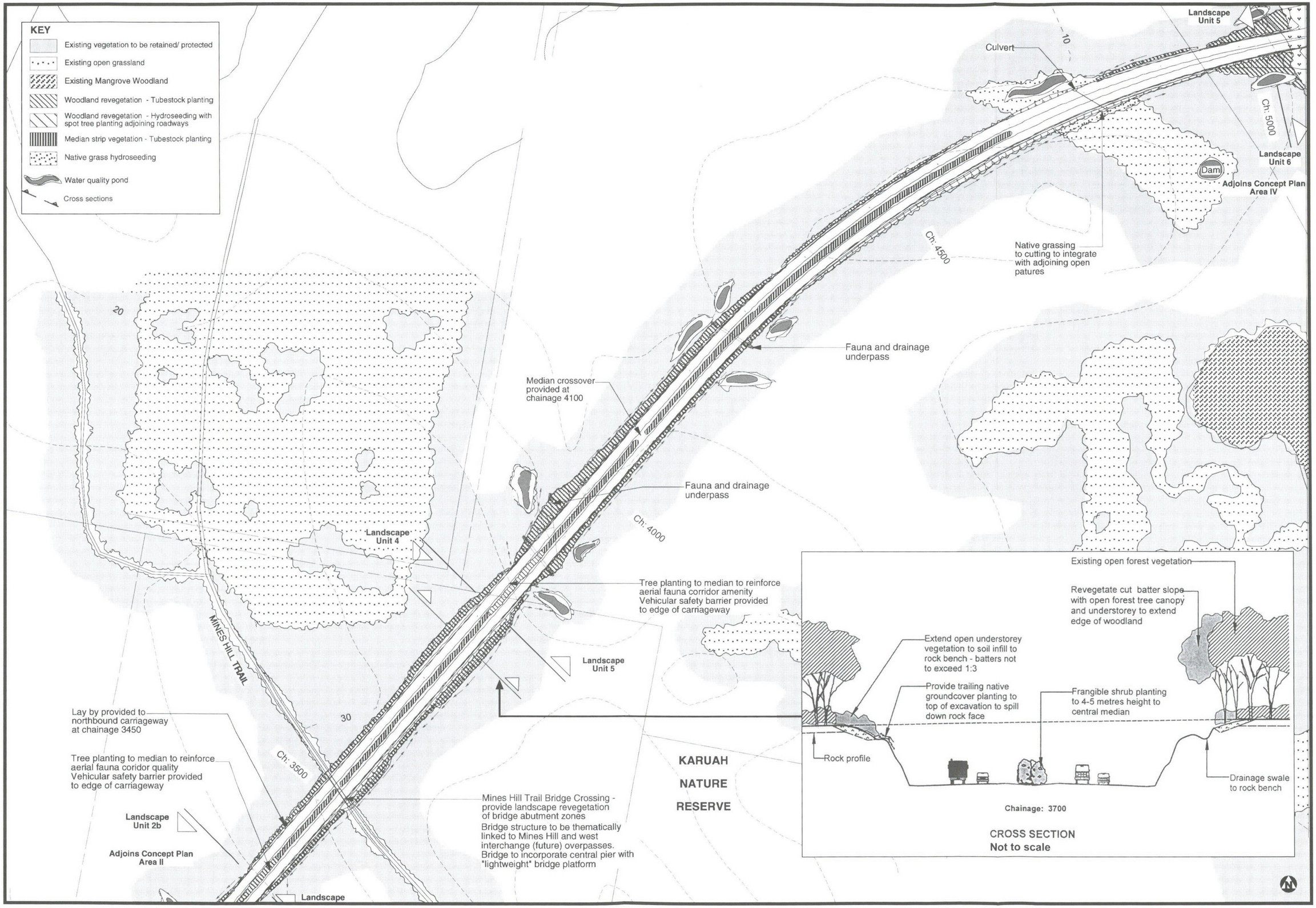


Figure 6.4C

Landscape and urban design strategy

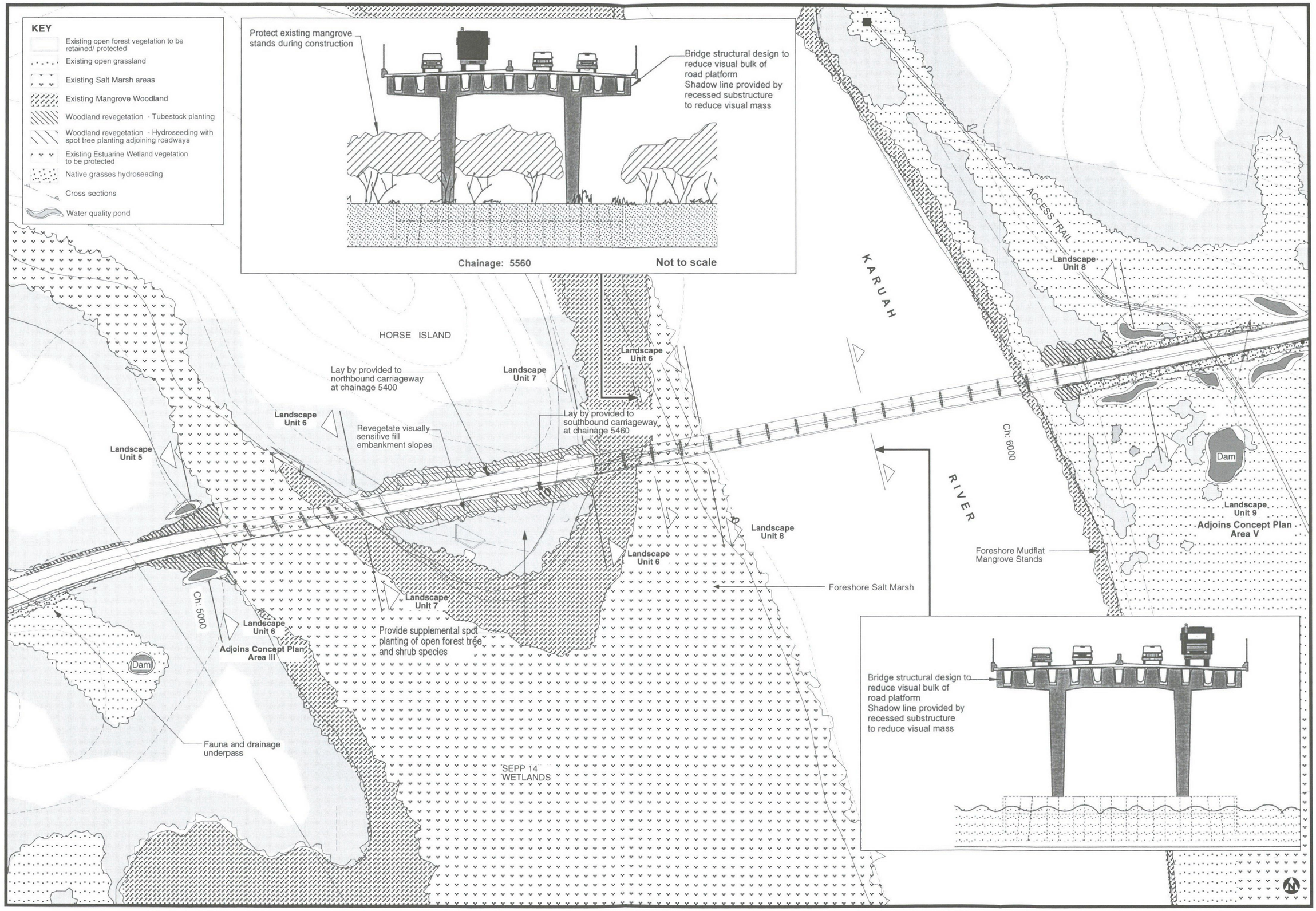


Figure 6.4D

Landscape and urban design strategy

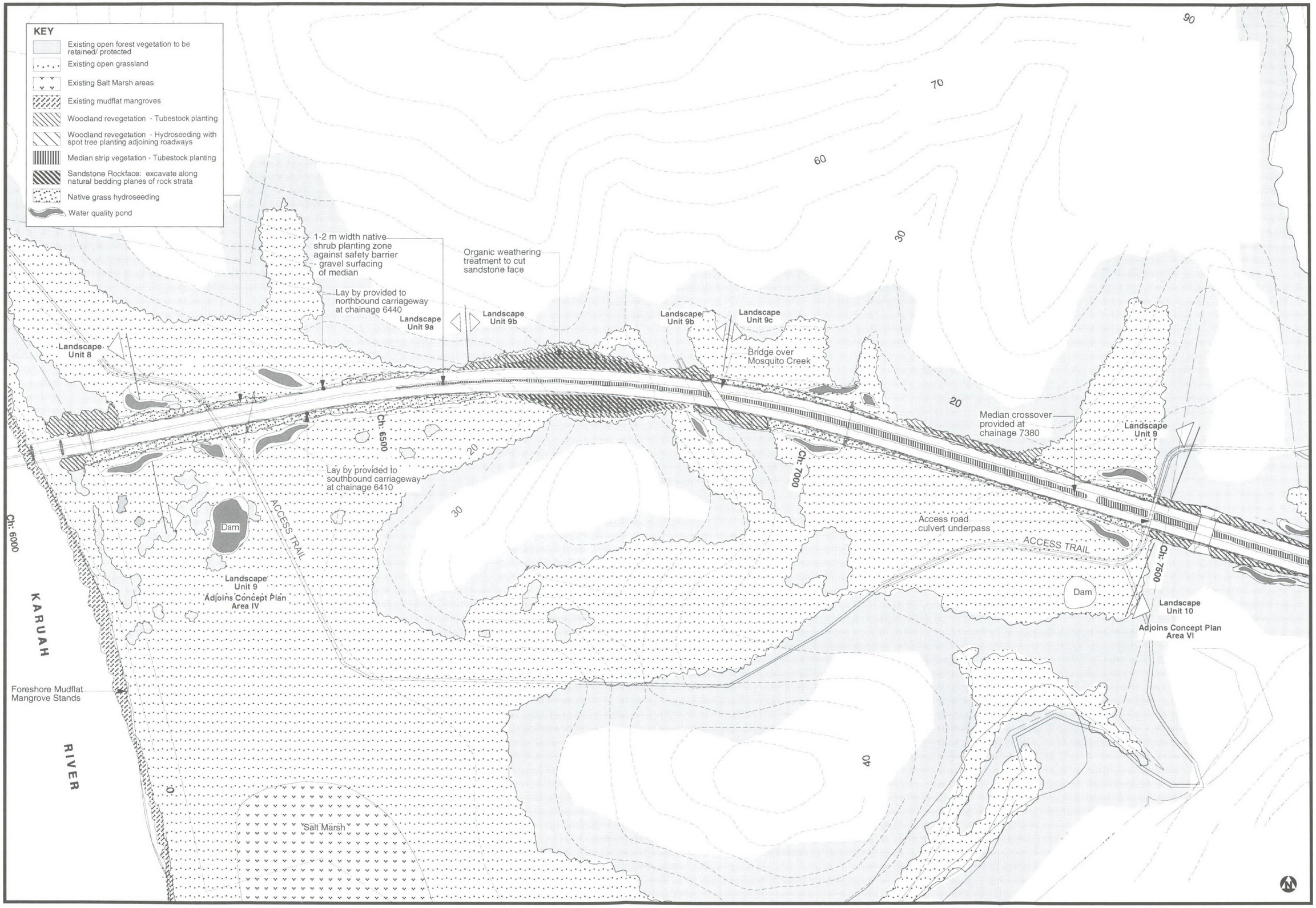


Figure 6.4E

Landscape and urban design strategy

Landscape Unit 9

Mosquito Creek bridge crossing - provide revegetation of bridge abutment zones

Landscape Unit 10

Ch: 7600

Landscape Unit 10

Adjoins Concept Plan Area V

Provide guard rail to edge of road to enable revegetation of fill batters to edge of roadway

Culvert Underpass

Landscape Unit 11a

20

Ch: 8000

40

50

Provide top soil over maximum 1:3 grade cutting to enable native grass revegetation

60

70

30

Lay by provided to northbound carriageway at chainage 8400

Landscape Unit 11a

Native grass revegetation of extended fill batters to provide visual continuation of open pasture character

Drainage Culvert

Ch: 8500

Landscape Unit 11b

Drainage Culvert

Dam

Lay by provided to southbound carriageway at chainage 8700

Landscape Unit 11b

Landscape Unit 11c

Adjoins Concept Plan Area VII

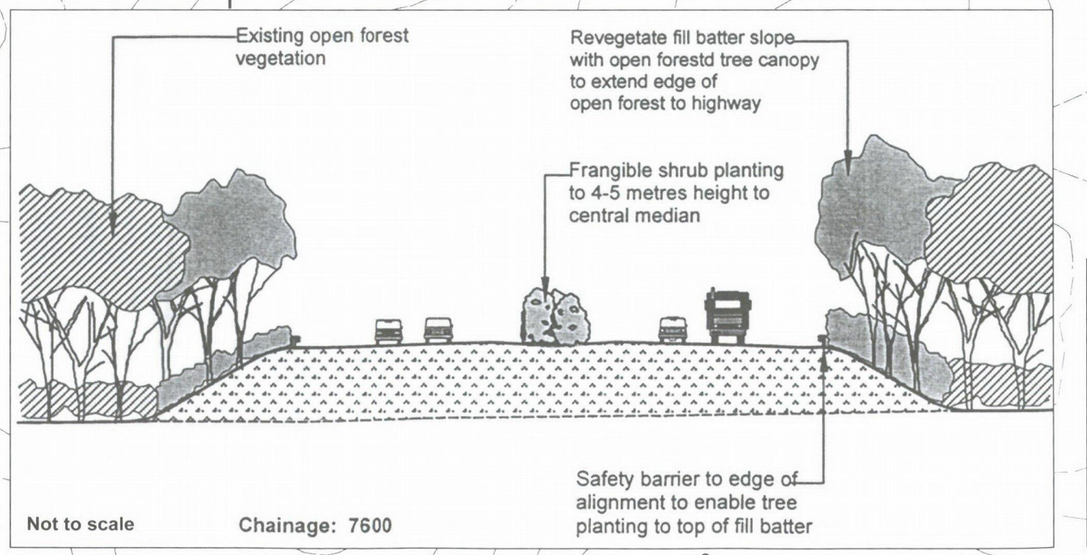
Landscape Unit 11c

Ch: 9000

Landscape Unit 12

THE BRANCH LANE

70



KEY

- Existing open forest vegetation to be retained/ protected
- Existing open grassland
- Woodland revegetation - Tubestock planting
- Woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip vegetation - Tubestock planting
- Pasture grass hydroseeding
- Cross sections
- Water quality pond

0 50 100 150 200 250 300m

Figure 6.4F

Landscape and urban design strategy

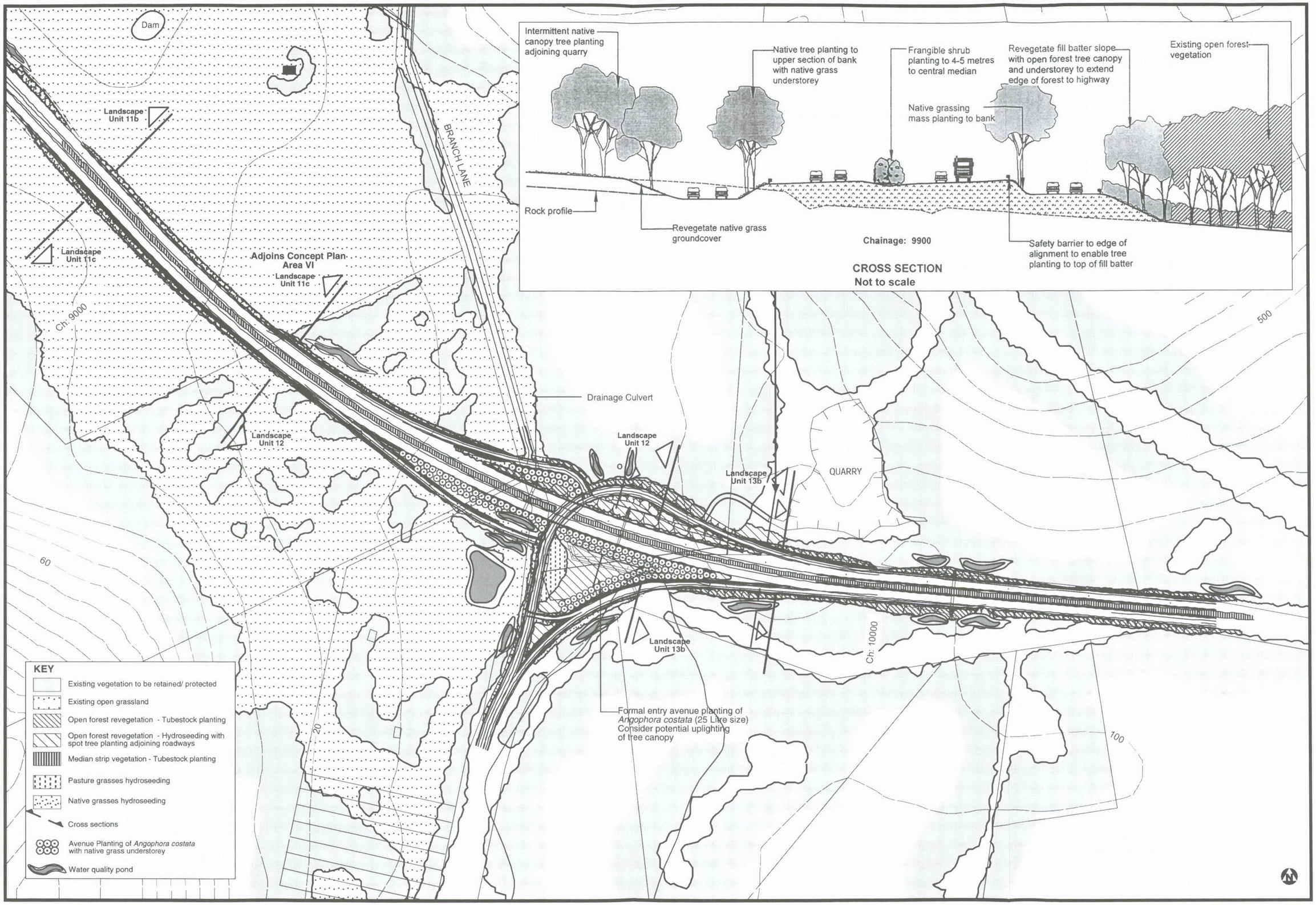


Figure 6.4G

Landscape and urban design strategy

Figure 6.5A

Proposed bypass - artists' impression
view towards Karuah River bridge



Figure 6.5B

Proposed bypass - artists' impression
view of a typical section of the Karuah Pacific Highway



Figure 6.6A

Proposed bypass - photomontage
western interchange (stage 2)
view north east towards Horse Island



Figure 6.6B
Proposed bypass - photomontage
wetlands bridge and Karuah River bridge
view east towards saddle



Figure 6.6C
Proposed bypass - photomontage
Karuah River bridge and wetlands bridge
view west towards Karuah Nature Reserve



Figure 6.6D
Proposed bypass - photomontage
eastern interchange
view towards Horse Island

6.13 Project cost estimate

Based on the design described in this EIS, the total cost of the project on completion has been estimated at $117 million. This figure takes inflation into account and is derived from a current dollar estimate (June 1999) of $103 million and a construction start in early 2002 (see Table 6.2).

Total project costs have been estimated by adding project costs associated with managing and implementing the project to the estimated construction cost. In accordance with Pacific Highway Office requirements, total project costs have been prepared in the form of a Project Estimate Summary which includes all costs associated with the design, construction and handover of the project.

Table 6.2 Project estimate summary (current dollar cost as at June 1999)

RTA Job Cost Item	Description	Estimated Cost (including contingencies)
Job 1	Concept Design and EIS	$3.60 million
Job 2	Investigation and Design	$2.27 million
Job 3	Land Acquisition	$3.28 million
Job 4	Utility Adjustments	$0.47 million
Job 5	Construction	$90.60 million
Job 6	Handover	$2.90 million
Total		**$103.12 million**

6.14 Economic evaluation

6.14.1 Types of road user benefits

A road user cost benefit analysis was undertaken of the proposed bypass based on a total estimated project cost of $103 million (including RTA management costs and land acquisition). There are three particular ways in which road user benefits accrue in major road projects. These, in fact, are estimates of future costs which would have accrued if the proposed project did not proceed, and thus become cost savings which accrue as a result of implementing the project. These three areas are:

- **Value of time (VOT)** savings that represent the value of travel time of the road users. Benefits can arise if, as a result of the proposed bypass at Karuah, the average speed of vehicles is increased and/or the trip length is reduced. In both cases, there is a resultant decrease in trip time that can be valued in dollar terms. This represents a major source of benefit for many road upgrading projects.
- **Vehicle operating cost (VOC)** savings are estimates of the change in operating costs for different vehicles based on the changed road conditions resulting from the proposed bypass. The future VOC is estimated for the existing and changed road conditions based on VOC curves for normal and heavy vehicles operating at different speeds on average grades. Where the new road conditions permit significantly higher speeds (for example, due to improved alignment), the VOC may be higher.
- **Accident cost** savings are estimated based on the historical record of accidents in the road corridor and projected into the future based on forecast traffic growth. Changes in the future accident profile are estimated based on experience with similar projects implemented in the past where post implementation studies have been carried out.

Maintenance saving benefits may also occur if major maintenance or upgrading an existing road can be avoided or delayed by the construction of a new road. In the case of Karuah, if an upgrade of the highway is not provided, the following maintenance and upgrading of the existing alignment would be required in the short to medium term (five to ten years):

- major pavement rehabilitation of the highway from Swan Bay Road to The Branch Lane;
- on-going maintenance of the roadway;
- improvements to intersections, including channelisation and turning lanes, to increase safety and efficiency of the road;
- improvements to and/or introduction of environmental controls especially in areas adjacent to SEPP 14 wetlands; and
- maintenance and possible upgrade of the bridge across the Karuah River.

6.14.2 Approach to analysis

Generally the approach to estimating the benefits of the proposed bypass at Karuah has been conservative such that benefits would be underestimated where uncertainty existed.

The analysis of road user benefits was conducted in accordance with standard RTA procedure as outlined in *Economic Analysis Manual, Version 1, Revision 13* (RTA, 1998). Parameters used were according to the RTA's June 1998 update and are discussed in Working Paper No 2 - Concept Design (Arup, 1999b).

6.14.3 Outcomes of economic analysis and road user benefits

6.14.3.1 Economic evaluation

The analysis revealed that, at a discount rate of 7%, the proposed bypass returns a Benefit Cost Ratio in the order of 1.9, with a net present value of $59.4 million (see Table 6.3). This indicates that the proposed bypass would be economically viable.

Table 6.3 Results of the economic evaluation for the proposed bypass

Economic parameter	Result
Benefit-cost ratio	1.9
Net present value	$59.0 million
Discount rate	7%

6.14.3.2 Road user benefits

A summary of the road user benefits is presented in Table 6.4. The primary source of road user benefits over a 27 year operational period from 2005 to 2031 is VOT. Due to the increased length of highway along the Horse Island route compared with the existing route of the highway through Karuah (9.8 km compared with 9.5 km) and higher vehicle speeds, VOC benefits are relatively small. In comparison to VOT benefits, accident benefits were also relatively low for the proposed bypass.

Table 6.4 Summary of total road user benefits, 2005 to 2031 (Present Value @ 7%)

Project	Capital costs	Annual maintenance	Vehicle operating costs	Travel time	Accident cost savings	Total benefits
Base case	$5.8 million	$1.7 million	$133.6 million	$243.1 million	$15.7 million	$399.8 million
Proposed bypass	$72.6 million	$0.8 million	$130.3 million	$124.7 million	$12.3 million	$340.8 million
Difference	-$66.9 million	$0.8 million	$3.2 million	$118.4 million	$3.4 million	$59.0 million

7. Construction issues

This chapter describes the general approach to the construction of the proposed Pacific Highway bypass at Karuah. Sites for ancillary construction activities are identified, together with likely environmental impacts and relevant mitigation measures. The approach to waste management is outlined and an energy statement presented. The likely schedule for the construction of the proposal is also presented as well as information on land acquisition.

7.1 Construction methods

7.1.1 Typical construction sequence

The method of construction for a project such as the Karuah bypass would generally involve the following sequence of activities:

- pre-clearing investigations to confirm locations of flora and fauna of conservation significance;
- installation of off-site noise mitigation measures;
- site establishment - survey setout, safety fencing of site, and establishment of site compounds and access;
- installation of temporary erosion, sediment and water quality controls including diversion drainage;
- clearing of vegetation and mulching of plant material for reuse;
- stripping, stockpiling and management of topsoil;
- bulk earthworks;
- installation of drainage lines, fauna underpasses and local access;
- bridge construction;
- foundation works and pavement construction;
- topsoil rehabilitation and revegetation of batters and berms;
- landscaping;
- installation of off-site noise mitigation measures;
- line marking and signposting;
- interchange lighting; and
- finishing works (including general site clean up and removal of site compounds).

As the delivery method for this project has not yet been decided, there may be some variation to this sequence and the preferred method of undertaking particular works. However, the construction method would have to comply with the construction concepts and environmental management requirements presented in this EIS and the Environmental Management Plan (EMP).

7.1.2 Delivery methods

Options under consideration for delivery of the proposed bypass project include:

- design by RTA or a consultant followed by competitive tendering by contractors for a construction-only contract;
- design and construction (D&C) contract awarded after competitive tendering to a contractor with design team; and
- design, construct and maintain (DCM) contract with maintenance for a nominated period (possibly ten years).

The Concept Design and the EIS are not predicated on any particular contract packaging, delivery or construction method. If the project proceeds, the RTA will consider the options for project delivery and select and implement the preferred method in compliance with conditions of approval.

7.1.3 Construction staging

The major element controlling the program for construction of the Karuah bypass is the construction of the two major bridges over the Karuah River and nearby SEPP 14 wetlands. Construction of these two bridges on either side of Horse Island is likely to take at least 18 months so that access across the bridges for equipment or materials would not be available until the latter part of the construction period (see Section 7.7).

To avoid unnecessarily extending the construction period, it is anticipated that the roadworks would proceed separately on both sides of the river and concurrently with bridge construction. This approach is not considered to have any major environmental implications because:

- access is available from existing roads to work areas for the roadworks and bridge construction on each side of the river; and
- an earthworks balance has been achieved on each side of the river thus there should not be major traffic movements between the two work sectors.

7.1.4 Construction of the major bridges

7.1.4.1 Approach to assessment of bridge construction impacts

Construction of the 612 m bridge over the Karuah River in environmentally sensitive areas and of the 200 m bridge over the SEPP 14 wetland west of Horse Island requires a method of construction that would reduce the extent and nature of adverse impacts and incorporate appropriate mitigation and management measures.

A feasible method of construction has been developed for these bridges (as described below) but detailed construction methods would be the prerogative of the contractor. The method of construction described is not intended to be prescriptive but is presented to allow a realistic assessment of the likely nature and extent of impacts during construction. Alternative construction methods may be adopted by the contractor provided that the level of impact during construction is not greater than the impact of the method presented below. This requirement will be reflected in the EMP and contract conditions for the proposal.

7.1.4.2 Construction of the bridge over the Karuah River

Construction approach

Construction of the substructure for this bridge in the river would be carried out using a barge-mounted pile-driving rig - it is not anticipated that there is any alternative to this approach. Hollow steel tubes are proposed for the piling as disturbance to PASS and the wetlands during construction is less than for other pile systems involving bored cast in-situ concrete piles or driven concrete piles. The rig would install the steel tube for the pile by vibrating the tubes through the marine silts and sediments.

Following the vibration, the steel tubes would be driven, using a piling rig to the required load capacity - this would probably be bedrock on the shallower, western side of the river and a varying depth on the deeper, eastern side of the river. This process would be repeated at each pile. Inclined piles would be installed to transfer horizontal forces to the substrates. When all of the piles in the pile groups are installed, the top 7 m of the piles would be concrete filled.

The pile cap would be formed up around the piles using the piles to support the formwork for the concrete pile cap. The bottom of each pile cap will be just above the low tide water level - the pile cap would extend out the water for approximately 2 m. Stainless steel cast in bolts would be attached to the pile cap and a concrete skirting panel could be installed around the pile cap to below the low water level to effectively cover the pile and to improve its appearance.

Concrete for the construction of the pile caps, piers and headstocks to support the bridge beams would be provided by barge using skips. Erection of the precast beams for spans above water would also take place using barges. A barge-mounted crane would lift the precast beams from a storage area (probably on the east bank of the Karuah River), transport them to the appropriate span, and lift them into position.

Environmental controls around pile construction in the Karuah River

It is anticipated that there would be little disturbance to the river bed during construction of the piles, pile caps and piers for the Karuah River bridge. Use of a silt curtain or similar containment device would be suitable because of the silty sand particle size of the riverbed deposits. The contractor would be required to ensure that relevant water quality levels were maintained during pile construction.

The contractor would also be required to ensure that there was no spillage into the river of concrete during transport or pouring into the pile tube or pile cap. This could be achieved by extending the formwork above the top of the pour to reduce the risk of spillage and by pumping concrete rather than handling by skip or crane.

7.1.4.3 Construction of the bridge across the SEPP 14 wetland

The concept design has identified construction processes least likely to affect this sensitive wetland environment in the medium to long term. To construct piers in the SEPP 14 area, it would be necessary to access the area around the pile groups. The required area is assumed to extend around the perimeter of each pile cap by approximately 1.5 m. This construction area, together with the actual area of the pile cap, was considered in the assessment of impacts on the ecology of SEPP 14 Wetland No 743 (see Section 11.3).

Access for construction of the wetland bridge

As indicated in this construction sequence, there would be a need for heavy machinery to access the area around the piers. To gain access to these areas, a temporary road approximately 10 m wide across the SEPP 14 wetland would be required. The environmental outcomes to be achieved with such a road would include:

- minimum area of wetland affected;
- construction method to facilitate recovery of the wetland; and
- temporary access road and construction areas to be drained away from the wetland.

Such a road could be constructed on fill but, if the desired environmental outcomes could be achieved, the contractor would be able to suggest alternative methods.

The steps in constructing a temporary road on fill would be:

- installing cross drainage to maintain environmental flows through the wetland;
- laying down geotextile on the wetland surface;
- installing bunding, drainage and environmental controls on the works area to ensure that there is no runoff direct to the wetland; and
- placing and compacting material on top of it to achieve the capacity required by the construction traffic.

The road would need to extend along the length of the bridge to the west of Horse Island (approximately 200 m) and for some 130 m to the east of Horse Island to assist in the construction of the Karuah River bridge. The road would run immediately adjacent to the works area on one side only of both bridge sites.

After the work at the piers is completed, the access road would be used by vehicles during installation of the superstructure above. After this work is completed, the material used to create the road formation as well as the geotextile would be removed, and the natural drainage reinstated.

Environmental controls around pile construction in the SEPP 14 wetland

The work areas around the pile locations would be bunded to ensure that contaminated water does not flow into the SEPP 14 wetlands. If required, water would have to be pumped out of these areas to nearby sedimentation basins. The contractor would be required to ensure that no building materials or waste is deposited in the wetlands.

Construction of the bridge across the SEPP 14 wetland

It is anticipated that the following sequence of construction would be followed for this bridge:

- piles are installed using a mobile piling rig positioned on the construction road;
- when all of the piles in the pile group are installed, the top 7 m of the piles would be concrete encased to provide corrosion protection;
- a platform for the underside of the pile cap would be constructed;
- from this working platform, the side forms of the pile cap would be attached and the steel reinforcement in the pile cap would be placed;
- the pile cap would be concreted;
- the optional precast skirting would be installed;
- the pier column is then formed up and reinforced;
- the headstock is then formed up, reinforced and concreted; and
- finally the superstructure is installed. The installation process may require access from below the construction road or areas around the pile cap.

7.2 Construction materials

It is anticipated that most of the material removed from cut areas along the proposed bypass would be suitable for use as general fill for the embankments. After allowing for likely levels of unsuitable materials, it is estimated that there would be sufficient material available for embankments without the need for borrow areas.

A number of quarries in the general area of the proposed bypass that supply pavement materials were contacted or visited during EIS investigations. Table 7.1 summarises the details of the quarries that responded to requests for product information. These investigations indicate that a full range of materials likely to be required for the construction of the proposed bypass are readily available from operating quarries and other sources within 60 km or less of the project area. Transport of imported quarry materials would be along local roads from the source and then the Pacific Highway to designated access points for construction access to the bypass project.

Table 7.1 Summary of quarry and supplies

Quarry	Location	Proximity to the proposed bypass (approximate)	Comments
Quarry supplies			
Boral Country	Seahampton	55 km	Full range of pavement materials available
Mountain Industries	Karuah and Tea Gardens	0-9 km	Full range of products would be available between both quarries
Boral Quarries	Newcastle	55 km	
McAndrew Collins	Salamander Bay	50 km	Pavement materials
Metromix - Steelstone	Newcastle	55 km	
Sand supplies			
Boral Quarries	Stockton	40km	Dune sand currently being supplied to the work on the Raymond Terrace to Karuah duplication
Tollbulk Sands	Williamtown	20 km	Pit has 10 to 15 year life and thus would be available for proposed bypass
McAndrew Collins	Williamtown	20 km	Pit will be opening in January 2000

Sand required for concrete (fine aggregates) could total up to 60,000 tonnes of clean, durable sand with a low alkali/silica reaction. No sand deposits sufficient for use on the project have been identified in the vicinity of the proposed bypass and, as a result, sand would have to be imported. All potential sources, discussed in Table 7.1, are within 20 to 40 km of Karuah and would be accessed along local roads and then the Pacific Highway to designated access points.

7.3 Ancillary construction facilities

7.3.1 Range of facilities

In addition to the physical footprint of the permanent works, the construction contractor would require temporary access to land for a range of construction-related activities including site compounds for offices and storage of plant and equipment, batch plants (possibly concrete and asphalt), crushing plants, and stockpile sites. Actual requirements would depend on the contractor, the final design and work methods adopted.

To ensure a comprehensive appreciation of the overall impacts of the construction of the proposed bypass, investigations have been undertaken to identify sufficient suitable areas for each possible ancillary construction activity, to assess likely impacts, and to describe appropriate mitigation measures. At the time of construction, the contractor would have the option of being able to carry out ancillary activities on site and would be able to select from the identified sites for each type of activity according to the final design and proposed work methods.

7.3.2 Spoil disposal areas

The approximate balance of cuts and fills on each side of the Karuah River would avoid the need for significant spoil disposal areas. However, disposal of material classed as unsuitable for use in embankments and acid sulphate soils would be required.

Based on geotechnical investigations, volumes of unsuitable material are not expected to total more than 50,000 cubic metres. The landscape strategy for the bypass identifies several areas where batter slopes could be flattened within the proposed road reserve to better integrate the bypass with the surrounding terrain (see Section 6.12). This would provide opportunities for disposal of unsuitable material that is environmentally benign.

Potential acid sulphate soil (PASS) would generally not be removed as part of any bulk excavations. However, small volumes may be excavated in isolated areas for drainage works, construction of sedimentation basins, and construction of bridge abutments. Any excavated PASS would be buried below the water table or treated and tested prior to placement in landscaped fill.

7.3.3 Identification of suitable sites for construction facilities

Identification of suitable areas for ancillary activities has been based on typical area requirements for projects on a similar scale, combined with appreciation of the Karuah area and the environmental constraints identified during the course of this EIS. Identification of suitable sites for ancillary construction facilities is based on the environmental criteria and construction requirements summarised in Table 7.2.

Using these criteria, a number of potentially suitable sites for ancillary construction facilities have been identified. The characteristics of these sites are summarised in Table 7.3 and the locations indicated in Figure 7.1. While a number of potentially suitable sites have been nominated, the contractor would have the option of using areas within the footprint of the permanent works for these activities subject to satisfying the locational criteria, complying with the works program and implementing environmental mitigation measures. If the Contractor identifies a potential construction site outside those identified in this EIS, a separate environmental impact assessment process would be undertaken.

As part of the development and approval of the Construction EMP (see Section 21.3), the contractor would be required to submit details on the location and arrangement of any ancillary facilities. The contractor would be required to address appearance, dust and noise generation, safe storage of construction materials, fuels, lubricants, hazardous chemicals, explosives, and waste management and minimisation. The ancillary facilities would all be temporary facilities to be used exclusively for works associated with construction of the bypass. On completion, the facilities would be removed and affected areas restored.

Table 7.2 Locational criteria for ancillary construction facilities

Locational criteria	Site compounds	Concrete batching plants	Asphalt batching plant	Crushing plants	Stockpile areas
Environmental criteria:					
• more than 100 m from waterways and SEPP 14 wetlands	✓	✓	✓	✓	✓
• not in protected conservation areas eg the Karuah Nature Reserve	✓	✓	✓	✓	✓
• low conservation significance for flora, fauna and indigenous or non-indigenous heritage	✓	✓	✓	✓	✓
• no substantial clearing of native vegetation required, or located where future clearing is required for permanent works	✓	✓	✓	✓	✓
• more than 250 m from residential uses or other activities that may be affected by operational noise or other impacts of the plant	✓	✓	✓	✓	✓
Construction requirements:					
• easy and safe access to the main road network	✓	✓	✓	✓	Not relevant
• adjacent to bypass route	✓	✓	✓	✓	✓
• relatively level ground but elevated to assist drainage and allow containment and treatment of runoff	✓	✓	✓	✓	✓
• minimum area preferred	2-3 ha	1 ha	1 ha	1 ha for plant and 2 ha for stockpile	3.5 ha on west of river and 3 ha on the east
• electricity and phone services should be available or able to be provided without additional environmental impacts	✓	✓	✓	✓	Not relevant
• preferably within existing road reservation boundaries or within areas to be acquired by RTA	✓	✓	✓	✓	✓
• at least one site on each side of the Karuah River	✓	✓	✓	✓	As required
• easily accessible potable water supply or suitable dam.	✓	✓	✓	✓	Not relevant
• adjacent to concrete batching plant and/or asphalt batching plant	Not relevant	Not relevant	Not relevant	✓	Not relevant

Table 7.3 Potential sites for ancillary construction activities

Site Location	Potential Area	Comments	Suitability*				
			1**	2**	3**	4**	5**
Ch 900 (on the alignment of future ramp to Karuah)	Ramp is approximately 900 m long and averages 25 m wide = 2.25 hectares.	Land to be acquired by RTA. Some parts are close to Reedy Creek. Good access but no ready water supply. Power and phone available.	✓	✗	✗	✗	✓
Ch 2500	Hunter Water site	Land is cleared but construction of the Sewage Treatment Plant will preclude use of this site.	✗	✗	✗	✗	✗
Ch 3850	Private land on north western side of bypass. Up to 3 hectares	Land is partially cleared. Access available from Mines Hill Trail Existing dam may be suitable batch plant water supply. Power and phone available	✓	✓	✓	✓	✓
Ch 4850	Private Land on right side of bypass. Up to 2 hectares	Land is substantially cleared. Existing dam may be suitable batch plant water supply. Limited road access at present. Convenient to major bridge across Horse Island wetlands	✓	✓	✓	✓	✓
Ch 6300	Private land north and south of the bypass. Up to 5 hectares	Land is substantially cleared Existing dam may be suitable batch plant water supply. Limited road access at present Convenient to major bridge across Karuah River	✓	✓	✓	✓	✓
Ch 7000 - 7500	Private land north and south of the Bypass Up to 5 hectares	Land is substantially cleared Existing dam may be suitable batch plant water supply. Limited road access at present Some sections close to Mosquito Creek	✓	✓	✓	✓	✓
Ch 8000 - 8200	Private land north side of the bypass. Up to 2 hectares	Land is cleared. Existing dam may be suitable batch plant water supply. Limited road access at present	✓	✓	✓	✓	✓
Ch 8300 - 9200	Private land south-west of the bypass Up to 10 hectares	Land is cleared. No existing dams. Limited road access at present.	✗	✗	✗	✗	✓
Ch 9300 - 9500	Private land north and south of the bypass. Up to 3 hectares.	Land semi-cleared. Existing dam may be suitable batch plant water supply. Good road access from The Branch Lane. Power and phone available.	✓	✓	✓	✓	✓
Ch 10000	Quarry	Good access to existing highway. Power and phone available. Dam available. Aggregates available. Disturbance to existing quarry operations would have to be avoided.	✗	✓	✓	✗	✗

* Subject to availability, access arrangements and appropriate environmental controls.

** 1 Site compound
2 Concrete batching plant
3 Asphalt batching plant
4 Crushing plant
5 Stockpile area

✓ Suitable
✗ Unsuitable

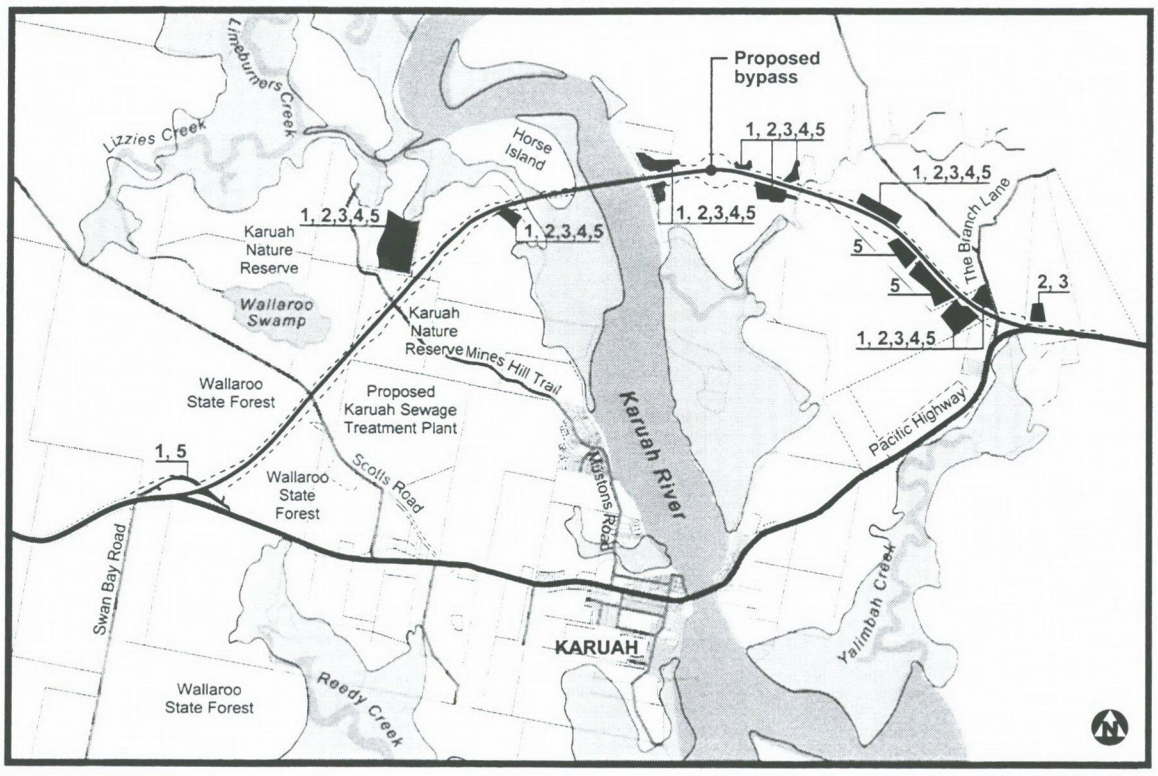


Figure 7.1
Locations of potential construction sites

7.3.4 Site compounds

The contractor would require site compounds for offices and storage areas for mobile plant and construction materials. Given that the Karuah River would divide the project works areas until the two major bridges are completed, the contractor would require at least one compound on the west side of the river and one on the east side. If the compounds are located close to the major bridges, they could also function as compounds for construction of the bridges. Otherwise, separate compounds would be required near the bridges.

The construction compounds would require up to 3 hectares of land and would be fenced for security and safety. Initial site works would involve site clearing and installation of environmental controls. Hard-standing areas would be provided for parking, storage, access roads, and site sheds. Where possible, services would be connected otherwise portable generators and toilets would be used.

Potential environmental impacts and related mitigation measures for construction compounds are summarised in Table 7.4.

Table 7.4 Ancillary construction facilities - potential environmental impacts and mitigation measures

Likely environmental impacts	Mitigation measures	Ancillary facility				
		1*	2*	3*	4*	5*
Soil erosion and sedimentation of water bodies	Reduce area of disturbance to vegetation and topsoil.	✓	✓	✓	✓	✓
Contaminated runoff adversely affecting water quality	Divert clean runoff around the site.	✓	✓	✓	✓	✓
	Install environmental controls downstream of disturbed areas.	✓	✓	✓	✓	✓
	Provide hardstand or similar to reduce infiltration to and contamination of soil and groundwater.	✓	✓	✓	✓	*na*
	Bund fuel and chemical storage areas in accordance with EPA requirements.	✓	✓	✓	✓	*na*
	Treat runoff from fuel storage and vehicle wash down areas prior to discharge from site.	✓	✓	✓	✓	*na*
	Prompt removal of spillages of materials.	✓	✓	✓	✓	*na*
Dust generation adversely affecting air quality	Water any unsealed areas during weather conditions conducive to dust generation.	✓	✓	✓	✓	✓
	Regular maintenance of vehicles and machinery to ensure efficient operation.	✓	✓	✓	✓	*na*
Vehicle and equipment noise	Compliance with relevant EPA requirements.	✓	✓	✓	✓	*na*
	Regular monitoring of noise levels.	✓	✓	✓	✓	*na*
	Regular maintenance of vehicles and machinery to ensure efficient operation.	✓	✓	✓	✓	*na*
	If required, installation of temporary noise mitigation measures at nearby residences.	✓	✓	✓	✓	*na*
Waste generation	Good site housekeeping to prevent littering.	✓	✓	✓	✓	*na*
	Remove liquid and solid waste by tanker or truck for disposal at an approved facility.	✓	✓	✓	✓	*na*
Impacts on visual quality	Install (colour coordinated) shade cloth on perimeter fencing to reduce visual impact.	✓	✓	✓	✓	*na*
	If site is particularly visible from key viewing points, consider supplementary planting external to perimeter fence.	✓	✓	✓	✓	✓
Impacts on flora and fauna	Reduce area cleared.	✓	✓	✓	✓	✓
	Inspect areas to be cleared for presence of native fauna.	✓	✓	✓	✓	✓
	Install temporary fauna crossing points across access roads if required.	✓	✓	✓	✓	*na*
	Revegetate sites on completion of construction.	✓	✓	✓	✓	✓

1 Site compound
2 Concrete batching plant
3 Asphalt batching plant
4 Crushing plant
5 Stockpile area

7.3.5 Concrete batching plants

Construction of the bridge structures would require about 10,000 cubic metres of concrete to be placed in-situ over a period of up to two years. If a rigid pavement is adopted for the road, an additional 75,000 cubic metres of concrete over a period of around 18 months would be required. Even if a flexible asphalt type pavement is adopted, the concrete requirements for the bridge alone are such that establishment of one or more concrete batching plants is likely to be cost-effective. The barrier presented by the Karuah River and the size of the proposed structures suggests that one concrete batching plant would be required on the west side of the river and another on the east side.

Concrete batching plants would have a schematic configuration similar to the one shown in Figure 7.2. Concrete aggregates and sand would be stockpiled on site and transferred by front-end loaders to aggregate bins. A conveyor would transfer aggregates to a surge bin and then to a mixer where water, cement and admixtures would be added. Trucks would be loaded directly from the drum mixer. Temporary buildings for staff amenities, offices and quality assurance control would also be required.

Potential environmental impacts and related mitigation measures for concrete batching plants are summarised in Table 7.4.

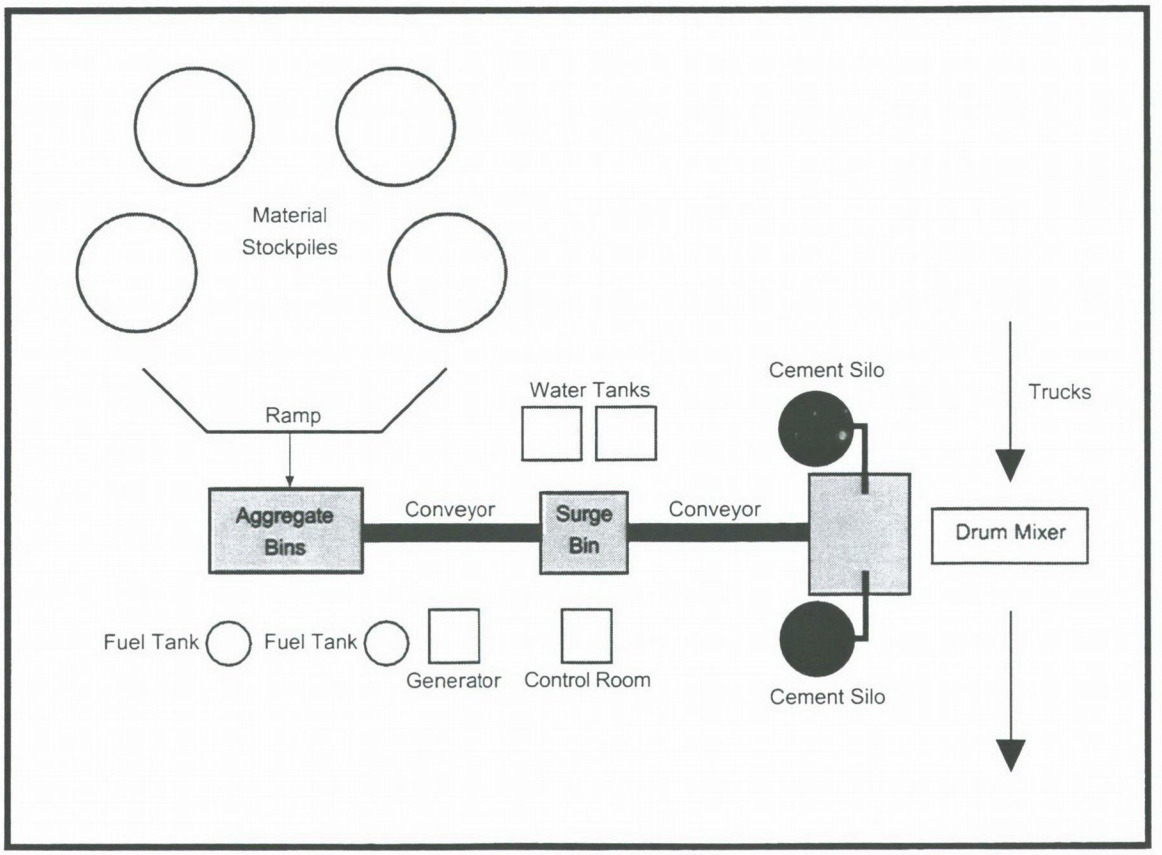


Figure 7.2
Concrete batching plant

7.3.6 Asphalt batching plants

Adoption of a flexible pavement for the bypass would require about 25,000 cubic metres of asphalt to be placed over a period of about 12 months. By delaying placement of asphalt until the major bridges are complete, it might be possible for the contractor to have only one asphalt batching plant. However, in the interests of allowing greater flexibility in the design and construction process, suitable sites for such plants have been identified on each side of the Karuah River.

Asphalt batching plants would have a schematic configuration similar to the one shown in Figure 7.3. Aggregates would be stockpiled on site and transferred by front-end loaders to aggregate bins. Filler would be stored in silos and bitumen in a large capacity tank. A conveyor would transfer aggregates to a mixing drum where filler and bitumen would be added. Fuel tanks would supply fuel to the plant, generators and burners. Asphaltic concrete would be loaded onto trucks from the mixing drum. Temporary buildings for staff amenities, offices and quality assurance control would also be required.

Potential environmental impacts and related mitigation measures for asphalt batching plants are summarised in Table 7.4.

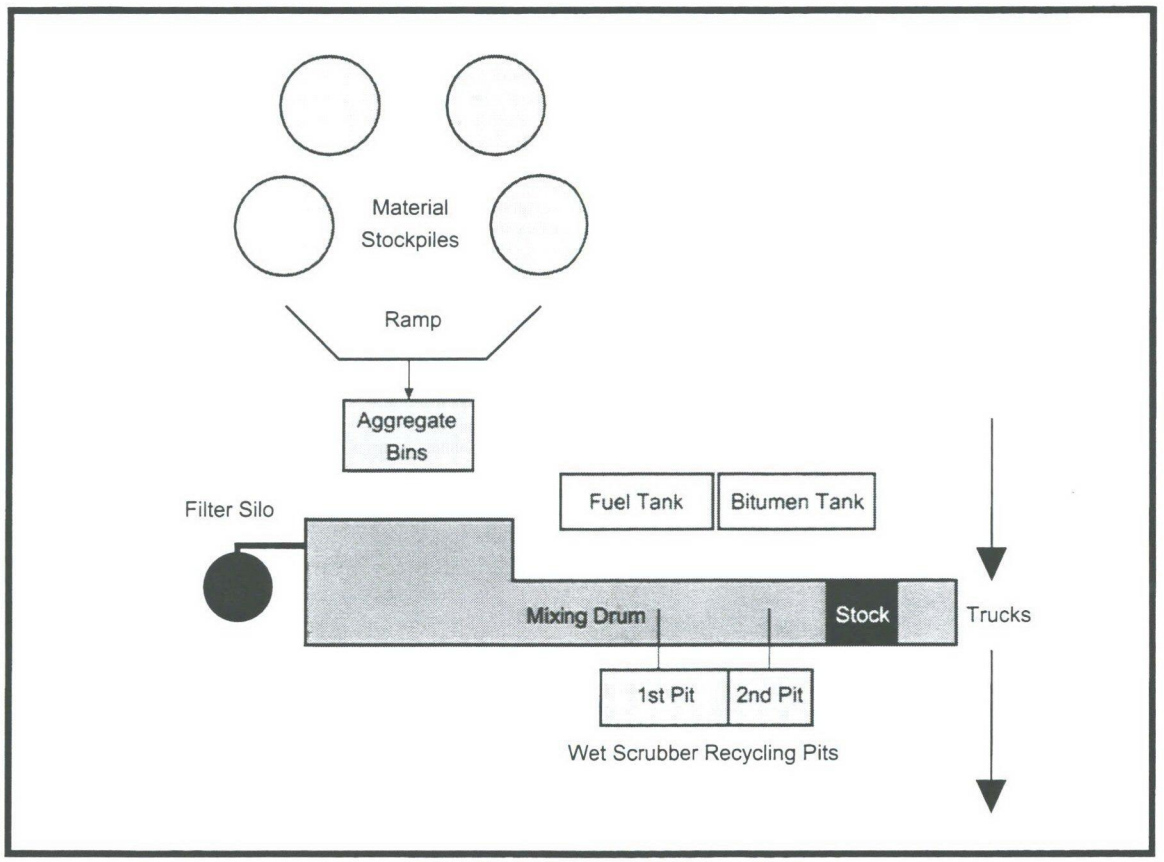


Figure 7.3
Asphalt batching plant

7.3.7 Crushing plants

Cuts to the saddle east of Chainage 2300 would generally require excavations in medium to high strength rock. According to geotechnical advice, blasting is likely to be required, followed by crushing to reduce the rock to sizes suitable for placement in fill embankments.

Rock excavation and placement in embankments would take place prior to completion of the major bridges so two crushing plants would be required - one on each side of the Karuah River. On the east side, there is the possibility that the contractor could negotiate with the owners of the adjacent quarry to use the crushing plant facilities in the quarry.

The crushing plant area should include areas for stockpiling as well. Based on providing storage for 20% of the cut volume on each side of the river, the crushing plant sites should each contain sufficient area for stockpiling of about 80,000 cubic metres, requiring a stockpile area of about 2 hectares.

The crushing plant could potentially produce aggregates for concrete and/or asphalt as well. To facilitate this option the crushing plants should preferably be located adjacent to concrete or asphalt batch plants.

Potential environmental impacts and related mitigation measures for crushing plants are summarised in Table 7.4.

7.3.8 Stockpile sites

The bypass profile has been adjusted to achieve an approximate balance of material on each side of the Karuah River. This would allow the contractor to reduce haulage and should also allow most material to be moved directly from cut areas and placed in fill areas without the need for stockpiling and the associated double handling.

The exception would be the stockpiling of topsoil materials from cut and fill areas prior to placement on medians, embankment slopes, and flatter cut batters. It is estimated that about 75,000 cubic metres of topsoil would be stockpiled on the west side of the Karuah River and about 55,000 cubic metres on the east side of the Karuah River. Assuming a maximum stockpile height of about 3 m, approximately 3 hectares would be required on the west side and 2.5 hectares on the east side.

There may also be a requirement for stockpiling of general fill material outside of the crushing plant areas, or for temporary storage of select material, rock material or other imported materials consistent with construction requirements. The stockpile requirements above have thus been increased slightly to 3.5 hectares on the west side and 3.0 hectares on the east side.

The contractor would be required to protect stockpiles of erodable material such as topsoil against erosion by mulching or other means. Potential environmental impacts and related mitigation measures for construction compounds are summarised in Table 7.4.

7.4 Waste management

7.4.1 Waste management and minimisation

Waste management would be a high priority during construction of the proposed bypass, consistent with the objectives of the *Waste Minimisation and Management Act 1995.* This Act sets a target of a 60% reduction in waste to landfill by 2000 based on 1991 per capita rates. The selected contractor would be required to include in the Construction EMP a Waste Management Plan that would set out objectives for minimising and managing waste during construction, and provide guidelines for managing waste, implementing re-use and recycling programs, and disposing appropriately of other non-reusable waste.

7.4.2 Recycling of materials during construction

There are no major structures to be demolished along the route of the proposed bypass. Where possible and consistent with other environmental or occupational health and safety requirements, waste materials would be recycled either on-site or through approved off-site recycling programs. Examples of potential opportunities for recycling of materials during construction include:

- tree and plant material generated during initial site clearing - with the exception of certain weeds and invasive plant species, this material would be mulched and used on-site during construction and landscaping;
- removal of 500 m of relatively new pavement would be necessary at the western end of the project where it joins with the duplication project from Raymond Terrace - it is anticipated that this material could be readily reused in pavement construction on the bypass project;
- rock and soil material found to be unsuitable for construction purposes would be recycled within the project area in batter extensions proposed for better integration of the road into the landscape; and
- on-site facilities for sorting of paper, plastic, glass and other waste from site compounds - this waste could be recycled through Local Council recycling programs.

7.4.3 Post construction waste management

Once the bypass is operational, the two waste streams generated would be waste from maintenance activities and litter from road users. Maintenance waste such as vegetation prunings would be collected and recycled for mulch within the road reserve or through Local Council programs. Other maintenance waste such as oils and greases would be disposed of to licensed landfills.

Litter from road users would be collected by the relevant maintenance organisation. Relevant materials such as glass and aluminium cans would be recycled and other material that can not be readily recycled would be disposed of to licensed landfills.

7.5 Energy statement

An energy statement for the proposed bypass considers the energy required during the construction of the project as well as the energy (fuel) that would be saved in vehicle operation on the completed bypass. Advice from the Department of Minerals and Energy indicates that no potential minerals or energy resources, in particular coal, would be sterilised by the construction of the project.

7.5.1 Energy required for road construction

Most of the construction work for the proposed bypass would be undertaken by diesel powered machinery. However, the construction equipment actually used would be dependent on the contractor selected and the actual conditions encountered during construction. The range of construction equipment is likely to include:

- light transport vehicles;
- graders and scrapers;
- bulldozers;
- front-end loaders;
- excavators;
- drilling rigs;
- compactors and compressors;
- water trucks;

- materials trucks (highway and off-highway);
- backhoes, paving machines and other heavy weight vehicles;
- pile driving rigs - barge-mounted and land-based;
- cranes - barge-mounted and land-based;
- concrete pumps and air compressors;
- concrete and/or asphalt batching plants; and
- crushing plants.

Given the extent and nature of the project, a large quantity of fuel is likely to be used. Fuel consumption would depend on factors including the age and condition of equipment, the speed of operation, and the site conditions encountered. The volume of fuel used would be generally proportional to the earthworks involved. A conservative estimate of fuel usage is 12 million litres of diesel. Energy would also be consumed in other construction activities such as bridge construction, batching plant operation, pavement laying and landscaping.

7.5.2 Energy considerations during operation

Energy consumption once the bypass is completed would be by vehicles using the bypass and the existing highway as well as by vehicles and equipment involved in maintenance of the bypass and the existing highway. It is anticipated that the improved vehicle operating conditions provided by the bypass would result in lower levels of energy usage for the equivalent number of vehicles on opening. Lower per vehicle energy usage is also anticipated for vehicles using the current Pacific Highway through Karuah as there will be lower traffic volumes and less congestion in peak holiday periods, thus improved vehicle operating conditions. Aggregate energy use would gradually increase in proportion to the overall growth in traffic volumes on the highway.

Maintenance of the bypass is anticipated to involve several medium sized vehicles and equipment such as tractors and slashers for grass cutting. Energy usage by these vehicles and equipment would be insignificant.

7.6 Environmental management measures

In addition to the project EMP prepared by the RTA, a Construction Environmental Management Plan (CEMP) would be prepared by the selected contractor for implementation throughout construction. An outline of the matters to be addressed in the CEMP is provided in Section 21.1.

7.7 Construction staging, programming and workforce

The proposed bypass would be constructed in one stage with the exception of the grade separation of the western junction that would be implemented when traffic levels warrant. It is estimated that, after acceptance of a tender, construction would take three years and eight months. The anticipated program for project implementation is shown in Figure 7.4.

For a project estimated to cost approximately $103 million, it is anticipated that the peak construction workforce on site would be approximately 200 people. The average size of the construction workforce on site would be approximately 100 people including management staff and subcontractors. It is expected that a large proportion of this workforce would be sourced locally from the lower Hunter region.

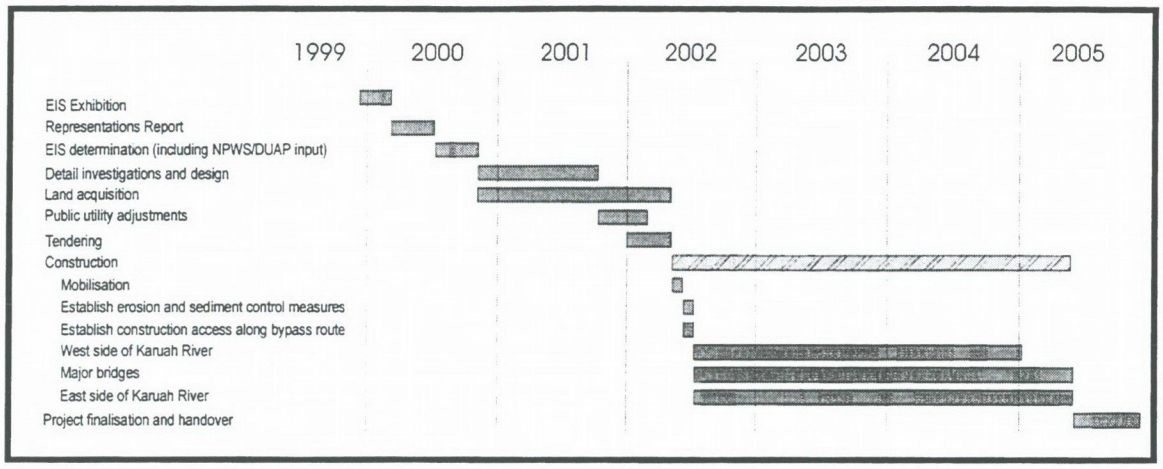


Figure 7.4
Construction schedule

7.8 Property acquisition and compensation

7.8.1 Property acquisition

Existing property boundaries in the vicinity of the alignment are shown in Figure 7.5. Land acquisition totalling 109 hectares would be required from seventeen property owners (see Table 7.5).

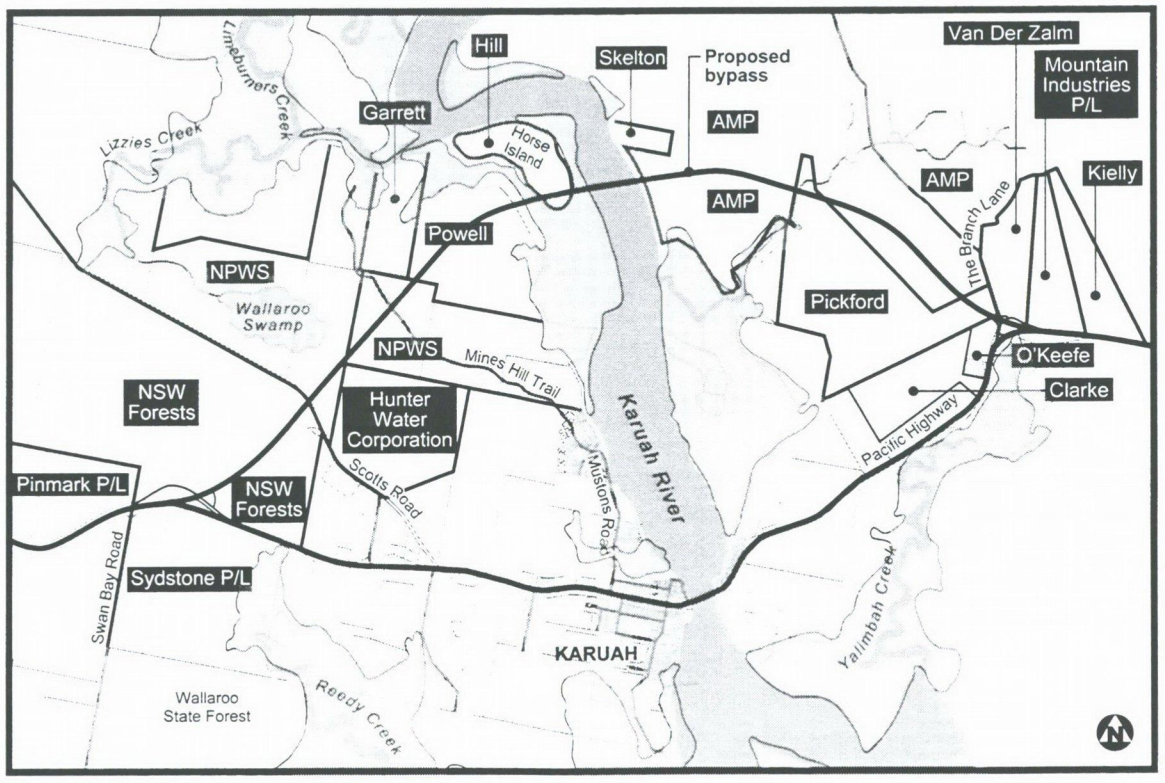


Figure 7.5
Land ownership

Table 7.5 Land holdings affected by acquisition

Approx. chainage	Property owner	Property address or description	Title description	Area of affected lot (ha)	Area to be acquired (ha)
200 - 550	Pinmark Pty Ltd	150 Pacific Highway, Karuah	DP753196 Pt Lot 101	55.44	0.3
750-900	Sydstone Pty Ltd	Pacific Highway, Karuah	DP 871041 Lot 1	116.5	0.3
550 - 2400	NSW Forests (Wallaroo State Forest)	148 Pacific Highway, Karuah 144 Pacific Highway, Karuah	Crown Land	Extensive	24.0
2400 - 3900	NPWS (Karuah Nature Reserve)	Scotts Road, Karuah Mines Hill Trail, Karuah	DP 753196 Lot 138 DP 753196, Lot 106	114.52	16.1
3000	Hunter Water Corporation	Scotts Road, Karuah	DP 874652 Lot 1	100.4	0.1
3850 - 4950	DN & LN Powell	Karuah	DP 753196 Lot 182	101.9	12.8
4950 - 5030	Crown	West of SEPP 14 Wetland No 743, Karuah	Crown Land	-	1.0
5030- 5060	Crown	Road 150 links wide, West of SEPP 14 Wetland No 743, Karuah	Crown Land	-	-
5060- 5210	Crown	SEPP 14 Wetland No 743	Crown Land	-	-
5210- 5250	Crown	Reserve 150 links wide around Horse Island	Crown Land	-	-
5250 - 5510	GA & DG Hill	Horse Island, Karuah	DP 753196 Lot 155	37.6	2.6
5510- 5540	Crown	Reserve 150 links wide around Horse Island	Crown Land	-	-
5540 - 6100	Crown	SEPP 14 Wetland No 743 and Karuah River (location of bridge piers in river)	Crown Land	-	-
6100 - 7500	AMP	The Branch Lane, Karuah	DP627770 Lot 8	1964	20.6
7500 - 7750	(Estate of late) R Pickford	The Branch Lane, Karuah	DP 95460 Lot 37	147.3	3.4
7750 - 9230	AMP	The Branch Lane, Karuah	DP627770 Lot 8	included above	18.1
9230- 9570	(Estate of late) R Pickford	The Branch Lane, Karuah	DP 95460 Lot 37	included above	3.9
9570- 9580	DB Clarke	The Branch Lane, Karuah	DP 596781 Lot 4	49.16	0.1
9580 - 9600	TN O'Keefe	1846 The Branch Lane, Karuah	DP 596779 Lot 3	9.7	1.1
9640 - 9800	MJ Van Der Zalm	1783 The Branch Lane, Karuah	DP 573153 Lot 223	41	2.7
9820- 9850	Great Lakes Council	Lot 1, Pacific Highway, Karuah	DP 719493 Lot 1	0.43	0.43
9850 - 10350	Mountain Industries Pty Ltd	1649 Pacific Highway, Karuah	DP 573153 Lot 222	41	1.1
10300- 10434	GB Myers & DL Heeps	South side, Pacific Highway, Karuah	DP 785172 Lot 4	-	0.15
10350 - 10440	MJ Kiely	North side, Pacific Highway, Karuah	DP 573153 Lot 221	-	0.22

7.8.2 Land acquisition process

Land required for the proposed Upgrade would be acquired in accordance with the provisions of the *Land Acquisition (Just Terms Compensation) Act 1991*. The RTA acquires property required for road works in accordance with its Land Acquisition Policy a copy of which is included in Appendix B of this EIS. This policy sets out the procedures for acquisition and the conditions that apply to acquisition, compulsory acquisition and hardship acquisition.

Pacific Highway Upgrade at Karuah

Species Impact Statement

APPENDIX M

Qualifications of Relevant Personnel

Gunninah Environmental Consultants
PO Box 513 Crows Nest NSW 2065
ph: 02 - 9906 5436 fax: 02 - 9906 7770 email: gecon@gunninah.com.au

CURRICULUM VITAE

Mr FRANCIS DOMINIC FANNING BSc(Hons1) MAIBiol MEIA MESA

33 King William St Greenwich NSW 2065.
phone: 02 - 9439 5436 fax: 02 - 9439 7770

ACADEMIC QUALIFICATIONS :

BSc with 1st class Honours, University of NSW, 1977.

EMPLOYMENT HISTORY :

1975 to 1979	- Technical Officer (research assistant) School of Biological Science, UNSW.
1979 to 1990	- Professional Officer (assistant researcher) School of Biological Science, UNSW.
1983 to 1989	- Principal Environmental Consultant and Partner, Gunninah Consultants.
1989 to present	- Director and Principal, Gunninah Holdings Pty Ltd, environmental consultants.
1989 to 1992	- Scientific Associate of the Zoological Parks Board of NSW at Taronga Zoo.
1990 to July 1991 -	- Research Fellow, Platypus Breeding and Conservation Research Program, the Conservation Research Centre, Taronga Zoo.
1990 to 1996	- Visiting Fellow, School of Biological Science, UNSW.

RELEVANT EXPERIENCE and EXPERTISE :

Research field trips for UNSW from 1974 to 1990, throughout NSW, South Australia, Queensland and the Northern Territory, studying the native vertebrate fauna of Australia.

Micro-computer programming (the development of dedicated programs for biological research) and the use of micro-computers for data analysis and report preparation.

Wildlife illustration (three books published) and photography of native wildlife.

Conference convenor - an international workshop on Platypus Conservation at Taronga Zoo, 1988, to discuss the directions for future research into the biology of the Platypus and methods for the management of the species in captivity.

Design of research studies and development of research techniques and equipment, including electronic and data acquisition equipment, radio-tracking techniques, design and implementation of research programs on the conservation and captive management of the Platypus. This last program involved the identification of land use practices throughout the range of the Platypus and analysis of their impacts, determination of the effects of pollutants, erosion and waterway controls on the species, assessment of the habitat and food requirements of the Platypus, analysis of the environmental limitations of Platypus in the wild, and determination of the appropriate captive maintenance techniques for this species.

RELEVANT EXPERIENCE and EXPERTISE contd :

Management of environmental consulting business (Gunninah Consultants), involved in biological and physical environment assessment, Environmental Impact Statement and Fauna Impact Statement preparation, impact analysis, environmental management, and ecosystem management for rare species, presentation of expert evidence at Commissions of Inquiry and in the Land & Environment Court.

Design, co-ordination and supervision, and execution of fauna and flora surveys and of natural resource surveys, ranging from one-day surveys of the fauna and flora of proposed developments to broad conservation assessments of large areas - one thousand to one million hectares (for example, proposed logging operations in southeastern and northeastern NSW, proposed army bases in NSW). Surveys have involved soils analysis, vegetation and wildlife identification and assessment, habitat evaluation, pollutant identification and assessment, recommendations regarding impact amelioration, and the design of management options.

Research, compilation, writing and presentation of consulting reports (from 5 to 300 pages), promotional material (for the Conservation Research Centre at Taronga Zoo), a journal (production editor of the *Australian Biologist* Special Issue 1990), a workshop proceedings and scientific research papers.

Author and illustrator of books on Australian animals, including two on the Platypus.

RESEARCH INTERESTS :

Conservation and habitat management of the Platypus and other native fauna (particularly the Koala and kangaroos).

The ecology, environmental requirements and life histories of native fauna.

Computing and technology in biological research, including the application of GIS and other remote-sensing techniques, and the development and application of radio-telemetry for biological survey and research.

The development of methods for environmental survey.

PROFESSIONAL :

Member of the Australian Institute of Biology MAIBiol
member of Executive and Chairman of Credentials Committee (1989/91),
Deputy Registrar (1991/92).

Member of the Environment Institute of Australia MEIA
member of committee to establish Professional Credentials for Environmental Practitioners (1991).

Member of - the Ecological Society of Australia,
the Royal Zoological Society of NSW,
the Royal Australasian Ornithologists Union,
the Australian Wildlife Management Society,
the Australian Mammal Society (past Executive Member & Treasurer).

Scientific Associate of the Zoological Parks Board at Taronga Zoo (1989 to 1992).

Visiting Fellow in the School of Biological Science at the University of NSW (1990 to 1996).

Member of the Water Working Group - NSW State of the Environment Report (1997).

Guest Speaker: UDIA Newcastle Branch (April 1996),
UDIA NSW Division (October 1996).

Guest Lecturer: UNSW Key Centre for Mines - Environmental Management (1994),
Macquarie University GSE - Development Approvals (1995, 1996, 1997),
UTS - Environmental Law and Practice (1996, 1997).

PUBLICATION LIST

F DOMINIC FANNING BSc(Hons1) MAIBiol MEIA MESA

CONSULTANCIES

Additional publications include the majority of consultancy reports on projects listed in the *Projects List* for GUNNINAH CONSULTANTS.

BOOKS

Illustrator of *Monotremes and Marsupials* by TJ Dawson. Edward Arnold. 1983.

The Platypus by TR Grant. NSW University Press. 1984, 1989.

Author and illustrator of *Platypus* published by Houghton Mifflin. 1991.

PUBLICATIONS and SCIENTIFIC PAPERS :

Fanning FD. 1977. Temperature regulation of the Australian water rat, *Hydromys chrysogaster*. Honours thesis, University of NSW.

Fanning FD and Dawson TJ. 1977. Is *Hydromys* really a water-rat ? *Aust Mamm Soc Bull* **4(1):** 25.

Fanning FD and Dawson TJ. 1978. Thermoregulation of the Australian water rat, *Hydromys chrysogaster*. *Aust Mamm Soc Bull* **5(1):** 19.

Dawson TJ, Fanning FD and Bergin TJ. 1978. Metabolism and temperature regulation in the New Guinea monotreme *Zaglossus bruijni*. *Aust Zoologist* **20(1):** 99-103.

Dawson TJ, Grant TR and Fanning FD. 1979. Standard metabolism of monotremes and the evolution of homeothermy. *Aust J Zool* **27:** 511-515.

Fanning FD. 1980. Nests of the Feathertail glider, *Acrobates pygmaeus* (Burramyidae: Marsupialia), from Sydney, New South Wales. *Aust Mammal* **3:** 55-56.

Fanning FD and Watkins KM. 1980. Growth and development in *Acrobates pygmaeus* (Burramyidae: Marsupialia). *Aust Mammal* **3:** 57-69.

Fanning FD and Dawson TJ. 1980. Body temperature variability in the Australian water rat, *Hydromys chrysogaster*, in air and water. *Aust J Zool* **28:** 229-238.

Fanning FD and Dawson TJ. 1980. Thermal energetic problems of a small semiaquatic mammal, *Hydromys chrysogaster*. *Aust Mamm Soc Bull* **6(2):** 33-34.

Dawson TJ and Fanning FD. 1981. Thermal and energetic problems of semiaquatic mammals: a study of the Australian water rat, including comparisons with the platypus. *Physiol Zool* **54(3):** 285-296.

Fanning FD. 1982. Reproduction, growth and development in *Ningaui* sp. (Dasyuridae: Marsupialia) from the Northern Territory. pp 23-37 in *Carnivorous Marsupials*. Archer M (*ed*). Royal Zool Soc NSW, Sydney.

Whitford D, Fanning FD and White AW. 1982. Some information on reproduction, growth and development in *Planigale gilesi* (Dasyuridae: Marsupialia). pp 77-81 in *Carnivorous Marsupials*. Archer M (*ed*). Royal Zool Soc NSW, Sydney.

Fanning FD and Dawson TJ. 1984. Insulative components of the thermal balance of semiaquatic mammals. pp 319-322 in *Thermal Physiology*. Hales JRS (*ed*). Raven Press, New York.

PUBLICATIONS and SCIENTIFIC PAPERS contd :

Fanning FD. 1988. Australia's Mr Platypus. *Aust Geographic* **12:** 64-65.

Fanning FD and Dawson TJ. 1989. The use of heart rate telemetry in the measurement of energy expenditure in free-ranging Red Kangaroos. pp 239-244 in *Kangaroos, Wallabies and Rat-kangaroos*. Grigg G, Jarman P and Hume I (*eds*). Surrey Beatty & Sons, Sydney.

Lutz PL, Dawson TJ, Bonnet E and Fanning FD. 1989. Oxygen affinities of Monotreme blood: Hypoxic adaptations. *J Exp Zoology* **251:** 285-289.

Wicken AJ and Fanning FD. 1989. The Australian Institute of Biology and a Biological Council of Australia: Their Roles and Relationships. *Australian Biologist* **2**(3): 15-18.

Fanning FD and Hughes RL. *In prep.* Unearthing more questions than answers. In *Strategic Planning for Conservation I: The Platypus*. Woodside DP and Fanning FD (*eds*). CSIRO Publications, Melbourne.

Woodside DP and Fanning (*eds*). *In prep. Strategic Planning for Conservation I: The Platypus. Proceedings of a Symposium at Taronga Zoo.* CSIRO Publications, Melbourne.

Fanning FD, Woodside DP and Kotlash A. *in prep.* Habitat Criteria and Platypus Populations: A Modelling Approach.

Hawkins M and Fanning FD. 1992. Courtship and mating behaviour of captive Platypuses at Taronga Zoo. In Augee ML (*ed*). *Platypus and Echidnas*. Royal Zoological Society of NSW, Sydney.

GUNNINAH ENVIRONMENTAL CONSULTANTS

REPORTS and PUBLICATIONS

1983

Fauna survey for proposed open cut mine extension near Warkworth, Hunter Valley. Buchanan Borehole Collieries.

Preliminary survey of flora and fauna along proposed rail link from Glenfield to East Hills.

1984

Flora and fauna survey on a proposed hard rock quarry at Seaham Hill, near Raymond Terrace, NSW.

Fauna survey - Grain Handling Facility at Port Kembla inner harbour.

Preliminary fauna survey on proposed army training facilities southwest of Cobar, NSW.

Preliminary fauna survey on proposed army training facilities northeast of Tamworth, NSW.

1985

Army training facilities project, northwest of Cobar, NSW - Fauna Survey.

Army training facilities project, schools training area, Bathurst/Orange, NSW - Fauna Survey.

1986

Fauna survey for the F4 Freeway Section - Dog Kennel Road, Prospect to Coleman Street, Mays Hill.

Fauna survey for BMI - Dunmore Quarry proposed extension.

1987

Wombats on the Hume Highway from Hoddles Crossroads to Marulan.

1988

Tantawangalo State Forest Study Area - vegetation project.

Tantawangalo State Forest South Study Area - fauna report. I. Terrestrial mammals with observations on arboreal species.

Natural resource survey on the South Rockton section of Bondi State Forest, southern NSW.

1989

Natural resource survey on the North Rockton section of Bondi State Forest, southern NSW.

Fauna and flora survey, Palm Beach subdivision.

Wombats on the Hume Highway: a supplementary report.

Nepean Dam flood protection measures - supplementary environmental surveys - preliminary report.

Nepean Dam flood protection measures - supplementary environmental surveys - final report.

1989 continued

Natural Habitats Study - Half Moon Farm, Hawkesbury River.

A Natural Resource Survey of Rockton Section, Bondi State Forest. III. Birds, Reptiles and Amphibians.

Widening of Forest Way: Vegetation Survey.

1990

Fauna survey on a proposed bridge and approaches over the Woronora River between Sutherland and Bangor.

Koalas in the Southeast Forests.

An environmental survey of the Myanba Creek catchment in Coolangubra State Forest, southern NSW.

Koala Surveys: Compartments 950 and 953, Tantawangalo State Forest.

An environmental survey of the upper Wog Wog River catchment (Mines Road area) in Coolangubra and Nalbaugh State Forests, southern NSW.

Duck Creek Survey for Parramatta City Council.

Proposed Concrete Batching Plant, West Gosford: Fauna Survey and Environmental Assessment.

Platypus: Conservation Status and Future Management. Final Report.

Widening of Forest Way: Vegetation Survey. Hews Parade to Ralston Avenue.

Report on Proposed Sand Mining at Sackville, NSW.

Proposed Limestone Mine at Attunga, NSW.
Appraisal of EIS for Attunga Residents Action Group.

Proposed Canal Development at Dunbogan, NSW.
Appraisal of EIS for the Total Environment Centre.

Physical constraints to urban development. In Cardew, R. *Wyong Urban Growth Study.*

Description and evaluation of potential release areas. In Cardew, R. *Wyong Urban Growth Study.*

Aspects of the flood hazard on the Central Coast. In Cardew, R. *Wyong Urban Growth Study.*

Implications of climatic change on urban growth on the Central Coast. In Cardew, R. *Wyong Urban Growth Study.*

Survey of Vegetation along New Line Road.

Gold Ridge Mine - Solomon Islands. Freshwater fauna survey and contaminant analysis.

Proposed Gunnedah Power Station - Gunnedah Coal Company. Report on flora and fauna surveys and assessment of potential environmental impacts.

An environmental survey of the Stockyard Creek catchment in Coolangubra State Forest, southern NSW.

An environmental survey of the Jingo Creek catchment in Nullica State Forest, southern NSW.

AGL Site, Tennyson Road, Mortlake: A Fauna Survey.

1991

Fauna and conservation study on Australian Defence Industries land at St Marys, western Sydney.

Fauna and Flora study on SEPP 26 Littoral Rainforest at Crescent Head, NSW.

Environmental Guidelines for International Projects.

Surveys for Koalas and other animals on coupes to be logged in the Tantawangalo State Forest in southeastern NSW.

Surveys for Koalas along a roadline in the Tantawangalo State Forest in southeastern NSW.

Fauna and Flora Surveys for a Gold and Antimony mine near Tamworth.

Resolution of land use conflict between Titanium-mining and 'endangered' fauna near Tea Gardens, NSW.

Wombats on the Hume Highway: implementation of impact mitigation measures.

Assessment of the native fauna and the potential impacts of the proposed construction of single dwellings on fourteen blocks in the Kedumba Valley.
Presentation (expert witness) in Land & Environment Court.

1992

Interactions between Koalas and Roads: a Review and Assessment of Preventative Measures.

Comprehensive fauna surveys in the State Forests of the Tenterfield District northern NSW.

Fauna Impact Statement for Commission of Inquiry on a Titanium-mining venture at Saltwater, NSW.

Submissions to the Commission of Inquiry on a Titanium-mining venture at Saltwater, NSW.
Presentation of expert evidence to Saltwater Commission of Inquiry.

Rehabilitation of SEPP 26 Littoral Rainforest at Crescent Head, NSW.
Ongoing.

Assessment of impact on fauna of a proposed subdivision at Avalon, Sydney.

Assessment of impact on fauna of sand and soil extraction at Elderslie, Sydney.

Vegetation mapping and conservation assessment on rural land at Coolongolook, NSW.

Assessment of impact on fauna of an export woodchip industry in NSW. Input into preparation of EIS for SEPL.

Assessment of impact on fauna of a proposed subdivision at Glenhaven, Sydney.

Possible biological and hydrological impacts of the extraction of water from the Duck River, Sydney.

Goulburn Wool Scour Ltd proposed wastewater management operation: assessment of environmental significance for native fauna and flora.

Assessment of impact on fauna of road widening on the Pacific Highway, between Port Macquarie and Taree.

Assessment of impact on vegetation of road widening along New Line Road, Cherrybrook.

Assessment of impact on fauna of proposed Titanium-mining operation on Moffats Dune near Raymond Terrace, NSW.

Advice on fauna requirements for a proposed house at Corrimal, NSW.

1992 continued

Management of wildlife issues on Australian Defence Industries land at St Marys, western Sydney.
Ongoing.

EIS studies on fauna and flora impacts of a chemical laboratory development at Wagga Wagga, NSW.

Assessment of impact on fauna of proposed subdivision at Kenthurst, Sydney.

Assessment of impact on fauna of proposed subdivision at Annangrove, Sydney.

1993

Monitoring of the impacts of a Titanium-mining operation on the Eastern Chestnut Mouse, and recolonisation of mined land by fauna, Hawks Nest, NSW (Ongoing).

Monitoring of Platypus populations above and below a major dam expansion project in northern NSW, at Pindari Dam near Inverell.
Ongoing.

Management of wildlife issues on Australian Defence Industries land at St Marys, western Sydney.
Ongoing.

Rehabilitation of SEPP 26 Littoral Rainforest at Crescent Head, NSW (Ongoing from 1992).

Assessment of impact on vegetation, native fauna and fauna habitats of road widening along the Great Western Highway, Linden.

Assessment of impact on fauna and fauna habitats of road widening along New Line Road, Cherrybrook.

Assessment of impact on fauna of proposed Titanium-mining operation at Big Swan Bay near Lemon Tree Passage, NSW.

Assessment of impact on fauna and fauna habitats in an SEPP wetland of a proposed retirement village at Toukley.
Presentation (expert witness) in Land & Environment Court.

Assessment of impact on flora, fauna and fauna habitats of a proposed water and sewerage treatment works at Fern Bay, NSW.

Environmental Impact Statement of a proposed Titanium-mining operation near Stockton, NSW.

Assessment of impact on fauna of proposed Titanium-mining at Nabiac, NSW.

Review of fauna survey and report for proposed forestry operations in north coastal NSW.

Review of fauna surveys and assessment of impact on fauna of proposed development at North Bonville, NSW.

Monitoring of the impacts of a Titanium-mining operation on the Queensland Blossom Bat, and recolonisation of mined land by fauna at Saltwater, NSW.
Ongoing.

Assessment of impact on fauna and fauna habitats of a proposed mining operation near Mt Isa, western Queensland.

Preliminary assessment of impact on fauna and fauna habitats of a proposed tourist development on the Murray River, near Albury, NSW.

Assessment of impact on fauna and fauna habitats of a proposed power transmission line between Lismore and Mullumbimby, NSW.

1993 continued

Fauna and flora surveys; assessment of impacts of a proposed subdivision at Dural, NSW.

Fauna and flora surveys and assessment of impacts of a proposed Telecom repeater tower in Ku-ring-gai Chase National Park, NSW.

Assessment of impact on fauna of a proposed subdivision at Avalon, Sydney.
Preparation of evidence for presentation (expert witness) in Land & Environment Court.

Submissions on native fauna to a Commonwealth Commission of Inquiry on the Shoalwater Bay Area, Queensland.
Expert evidence presented to the Commission of Inquiry.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats of a proposed major bypass road at Bangor, western Sydney.

Assessment of impact on vegetation, native fauna and fauna habitats of further road widening along the Great Western Highway, Linden.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats of road widening at Picton, NSW.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats of a realignment of the New England Highway near Murrurundi.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats and heritage values of a proposed rail deviation at Banyabba.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats for the proposed expansion of a piggery near Scone, NSW.

Fauna survey and assessment of a proposed dwelling on land near Wyong, NSW. Expert witness in the NSW Land & Environment Court.

Review of Environmental Factors for vegetation disturbance in the eastern portion of the St Mary's site.

Assessment of the potential impacts of a proposed walking track on Dobroyd Head, Sydney Harbour National Park, NSW.

1994

Ongoing:

Monitoring of Queensland Blossom Bat at Saltwater.

Monitoring of Eastern Chestnut Mouse at Viney Creek.

Monitoring of Platypus around Pindari Dam.

Monitoring rainforest rehabilitation at Crescent Head.

Management of wildlife and vegetation issues at St Marys.

Assessment of the potential impacts on fauna and flora of a proposed urban development at Pennant Hills, including a Bushland Management Plan.

Environmental assessment of a water supply augmentation scheme at Tumbarumba in southern NSW.

Fauna surveys on a potential coal mine extension in the Hunter Valley.

Fauna surveys and impact assessment on a proposed quarry at Hartley, NSW.

Review of Fauna Impact Statement - Crown Land, Pambula.

1994 continued

Review of Fauna Impact Statement - development at Taree.

Fauna surveys and impact assessment on a proposed residential subdivision site at Byron Bay, NSW.

Assessment of impact on fauna and fauna habitats of a proposed mining operation near Mt Isa, western Queensland.

Impact assessment on native fauna for a proposed helipad at Arcadia, NSW.
Report preparation and expert witness in the Land & Environment Court.

Assessment of significance for native fauna of a proposed development at City Hill, Coffs Harbour.

Survey of native fauna and flora and assessment of potential impacts of a housing development at Stonequarry Creek, Picton.

Development of a Management Plan for a population of Green & Golden Bell Frogs at Rosebery, NSW.

Assessment of the potential impacts on vegetation, native fauna and fauna habitats of the Albury-Wodonga bypass along the Hume Highway.

Urban development design to accommodate fauna issues, and preparation of a Fauna Impact Statement - North Bonville, NSW.

Impact assessment on native fauna and flora of proposed road widening, Eternity Corner, the Putty Road.

Impact assessment on native fauna and flora of proposed road widening and safety ramp on the Putty Road.

Fauna and flora surveys and impact assessment on 2 proposed residential subdivision sites at Blaxland, NSW.
Report preparation and expert witness in the Land & Environment Court.

Survey of native fauna and flora and assessment of potential impacts of expansion of the Mount Thorley Coal Loader, NSW.

Assessment of potential impacts on fauna and flora of proposed additional extraction at a limestone mine at Marulan, NSW.

Fauna and flora surveys and impact assessment on a proposed residential subdivision sites at Blaxland, NSW.
Report preparation and expert witness in the Land & Environment Court.

Fauna and flora surveys and impact assessment on a proposed tourist and golf course development at Cattai, NSW.

Assessment of impacts on fauna and on flooding of quarrying operations and horse training facilities at Muskoka Farm, Gunderman, NSW.
Statement of Evidence for the NSW Land & Environment Court.

Assessment of the potential impacts on native fauna and fauna habitats for a proposed Gold Mine Prospect at Lake Cowal, NSW.

Fauna and flora assessment for a proposed Grafton water supply pipeline.

Fauna and flora surveys and assessment of a proposed quarry at Jugiong, NSW.

Impact assessment on native fauna and flora of a proposed quarry at Windellama, NSW.

Fauna Impact Statement for a proposed Golf Course at Pambula - Merimbula.

1994 continued

Assessment of potential impacts on fauna and flora of continuing operations at the limestone mine at Marulan, NSW.

Assessment of potential impacts on fauna and fauna habitats of the construction of a transmission line between Lismore and Mullumbimby, NSW.

Independent report and input into Environmental Impact Statement.

Preparation of the Fauna Impact Statement for a transmission line between Lismore and Mullumbimby, NSW.

Monitoring of the effects of discharges from Windamere Dam on Platypus populations in the Cudgegong River and the storage.

Consideration of the fauna and flora issues, and assessment of the potential impacts, for a proposed urban development at South Dural, Sydney.

Management of disturbance to vegetation for site investigation and decontamination at the St Mary's facility.
Proceeding.

Survey and assessment of vegetation at the St Mary's facility

Assessment of potential impacts on fauna and fauna habitats of a proposed deviation of the Pacific Highway north of Raleigh near Coffs Harbour.

Fauna and flora surveys, and preparation of an Environmental Audit and Environmental Management Plan at the Myambat Logistics Co, Denman, NSW.

Assessment of the potential impacts on flora and fauna of a mining operation at Hillgrove, NSW.

1995

Ongoing:

Monitoring of Queensland Blossom Bat at Saltwater.

Monitoring of Eastern Chestnut Mouse at Viney Creek.

Monitoring of Platypus around Pindari Dam.

Monitoring of Platypus around Windamere Dam.

Monitoring rainforest rehabilitation at Crescent Head.

Management of wildlife and vegetation issues at St Marys.

Fauna and flora surveys and reports for a horse and pony trail in Ku-ring-gai Chase National Park, Sydney.

Fauna monitoring for the construction of the M2 Motorway in Sydney. Pre-clearing and clearing stages

Survey and tracking of the Squirrel Glider at Lake Macquarie (Caves Beach), and preparation of a Fauna Impact Statement.

Impacts of a proposed development at Byron Bay on endangered fauna: preparation of Statement of Evidence, appearance as expert witness in the Land & Environment Court.

Environmental Assessment Report for fauna and flora - North Boambee Valley urban release project.

Koala Management Plan - North Boambee Valley, Coffs Harbour.

1995 continued

Assessment of the potential impacts on flora and fauna of a proposed reconstruction of Delhi Road, between the Crematorium and the CSIRO Riverside Park.

Review of environmental factors and potential fauna impacts of proposed reservoir and aqueduct re-painting in Northern Sydney.

Preparation of the Fauna Impact Statement for existing and future operations of two Sand Mining Plants in the Tomago Sandbeds.

Fauna Impact Statement for a proposed deviation of the Pacific Highway north of Raleigh near Coffs Harbour.

Preparation of the Fauna Impact Statement for existing and future operations of a Sand Mining Plants at Hawks Nest.

Assessment of the flora and fauna issues for an extraction site, Canoelands, including assessment of SEPP 44.

Preparation of A Fauna Impact Statement for residential development, Salamander Way.

Preparation of the Fauna Impact Statement for a proposed Gold Mine Prospect at Lake Cowal, NSW.

Assessment of the fauna issues for a proposed dam on the Perry River, QLD.

Fauna and flora investigations for the upgrading of Elizabeth Drive (access to Badgerys Creek Airport). Input into Elizabeth Drive Environmental Impact Statement.

Fauna and flora investigations for the Western Sydney Orbital - Prestons to Cecil Park. Input into Environmental Impact Statement for National Highway - Western Sydney Orbital.

Fauna and flora investigations for the Western Sydney Orbital - Cecil Park to West Baulkham Hills. Input into Environmental Impact Statement for National Highway - Western Sydney Orbital.

Fauna survey and impact assessment for a residential subdivision at Waterfall, including assessment of SEPP 44.

Assessment of the flora and fauna issues for a proposed development site, Padstow.

Fauna and flora investigations for a residential subdivision, Menai.

Assessment of the flora and fauna issues for a residential subdivision, Kellyville.

Fauna and flora investigations for a proposed coal washery reject emplacement site, Maddens Plains.

Fauna and flora investigations for the upgrade of the Federal Highway between Sutton, NSW and North Canberra, ACT.

Fauna and flora investigations for the upgrade of a sewerage treatment plant, Morpeth.

Fauna investigations for a proposed deviation of Main Road #84, Binalong NSW.

Fauna investigations for a proposed golf course re-development, Katoomba, including assessment of SEPP 44.

Fauna investigations for a proposed residential subdivision, Yarramundi, Coffs Harbour, including assessment of SEPP 44.

Assessment of fauna issues for the Newington RANAD site, Sydney.

SEPP 44 Assessment Report for proposed residential development sites and associated drainage lines, Casula.

SEPP 44 Assessment Report for proposed residential development sites, Dural.

1995 continued

SEPP 44 Assessment Report for a proposed golf course extension, Pambula-Merimbula.

SEPP 44 Assessment Report for a proposed subdivision, Cawdor.

SEPP 44 Assessment Report for a proposed residential development, Hoxton Park.

SEPP 44 Assessment Report for a proposed residential development, Carnes Hill.

Fauna and flora assessment for the Holsworthy Sewerage Scheme Transfer Environmental Impact Statement.

Flora and fauna assessment for a Development Control Plan, Kings Beach, Tweed Shire.

Flora and fauna assessment for the proposed Queanbeyan Bypass, ACT.

Fauna and flora assessment for a proposed residential development Palmtrees Nursery site, North Bonville.

Assessment of impact on fauna and fauna habitats of a proposed mining operation near Bundaberg, Queensland.

Assessment of impact on fauna and fauna habitats of a proposed quarry extension near Coffs Harbour.

Fauna and flora assessment for two proposed residential developments at Castle Hill.

Tree inspections for two proposed residential developments at Castle Hill.

Fauna Impact Assessment for a proposed tailings dam near Parkes, NSW.

Fauna and flora assessment for a proposed mine extension in the Hunter Valley, including SEPP44 assessment.

Review of information and preparation of a fauna and flora assessment report for inclusion in a Local Environmental Plan for Seven Mile Beach, NSW.

Assessment of impacts of a proposed residential development at Brooklyn on the Red-crowned Toadlet.

Assessment of impacts on fauna and flora for a proposed gas pipeline from Wodonga to Wagga Wagga, NSW.

Assessment of impact on fauna, flora and hydrology of a proposed quarry extension at Wyong, NSW.
Preparation of evidence for presentation (expert witness) in Land & Environment Court.

Assessment of the potential impact on Koalas of a proposed residential development on Lady Belmore Drive, Coffs Harbour, NSW.

Assessment of impact on fauna of a proposed bus depot at St Ives, Sydney.
Preparation of evidence for presentation (expert witness) in Land & Environment Court.

Assessment of impact on fauna of a proposed residential subdivision at Suffolk Park, Byron Bay.
Preparation of evidence for presentation (expert witness) in Land & Environment Court.

Fauna Assessment for a proposed sandmine at Fullerton.

1996

Ongoing:

Management of the Rosebery Green & Golden Bell Frog Population.

Monitoring of Queensland Blossom Bat at Saltwater.

1996 continued

Monitoring of Eastern Chestnut Mouse at Viney Creek.

Monitoring of Platypus around Pindari Dam.

Monitoring of Platypus around Windamere Dam.

Monitoring rainforest rehabilitation at Crescent Head.

Management of wildlife and vegetation issues at St Marys.

Flora and Fauna Assessment for a proposed rezoning for residential development at Castle Hill, Sydney.

Flora and Fauna Assessment for a proposed residential/recreational estate at Rossmore Park, Bathurst, NSW.

Flora and Fauna Assessment for a proposed deviation in the Albury to Australian Newspaper Mill 132KV transmission line.

Flora and Fauna Assessment for a proposed deviation in the Albury-Hume 132KV transmission line.

Assessment of Flora and Fauna issues for a proposed hospital site at Newports Creek, Coffs Harbour, NSW.

Flora and Fauna Assessment for an Environmental Impact Statement on the Basalt Hill Quarry, Kulnura.

Flora and Fauna Assessment for 'The Glades' housing development, West Pennant Hills, NSW.

Investigation of flora and fauna issues for the proposed Federal Highway upgrade and re-alignment.

Vegetation and Fauna Habitat Assessment Report for a proposed road widening at Abbott Road, Seven Hills.

Fauna and Fauna Habitat Assessment Report for the Eastlink Transmission Line from Armidale (NSW) to Springdale (QLD).

Fauna and Flora Assessment Report for a proposed convention centre and tourism development on the Kurnell Peninsula, North Cronulla.

Sewerage overflow licensing project - assessment of the significance of impacts on fauna and flora, and measures to ameliorate them.

Investigations of flora and fauna issues and consequent impacts of development site at Rosebery Road, Kellyville.

Investigations of flora and fauna issues and consequent impacts of development site at Green Road, Kellyville.

Environmental Management Plan for the subdivisions at Rosebery Road and Green Road, Kellyville.

Investigations of flora and fauna issues and consequent impacts of development at Poole Road, Kellyville.

Flora and Fauna issues, and consequent biological constraints on proposed development at Myall St, Teagardens.

Flora and Fauna Impact Assessment at Kings Beach, including a SEPP44 Assessment and Koala Management Plan and Section 5A Assessment.

Species Impact Assessment for a residential and tourist development at Kings Beach, Tweed Shire.

1996 continued

Post-clearing fauna monitoring for the construction of the M2 Motorway in Sydney.

Assessment of flora and fauna issues for proposed expansion of the Raleigh bypass of the Pacific Highway.

Assessment of impacts on flora and fauna of a proposed Telstra communications tower, near Mt Victoria.

Assessment of impacts on flora and fauna of a proposed residential development at Queanbeyan.

SEPP 44 Assessment Report for a proposed residential development site at Bonville, near Coffs Harbour.

Fauna and Flora Assessment Report for proposed residential development at Valla Beach, south of Coffs Harbour.

Assessment of impacts on flora and fauna of a proposed water storage facility for a mining operation near Helensburgh.

SEPP 44 Assessment Report for a proposed development site, Glenfield.

Preparation of a Species Impact Statement for the proposed Federal Highway upgrade between Sutton, NSW and North Canberra, ACT.

Fauna and flora investigations for proposed flood mitigation works for the Western Sydney Orbital - Prestons to Cecil Park.

Assessment of impacts on flora and fauna of a proposed transmission line from Forbes to Lake Cowal, NSW.

Review of an Environmental Impact Statement and Fauna Impact Statement for the F3 Motorway, northern end.

Assessment of flora and fauna issues for a proposed residential development site at Bonville, near Coffs Harbour.

Impact assessment on native fauna for existing and future operations of a mineral sand mining operation in the Tomago Sandbeds. Report preparation and expert witness in the Land & Environment Court.

Consideration of the potential impacts on the Green & Golden Bell Frog of a proposed development at Botany.
Report preparation and expert witness in the Land & Environment Court.

Assessment of the flora and fauna issues for a proposed development site along the foreshores of the Georges River at Padstow.
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for a proposed bridge over the Lachlan River at Willanthry, NSW.

Flora and Fauna Assessment for a proposed gravel quarry near Hillston, NSW.

SEPP 44 Assessment Report for a proposed development site, Prestons.

Survey and Mapping of Threatened Flora at the ADI facility at St Marys.

Assessment of flora and fauna issues for a proposed subdivision at Chisholm Ave, Avalon.

Assessment and Review of Potential Impacts of a proposed residential subdivision at North Boambee Valley, Coffs Harbour.

Impacts on flora and fauna issues of a proposed development site at Killcare.
Report preparation and expert witness in the Land & Environment Court.

1996 continued

Review of a Rural Land Study Report prepared by Hornsby Shire Council.

Assessment of flora and fauna issues for a proposed mining operation at the North Parkes Mine.

Assessment of Impacts of soil fill on Flora and Fauna.

Flora and Fauna Assessment for a proposed subdivision at Barina Downs Road, Baulkham Hills.

Flora and Fauna Assessment for a proposed subdivision of Lots 1, 2 & 12, Castle Hill.

Flora and Fauna Assessment for a proposed industrial development at Menai.

Assessment of flora and fauna issues for extensions to the existing Warnervale Airport.

Assessment of flora and fauna issues for a proposed bypass of the Bruxner Highway at Alstonville.

Impact on Flora and Fauna of a proposed Subdivision at Frenchs Forest.
Report preparation and expert witness in the Land & Environment Court.

Impact on Flora and Fauna of a proposed Subdivision at Kurrajong.
Report preparation and expert witness in the Land & Environment Court.

Development of Planning Strategies and Management Concepts for the Olympic Village Site.

Impacts of a proposed driveway on Flora and Fauna, Avalon.
Report preparation and expert witness in the Land & Environment Court.

Effects on Flora and Fauna of a proposed subdivision at South Dural.
Report preparation and expert witness in the Land & Environment Court.

Flora and Fauna Assessment for a proposed site for a telecommunications tower at Ourimbah.

Flora and Fauna Assessment for a proposed quarry at Central Bucca near Coffs Harbour.

Flora and Fauna Assessment for a proposed industrial development at Park Hill Road, Minchinbury

Flora and Fauna Assessment for a proposed site for a telecommunications tower at Jannali.

Fauna survey of a proposed Chemical Plant at Botany.

Fuel Reduction Zone and Development Application at Merrilyne Ave, West Pennant Hills.

Tree Assessment for a proposed school at Oakhurst.

Flora and Fauna Issues for the Strathfield Planning Strategy.

Consideration of Impacts on Green & Golden Bell Frogs at Botany.

Report preparation and expert witness in the Land & Environment Court.

Management Plan for the Plains Wanderer at Morundah.

Management Plan for Native Grasslands at Morundah.

Review of Environmental Factors for the proposed installation of a sewer pipeline at South Dural, including active management and replanting of *Hibbertia nitida*.

Review of Environmental Factors for proposed flood mitigation works at Middle Creek, Sawtell.

Flora and Fauna Assessment for a proposed residential development at Fern Bay.

1996 continued

Flora and Fauna Assessment for a proposed open cut coal mine at Kayuga, near Muswellbrook.

Flora and Fauna Assessment for a proposed Environmental Interpretive Centre near Ebor.

Flora and Fauna Assessment for proposed duplication of the Pacific Highway at Brunswick Heads.

Flora and Fauna Assessment for proposed Brunswick to Billinudgel re-alignment of the Pacific Highway.

Flora and Fauna Assessment for a proposed re-development at Walsh Bay, Sydney.

Flora and Fauna Assessment for a proposed development at Sawtell, NSW.

Flora and Fauna Assessment for a proposed subsidence area at Northparkes Mines, NSW.

Preparation of a Species Impact Statement for the proposed M5 Motorway.

Flora and Fauna Baseline Studies for a proposed mining operation, South Australia.

Assessment of the flora and fauna issues for the proposed St Patricks development site, Manly. Expert witness in the Land & Environment Court.

Review of existing data and preparation of a Fauna Impact Statement for a proposed development at Culburra.
Expert witness at the Culburra Commission of Inquiry.

Assessment of fauna and flora and preparation of a Species Impact Statement for a large development site at Kurnell, with design details for revegetation of the site and for the creation of habitat for the Green & Golden Bell Frog.

1997

Ongoing:

Management of the Rosebery Green & Golden Bell Frog Population.

Monitoring of Platypus around Pindari Dam.

Monitoring of Platypus around Windamere Dam.

Management of wildlife and vegetation issues at St Marys.

Monitoring of the Green & Golden Bell Frog population at North Cronulla.

Preparation of a Species Impact Statement for the Green & Golden Bell Frog and migratory birds for the proposed M5 East Motorway - Eve Street and Marsh Street Wetlands.

Flora and Fauna investigations for a Review of Environmental Factors for the proposed duplication of the Pacific Highway at Wang Wauk.

Flora and Fauna investigations for the Mungerie Park Town Centre Ecological Study.

Assessment of the flora and fauna issues for a proposed development at Cronulla (the North Cronulla Integrated resort).
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for modifications to coal preparation plant and transportation system at Bayswater, near Muswellbrook.

Flora and Fauna Assessment for a proposed under ground coal mine at Mandalong NSW.

1997 continued

Flora and Fauna Assessment for the proposed rezoning for residential development of the CSIRO Clunies Ross Research Station, Prospect.

Assessment of potential impacts on fauna and flora of continuing operations at a limestone mine at Marulan, NSW.

Flora and Fauna Assessment for a proposed environmental management plan at Cooranbong, near Morisset.

Flora and Fauna Assessment for a proposed underground coal mine and waste emplacement near Awaba, in the Newcastle Coalfields.

Flora and Fauna Assessment for the widening of the Great Western Highway between Weemala Ave and Martin Place, at Linden.

Flora and Fauna Assessment for proposed Telstra mobile phone base station at Mount Colah, NSW.

Fauna Assessment of proposed upgrade of the Illawarra Highway, east of Robertson, NSW.

Assessment of the flora and fauna issues on a site involving the removal of trees in contravention of a tree preservation order (Sutherland Shire).
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for proposed upgrade of the Pacific Highway between Raymond Terrace and Karuah.

Flora and Fauna Assessment for proposed upgrade of the Pacific Highway at Karuah.

Flora and Fauna Assessment of Residential Investigation Land at Blaxland, in the Lower Blue Mountains.

Assessment of the flora and fauna issues on a proposed development site at Woronora (Sutherland Shire).
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for proposed telecommunications tower at Mount Gingenbullen.

Flora and Fauna Assessment for proposed residential development Walco Drive, Coffs Harbour.

Platypus monitoring program for construction of Walla Weir on the Burnett River, Bundaberg, Qld.

Flora and Fauna Assessment for proposed hard rock quarry at Karuah.

Flora survey for a proposed residential development at Beech Road, Prestons.

SEPP 44 Assessment for proposed residential subdivision at Beech Road, Prestons.

Flora and Fauna Assessment for proposed rezoning for future development on Department of Defence land at Woolwich.

Assessment of the conservation values of waterfront land at Padstow.
Expert witness in the Land & Environment Court.

Assessment of the flora and fauna issues on a proposed development site at Cherrybrook (Hornsby Shire).
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for proposed residential subdivision at Highs Road, Castle Hill.

Flora and Fauna Assessment for proposed rezoning for residential subdivision at Harrington Park.

1997 continued

Flora and Fauna Assessment for proposed ventilation shaft at Dartbrook Underground Coal Mine at Muswellbrook.

Flora and Fauna Assessment for proposed tourist development in the Megalong Valley.

Flora and Fauna Assessment for Development Application for a proposed swimming pool at Merelynne Ave, West Pennant Hills.

Flora and Fauna Management Plan for proposed Eastern Distributor.

Flora and Fauna Investigation for proposed rezoning for residential development at Springwood.

Koala Issues - Initial Investigation for proposed Pacific Highway reconstruction at Korora Hill, Coffs Harbour.

Red-crowned Toadlet and Giant Burrowing Frog - Assessment of potential habitat for proposed residential development at Roseville.

Flora and Fauna Assessment for proposed residential development at Boldrewood Place, Cherrybrook.
Expert witness in the Land & Environment Court.

Assessment of the flora and fauna issues on a proposed development site at Avalon (Pittwater Shire).
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for Delhi Road upgrading and wet detention basin.

Flora and Fauna Habitat Assessment for proposed resort development at Kurrajong.

Flora and Fauna Assessment for proposed residential development at Darlington Drive, Cherrybrook.

Flora and Fauna Issues for proposed Suffolk Park development.

Flora and Fauna Assessment for proposed Evergreen Elderly Centre, Dural.

Assessment of Significance for Flora and Fauna Issues regarding the Pacific Highway re-alignment from Ewingsdale to Tyagarah.

Potential impacts on habitats of gliders for proposed Telstra Broadband Cabling in Pittwater.

Proposed frog habitat enhancement works for proposed resort at North Cronulla.

SEPP 44 Assessment for proposed residential development at Prestons.

Flora and Fauna Assessment for proposed container storage facility at Botany.
Expert witness in the Land & Environment Court.

Flora and Fauna Assessment for a proposed staged discharge dam and underground pipeline for Dartbrook Underground Coal Mine, near Muswellbrook.

Assessment of the conservation values of land resumed for a National Park on Box Head.
Expert witness in the Land & Environment Court.

Tree survey for a proposed residential development in Junction Road, Wahroonga.

Assessment of Significance for proposed dwellings on the St Patricks Estate at Manly.

Assessment of Significance for proposed aged housing and childcare proposal on the St Patricks Estate at Manly.

Fauna and Flora Issues report and Assessment of Significance for proposed aged housing and childcare project at St Patricks Estate, Manly.

1997 continued

Fauna and Flora Issues report and Assessment of Significance for proposed development on Precinct 2 of St Patricks Estate at Manly.

Submission to the National Parks and Wildlife Service for proposed developments on Precinct 2 of St Patricks Estate, Manly.

Assessment of Significance for a proposed children's hospice at St Patricks Estate at Manly.

Fauna & Flora Issues report and Assessment of Significance for a proposed residential development on Precinct 5 of St Patricks Estate at Manly.

Integrated Assessment of Significance for the Southern Precincts of St Patricks Estate at Manly.

Fauna and Flora Assessment and Residential Investigation Land Study for a residential development on the Great Western Highway at Blaxland in the Blue Mountains.

Fauna and Flora Issues report for a proposed rezoning and development at Delhi Road, North Ryde.

Fauna and Flora Assessment report for a proposed mobile phone base station on Mona Vale Road at Terrey Hills.

Fauna and Flora Issues report for a proposed Bellbird Retreat at Kurrajong Heights.

Tree Survey for proposed residential development of Nile Close, Marsfield.

Submission for Transgrid of a Review of the NSW Threatened Species Conservation Act 1995.

Supplementary Fauna and Flora Assessment report for a proposed tunnel access portal upgrade at Tunks Park, Cammeray.

Yellow-top Ash Assessment for a proposed access road upgrade at Scotts Creek, Castle Cove.

Supplementary Flora and Fauna Assessment for a proposed access road upgrade at Scotts Creek, Castle Cove.

Supplementary Red-crowned Toadlet Assessment for a proposed access road upgrade at Thorn Street, Hunters Hill.

Tree-hollow Report for a proposed access road upgrade at Scotts Creek, Castle Cove.

Fauna and Flora Assessment for a proposed rezoning of a Parking Lot at Rooty Hill RSL, Mt Druitt.

Fauna and Flora Assessment for a proposed subdivision and development of Smalls Creek at Kellyville.

Fauna Habitat Assessment for the proposed re-development of the NSW Conservatorium of Music.

Flying-fox Report for a proposed centacare development at St Paul's Street, Brigidine Convent, Randwick.

Fauna and Flora Assessment for a proposed subdivision on Molong Street at North Curl Curl.

Fauna and Flora Assessment report for a proposed new senior classroom at The Hills Grammar School in Kenthurst.

Fauna and flora Assessment report for a proposed mobile telephone base station on the Pacific Highway at Catherine Hill Bay.

Fauna and Flora Assessment for a proposed residential development on Nelson Bay Road, Fern Bay.

1997 continued

Fauna and Flora Assessment for a proposed residential development on Highfield Road at Quakers Hill.

Long-nosed Bandicoot Section 5A Assessment for a proposed construction of a garage and associated driveway, Manly.

Fauna and Flora Assessment report for a proposed rural residential development on Byrne's Run at Jamberoo.

Microchiropteran Bat Activity Survey for Sydney Water,

Fauna and Flora Assessment for a proposed development at Kenyons Road, Merrylands.

Design of a tree planting regime for a proposed development at Randwick.

Fauna and Flora Assessment for a proposed industrial subdivision at Pembroke Rd, Minto.

Fauna and Flora Assessment for a proposed development on Greenfield Road.

Management of *Grevillea caylei* for a proposed residential development at Oates Place, Belrose.

Report on Flying-foxes for a proposed Centacare development at St Pauls Street, Randwick.

Fauna and Flora Assessment for a proposed development at Erina.
Expert witness in the Land & Environment Court.

Interim Protection Order, Old Toongabbie.
Expert witness in the Land & Environment Court.

Assessment of Flora and Fauna Issues for a proposed rezoning of the Mater Dei property at Camden.

1998

Ongoing:

Management of the Rosebery Green & Golden Bell Frog Population.

Monitoring of Platypus around Pindari Dam.

Monitoring of Platypus around Windamere Dam.

Monitoring of Playtpus in the vicinity of Walla Weir on the Burnett River, Bundaberg, Qld.

Management of wildlife and vegetation issues at St Marys.

Monitoring of the Green & Golden Bell Frog population at North Cronulla.

State Environmental Planning Policy No 46 Assessment, Moree.
Expert witness in the Land & Environment Court.

Fauna and Flora Assessment for a proposed development at Bullaburra.

Vegetation and bushland mapping for Baulkham Hills Shire Council.

Flora and Fauna Investigations for proposed residential subdivision at Kurrajong and Cedar Roads, Prestons.

Flora & Fauna Assessment for proposed residential development at Knox Road, Glenmore Park.

Preliminary Conservation Assessment for proposed residential development at Glenmore Park.

1998 continued

Flora and Fauna Assessment for a proposed residential development at Warriewood Road, Warriewood.

Flora & Fauna Assessment for proposed residential development at O'Hares Road, Wedderburn.

Flora & Fauna Investigations for proposed rezoning at The Oaks Road, Camden.

Queensland Interconnection Flora Report, Section 5A Assessment of Significance and Flora and Fauna Habitat Report for the proposed transmission line between New South Wales and Queensland.

Fauna and Flora Assessment component of a Review of Environmental Factors, including supplementary fauna and flora surveys, for the proposed Pacific Highway Re-alignment at Warrell Creek.

Section 5A Assessment of Significance for a proposed swimming pool at Reddall Street in Manly.

Flora and Fauna Assessment for a proposed development and drainage line works at Matingara Way, Wallacia.

Flora & Fauna Assessment for proposed residential development at Smiths Lane, Glenorie.

Flora and Fauna Assessment Report for a proposed quarry and landfill site on Richmond Road at Marsden Park.

Flora and Fauna Assessment for a proposed subdivision of land on The Northern Road at Bringelly.

Natural Resources Database for the Fibre Optic Cable Placement at the Belrose and Oxford Falls Initial Assessment Area.

Natural Resources Database for the Fibre Optic Cable Placement at the Rosebery Initial Assessment Area.

Flora & Fauna Investigations and Reporting and SEPP 44 on a landfill site at Dartford Road in Thornleigh.

Supplementary fauna survey for the South Lemington Open Cut Mine Environmental Impact Statement.

Species Impact Statement for the St Patricks Estate Dwelling House on Lot 5, Fairy Bower Road at Manly.

Species Impact Statement for the St Patricks Estate Dwelling House on Lot 6, Fairy Bower Road at Manly.

Species Impact Statement for the St Patricks Estate Precinct 2 Apartments at Manly.

Species Impact Statement for the St Patricks Estate Precinct 2 Attached Dwellings at Manly.

Site Characteristics, Fauna & Flora Report and Response to the Statement of Issues of Hornsby Shire Council for a development and subdivision application on Malton Road and Hanover Road at North Epping.

Flora & Fauna Issues report for a proposed residential development of Kenyons Road, Merrylands.

Flora and Fauna Assessment for a proposed shopping complex, City of Armidale.

Flora and Fauna Assessment for a proposed Telstra mobile phone base station at Kentish Trig, Picton Road.

Flora and Fauna Assessment for a proposed Telstra mobile phone base station at Gheeger Trig, Picton Road.

1998 continued

Flora and Fauna Assessment for a proposed Telstra mobile phone base station at Letterbox Trig, Appin Road.

Flora and Fauna Issues for a proposed Telstra mobile phone base station at 'Option A' along Ku-ring-gai Chase Road.

Natural Resources Inventory of the Rosebery Preferred Route Option for the Southern Cross International Cable Fibre Optic Cable Placement.

Responses to Reports and Statement of Evidence in Reply for a development at Toongabbie. Expert Witness in the Land & Environment Court.

Statement of Evidence in Reply for a removal of sand overburden from a site on the Kurnell Peninsula.
Expert Witness in the Land & Environment Court.

Fauna and Flora Assessment report and Section 5A Assessment of Significance for the proposed demolition of the Balmain Power Station.

Green & Golden Bell Frog Survey for a former waste disposal depot at Lucas Heights.

Biological Constraints and Issues for the proposed Cherrywood Village site at Llandilo.

Preliminary assessment of development potential on CSR land at Masonite Road, Heatherbrae.

Statement of Evidence for a proposed Woolworths supermarket development at Round Corner, Dural.

Assessment on Cumberland Plain Woodland and of the Geographical Location of the site for the proposed Highlands Resort at Picton.

Fauna and Flora Assessment and a Section 5A Assessment of Significance for an installation of a 132kV transmission line from Tuggerah to Munmorah Substations.

Fauna and Flora Assessment for a proposed subdivision at Cobbitty.

Fauna and Flora Investigations for the Mt Annan Development Control Plan (DCP) of Camden Council.

Section 5A Assessment of Significance for a proposed modular home construction project on the ADI site at St Marys.

Tree Assessment for a proposed residential development on Longueville Road at Lane Cove.

Comission of Inquiry, Presentation of Fauna and Flora Issues and Expert Witness for the Cooranbong Colliery Life Extension project.

Fauna and Flora Assessment for a proposed residential subdivision on the Great Western Highway at Warrimoo.

Fauna and Flora Assessment for a proposed subdivision at Neville Court, Castle Hill.

Vegetation Management Plan with the Department of Land & Water Conservation and a Supplementary Fauna and Flora Assessment for a mine and associated tailings dam extensions at Hillgrove.

Survey for the Red-crowned Toadlet at the North Side Storage Tunnel Alliance in North Head.

Fauna Monitoring for the M2 Hills Motorway - Autumn/Winter.

Flora Monitoring for the M2 Hills Motorway.

Review of fauna and flora documents and a Fauna and Flora Issues report for rural and residential developments at Hallidays Point

1998 continued

Statement of Evidence for a proposed residential development at Milray Avenue, Wollstonecraft. Expert Witness in the Land & Environment Court.

Flora and Fauna Assessment for a proposed residential subdivision at Hudson Parade, Clareville.

Flora and Fauna Assessment for a proposed residential subdivision at the Armenian School, Kellyville.

Supplementary Reporting for a proposed development at Valla Beach.

Public Hearing and Expert Witness for Environment and Planning regarding the Blue Mountains Draft Local Environmental Plan 1997 at St Columbas in Springwood.

Section 5A Assessment of Significance on Cumberland Plain Woodland for a proposed relocation of a drainage channel at the Bells Creek Tributary on Jersey Road, Plumpton.

Fauna and Flora Assessment for a proposed subdivision at Amaroo Park, Annangrove.

Flora and Fauna issues throughout the Camden Local Government Area for the Camden Structure Plan.

Flora and Fauna Assessment for a proposed new Grandstand and playing field at the St Marys Rugby League Club, St Marys.

Flora and Fauna Assessment for a proposed residential subdivision at Prince Alfred Parade, Newport.

Flora and Fauna Assessment for a proposed development at Macpherson St, Warriewood.

Flora and Fauna Assessment for a proposed temporary senior classroom at Xavier College, The Northern Road, Cranebrook.

Flora and Fauna Assessment for a proposed residential subdivision at Quakers Hill Parkway, Quakers Hill.

Flora and Fauna Assessment for a proposed residential subdivision at Windsor Road, Kellyville.

Flora Assessment for a proposed industrial development at Austlink Park, Belrose.

Flora Issues Report, including detailed consideration of *Grevillea caylei* at Austlink Park, Belrose.

Flora and Fauna Assessment for a proposed residential subdivision at Minmi Rd, Fletcher.

Creekline investigation report for the Dixon Sands Maroota North operations.

Flora and Fauna constraints for the proposed sand extraction on Old Northern Road, Maroota,

Flora and Fauna Assessment for a proposed sand extraction from a crown land road reserve at Maroota.

Threatened orchid survey through the Wyong Shire for Wyong Shire Council, involving GIS mapping.

CURRICULUM VITAE

JAYNE M TIPPING **BSc(Zoology) University of Sydney**

10/26 Morden St Cammeray NSW 2062
phone: (H) 02 - 9955 6019 (W) 02 - 9906 5436
email: gecon@gunninah.com.au

DATE of BIRTH :

18th December 1968

ACADEMIC QUALIFICATIONS :

1987-90 University of Sydney, Faculty of Science.
Bachelor of Science:

Terrestrial Vertebrates & Terrestrial Ecology.
Marine Biology & Botany.
Animal Physiology.

1995-97 Master of Environmental Law.
University of Sydney, Faculty of Law.

EMPLOYMENT HISTORY :

1992 Science Assistant at West Port High School, Port Macquarie. Temporary position.

1992-1994 Graduate Assistant at Gunninah Consultants Pty Ltd. Involvement in all projects conducted by Gunninah Consultants.

1995-1996 Senior Environmental Consultant at Gunninah Consultants Pty Ltd. Responsibilities including project management, field surveys, interpretation and implementation of relevant environmental legislation, liaison with clients and project managers, the preparation and writing of reports including Flora and Fauna surveys, Species Impact Statements, Review of Environmental Factor Reports and Environmental Impact Statements *etc*.

RELEVANT EXPERIENCE and EXPERTISE :

FIELD EXPERIENCE :

1989-1992 Volunteer assistant for numerous field surveys and studies on native fauna in NSW (including work with Koalas, microchiropteran bats, foxes, small mammals, avifauna and herpetofauna).

1992-1996 Participation in Gunninah Consultants field work in NSW and Qld. Involvement in fauna and flora surveys, habitat evaluation and environmental monitoring investigations.

VOLUNTEER WORK :

1989-1992 Volunteer assistant for numerous field surveys and studies on native fauna in NSW (including work with Koalas, microchiropteran bats, foxes, small mammals, avifauna and herpetofauna).

1990 Live capture, mark and release of small mammals in Ku-ring-gai Chase NP. Description of habitat and microhabitat components for a habitat selection investigation.

VOLUNTEER WORK contd:

1991 Treatment and care of injured Koalas at the Koala Hospital Port Macquarie.

Ground survey of small carnivorous marsupial and native rodent fauna in the Blue Mountains. Insect pitfall trapping and subsequent identification and data collation. Blue Mountains National Park ACT.

Mist-netting of insectivorous Blossom Bats; live capture, mark and release. NSW North Coast.

1992 Live capture, processing and release of small mammals, Blue Mountains.

Live capture and release of foxes using snare traps and exploding net guns. Spotlighting surveys of arboreal fauna; ground and aerial radiotracking of foxes. Scat identification; hairtube and sand trap sampling techniques. Data collation and analysis. Namadgi National Park ACT.

CONSULTANCIES :

1992-1996 Research, preparation and writing of reports for Gunninah Consultants including many of the consultancy reports listed in the *Projects List* for Gunninah Consultants from 1992.

Included below are a selection of projects completed or in preparation, with which I have been involved:

Management Plans & Species Monitoring under Planning or EFIP requirements.

Monitoring of the impacts of a Titanium-mining operation on the Queensland Blossom Bat, and recolonisation of mined land by fauna at Saltwater, NSW.
Ongoing: for Mineral Deposits Ltd.

Monitoring of the impacts of a Titanium-mining operation on the Eastern Chestnut Mouse, and recolonisation of mined land by fauna, Hawks Nest, NSW.
Ongoing: for Mineral Deposits Ltd.

Monitoring of Platypus populations above and below a major dam expansion project in northern NSW, at Pindari Dam near Inverell.
Ongoing: for the department of Land and Water Conservation.

Monitoring responses of Platypus populations to increased flows from Windamere Dam near Mudgee.
Ongoing: for the department of Land and Water Conservation.

Fauna/Flora studies for Environmental Impact Statements.

Fauna surveys and impact assessment on a proposed quarry at Hartley, NSW.
Prepared for Hartley Pastoral Co and Sinclair Knight Merz.

Assessment of impact on fauna and fauna habitats of a proposed mining operation near Mt Isa, western Queensland.
Prepared for Placer Explorations Ltd, Sydney.

Assessment of impact on fauna and fauna habitats of a proposed dam and mining operation near Bundaberg, Queensland.
Prepared for Placer Explorations Ltd, Sydney.

Assessment of impact on fauna and fauna habitats of the proposed Western Sydney Orbital-Cecil park to West Baulkham Hills.
In preparation for Sinclair Knight Merz, Sydney and the NSW RTA.

Assessment of potential impacts on fauna and fauna habitats of the construction of a transmission line between Lismore and Mullumbimby, NSW.
Prepared for Sinclair Knight Merz and Pacific Power.

Fauna Impact Statements:

Fauna Impact Statement for a proposed Golf Course at Pambula-Merimbula.
Prepared for Pambula - Merimbula Golf Club Limited.

Fauna Impact Statement for a proposed residential development near Salamander Bay.
Prepared for Salamander Projects.

Preparation of the Fauna Impact Statement for a transmission line between Lismore and Mullumbimby, NSW.
Prepared for Sinclair Knight Merz and Pacific Power.

Fauna Impact Statement for a proposed residential development near Salamander Bay.
Prepared for Salamander Projects.

Fauna Impact Statement for a proposed development at North Bonville, Coffs Harbour.
Prepared for GHD, Coffs Harbour.

Species Impact Statements

Preparation of a Species Impact Statement for the proposed Federal Highway, ACT.
In preparation for for Ove Arup, Canberra.

CURRICULUM VITAE

Amelia M Hurren **BSc. Grad. Dip. Env. Stu.**

6/80 Bent St, Neutral Bay, NSW, 2089
ph: 02 9904 4465 (h) 02 - 9906 5436 (w)

DATE OF BIRTH

25th January 1973

ACADEMIC QUALIFICATIONS :

1990-94 University of Adelaide - Bachelor of Science majored in Botany and Zoology.

1995 Macquarie University - Post-graduate Diploma in Environmental Studies Subjects included Environmental Law, Environmental Policy and Field Based Problems and Analysis.

1997 University of Sydney (Continuing Education) - Flora of the Sydney Region.

EMPLOYMENT HISTORY :

November 1996 to present
Gunninah Environmental Consultants - Project Manager

Responsibilities include project management, site inspections and field surveys, application of relevant environmental legislation (including the *NSW Threatened Species Conservation Act 1995* and *NSW Environmental Planning & Assessment Act 1979*, and State Environmental Planning Policies - SEPPs), liaison with clients, participation in planning workshops, preparation of proposals, research, compilation and interpretation of data, writing of reports including Flora and Fauna surveys, Species Impact Statements and Review of Environmental Factor Reports.

March to November 1996
Gunninah Environmental Consultants - Research Assistant

Responsibilities included research and compilation of data, data interpretation and input into report writing, preparation of maps, figures and appendices, editing reports, general office duties.

March 1994 - Feb 1995

Childcare worker (South Australia):
Mitcham Hills Out of School Hours Care;
Stirling Districts Out of School Hours Care.

FIELD EXPERIENCE

1993 Flora survey and investigation of plant survey techniques near Keith, in south-eastern South Australia;

1994 Investigation of the palatability of chenopods to sheep at Middleback Station, north of Whyalla;

FIELD EXPERIENCE continued

Assessment of the age structure and health of Western Myall trees north of Whyalla;

Studies of wetland communities at Bool Lagoon in south-eastern South Australia, including plant survey techniques, soil sampling, community dynamics and plant physiology.

Analysis and monitoring of water quality, including nutrients and invertebrate identification, of the Finniss River near Meadows, South Australia;

Experiments in Plant Physiology and community dynamics at Coonamore Station, southwest of Broken Hill

1995 Studies of field techniques, including flora and fauna surveying, water quality and marine issues at Jervis Bay;

1996 Assistant for trapping and tagging of Platypus at Pindari Dam, north of Inverell. Gunninah Environmental Consultants.

1997 Frog and Bat Training Course, Wild Cattle Creek State Forest, north of Dorrigo. State Forests of NSW.

General fauna surveys for projects in the Sydney Basin, Blue Mountains, Central Coast and Hunter Region for Gunninah Environmental Consultants.

1998 Assistant for trapping and tagging of Platypus in the Burnett River, Bundaberg, QLD. Gunninah Environmental Consultants.

Opportunistic and transect-based bird surveys along the Burnett River, Bundaberg, QLD. Gunninah Environmental Consultants.

Site Assessment and opportunistic bird surveys at a proposed in situ leach uranium mine site, near Arkaroola, Flinders Ranges, SA. Gunninah Environmental Consultants.

General fauna surveys for projects in the Sydney Basin, Blue Mountains, Central Coast and Hunter Region for Gunninah Environmental Consultants.

VOLUNTEER ACTIVITIES

1995/1996	Bat counting at the Gordon Bat Colony Ku-ring-gai Friends of Bats.
1997-current	Homebush Bay Bird Monitoring Project Birds Australia
1997	Regent Honeyeater Survey in the Capertee Valley Regent Honeyeater Recovery Team and the Cumberland Bird Observers Club

MEMBERSHIPS

Frog & Tadpole Study Group of NSW Pty Ltd
Birds Australia

RECENT PROJECT MANAGEMENT EXPERIENCE:

Flora & Fauna Assessments

Flora and Fauna Assessment for an Environmental Impact Statement on the Basalt Hill Quarry, Kulnura, including SEPP 44 Assessment.

Flora and Fauna Assessment for a proposed residential development at Fern Bay, including SEPP 44 Assessment.

Flora and Fauna Assessment for a proposed open cut coal mine at Kayuga, near Muswellbrook.

Flora & Fauna Assessments contd

Flora and Fauna Assessment and Commission of Inquiry for proposed underground coal mine and associated waste emplacement in the Mandalong Valley, near Morisset.

Flora and Fauna Assessment for a coal preparation plant and transportation system at Bayswater Colliery, in the Hunter Valley.

Flora and Fauna Assessment for the proposed widening of the Great Western Highway, Linden Bends, Blue Mountains.

Flora and Fauna Assessment for a proposed ventilation shaft at Dartbrook Underground Coal Mine, near Muswellbrook.

Flora and Fauna Assessment for a proposed staged discharge dam and underground pipeline at Dartbrook Underground Coal Mine, near Muswellbrook.

Flora and Fauna Assessment for a proposed underground coal mine and waste emplacement site at Awaba, near Lake Macquarie.

Flora and Fauna Assessment for a proposed quarry and landfill at Marsden Park, in Western Sydney.

SEPP 44 Assessments

SEPP 44 Assessment Report for a proposed development site, Glenfield.

SEPP 44 Assessment Report for a proposed residential development, Beech Road, Prestons.

Review of Environmental Factors

Review of Environmental Factors for the proposed installation of a sewer pipeline at South Dural.

Review of Environmental Factors for proposed flood mitigation works at Middle Creek, Sawtell.

Review of Environmental Factors for proposed rezoning of St Columba's site at Springwood, in the Blue Mountains.

Management Plans & Monitoring

Management Plan for the Plains Wanderer at Morundah.

Management and replanting of *Hibbertia nitida* at Dural.

Flora and Fauna Assessment and advice for a proposed Environmental Management Plan at Cooranbong Colliery, near Morisset.

Management of *Tetratheca juncea* and *Acacia bynoeana* in the Lake Macquarie area.

Monitoring and Management of Platypus in the Burnett River, Bundaberg, QLD.

Species Impact Statements

SIS for *Tetratheca juncea* and the Squirrel Glider at a proposed underground coal mine waste emplacement near Toronto, in the Lower Hunter Region.

SIS for the Proposed Brunswick Bypass Duplication and Pacific Highway Upgrade between Brunswick and Yelgun, on the NSW North Coast.

CURRICULUM VITAE

MATTHEW ALEXANDER CHAMBERS

31 Carrington Street
Maitland NSW 2320

ph: 024934 3670

DATE OF BIRTH

5th May 1971

ACADEMIC QUALIFICATIONS :

1993-95 Southern Cross University Lismore NSW
Bachelor of Applied Science - Conservation Technology

EMPLOYMENT HISTORY :

1992-5 Casual Laboratory Assistant (HEW Level 3) at Southern Cross University

1993 Casual Research Assistant (HEW Level 5) at Southern Cross University

RELATIVE EXPERIENCE :

1986 Voluntary Field Assistant; bird banding, Brisbane Waters National Park for Australian Museum.

1986 Field Assistant; Cave Surveyor, Jenolan Caves, Kanangra Boyd National Park.

1987 Voluntary Field Assistant, Cave Surveyor, Nullarbor Plains, SA.

1987 Voluntary Field Assistant; Cave Surveyor, Moro Gorge National Park, SA.

1991 Voluntary Field Assistant; Effects of Habitat Fragmentation on Rodents in the Big Scrub Remnants.

1992 Voluntary Field Assistant; Chromosomal Identification of *Rattus tunneyi* in the Bundjalung National Park.

1993 Voluntary Field Assistant; Ecology of *R. tunneyi* in the Bundjalung National Park.

1993 Field Assistant; Genetic Variability in the Bristlebird, *Dasyornis* sp.

1994 Field Assistant; Home Range and Ecology of *R. tunneyi* in the Bundjalung National Park (In progress).

1994 Lab Assistant; Genetic Phylogeny of Australian Wrens (In progress).

Fauna Assessment

Baverstock, P.R. and Chambers, M.A. 1993. Comprehensive Fauna Impact Statement for the Northern Ridges, Goonellabah. UNE-NR for Lismore City Council.

Baverstock, P.R. 1993. Fauna Assessment of Proposed Subdivision of Lot 3 in DP 259918 - Ashby. For Gulaptis & Smith Pty Ltd Consulting Surveyors, (assisted in Fauna Survey).

Baverstock, P.R. 1993. Fauna Assessment of Proposed Subdivision of Lots 1, 2, 3 & 4 in DP 37957 - Ashby. For Gulaptis & Smith Pty Ltd Consulting Surveyors, (assisted in Fauna Survey).

Chambers, M.A. 1991. Vertebrate Fauna Survey of the Boyd Property, Evans Head. UNE-NR for NPWS, Alstonville Office and Helen Boyd.

Fauna Assessment contd:

Chambers, M.A. 1991. Vertebrate Fauna Survey for Bundjalung National Park. UNE-NR for NPWS, Alstonville Office.

Chambers, M.A. 1991. Vertebrate Fauna Survey of Banyabba Nature Reserve. UNE-NR for NPWS, Grafton Office.

Chambers, M.A. 1992. Aquatic Vertebrate Fauna Survey of Sportsman's Creek, Banyabba Nature Reserve. UNE-NR for Dept. Agriculture, Fisheries Division.

Baverstock, P.R. and Chambers, M.A. 1992. Murwillumbah Bat Survey. UNE-NR for Forestry Commission of NSW.

Chambers, M.A. 1993. Field Identification of *Melomys* on the North Coast of New South Wales. UNE-NR Integrated Project. (To be published).

Chambers, M.A. 1994. Rodents in Cane Fields of the Broadwater Mill Area. For Broadwater Mill Co-operative. (In progress).

Fauna field surveys conducted for the following Gunninah Environmental Consultants Projects :

1994

Monitoring of Queensland Blossom Bat at Saltwater (Mineral Deposits Ltd).

Impact assessment on a proposed residential subdivision site at Byron Bay, NSW.

Urban development design to accommodate fauna issues, and preparation of a Fauna Impact Statement - North Bonville, NSW.

Native fauna and flora and assessment of potential impacts of expansion of the Mount Thorley Coal Loader, NSW.

Preparation of the Fauna Impact Statement for a transmission line between Lismore and Mullumbimby, NSW.

Assessment of potential impacts on fauna and fauna habitats of a proposed deviation of the Pacific Highway north of Raleigh near Coffs Harbour.

Fauna and flora surveys, and preparation of an Environmental Audit and Environmental Management Plan at the Myambat Logistics Co, Denman, NSW.

Assessment of the potential impacts on flora and fauna of a mining operation at Hillgrove, NSW.

1995

Monitoring of fauna for the construction of the M2 Motorway in Sydney.

Fauna and flora surveys and impact assessment on a proposed tourist and golf course development at Cattai, NSW.

Management Plan for fauna and flora - North Boambee valley urban release project.

Koala Management Plan - North Boambee Valley, Coffs Harbour.

Preparation of the Fauna Impact Statement for existing and future operations of two Sand Mining Plants in the Tomago Sandbeds.

Fauna Impact Statement for a proposed deviation of the Pacific Highway north of Raleigh near Coffs Harbour.

Preparation of the Fauna Impact Statement for a residential development, Salamander Way.

Fauna investigations for a proposed golf course re-development, Katoomba, including assessment of SEPP 44.

1995 contd:

Fauna investigations for a proposed residential subdivision, Yarramundi, Coffs Harbour, including assessment of SEPP 44.

Fauna Assessment for a proposed sandmine at Fullerton.

1996

Post clearing fauna monitoring for the construction of the M2 - Motorway in Sydney.

Flora and Fauna Assessment for an Environmental Impact Statement on the Basalt Hill Quarry, Kulnara.

Flora and Fauna Assessment for "The Glades" housing development, West Pennant Hills, NSW.

Flora and Fauna Habitat Assessment for the Eastlink Transmission Line from Armidale (NSW) to Springdale (QLD).

Flora and Fauna Assessment Report for a proposed convention centre and tourism development on the Kurnell Penninsula, North Cronulla.

Investigations of fauna and flora issues and consequent impacts of developments an two sites at Roseberry Road, Kellyville.

Investigations of fauna and flora issues fro a subdivision on Poole Road, Kellyville.

Investigations of fauna and flora issues and consequent impacts of a subdivision in Gumnut Close, Kellyville.

Flora and Fauna Impact Assessment at Kings Beach, Kingscliff, including a SEPP 44 Assessment and Koala Management Plan and Section 5a Assessment.

Flora and Fauna Assessment for a proposed upgrade of the under construction Pacific Highway Raleigh Bypass.

Flora and Fauna Assessment and SEPP 44 Assessment of a proposed residential development at Bonville, Coffs Harbour.

Flora and Fauna Assessment for a proposed residential development at Valla Beach, Coffs Harbour.

Flora and Fauna Assessment for the upgrade of the Lachland Highway, and bridge over the Lachlan River at Willanthry.

Flora and Fauna Assessment for a proposed gravel extraction quarry near Hillston.

Flora and Fauna Assessment for a proposed subdivision at Chisholm Ave, Avalon.

Assessment and review of potential impacts of a proposed residential subdivision at North Boambee Valley, Coffs Harbour.

Impacts on flora and fauna of a proposed development site at Kilcare.

Assessment of fauna and flora issues for proposed mining operations at North Parkes Mine.

Flora and Fauna Assessment for a proposed subdivision at Barina Downs Road, Baulkham Hills.

Flora and Fauna Assessment for a proposed subdivision of Lots 1,2 &12 Castle Hill.

Flora and Fauna Assessment for a proposed site for a telecommunications tower at Ourimbah.

Flora and Fauna Assessment for a proposed industrial development at Menai.

Flora and Fauna Assessment for a proposed quarry at Central Bucca near Coffs Harbour.

1996 contd:

Flora and Fauna Assessment for a proposed industrial development at Park Hill Road, Minchinbury.

Flora and Fauna Assessment for a proposed site for a telecommunications tower at Jennali.

Fuel reduction zone and development application at Merrilynne Way, West Pennant Hills.

Flora and Fauna Assessment for a proposed residential development at Fern Bay, Newcastle.

Flora and Fauna Assessment for a proposed open cut mine at Kyuga, Muswellbrook.

Flora and Fauna Assessment for a proposed environmental interpretive centre near Ebor.

Flora and Fauna Assessment for a proposed redevelopment at Walsh Bay, Sydney.

Flora and Fauna Assessment for a proposed upgrade and realignment of the Pacific Highway between Billinudgel and Brunswick Heads.

Flora and Fauna Assessment for a proposed residential development at Sawtell, NSW.

Flora and Fauna Assessment for a proposed subsidence area at North Parkes Mines, NSW.

Flora and Fauna Assessment for a proposed coal washery and waste emplacement at Dartbrook Coal Handling and Processing Plant, Muswellbrook.

1997

Fauna Monitoring during clearing operations at RZM Plant 6, Tomago Sand Beds, Raymond Terrace.

Monitoring and removal of the Green and Gold Bell Frog at a development site at Roseberry.

Flora and Fauna Assessment for an upgrade of the Pacific Highway at Wang Wauk.

Flora and Fauna Assessment for modifications to coal preparation plant, Bayswater Coal Mine.

Flora and Fauna Assessment for the conveyor belt route from Bayswater Coal Mine to Howick Coal Loader, Muswellbrook.

Flora and Fauna Assessment for a proposed underground coal mine at Cooranbong.

Flora and Fauna Assessment for the proposed rezoning for residential development of the CSIRO Clunies Ross Research Station, Prospect.

Assessment of the potential impacts on fauna and flora of continuing operations at a limestone mine at Marulan, NSW.

Flora and Fauna Assessment for the proposed upgrade and bypass of the Bruxner Highway, Alstonville.

Flora and Fauna Assessment for a proposed underground coal mine at Awaba, Newcastle.

Flora and Fauna Assessment for the proposed upgrade of the Pacific Highway between Raymond Terrace and Karuah.

Flora and Fauna Assessment for an environmental management plan at Cooranbong Underground Coal Mine.

Flora and Fauna Assessment for a proposed waste emplacement at Newstan Underground Coal Mine, Toronto.

Flora and Fauna Assessment for a proposed haul road at Cooranbong Underground Coal Mine.

Flora and Fauna Assessment for the proposed upgrade of the Pacific Highway at Karuah.

1997 contd:

Flora and Fauna Assessment of Residential Investigation Land at Springwood, in the Lower Blue Mountains.

Flora and Fauna Assessment for a proposed residential development Walco Drive, Coffs Harbour.

Flora and Fauna Assessment for a proposed hard rock quarry at Karuah.

Flora and Fauna Assessment for a proposed residential subdivision at Highs Road, Castle Hill.

Flora and Fauna Assessment for a proposed ventilation shaft at Dartbrook Underground Coal Mine, Muswellbrook.

Flora and Fauna Assessment for a Development Application for a swimming pool at Merelynne Way, West Pennant Hills.

Flora and Fauna Assessment for a proposed dam at Dartbrook Underground Coal Mine, Muswellbrook.

Flora and Fauna Assessment for upgrade of the Pacific Highway at Warrell Creek.

Assessment of koala population and road management strategy at Korora Hill, Coffs Harbour.

Flora and Fauna Assessment of the proposed upgrade and bypass of the Princess Highway between Ulladulla and Milton.

Flora and Fauna Investigation for proposed rezoning for residential development at Springwood.

Assessment of the flora and fauna issues on a proposed development site at Avalon (Pittwater Shire).

Flora and Fauna Habitat Assessment for proposed resort development at Kurrajong.

Assessment of Significance for Flora and Fauna Issues regarding the Pacific Highway re-alignment from Ewingsdale to Tyagarah.

Flora and Fauna Assessment for a proposed staged discharge dam and underground pipeline for Dartbrook Underground Coal Mine, near Muswellbrook.

Assessment of the conservation values of land resumed for a National Park on Box Head.

Assessment of Significance for proposed aged housing and childcare proposal on the St Patricks Estate at Manly.

Fauna and Flora Issues report for a proposed Bellbird Retreat at Kurrajong Heights.

Fauna and Flora Assessment for a proposed residential development on Nelson Bay Road, Fern Bay.

1998

Flora and Fauna Assessment for the Species Impact Statement for the St Patricks Estate at Manly.

Statement of Evidence in Reply for a removal of sand overburden from a site on the Kurnell Peninsula.

Green & Golden Bell Frog Survey for a former waste disposal depot at Lucas Heights.

Fauna and Flora Assessment and a Section 5A Assessment of Significance for an installation of a 132kV transmission line from Tuggerah to Munmorah Substations.

1998 contd:

Fauna and Flora Assessment for a proposed residential subdivision on the Great Western Highway at Warrimoo.

Vegetation Management Plan with the Department of Land & Water Conservation and a Supplementary Fauna and Flora Assessment for a mine and associated tailings dam extensions at Hillgrove.

Fauna and Flora Assessment for a proposed subdivision at Amaroo Park, Annangrove.

CURRICULUM VITAE

ANNE MAREE CAREY

31 Carrington Street
Maitland NSW 2320

ph: 024934 3670

DATE OF BIRTH

26th October 1965

ACADEMIC QUALIFICATIONS :

1994 - current	Undergraduate at Macquarie University Enrolled as external student in Bachelor of Science (Ecology and Biodiversity majors).

EMPLOYMENT HISTORY :

1994-1997	Field Biologist Contracted to NPWS to conduct radio-tracking of koalas in the Port Stephens LGA together with recording tree measurements and animal data, catching koalas and transporting to veterinary surgeons, various field trials, vegetation mapping and assessment and database management.
1995-current	Field Biologist. Contracted to Ishta Consultants to monitor the effect of the Raymond Terrace bypass on koala movements .
1996	Education Campaign Design educational material ,liaise with media and implement community education campaign on "Living with koalas in the Wild" focussing on responsible pet ownership and habitat loss as part of an Environmental Trust Grant to the Tilligerry Habitat Centre, Port Stephens Council and the Hunter Koala Preservation Society.
1998-current	Data analysis for the Iluka Koala Studies Program - NSW NPWS.
1995-current	Field Biologist. Contracted to Gunninah Consultants for Fauna Surveys listed below.

Fauna field surveys conducted for the following Gunninah Environmental Consultants Projects:

1995

Fauna Monitoring for the clearing operations on the RZM Plant 6 Mine, Raymond Terrace.

Fauna Report for: Koala Management Plan - North Boambee Valley, Coffs Harbour.

1996 contd:

Fauna Report for: Preparation of a Fauna Impact Statement for existing and future operations of two sand mines in the Tomago Sand Beds.

1996

Fauna Report for: Flora and Fauna Assessment for an Environmental Impact Statement on the Basalt Hill Quarry, Kulnara.

Fauna Report for: Flora and Fauna Assessment and SEPP 44 Assessment of a proposed residential development at Bonville, Coffs Harbour.

Fauna Report for: Flora and Fauna Assessment for a proposed quarry at Central Bucca near Coffs Harbour.

Fauna Report for: Flora and Fauna Assessment for a proposed coal washery and waste emplacement at Dartbrook Coal Handling and Processing Plant, Muswellbrook.

1997

Fauna Monitoring during clearing operations at RZM Plant 6, Tomago Sand Beds, Raymond Terrace.

Flora and Fauna Assessment for an upgrade of the Pacific Highway at Wang Wauk.

Flora and Fauna Assessment for modifications to coal preparation plant, Bayswater Coal Mine.

Flora and Fauna Assessment for the conveyor belt route from Bayswater Coal Mine to Howick Coal Loader, Muswellbrook.

Flora and Fauna Assessment for a proposed underground coal mine at Cooranbong.

Assessment of the potential impacts on fauna and flora of continuing operations at a limestone mine at Marulan, NSW.

Flora and Fauna Assessment for the proposed upgrade and bypass of the Bruxner Highway, Alstonville.

Flora and Fauna Assessment for a proposed underground coal mine at Awaba, Newcastle.

Flora and Fauna Assessment for the proposed upgrade of the Pacific Highway between Raymond Terrace and Karuah.

Flora and Fauna Assessment for an environmental management plan at Cooranbong Underground Coal Mine.

Flora and Fauna Assessment for a proposed waste emplacement at Newstan Underground Coal Mine, Toronto.

Flora and Fauna Assessment for a proposed haul road at Cooranbong Underground Coal Mine.

Flora and Fauna Assessment for the proposed upgrade of the Pacific Highway at Karuah.

Flora and Fauna Assessment of Residential Investigation Land at Springwood, in the Lower Blue Mountains.

Flora and Fauna Assessment for a proposed hard rock quarry at Karuah.

Flora and Fauna Assessment for a proposed residential subdivision at Highs Road, Castle Hill.

Flora and Fauna Assessment for a proposed ventilation shaft at Dartbrook Underground Coal Mine, Muswellbrook.

1997 contd:

Flora and Fauna Assessment for a Development Application for a swimming pool at Merelynne Way, West Pennant Hills.

Flora and Fauna Assessment for a proposed dam at Dartbrook Underground Coal Mine, Muswellbrook.

Flora and Fauna Assessment for upgrade of the Pacific Highway at Warrell Creek.

Assessment of koala population and road management strategy at Korora Hill, Coffs Harbour.

Flora and Fauna Assessment of the proposed upgrade and bypass of the Princess Highway between Ulladulla and Milton.

Flora and Fauna Investigation for proposed rezoning for residential development at Springwood.

Assessment of the flora and fauna issues on a proposed development site at Avalon (Pittwater Shire).

Flora and Fauna Habitat Assessment for proposed resort development at Kurrajong.

Assessment of Significance for Flora and Fauna Issues regarding the Pacific Highway re-alignment from Ewingsdale to Tyagarah.

Flora and Fauna Assessment for a proposed staged discharge dam and underground pipeline for Dartbrook Underground Coal Mine, near Muswellbrook.

Assessment of the conservation values of land resumed for a National Park on Box Head.

Assessment of Significance for proposed aged housing and childcare proposal on the St Patricks Estate at Manly.

Fauna and Flora Issues report for a proposed Bellbird Retreat at Kurrajong Heights.

1998

Flora and Fauna Assessment for the Species Impact Statement for the St Patricks Estate at Manly.

Statement of Evidence in Reply for a removal of sand overburden from a site on the Kurnell Peninsula.

Green & Golden Bell Frog Survey for a former waste disposal depot at Lucas Heights.

Fauna and Flora Assessment and a Section 5A Assessment of Significance for an installation of a 132kV transmission line from Tuggerah to Munmorah Substations.
Fauna and Flora Assessment for a proposed residential subdivision on the Great Western Highway at Warrimoo.

Fauna and Flora Assessment for a proposed subdivision at Amaroo Park, Annangrove.

SPECIAL INTERESTS AND EXPERTISE:

Identification and assessment of SEPP44 koala habitat, eucalypt vegetation mapping, identification, ecology and biology of herptofauna and koalas. Identification of wildlife species under field conditions utilising survey techniques/technology available.

VOLUNTEER EXPERIENCE:

Senior herptofauna co-ordinator for the NATF(7 years)- including relocation and care of all dangerously venomous snakes. Koala rescuer-including relocation and retrieval of vulnerable or injured koalas. General rescuer and carer of all species.

CURRICULUM VITAE

STEVEN CHAMBERLAIN

16 Pacific Crescent,
Maianbar NSW 2230

ph: 02 9544 3941

ACADEMIC QUALIFICATIONS :

1994-current	Associate Diploma Applied Science - Southern Sydney Institute of TAFE.
1993	Certificate of Arboriculture - Southern Sydney Institute of TAFE

EMPLOYMENT HISTORY :

5 years of Environmental Consulting.

Employed by three environmental consultancies

Responsibilities as a flora surveyor and has focused mainly on NSW coast from Wollongong to Coffs Harbour

Has undertaken extensive flora survey work in Western New South Wales

Duties in these capacities include:

- literature searches in preparation for surveys;
- the interpretation of aerial photographs and maps;
- preparation of reports and species lists;
- the interpretation of cadastral, topographic and orthophoto maps;
- mapping vegetation communities;
- assessment of soil mapping in preparation for vegetation mapping;
- researching database information on rare or endangered flora species; and
- interpretation of satellite imagery for vegetation mapping.

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS :

Australian Defence Industries, St Mary's

Vegetation survey at Donaldson Mine Site, Maitland

Vegetation survey at Cooranbong Colliery, Central Coast

Vegetation survey at Mandalong Valley, Central Coast

Vegetation survey at Newstan Colliery, Central Coast

Flora survey for the Karuah Bypass (options 1-5)

Flora survey for Karuah to Raymond Terrace

RTA Pacific Highway widening of Wang Wauk to Bundacree Cr., North Coast

Flora survey for powerline upgrade at Tuggerah to Charmhaven

Administering of tree removal / protection protocols for the Eastern Distributor

Mapping and monitoring of rare / threatened species for upgrade of the Karuah Bypass, Central Coast

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS contd :

Mapping of vegetation communities along 120km stretch for upgrade of powerlines at Coffs Harbour to Kempsey for Transgrid Power

Vegetation mapping at Bayswater Colliery, Muswellbrook

Mapping and monitoring of rare / threatened species for widening of the Pacific Highway at Karuah to Raymond Terrace

Mapping of Duffy's Forest vegetation

Llandilo

Maroota Sand Extraction

Minmi Residential Proposal, Central Coast

Dungog

Charmhaven Substation

Lakehaven Retirement Village

Berkeley Vale

Kellyville waste management (Mungerie Creek)

mapping of Cumberland Plain vegetation, St Mary's RLFC, St Mary's

Cronulla Sewerage Treatment Plant

Extraction quarry, Marulan

Proposed residential development, New Line Rd., Dural.

CSIRO, Prospect.

Decorative Red Gravel Extraction Pit, Karuah.

The Glades, Pennant Hills.

Glen Rd., Pennant Hills.

Cattai Creek, Baulkham Hills.

Dartbrook Colliery, Muswellbrook

Green Road, Kellyville.

Rosebery Road, Kellyville.

Gravel extraction site, Hillston, far western NSW

Kurrajong Road, Prestons, Western Sydney.

Cedar Road, Prestons, Western Sydney.

Glenmore Park, Penrith.

Nile Close, Marsfield.

Dehli Road, Lane Cove.

Harrington Park.

New Line Road, Oakhurst.

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS contd :

Blaxland.

Springwood, including survey of threatened tree species

Warrimoo - widening of Great Western Highway

Nundah Place, Woronora.

Walsh Bay.

RELEVANT PROJECTS for GARY LEONARD, BOTANICAL and HORTICULTURAL CONSULTANT:

Cross pollination and bagging Vulnerable species - *Pomaderris brunnea* - for the Dept. Agriculture, Menangle and Sand Extraction Industry, Elderslie.

Vegetation survey of road easements for the Newell Highway corridor enhancement, from New South Wales to Victorian border, Western Plains and Slopes of NSW

Cumberland Plain vegetation mapping in Blacktown LGA

ROTAP search at proposed residential development - Turner Road, Berowra

Tree survey at proposed residential development - Thornleigh Presbytarian Church School.

Flora survey and threatened species searches at proposed residential development at Duncraig Estate, Baulkham Hills.

Flora survey at sand extraction pit, Springs Creek, Elderslie.

RELEVANT PROJECTS for OTHER CONSULTANTS:

Vegetation surveys at Illawarra State Recreation Area

Flora survey at Bathurst Agrodrome

Flora survey and threatened species searches at Woodcroft/PGH quarry, Woodcroft

Endangered species search and vegetation mapping at St Mary's, Ropes Creek Corridor

Endangered species search and vegetation mapping at Mulgrave

Tree survey and management plan at Nile Close, Marsfield

CURRICULUM VITAE

CLAIRE DE LACEY

16 Pacific Crescent,
Maianbar NSW 2230

ph: 02 9544 3941

ACADEMIC QUALIFICATIONS :

1997-current	Macquarie University - Bachelor of Science Zoology and Botany.
1991-94	TAFE Southern Sydney Institute - Associate Diploma of Applied Science (Landscape)

EMPLOYMENT HISTORY :

- 5 years of Environmental Consulting.
- Employed by three environmental consultancies
- Responsibilities as a flora surveyor and has focused mainly on NSW coast from Wollongong to Coffs Harbour.
- Compilation of profiles on Threatened species protected by the Threatened Species Conservation Act 1995.

Duties in these capacities include:

- literature searches in preparation for surveys;
- the interpretation of aerial photographs;
- the interpretation of cadastral, topographic and orthophoto maps;
- preparation of reports and species lists;
- mapping vegetation communities;
- assessment of soil mapping in preparation for vegetation mapping;
- researching database information on rare or endangered flora species; and
- interpretation of satellite imagery for vegetation mapping.

1996	Wollongong City Council. Undertook a contract involving the co-ordination of the construction of a sensory garden in Wollongong.

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS :

Australian Defence Industries, St Mary's

Vegetation survey at Donaldson Mine Site, Maitland

Vegetation survey at Cooranbong Colliery, Central Coast

Vegetation survey at Mandalong Valley, Central Coast

Vegetation survey at Newstan Colliery, Central Coast

Flora survey for the Karuah Bypass (options 1-5)

Flora survey for Karuah to Raymond Terrace

RTA Pacific Highway widening of Wang Wauk to Bundacree Cr., North Coast

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS contd :

Flora survey for powerline upgrade at Tuggerah to Charmhaven

Administering of tree removal / protection protocols for the Eastern Distributor

Mapping and monitoring of rare / threatened species for upgrade of the Karuah Bypass, Central Coast

Mapping and monitoring of rare / threatened species for widening of road at Highway Reserve between Parramatta and Nepean River

Mapping and monitoring of rare / threatened species for widening of the Pacific Highway at Karuah to Raymond Terrace

Mapping of Duffy's Forest vegetation

Llandilo

Maroota Sand Extraction

Minmi Residential Proposal, Central Coast

Dungog

Charmhaven Substation

Lakehaven Retirement Village

Berkeley Vale

Kellyville waste management (Mungerie Creek)

Department of Defence, Woolwich.

Cronulla Sewerage Treatment Plant

Warrell Creek, Pacific Highway upgrade, North Coast NSW.

Proposed residential development, New Line Rd., Dural.

CSIRO, Prospect.

Decorative Red Gravel Extraction Pit, Karuah.

The Glades, Pennant Hills.

Glen Rd., Pennant Hills.

Cattai Creek, Baulkham Hills.

Merelynne Ave., Castle Hill.

Green Road, Kellyville.

Rosebery Road, Kellyville.

Proposed section of M2 at Baulkham Hills.

Kurrajong Road, Prestons, Western Sydney.

Cedar Road, Prestons, Western Sydney.

Glenmore Park, Penrith.

New Line Road, Oakhurst.

Nile Close, Marsfield.

RELEVANT PROJECTS for GUNNINAH ENVIRONMENTAL CONSULTANTS contd :

Dehli Road, Lane Cove.

Harrington Park.

Retirement village, Kurrajong Heights.

Blaxland.

Springwood, including survey of threatened tree species

Warrimoo - widening of Great Western Highway

Nundah Place, Woronora.

Walsh Bay.

RELEVANT PROJECTS for GARY LEONARD, BOTANICAL and HORTICULTURAL CONSULTANT :

Cross pollination and bagging Vulnerable species - *Pomaderris brunnea* - for the Dept. Agriculture, Menangle and Sand Extraction Industry, Elderslie.

Flora survey for Lighthouse to Fairy Meadow Creek, Wollongong

Environmental audit for decommissioned mine sites at Kemira, Corrimal and Bulli

Flagging and reporting on the distribution of threatened species within road reserve at Ropes Creek, Western Sydney for the M4 Motorway

Tree survey and vegetation assessment in the Randwick Local Government Area (LGA)

Cumberland Plain vegetation mapping in Blacktown LGA

ROTAP search at proposed residential development - Turner Road, Berowra

Tree survey at proposed residential development - Thornleigh Presbytarian Church School.

Flora survey and threatened species searches at proposed residential development at Duncraig Estate, Baulkham Hills.

Flora survey at sand extraction pit, Springs Creek, Elderslie.

Flora survey at Hornsby open cast sandstone mine

Flora survey at Marulan open cast limestone mine

RELEVANT PROJECTS for OTHER CONSULTANTS:

Vegetation surveys at Illawarra State Recreation Area

Wetland design, planting schedule & maintenance program for the RTA at Elizabeth Drive, Bonnyrigg

Flora surveys for proposed residential development at Yarramundi

Tree survey at Crimea and Waterloo Roads, Marsfield

Endangered species search and vegetation mapping at St Mary's, Ropes Creek Corridor

Endangered species search and vegetation mapping at Mulgrave

Tree survey and management plan at Nile Close, Marsfield

Touchstone Sensory Garden

Thomas Dalton Park, Pioneer Road, Towradgi

OTHER

Member of Queensland State Emergency Service - Reg. No. 031002

Advanced Diver - Reg. No. AUA00729; Rescue Speciality Diver; Divemaster - Reg. No. DO2676