625.7113
PA.67.1
Vol. 2

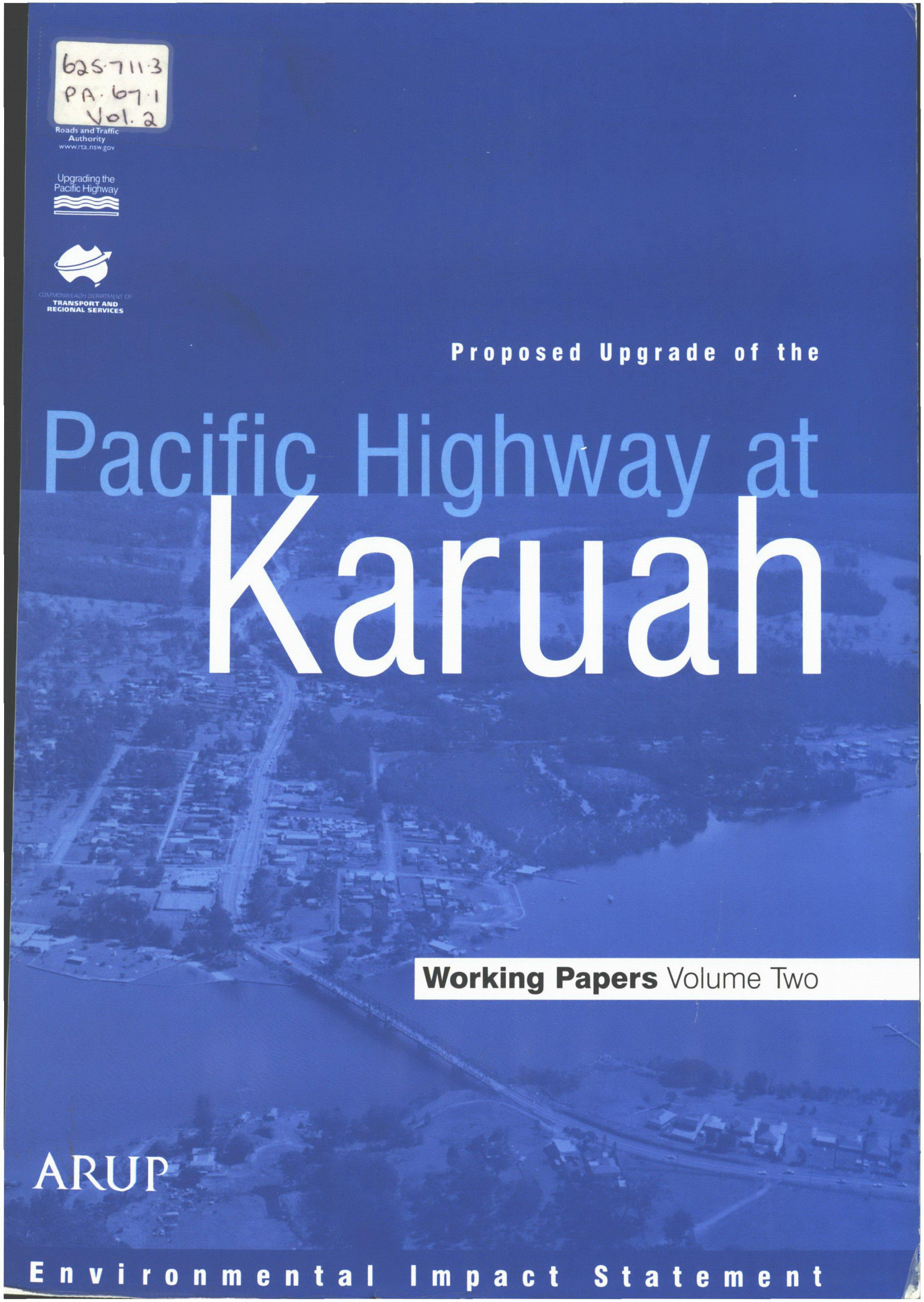
Roads and Traffic Authority
www.rta.nsw.gov

Upgrading the Pacific Highway

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Proposed Upgrade of the

Pacific Highway at Karuah



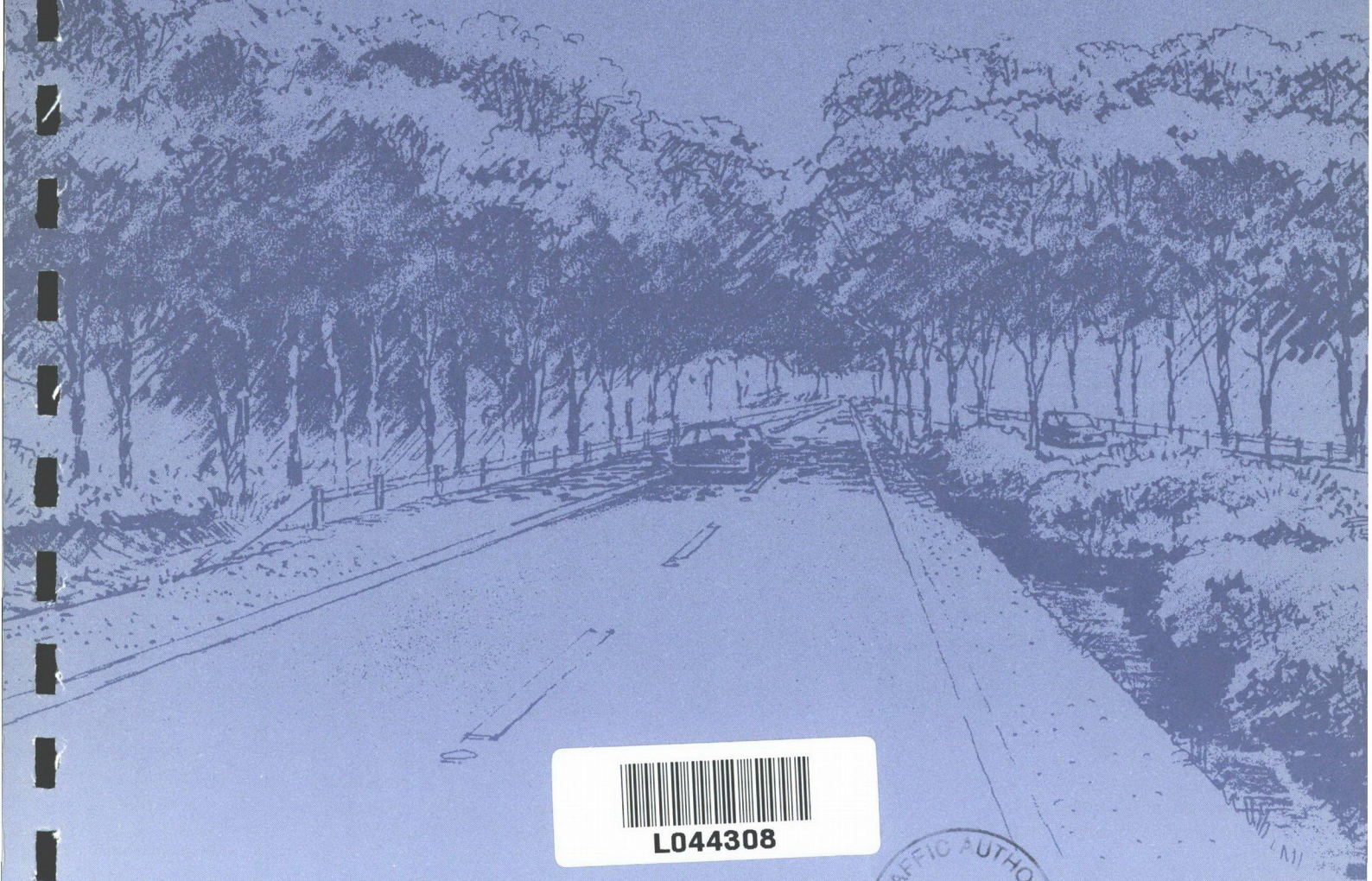
Working Papers Volume Two

ARUP

Environmental Impact Statement

7

Aquatic ecology and water quality



L044308

ROADS & TRAFFIC AUTHORITY
LIBRARY
Dec 99

Report to:

Ove Arup and Partners

Aquatic Investigations

For the Pacific Highway Upgrade at Karuah

FINAL

June 1999

Report prepared by:

The Ecology Lab Pty Ltd

25/28-34 Roseberry Street

Balgowlah, NSW

Australia 2093

Phone: (02) 9907-9399

Fax: (02) 9907-9386

E-mail: ecolab@ozemail.com.au

TABLE OF CONTENTS

SUMMARY I

Water Quality i
Wetland Habitats i
Fish and Mobile Invertebrates in the Karuah River ii
Fish and Mobile Invertebrates in Tidal Creeks iii
Recreational and Commercial Fishing iii

1.0 INTRODUCTION 1

1.1 Background and Aims 1
1.2 Review of Existing Information 1
1.2.1 Estuarine Habitats 1
1.2.2 Flora and Fauna 2
1.2.3 Fisheries 2
1.2.4 Water Quality 5

2.0 STUDY METHODS 7

2.1 Surveys and Observations of Mangrove and Saltmarsh Habitats 7
2.1.1 Sampling Sites and Methods 7
2.1.2 Data Analysis 8
2.2 Fish and Mobile Invertebrates 8
2.2.1 Sampling Sites and Methods 8
2.2.2 Data Analysis 9
2.3 Water Quality 10
2.3.1 Sampling Sites and Methods 10
2.3.2 Data Analysis 10

3.0 RESULTS 11

3.1 Descriptions of Surveyed Wetlands 11
3.1.1 Location 1 11
3.1.2 Location 2 11
3.1.3 Location 3 12
3.1.4 Location 4 12
3.2 Mangrove Forests 12
3.2.1 Existing Damage 12
3.2.2 Percent Cover along Transects 13
3.2.3 Flora and Fauna in Quadrats 13
3.3 Description of Other Habitats 14
3.3.1 Northern Tip of SEPP 14 No. 776 14
3.3.2 Northern Tip of SEPP 14 No. 777 14
3.4 Fish and Mobile Invertebrate Surveys 14
3.4.1 General Findings - Beach Seining 14
3.4.2 Analysis of Assemblages - Beach Seining 15
3.4.3 Analysis of Populations - Beach Seining 15
3.4.4 General Findings - Block Netting 16
3.5 Water Quality 17
3.5.1 Comparison to ANZECC Guidelines 17
3.5.2 Comparison among Sites and Depth 17
3.5.3 Quality Control 18

4.0 ADDITIONAL WATER QUALITY INFORMATION 19

4.1 Background and Aims 19
4.2 Study Methods 19
4.2.1 Description of Sampling Sites 19
4.3 Results 20
4.3.1 Comparison to ANZECC Guidelines 20
4.4 Discussion 21

5.0 ASSESSMENT OF IMPACTS 22

5.1 Description of Proposal 22
5.2 Impacts on the Saltmarsh Habitat 22
5.2.1 Impacts Due to Construction 22
5.2.3 Long-Term Impacts 23
5.3 Impacts on the Mangrove Habitat 23
5.3.1 Construction Impacts 23
5.3.2 Long-Term Impacts 24
5.4 Impacts on Fish, Mobile Invertebrates and Oysters 24

6.0 MITIGATION OF IMPACTS 26

6.1 Design Phase 26
6.2 Construction Phase 26
6.2.1 Construction Roads 26
6.2.2 Mitigation of Other Construction Impacts 27
6.3 Post-Construction Phase 27

7.0 RECOMMENDATIONS FOR MONITORING 28

8.0 ACKNOWLEDGEMENTS 30

9.0 REFERENCES 31

LIST OF TABLES

Table 1: Estimates of Commercial Fishing for the Karuah River.

Table 2: Categories of damage used to assess mangrove and saltmarsh habitats.

Table 3: Sampling locations and dates for wetlands survey, fish seine and block net samples and water quality samples.

Table 4: Percent of each category of mangrove components recorded from 3 locations adjacent to Karuah River.

Table 5: Global R values for multivariate analyses comparing assemblages within quadrats between sites and within locations for upper and lower portions of the transects.

Table 6: Mean abundance (&SE) of fish and mobile invertebrates caught in beach seines in Karuah River.

Table 7: Results of SIMPER analyses of assemblages of fish and mobile invertebrates caught seining, summarised as the taxa contributing most to the dissimilarity between sites.

Table 8: Results from ANOVAs on abundance of fish sampled at 4 locations within Karuah River.

Table 9: Fish caught in block nets in Karuah River.

Table 10: Mean (+/-SE) values for physico-chemical properties, nutrients and metals at Karuah.

Table 11: Sampling locations and general observations for additional water quality sites sampled 18 and 19 March, 1999. See Figure 1 for sampling locations.

Table 12: Mean values for water quality variables at additional sampling sites near Karuah. Samples taken on 18 and 19 March, 1999.

LIST OF FIGURES

Figure 1: Map of Karuah area showing sampling sites for wetlands, fish beach seines, fish block nets and water quality.

Figure 2: Profiles of saltmarsh vegetation along four transects near Horse Island.

Figure 3: Mean (+/-SE) of damage in 4 categories in transects at 4 locations.

Figure 4: 3-dimensional MDS plot of fish and mobile invertebrates caught in beach seine at four locations in the Karuah River.

Figure 5: 3-dimensional MDS plot of water quality variables from 8 locations in the Karuah River.

LIST OF APPENDICES

Appendix 1: Statistical Procedures used by The Ecology Lab for analysis of data.

Appendix 2: Mean (+/-SE) for field and laboratory data for mangrove quadrats.

Appendix 3: Results of ANOVAs on laboratory and field abundance data from mangrove quadrats.

SUMMARY

As part of the ten year Pacific Highway Upgrade Program, the RTA has commissioned Ove Arup and Partners to undertake the route selection studies, concept design and preparation of an environmental Impact Statement for the upgrade of the highway at Karuah. The selected route will pass to the west and north of the Karuah township, crossing the Karuah River at Horse Island. The selected route passes through several wetlands designated under State Environment Protection Policy (SEPP 14), and so requires that assessment is made of the likely impact of the highway on the nominated wetland habitats. These include extensive areas of saltmarsh and mangrove forests. The Ecology Lab Pty Ltd was commissioned by Ove Arup to undertake studies of the wetland and riverine ecosystem, assess the likely impact of the highway on those habitats and suggest ameliorative measures that may reduce the identified impacts.

The specific aims of this study were to:

1. Assemble and review the existing information on local wetland and riverine habitats and identify gaps in that information.
2. Undertake field surveys of flora and fauna within SEPP 14 wetlands that may be affected by the proposed road works.
3. Verify habitat characteristics at margins of protected areas that may be affected by proposed road works.
4. Identify the uses of wetland and riverine habitats by commercial and recreational fishers.
5. Undertake an assessment of impacts.
6. Identify measures at the planning, construction and follow-up stages that may ameliorate the identified impacts.

Field sampling was done in November 1998, January and March 1999 using a combination of qualitative and quantitative sampling techniques. Because very little information was available on the flora and fauna of mangrove and saltmarsh habitats in the areas, the study focused on characterising these habitats, particularly with the aim of assessing their condition. Another focus was the characterisation of communities of fish and invertebrates in the Karuah River and in the tidal creeks that drain into the river.

Water Quality

Existing information on water quality identified levels of phosphorus in some sections of the that exceeded recommended limits. Upstream, releases from the Stroud sewage treatment plant and livestock wastes were identified as potential sources of water quality problems. Further downstream, effluent from the now decommissioned effluent ponds within the Reedy Creek catchment may be a source of phosphorus. Results from this study indicate higher than recommended levels of phosphate at some locations but, overall, water quality appeared to be within guidelines applicable to estuarine waters. While there were no indications that run-off from acid sulphate soils affected water quality, there was visual evidence acid sulphate soils in one location. The monitoring of water quality during construction is recommended, focusing on levels of turbidity and pH. Also recommended is a specific and targeted water and sediment sampling programme to quantify the extent of potential acid sulphate soils. After construction, the efficacy of run-off control measures should be evaluated after rainfall events of various intensity. The monitoring of water quality for heavy metals and oil and grease typically present in run-off from roads is recommended.

Wetland Habitats

No previous studies on the biota of wetland habitats in Karuah River near Horse Island were found. Surveys for this study indicated that the saltmarsh and mangrove habitats were in good condition, with minimal damage due to human activities. The communities present were representative of geographical area and occurred in reasonable abundance. There appear to be no differences in assemblages of mangrove flora and fauna among the habitats sampled. However, there were differences in the abundance some components of the biota between locations. No species of threatened or endangered plants or animals were found.

Construction and long term impacts due to bridge construction were identified for saltmarsh and mangrove forests directly in the path of the proposed bridge. The main long term impacts would be the loss of habitat in the positions of bridge piles. Other long-term impacts include shading by the road bridge of the saltmarsh and mangrove habitats, although the height of the bridges would minimise this effect. Lack of existing information on the effects of shading by artificial structures on wetland plants hampers a precise estimate of the magnitude of this effect. Construction impacts include damage to wetlands due to vehicle access and an increase in turbidity in adjacent creeks and the river. Other impacts include small-scale changes in the distribution of biota due to the altered flow of water around bridge piles.

Recommendations for mitigation include the use of the longest possible bridge spans over the wetland habitats to minimise the number of piles required. Piles should be located away from creek banks to avoid disturbances that would degrade the creeks as fish habitats and to maintain water quality. During construction, the movement of heavy machinery across the saltmarsh should be restricted to roads constructed for that purpose. The construction road should include culverts to avoid damage to creek banks and retain creek function during construction. Silt curtains or other retention devices should be used to avoid the movement of sediment into the creeks and river. Spoil from pile excavations should not be disposed of in the water, and its sulphate content should be determined when considering the appropriate method for its disposal. Stockpiles of building materials should be bunded to avoid run-off into wetland habitats.

Post construction mitigation measures include returning the surface of the saltmarsh and mangrove forest to its original level and replacing retained surface sediments. Re-leveling of the wetland surface should aim to eliminate small-scale depressions and elevations which would hamper recolonisation by plants and animals. RTA is understood to be undertaking further studies into the issue of compensation for the wetland area lost permanently due to the presence of the road bridge.

Monitoring of wetlands during construction is recommended to ensure compliance with the environmental management plan. Post-construction monitoring should assess mangrove and saltmarsh condition and focus on recovery of wetland communities and the quantification of the effects, if any , of shading from the road bridge.

Fish and Mobile Invertebrates in the Karuah River

No previous studies were found on the community of fish and mobile invertebrates in the Karuah River near Horse Island. Results from this study showed that the fish assemblage caught in seine nets in the Karuah River was diverse and featured 13 species of economic importance. Their distribution within the stretch of river sampled (from Horse Island in the north to north of the existing road bridge at Karuah) showed differences from north to south, a pattern consistent with the overall pattern of salinity in the river. There were differences in the abundance of commercially important prawns, but another commercially important species, flat-tailed mullet, showed no differences in abundance among locations.

The construction of bridge piles may cause a temporary increase in the turbidity of the water which fish and mobile invertebrates are likely to avoid. The monitoring of fish and mobile invertebrates using non-destructive techniques is recommended after construction is complete.

Fish and Mobile Invertebrates in Tidal Creeks

The small creeks that drain saltmarsh and mangrove habitats are used by fish and mobile invertebrates, including 12 species of fish and 3 species of invertebrates of economic importance. The creeks near Horse Island had the most species, individuals and species of economic importance of the creeks sampled. No threatened or endangered fish species were caught, and are considered unlikely to be present. Loss or degradation of the creeks as fish habitats would be likely to affect the local fish community by reducing numbers of fish and/or the composition of the fish community. Such changes may to have consequences on the larger fish community in Port Stephens, but lack of appropriate data make it difficult to estimate the magnitude of the effect.

Measures recommended to avoid the degradation or loss of fish habitats are listed in the section on wetland habitats above.

Recreational and Commercial Fishing

Very little information was available about recreational fishing within Karuah River and in particular within the area near Horse Island. Personnel from NSW Fisheries Officers at Port Stephens suggested that the species typically targeted in the river were bream and flathead throughout the river, Australian bass in the upper reaches and sometimes mulloway adjacent to the existing highway bridge and in the deep holes thought to exist adjacent to 'the bend' near Horse Island. No data are available for estimating the economic value of the recreational fishing industry in the area. Apart from a temporary increase in turbidity during the construction of piles, the road bridge is likely to have little effect on the recreational fishing industry. The use of silt curtains or other retention devices to limit turbidity is recommended.

The most common commercial fishing activities in the area near the proposed road bridge include mesh netting, eel trapping crab trapping and oyster cultivation. Statistics on the economic value of the finfish portion of commercial fisheries are not separable from data for Port Stephens as a whole due to data recording procedures used by NSW Fisheries. Port Stephens is ranked fifth in the state in terms of volume and value of finfish landed, estimated to be worth $1,365,301 in the 1992/1993 financial year, the most recent period for which data are available.

There are just over 400 oyster leases within Karuah River, covering an area of over 3.5km^2. Karuah consistently produces just under 2% of the State's total Sydney rock oyster production. Oyster cultivation in the Karuah River was worth $447, 608 in the 1996/97 fiscal year. The impact of the construction of the road bridge near Horse Island on the oyster leases would include a temporary increase in turbidity, which may cause the oyster to cease feeding for some period of time. The use of silt curtains or other retention devices during pile construction is recommended to mitigate this impact. Long term impacts on oyster leases would depend on the location of the piles with respect to the oyster leases. If the position of the piles is such that the eddies around them erode the bottom or the bank and increase local turbidity on a permanent basis, the leases affected may be unviable and will require relocation.

1.0 INTRODUCTION

1.1 Background and Aims

As part of the ten year Pacific Highway Upgrade Program, the RTA has commissioned Ove Arup and Partners to undertake the route selection studies, concept design and preparation of an environmental Impact Statement for the upgrade of the highway at Karuah. The selected route will pass to the west and north of the Karuah township, crossing the Karuah River at Horse Island. The selected route passes through several wetlands designated under the State Environment Protection Policy (SEPP 14), and so requires that assessment be made of the likely impact of the highway on the nominated wetland habitats (Figure 1). These include extensive areas of saltmarsh and mangrove forests. The Ecology Lab Pty Ltd was commissioned by Ove Arup to undertake studies of the wetland and riverine ecosystem, assess the likely impact of the highway on those habitats and suggest ameliorative measures that may reduce the identified impacts.

The specific aims of this study were to:

1. Assemble and review the existing information on local wetland and riverine habitats and identify gaps in that information,
2. Undertake field surveys of flora and fauna within SEPP 14 wetlands that may be affected by the proposed road works,
3. Verify habitat characteristics at margins of protected areas that may be affected by proposed road works,
4. Identify the uses of wetland and riverine habitats by commercial and recreational fishers,
5. Undertake an assessment of impacts,
6. Identify measures at the planning, construction and follow-up stages that may ameliorate the identified impacts.

1.2 Review of Existing Information

The library database of The Ecology Lab was searched for studies on flora and fauna from wetland habitats in the Karuah River. This database contains over 12,000 journal articles held as reprints from the scientific literature and more than 1,700 books. This database is updated weekly from the Current Contents™ bibliographic facility. The relevant legislation was reviewed to determine whether any of the species found during this study are listed under the New South Wales Threatened Species Conservation Act 1995 or the Fisheries Management Act 1994. The occurrence and distribution of rare and threatened flora and fauna species as defined under the National Parks and Wildlife Act 1974 was determined by referring to the National Parks and Wildlife Atlas database for the Karuah and Clarence Town 1:25,000 map sheets (NSW NPWS 1999a, 1999b). In addition, representatives of user groups such as recreational and commercial fishers, oyster farmers and NSW Fisheries were also contacted for information regarding the human use of the waterways within the study area. This material was synthesised into a summary of existing data on the estuarine flora and fauna and human activities of the Karuah area.

1.2.1 Estuarine Habitats

There are two main sources of information about the distribution of estuarine habitats which encompass the study area. West *et al.* (1985) mapped the distribution of seagrass, mangroves and saltmarsh based on aerial photographs from 1981 and ground-truthing in 1984. They recorded 0.38km^2 of Zosteraceae seagrass, 3.48km^2 of grey (*Avicennia marina*) and river mangroves

(*Aegiceras corniculatum*), and 4.83km^2 of saltmarsh. There are only three larger stands of saltmarsh in NSW and they are located in the Hunter River (5.05km^2), Lake Innes Nature Reserve (5.98km^2) and Port Stephens (7.72km^2). Adam *et al.* (1985) mapped the distribution of SEPP 14 coastal wetlands within NSW. The habitats mentioned above were included in this classification, but also included other wetland habitats such as *Casuarina* swamps, heathlands and *Melaleuca* swamps. There are 27 such wetlands north of the Pacific Highway bridge at Karuah.

1.2.2 Flora and Fauna

No studies were found specifically on the flora and fauna of wetland habitats near Karuah. Only one threatened plant species (*Tetratheca juncea*) listed under the *National Parks and Wildlife ACT 1974* and the *Threatened Species Conservation Act* 1995 was recorded on the NPWS Wildlife Atlas Database as occurring within the study area. However, none of the records for this species falls within estuarine habitats or habitats closely associated with the estuary.

Only one vulnerable faunal species is recorded near estuarine habitats in the study area, the koala (*Phascolarctos cinereus*). The NPWS Wildlife Atlas indicates that the koala has been recorded only once within a one-kilometre grid within the study area, south of Horse Island. However, it is unlikely that this species utilises the wetland portion of the grid in which it was recorded. It is more likely that that the koala is restricted to the portion of the grid which contains eucalypt forest. The occurrence of the koala in the terrestrial section of this grid (401000 638900) should be considered in the assessment of impacts on terrestrial habitats for the EIS.

1.2.3 Fisheries

1.2.3.1 Recreational Fisheries

Very little information was available about recreational fishing within Karuah River and in particular within the area near Horse Island. During the field studies done by The Ecology Lab several boats were observed fishing just upstream of the study area. Discussions with some fishers suggested that there were some deep holes 'at the bend', which is that part of Karuah River that turns almost due west at the north-eastern tip of Horse Island. Most fishers did not appear to be targeting particular species, rather that they were 'just fishing'. Discussions with NSW Fisheries Officers at Port Stephens suggested that the species typically targeted in the river were bream and flathead throughout the river, Australian bass in the upper reaches and sometimes mulloway adjacent to the existing highway bridge and in the deep holes thought to exist adjacent to 'the bend'. In order to more comprehensively assess the impact that the proposal could have upon recreational fishing within the estuary, a detailed recreational fishing survey would be required, including interviews with fishers where they fish and at important gathering points such as tackle stores within Karuah and Port Stephens. Such a study was beyond the scope of the current study. NSW Fisheries Research Institute is currently researching the value of recreational fishing in NSW in their National Recreational Fishing Survey, but no data are yet available for the Karuah or Port Stephens areas.

1.2.3.2 Commercial Fisheries

This study was unable to estimate the value of commercial fishing within Karuah River because the catch data is incorporated into the Port Stephens figures, which also includes the Myall River. NSW Fisheries were unable to extract the Karuah data from within the catch database as this is a timely and expensive exercise. Further, they are not allowed to divulge the names of commercial fishermen, which could have enabled The Ecology Lab to contact the fishermen and obtain the data directly and discuss preferred fishing grounds. In the context of this study and the nature of the proposal, it is unlikely that discussions with the fishermen would have obtained more than a rough estimate of the dollar value of the estuary, as they rarely divulge the locations of their preferred fishing grounds. If it

eventuated that the proposal was to directly affect the primary fishing grounds of the Karuah River, then we may have been able to estimate the cost of the proposal on commercial fishing. However, without such detailed information this is not possible. As such, the following information is a discussion of the value of the Port Stephens commercial fishery, which includes Karuah River, with specific references where possible.

General Information

The total number of commercial fishers varies throughout the year, however, there are usually about 60 commercial fishermen working Port Stephens. Port Stephens has a combined fishing effort of about 10 000 days per year, or about the 5th most intensive estuarine fishery in NSW. Fishing hours are dependent on the season, species being targeted and other factors, but it can be generally said that fishing activity occurs 24 hours a day for 365 days a year. The major methods are pound netting, mesh netting and hauling for finfish and traps for crabs and eels. No prawning takes place within Karuah River, as there is a closure to all methods of prawning west of Soldiers Point, Port Stephens.

The major finfish species targeted include yellow-finned bream (*Acanthopagrus australis*), sea mullet (*Mugil cephalus*), luderick (*Girella tricuspidata*), tarwhine (*Rhabdosargus sarba*), river eels (*Anguilla australis* and *A. reinhardtii*) and dusky flathead (*Platycephalus fuscus*), with sea garfish (*Hyporhamphus melanochir*) and sand whiting (*Sillago ciliata*) also being very important within Port Stephens. The major invertebrate species targeted are blue-swimmer crabs (*Portunus pelagicus*), mud crabs (*Scylla serrata*) and school prawns (*Metapenaeus macleayi*), with some eastern rock lobster (*Jasus verreauxi*) also taken along the rocky headlands near the ocean entrance.

Techniques

Techniques used for commercial capture of finfish in Port Stephens are pound netting, mesh netting, haul netting, eel trapping and demersal (bottom) fish traps. Pound netting is only permitted at Shoal Bay and Jimmys Beach in lower Port Stephens, and due to the extensive foreshore oyster leases within Karuah River, it is unlikely that any haul netting takes place.

Mesh nets range from about 100 m in length to a legal maximum of 800 m. The minimum stretched mesh length is about 80 mm. About 25 species are caught by mesh nets, but the major species are bream, whiting, luderick, mullet and tarwhine. Mesh nets also catch crabs occasionally, but they are not targeted due to the difficulty of removing them without damage.

Garfish "bullringing" is a specialised hauling technique that targets garfish, using a smaller mesh haul net that is hauled in to a boat.

Only 10 eel traps are permitted per fisher, and probably fewer than 10 professional fishers are involved in this fishery in Port Stephens. Adult individuals of both *Anguilla* species are targeted. Some fish trapping occurs, but most traps target crabs. It is likely, but unconfirmed, that mesh netting, eel trapping and crab trapping are the most popular methods within Karuah River.

Commercial Catch Statistics

Published fisheries production data for NSW estuaries are available for the years 1954/55 to 1992/93 (Pease and Grinberg, 1995). Examination of these data reveals that Port Stephens is about the fifth most important estuarine fishery in NSW, both in terms of volume and value. For the financial years of 1990/91, 1991/92 and 1992/93, Port Stephens was ranked 5th, 4th and 5th in the state, with values of $ 1 417 357, $ 1 358 026 and $ 1 365 301, respectively (Pease and Scribner, 1993; Pease and Scribner, 1994; Scribner and Kathuria, 1996). Sea mullet, bream and luderick dominate the volume of finfish catch, but sand whiting and bream provide the greatest return, about $7.90 and $4.80/kg, respectively. Blue-swimmer and mud crabs make up the bulk of the crustacean catch, worth about $6.10 and $13.60/kg, respectively.

In an attempt to extrapolate a dollar-value of the Karuah River commercial fishery from the Port Stephens figures for the previously mentioned fiscal years, the following assumptions have been made and the figures are presented in Table 1 below:

- Karuah River makes up 10% of the value, and this is probably a considerable overestimate given its size in relation to the rest of the port;
- That the values for hauling (proportion of fishing effort to catch finfish) and prawning have been removed from the total Port Stephens figures, as these methods are unlikely to take place and illegal within the Karuah River, respectively.

Table 1: Estimates of Commercial Fishing for the Karuah River.

	90/91	*91/92*	*92/93*
Fish hauling proportion of effort (R1)	0.24	0.22	0.24
Fish $ (R2)	1111391	1087766	1073719
Prawn $ (R3)	65920	20634	23832
Total $ Port Stephens (R4)	1417357	1358026	1365301
Adjusted $ Port Stephens (=R4 - R3 - (R2*R1))	1084703	1098083	1083776
Karuah $ (10%Port Stephens)	**108470.3**	**109808.3**	**108377.6**

Fishing Closures

A number of restrictions are placed on commercial fishing within Port Stephens, but those that also apply to the Karuah River include:

- No prawning can occur west of Soldiers Point (i.e. all of the upper basin);
- Trumpeter whiting nets are only permitted in the western part of the lower port;
- Garfish cannot be netted in the estuary from December 1 to January 31, and hauling for garfish is only permitted in an area in the central, lower port.
- From December to January, no set mesh nets, splash mesh nets only;
- From February to March, mesh nets have a maximum 3 hour night set and cannot be set between sunrise and sunset;
- From April to May, only 3 hour sets day and night;
- From June to August mesh nets can be set all night but only a 3 hour day set;
- In September mesh nets can be set for 3 hours day and night; and
- From October to November mesh nets have a maximum 3 hour night set and cannot be set between sunrise and sunset.

1.2.3.3 Oyster Farming

The following information has been compiled based on discussions with John Verdich, a major oyster grower in Karuah River and whose leases are in the area of the proposed road, and from NSW Fisheries oyster production figures.

Although the statistics for oyster production in the Karuah River are incorporated into the Port Stephens figures, each of the estuaries making up the system, Tea Gardens, Karuah and Nelson Bay are also presented separately and those for Karuah are presented below. It is worth noting however, that Mr Verdich was somewhat concerned by the figures presented in the NSW Fisheries statistics regarding the production of Pacific oysters (*Crassostrea gigas)*. Port Stephens is the only legal outlet

for Pacific oysters which are classified as noxious in all other NSW waters, where they are required to be removed from leases. Mr. Verdich reported that growers in the Karuah River have a 'gentlemen's agreement' to clean them from their leases as soon as they appear, despite their legal status in Port Stephens. Yet Fisheries figures show that the Karuah River is rapidly becoming a major producer, worth just under $250 000 in the 96/97 fiscal year. Hence, there may be some discrepancy between reported and actual production figures for this species.

Mr Verdich's other concerns were the locations of the bridge piers, as these obviously have the greatest potential to have an economic impact upon his business. If the piers were located on the foreshore, then up to 5 leases would be destroyed completely. If the piers were located just offshore, then they could interfere with his operations and make some leases or parts of leases untenable. His final concern about pier locations was the degree to which currents would be created around the piers, which could potentially stir up sediment and or make working adjacent to them too difficult. It was not possible to speculate how many leases could be affected by this aspect, but if erosion and turbidity became a problem then it could affect more leases up and downstream of the immediately impacted site.

Oyster Production Statistics

The following information is a summary of various volumes of Commercial Fisheries Statistics and Oyster Production figures produced by NSW Fisheries, but only considers the production of Sydney rock oysters as there is some uncertainty regarding production of Pacific oysters within Karuah River.

There are just over 400 leases within Karuah River, covering an area of over 3.5km^2. Karuah consistently produces just under 2% of the State's total Sydney rock oyster production. It was worth $497 600, $495 573 and $447 608 in the 1994/95, 1995/96, 1996/97 fiscal years, respectively. About 60% of this is made up of plate grade oysters, the highest priced oysters, with bistro and bottle grade oysters comprising about 30% and 10%, respectively. As with all oyster growing estuaries, Karuah River is involved in inter-estuary transfer of various stages of Sydney rock oyster development and production equipment. Karuah oyster producers account for about 40% of the State's total transfer of culled spat, and about 15% of its trayed oysters. Such features are not included in the production values of estuaries, and thus may slightly underestimate the true value of the estuary. In the context of the current proposal, without information that can clearly ascertain the number of leases directly and indirectly affected, it is not readily possible to precisely estimate the economic impact of the proposal upon the oyster industry of the Karuah River.

1.2.4 Water Quality

There have been very few studies of water quality within the Karuah River and most of these have focussed on the estuary area. Existing information on the water quality within the Port Stephens region were summarised in the Port Stephens/Myall Lakes Estuary Processes Study (MHL, 1999) which includes the Karuah River.

The New South Wales EPA collected water quality data on an ad-hoc basis from numerous areas within Port Stephens including the Karuah River between 1973 and 1994 (MHL, 1999). No measurements were taken within the Karuah River for orthophosphates or chlorophyll-*a*. Major findings of from these data revealed that:

- dissolved oxygen measurements were generally within the ANZECC (1992) guidelines;
- Approximately 70% of the total phosphorus (TP) measurements within the Karuah River exceeded the ANZECC guideline of 0.05 mgL^{-1} suggesting nutrient enrichment;
- More than 30% of the measurements within the Karuah River for oxidised nitrogen (NOx) were below the lower ANZECC guideline (0.01 mgL^{-1}).

Water quality monitoring indicated that within Port Stephens/Myall Lakes water quality generally satisfies the ANZECC guidelines. In the Karuah River some parameters exceed the ANZECC guidelines and may be indicative of a gradual increase in nutrient loads and eutrophication. Chlorophyll-*a* levels were below the guidelines in the main waterway but some greater levels were observed in inflow from rivers and creeks (MHL, 1999).

Water quality in the Karuah River was also investigated by Bishop (1995), although study sites were restricted to the River and tributaries upstream of the tidal limit. He noted a shift to more acidic conditions in the water quality of the upper river over the 11 years of the study. He concluded that landuse is not the basis of the trend and instead atmospheric pollutant inputs were found to be a likely cause. The two major concerns he identified were greater than "safe limit" concentrations of phosphorus and poor microbiological water quality. The land and water uses considered to be major contributors to these conditions included releases from the Stroud sewerage treatment works, application of chicken litter to river flats, and particularly stockpiling of litter near chicken sheds.

The significant water quality issues as identified by the Estuary Processes Study (MHL, 1999) include:

- Water quality within the Karuah River is likely to be highly variable, depending on the river flow conditions;
- Recent studies undertaken for the EPA suggested that rural runoff is the dominant nutrient source in the Karuah catchment. The report was not available to the consultants at the time of this investigation;
- Development along the river (including residential and agriculture) has the potential for generating high nutrient and sediment loads within the river;

The river is efficient at delivering nutrient and pollutant loads to the upper port. Flushing times in the vicinity of the river entrance are low and pollutants would tend to remain trapped within the upper port.

Hunter Water Corporation has determined that Karuah is to be provided with sewage infrastructure. The Environmental Impact Statement has been completed and the plant is in final design stage. The EIS reviewed current water quality data in the Karuah River and found that, in most cases, water quality measurements conformed to the ANZECC guidelines (1992). The major exception was in levels of ammonium, which generally exceeded the guidelines. It was noted however, that chlorophyll-*a* data are within recommended limits, suggesting that the existing nutrient concentrations were not being reflected in excessive plant growth. The environmental impacts of the Scheme on water quality, flora and fauna, community health, air quality, soil landscapes, aboriginal heritage, other and other environmental impacts were not considered to be significant if all recommended mitigation strategies were implemented.

2.0 STUDY METHODS

2.1 Surveys and Observations of Mangrove and Saltmarsh Habitats

The following methodology is based on a modified procedure from Skilleter (1996). It involves a rapid assessment technique to examine physical damage in urban mangrove forests and the relationship to characteristics of the mangroves themselves and to the fauna present in them. Data collected also provide a baseline upon which to compare future surveys. Although physical damage is specifically addressed, other factors that may play an influential role in determining the condition of mangroves were not addressed in this study, as they are beyond the scope of the survey, for example, the accumulation of heavy metals in sediments and toxicity to fauna.

In addition to these sampling locations described below, qualitative descriptions were also made of the habitats of SEPP 14 wetlands that were adjacent to the proposed route, but would not actually be crossed by the highway (Figure 1). These locations were the north-eastern tips of SEPP 14 Nos 776 and 777.

2.1.1 Sampling Sites and Methods

Four locations were selected within Karuah River for quantitative sampling (Figure 1, W1-4). Locations 1 and 2 were sampled on 17 and 18 November and Locations 3 and 4 on 25 and 26 November, 1998. Locations 1 and 2 were located on the eastern and western sides of Horse Island, respectively, under the approximate route of the proposed highway. These locations were both within SEPP No 743 (Figure 1). Location 3 was located downstream on the eastern shoreline, near the mouth of Mosquito Creek that drains SEPP 14 No 776. Location 4 was located on the north-eastern tip of Horse Island. Although it was initially planned to have both reference locations in other SEPP 14 wetlands, difficulties with access and the lack of suitable locations meant that the northern tip of Horse Island was selected as Location 4, ie. also SEPP No 743.

2.1.1.1 Estimating Damage

At each location, 2 sampling sites were established. At each site, 2 replicate transects approximately 10 m apart were marked with a measuring tape from the top of the mangrove forest to the bottom of the shore, which was where the pneumatophores (commonly known as 'peg roots') ended. The forest was then divided into 2 sections and referred to as the 'upper' and 'lower' forest. The division within the forest was based either on obvious structural differences, e.g. mature trees in the first section and saplings in the upper section, or into equal halves if no structural differences were observed. The pneumatophore zone was not divided further. Along each transect and within a 30 cm band on either side, the total length of each habitat was measured and the position, to the nearest centimetre, of each of four categories of damage was recorded (Table 2 below). These categories were used to estimate the relative amounts of existing damage at each site and were independent of any measures of abundance or diversity of plants and animals.

The four categories used were those from Skilleter (1996):

Table 2: Categories of damage used to assess mangrove and saltmarsh habitats.

A – completely damaged	Covered with landfill, dead trees, stormwater drains, pathways, large rocks (>15 cm), urban debris (fridges, car bodies, tyres), large

	flotsam.
B – partially damaged	Large branches and stumps from nearby dead trees, household garbage, small rocks.
C – slightly damaged	Occasional rubbish, small branches, light flotsam.
D – undamaged	No visual signs of external damage.

2.1.1.2 Sampling Fauna and Characteristics of the Wetlands

Along each transect, 3 randomly selected 0.1 m^2 quadrats were sampled within the upper and lower halves of the mangrove forest, giving 12 quadrats per site. In each quadrat, the number of saplings, seeds, crab holes, and pneumatophores were counted. The percent cover of leaf litter, algae, crab holes, pneumatophores, saplings, saltmarsh plants and trash were estimated by the point-intercept method (using 100 points per quadrat). All leaf litter, debris and top few millimetres of sediment within the quadrat were removed using a spoon and placed into a labelled plastic bag to be returned to the laboratory. In the laboratory, the contents of each bag were washed over a 1mm sieve and any animals removed, counted, identified and added to the quadrat data sheets. No faunal counts or sediment removal was done in saltmarsh habitats due to the high variability and overall scarcity compared to mangroves.

2.1.1.3 Percent Cover within Wetlands

Along each transect, the percent cover of wetland components was recorded by determining the components at every metre. Where 2 or more components occurred together, such as an overstorey of a mature tree with an understorey of saplings and saltmarsh plants, all features were recorded and assigned equal proportions. The components recorded were: species of mangrove, saltmarsh and fringing plants and their level of maturity (e.g. mature or sapling), pneumatophores, crab holes, debris, other plant species and bare mud.

2.1.2 Data Analysis

The statistical procedures used in the analysis are presented in Appendix 1. Differences in the degree of damage between transects was compared among locations and between sites using multivariate analyses. Multivariate procedures were also used to examine components of the mangrove forests by comparing percent cover data along transects at different locations and sites.

Differences in the structure of assemblages of biota in quadrats within mangrove forests were examined using multivariate procedures and differences between locations, sites, transects and heights in the abundances of individual groups were investigated using ANOVA (Appendix 1).

2.2 Fish and Mobile Invertebrates

2.2.1 Sampling Sites and Methods

Estuarine fish and mobile invertebrates were sampled at four locations (Figure 1, F1-4). Sampling was done from 25 to 27 November 1998. All locations were mangrove-lined creeks up to 10m wide that had oyster leases nearby which is typical habitat for the foreshores at Karuah River. Location 1 drained SEPP 14 No 743, and entered Karuah River on the north-western side of Horse Island.

Location 2 also drained SEPP 14 No 743 but on the southern side of Horse Island (also W1). Location 3 was located in a tributary on the northern side of Mosquito Creek that drains SEPP 14 No 776 (also W3). Location 4 also drained out of SEPP 14 No 776, about 800m north of the Pacific Highway Bridge.

Two sampling methods were used to catch fish and mobile invertebrates. A 10m long seine net, approximately 1m deep with 2mm mesh was used to sample juvenile and sub-adult fish. It was used on the muddy shores fronting mangrove forests, behind oyster leases that occupy most of the foreshore in the study area. Sampling was done at mid-high tide so that there was enough water through which to haul nets, but not so much that the waterline extended into the mangrove forest, preventing sampling. The net is set in a U-shape and then hauled up onto the shoreline. Three consecutive replicate seine hauls were done at each location, giving 12 samples. Where samples were small or time was available, fish were emptied from the nets into a large fish box with water. They were then identified, counted and released. The length of the caudal fork (LCF, mm) of species of economic importance were also measured. Larger samples were preserved in dilute formalin (10%) and returned to the laboratory for identification, counting and measurement.

The second method was the use of either a block or fyke net. These were used to sample fishes of all ages. Block nets were set in a V-shape at the mouths of creeks at high tide and retrieved at low tide. The net has two wings up to 10m long, with 20mm mesh that feeds into a funnel supported by two rings about 0.8m high, with 10mm mesh. The fish are removed from the funnel periodically during sampling and finally at low tide. Block nets were used at all but location 3. Fyke nets are similar to block nets, but are set from one bank to the other and consist of a single wing that terminates at the funnel. The wings and funnel are 8m and 3.5m long, respectively, with 18-30mm mesh. Fyke nets were used at location 3. Again, small samples were identified, measured and released in the field and larger samples were preserved and returned to the laboratory.

2.2.2 Data Analysis

Multi- and univariate procedures described in Section 2.1.2 and Appendix 1 were also used to examine differences in the assemblages of fish and mobile invertebrates at each location. To examine the relationship between water quality variables and the fish seine data, weighted Spearman correlation coefficients p_w were calculated between the matrix of similarity for biotic data and the matrix of similarity for the shallow water quality variables (Appendix 1). No quantitative data analyses were done for block net data because it was not possible to take replicate samples at one location however, trends in abundance and composition are discussed in the results section.

2.3 Water Quality

2.3.1 Sampling Sites and Methods

Measurements of water quality were taken from 8 sites within Karuah River, 4 of which coincided with fish sampling sites (Figure 1, WQ1-8). They were collected on 27 November 1998. *In situ* physico-chemical variables were measured at 2 depths, surface and bottom, to allow analysis of stratification. At both depths, at each site, 2 replicate readings 5 – 10 m apart were taken *in situ* of the following water quality variables: oxidation-reduction potential, pH, dissolved oxygen, turbidity, temperature, conductivity and salinity, using a Yeo-Kal 611probe. The probe was lowered below the surface to a depth of 10 – 20cm (surface sample) and/or approximately 1m (bottom sample) and switched on for a one-minute adjustment period before any measurements were recorded.

In addition to *in situ* measurements, water samples were collected for analysis of nitrate (NO_3-N), orthophosphate (PO_4-P), suspended solids, aluminium and iron. Two replicate water samples were taken 5 – 10 m apart at each site. The samples were stored on ice and transported on the same day to the Australian Government Analytical Laboratory (AGAL) for analysis.

To allow quality assurance evaluation of the analytical laboratory results, a field duplicate and field blank sample was taken at one of the sites. The duplicate was filled simultaneously with the true replicate and the blank sample was filled with purified (Milli-Q) water while its corresponding sample was being collected. The duplicate and blank samples were labelled as a separate site so that the laboratory was unaware that it was analysing duplicates and blanks.

2.3.2 Data Analysis

Multivariate analysis (MDS, ANOSIM and SIMPER) of water quality variables was used to examine the similarities among sites sampled in Karuah River. Where applicable, results were also compared to ANZECC (1992) water quality guidelines for the protection of aquatic ecosystems in estuarine waters.

3.0 RESULTS

3.1 Descriptions of Surveyed Wetlands

Global Positioning System (GPS) readings for the Locations are given in the following table.

Table 3: Sampling locations and dates for wetlands survey, fish seine and block net samples and water quality samples. See Figure 1 for location map.

Type of Habitat	Location	GPS location ° S	° E	Dates Sampled
Mangrove	1	32°37'18"	151°57'27"	17-11-98
Saltmarsh	2	32°37'26"	151°57'10"	18-11-98
Mangrove	3	32°37'43"	151°57'54"	25-11-98
Mangrove	4	32°37'01"	151°57'20"	26-11-98

3.1.1 Location 1

Location 1 was located on the southeastern edge of Horse Island (Plates 1-4), behind oyster leases OL 77-169 and OL 82-155-1. At high tide, this area was inundated, but at low tide only the creek at the southern end of the location retained water. There were large numbers of crab holes at this location, as well as several sea slugs (*Onchidium damelii*), particularly at the northern end of the location. There was a discernible profile of plant species present at this location from the riverside to the foot of Horse Island, a distance of approximately 110m metres. The lower shore comprised of a few metres of pneumatophores. For about 60m landward of the lower shore, the mangrove forest consisted of a dense understorey of river mangroves (*Aegiceras corniculatum*) with an overstorey of mature grey mangroves (*Avicennia marina*) up to about 5m tall. At about 60m along the transect the substratum changed from mud to predominantly sand overlying mud. From this point to the foot of the island, patchy grey and river mangroves and scattered mature greys dominated, with a band of the rush *Juncus kraussii* at the foot of the island. A creek about 10m wide marked the southern extremity of this location, which was used for fish and mobile invertebrate sampling.

3.1.2 Location 2

Location 2 was located on the south-western side of Horse Island (Plates 7-10). The following description is based moving east from Horse Island south-westward to the terrestrial forests on the property of D & L Powell. Vegetation profiles along four transects at this location are illustrated in Figure 2. The foot of Horse Island had a large paperbark swamp (*Melaleuca quinquenervia*), with an understorey of *Juncus* sp. and creeping brookweed (*Samolus repens*). Saltmarsh, particularly samphire (*Sarcocornia quinqueflora*) and some salt couch (*Sporobolus virginicus*) dominated about 80% of the flat areas west of the swamp. At the time of sampling there were also extensive areas of bare mud that had been hard-baked by the sun and cracked, forming clay-pans although this may not be evident at different times of the year. Most of these areas contained dead samphire plants. There was a narrow, mangrove-lined creek about 50m from the western edge of the wetland (indicated in Figure 2 with a symbol for water). This creek appeared to be tidal and it appeared that a semi-permanent connection was maintained between the north-western (Fish Site 1, Plate 15) and southeastern ends (Fish Site 2, Plate 16). Westward of the creek, swamp she-oaks (*Casuarina glauca*) formed an overstorey above *Juncus* sp., *Sporobolus* and *Sarcocornia*.

3.1.3 Location 3

Location 3 was located on the eastern shore of the Karuah River, behind oyster leases OL 67-267 and OL 59-085 (Plates 11-12). Mosquito Creek marked the northern extremity of this location. This location had a wider and more dense pneumatophore zone than other sites. Zonation within the mangrove forest was not as clear as at Location 1, with a narrow band of river mangroves at the riverside edge with greys above. The grey mangroves at this location grew up to about 8m and had large numbers of oysters growing on their trunks. Landward of the band of river mangroves, the understorey was comprised of scattered grey and river mangrove saplings. There were also many elevated or island-like mounds at this location, many were densely covered in river mangroves. This site was also typified by a large amount of debris, primarily old sticks and racks from oyster leases, particularly in Mosquito Creek.

The small creek draining into Mosquito Creek from the north was used as a site for sampling fish using a block net (Fish Site 3, Plate 17).

3.1.4 Location 4

Location 4 was on the north-eastern tip of Horse Island (Plates 13-14), behind oyster lease OL 69-457. There was small creek running out of the wetland that separated the two sites at this location. This creek was used as a sampling site for fish using block nets (Fish Site 4, Plate 18). The wetland was very similar to Location 1, which was about 750m south. Zonation was similar, except that the band of river mangroves at the riverside edge was smaller and most of the site's substratum consisted of sand overlying mud. Similar to Location 1, there were large numbers of crab holes and sea slugs, although the area covered by saplings appeared to be greater at this location.

3.2 Mangrove Forests

3.2.1 Existing Damage

The 3 mangrove forests and the saltmarsh location showed very little damage (Figure 3). The averages for each forest revealed that undamaged forest (Category D) accounted for more than 92% of transects at all locations (Figure 3) and only very small proportions of the transects were classified as slightly damaged (Category C: < 3%) or partially damaged (Category B: < 5%). The few instances (< 2%) where Category A damage (completely damaged) was recorded were accounted for by large rocks or Eucalyptus tree debris.

Multivariate analyses of damage comparing transects between sites and among locations revealed no significant differences in the extent of damage among forests in either the upper or lower portion of the transects or between sites in the lower transects (Global R:-0.167, -0.056, 0.083 respectively $p >$ 0.05). There was, however, a significant difference between sites in the upper portion of the transects (Global R:0.333, $p < 0.05$), although it is not possible to determine where these differences are due to the small number of sites per location. This is likely to be due to natural small scale variability within the habitats.

Along with the lack of significant differences among locations (as revealed by multivariate analyses), the very small standard errors shown in Figure 3 indicate very small variation amongst the spatial scales of sites, transects or heights. It was therefore unnecessary to attempt to correlate damage with biota, as all 4 locations were dominated by undamaged wetlands and any differences in abundances were unlikely to be correlated with damage.

3.2.2 Percent Cover along Transects

The components of the 3 mangrove forests, as determined by percent cover along transects, are summarised in Table 4. For all transects, between 20 and 80% of the lower forest and 18 and 55% of the upper forest were covered with either river mangroves *Aegiceras corniculatum* or grey mangroves *Avicennia marina*. For more detailed descriptions of the individual forests refer to Plates 1-14, Sections 3.1.1, 3.1.3 and 3.1.4 and Table 4.

There were no significant differences among locations in either the upper or lower forests or between sites in the upper forest (Global R:-0.056, -0.222, 0.250 respectively $p > 0.05$). Significant site differences in the lower transects (Global R:0.333, $p < 0.05$) again could not be attributed to particular sites due to lack of power of the statistical test between sites.

3.2.3 Flora and Fauna in Quadrats

Bare space and leaf litter accounted for most of the percent cover within quadrats. Densities of crab holes and pneumatophores ranged from 0 to 62 and 3 to 28 per $0.1m^2$ quadrat respectively. Mangrove quadrat data from the field and laboratory are summarised in Appendix 3.

A total of 3 728 individuals were collected from quadrats within Locations 1, 3 and 4 and identified in the laboratory. Of these, 79% were molluscs from 12 different taxa, 10% were crustaceans (amphipods, isopods and crabs), 5% were annelids (polychaetes and oligochaetes) and the remaining 6% were insect larvae and pulmonates (*Onchidium damelii*).

Univariate analysis on the major groups from laboratory and field quadrat data revealed significant differences among locations and significant interaction between locations and heights for some of the groups. ANOVA results are presented in full in Appendix 4. There were no significant differences in the numbers of pneumatophores or saplings per quadrat. Polychaetes were significantly more abundant at Site 1 compared to Site 2 at Locations 3 and 4 and molluscs were more abundant at Location 3 than Locations 4 and 1 which were equal. There was a significant interaction between locations and zones in both the percentage cover of leaf litter and the number of crab holes. The number of crab holes was also significantly different between the 2 transects at both sites at Location 3 (See Appendix 4 for details). These small scale variations in individual abundance are likely to be natural and due to variation in environmental variables. For example, small differences in sediment types at each site may affect the numbers of polychaetes and in turn the numbers of crabs can have an effect on the sediment composition (Warren and Underwood, 1986). Also, the amount of leaf litter present at any location can be influence by the number of mangrove trees present and the pattern of tidal exchange which redistributes leaf litter.

Multivariate analyses of the field and laboratory data showed no significant differences in the assemblages amongst locations or sites for either the upper or lower portion of transects when the two transects within each site were combined ($p > 0.05$). The Global R values from these analyses are presented in Table 5. Similar assemblages of mangrove flora and fauna were therefore present in all 3 mangrove forests sampled.

Table 5: Global R values for multivariate analyses comparing assemblages within mangrove quadrats between sites and within locations for upper and lower portions of the transects.

	Locations	Sites
Upper Transect	0.889	-0.030
Lower Transect	0.833	-0.009

3.3 Description of Other Habitats

3.3.1 Northern Tip of SEPP 14 No. 776

The proposed highway is planned to pass approximately 500 m to the north of the perimeter of this wetland, however, it does cross Mosquito Creek, upstream of where it passes through the wetland. The habitat in this area of the creek is *Melaleuca* swamp, with *Casuarinas* growing on the river banks (Plates 19 and 20). The banks are eroded and undercut in many sections, with fallen trees spanning the creek. Pink flagging tape was present on several trees, presumably marking the path of the proposed highway through the property of R. Pickford. The habitat along the route within the property was also extensive *Melaleuca* swamp south of the creek, and pastureland to the north.

3.3.2 Northern Tip of SEPP 14 No. 777

There was a large stand of common reeds (*Phragmites australis*) between the Pacific Highway and the wetland, which was composed of *Casuarinas*, *Melaleucas* and Eucalypts, often with an understorey of bracken ferns (*Pteridium esculentum*) and grasses (Plates 21-23). The highway is proposed to pass through the southern corner of MJ Van Der Zalm's property, which is on the northern side of the Pacific Highway, directly opposite SEPP 14 No. 777. The area of private property that the highway is proposed to pass through appears very similar to the SEPP wetland. *Melaleucas* dominate the area (Plates 24-26), particularly in the middle of the property where the land is lower lying and provides drainage for the surrounding area. Eucalypt saplings dominate the edge of the area, and other plants observed within the highway route included sawsedge (*Gahnia* sp.), wattles (*Acacia longifolia*), tea-trees (*Leptospermum laevigatum*), grasses and weeds, particularly lantana (*Lantana camara*). Cumbungi (*Typha* sp.) was also present adjacent to the existing highway.

3.4 Fish and Mobile Invertebrate Surveys

3.4.1 General Findings - Beach Seining

A total of 3,324 individuals, comprising 25 species of fish and 5 species of invertebrates were caught seining at the four locations. Of these species, 10 species of fish and 2 species of invertebrates were of economic importance, and accounted for about 13% of the total abundance (Table 6). Flat-tail mullet (*Liza argentea*) and greasyback (*Metapenaeus bennettae*) and eastern king prawns (*Penaeus plebejus*) were the most abundant species of economic importance. Overall, glass gobies (*Gobiopterus semivestita*), Ramsay's perchlets (*Ambassis marianus*), sandy sprats (*Hyperlophus vittatus*) and mysid shrimps were the most abundant species, accounting for 60, 14, 8 and 8% of the total number of individuals, respectively. None of the species caught were introduced or listed as endangered or vulnerable under Schedule 4 Part 1 of the Fisheries Management Amendment Act 1997. Of the species listed in the Act, none would be found within the study area as they are all freshwater species.

Location 3 (Mosquito Creek) had the highest number of species (23), individuals (1,488) and species of economic importance (10) of all locations. Location 3 had almost twice as many species and individuals as Location 2 (12 and 750, respectively), yet species of economic importance made up 20% of the abundance at Location 2, as opposed to less than 10% at Location 3. These differences were largely attributable to the large numbers of glass gobies and carid shrimp caught at this location. The reasons for this are unclear as there were no apparent habitat differences between locations.

3.4.2 Analysis of Assemblages - Beach Seining

The 3-dimensional MDS plot has a stress value of 0.05, indicating a good 3-dimensional representation of the relationship between samples. The plot indicated that the fish and mobile invertebrate assemblages caught in seine nets differed between locations and between replicates within each location (Figure 4). Replicates from Location 1 were different from each other and widely separated on the plot, while at Locations 2 and 4 replicate samples appear grouped, and were most similar to each other.

Analysis of Similarity (ANOSIM) detected a significant difference among locations (Global R value of 0.716, $p< 0.05$), although it was not possible to use pairwise tests to confidently determine which locations differed, due to the small number of replicate samples.

Analysis by SIMPER identified those fish and invertebrates that contributed the most to dissimilarities between locations (Table 7). Although no one species consistently distinguished between sites, sandy sprat (*Hyperlophus vittatus*), Ramsay's perchlets (*Ambassis marianus*), silverbiddies (*Gerres subfasciatus*) and carid shrimp regularly contributed high proportions of the dissimilarity between locations. Locations 1 and 4 were the most dissimilar, largely attributable to the greater abundance of perchlets and sandy sprats at Location 4. Locations 4 and 3 were the most similar. While these results are consistent with patterns of salinity within the Karuah River (Table 10), it is likely that some combination of the physiological preferences of individual species, biological factors and chance jointly operate to produce the patterns observed.

When the biotic data from fish seine samples were compared to water quality variables the highest value of mutual correlation was obtained with the combination of the variables dissolved oxygen, oxidation-reduction potential and ammonia (Spearman's $p_w = 0.781$). As discussed in section 3.5.1, due to large diurnal fluctuations in dissolved oxygen, one-off measurements alone of are of limited value. The next best correlation was the combination of oxidation-reduction potential and ammonia (Spearman's $p_w = 0.778$). The relationship deteriorated when the other physical parameters were compared singly, or any other combination of physical parameters were compared with the biotic data. Thus the combined effects of oxidation-reduction potential and ammonia explained a great deal of the variation observed in the patterns of distribution and abundance of the fish fauna. The biological reasons for this correlation are unclear.

Global comparison for the Index of Multivariate Dispersion (IMD) yielded the following values for relative dispersion: Location 1 = 1.69; Location 2 = 0.41; Location 3 = 1.23 and; Location 4 = 0.67. Pairwise comparisons revealed that Location 1 is dispersed to a much greater extent than all other locations and Location 3 is much more dispersed than either of Locations 2 or 4 (All IMD values = 1). Location 4 is moderately more dispersed than Location 2 (IMD = -0.556). These results support the visual interpretation of the 3-dimensional MDS plot given above, which suggest that there were greater differences between replicate hauls at Location 1 than at the other 3 locations.

3.4.3 Analysis of Populations - Beach Seining

Populations of abundant species and abundant commercial species as identified in section 3.5.1 were analysed using ANOVA. The results of these analyses are given in Table 8. Of the 3 commercial species, only flat-tail mullet showed no significant differences among locations. There were more

greasyback prawns at Locations 2 and 3 compared to Locations 4 and 1 and eastern king prawns were more abundant at Location 4 than the other 3 locations. Of the abundant non-commercial species, all except mysid shrimps showed significant differences among locations. All 4 locations had significantly different abundances of Ramsay's perchlets (Table 8). Glass gobies were more abundant at Location 3 than all other locations and the abundance of sandy sprats at Location 3 was intermediate between Location 1 and Locations 4 and 2 which were equal (Table 8). Again, the reasons for these results are unclear as there were no obvious differences between locations with respect to fish habitat.

3.4.4 General Findings - Block Netting

A total of 1,001 individuals, comprising 18 species of fish and 4 species of invertebrates were caught block or fyke netting at the four locations. Of these species, 12 species of fish and 3 species of invertebrates were of economic importance, and accounted for about 30% of the total abundance (Table 9). Silverbiddies (*Gerres subfasciatus*), flat-tail mullet (*Liza argentea*), yellow-finned bream (*Acanthopagrus australis*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*) and fantail mullet (*Velamugil georgii*) were the most abundant species of economic importance. Overall, common toadfish (*Gobiopterus semivestita*), Ramsay's perchlets (*Ambassis marianus*) and silverbiddies were the most abundant species, accounting for 48, 20 and 10% of the total number of individuals, respectively. No threatened or introduced species were caught.

Sites 1 and 2 (both at Horse Island) had the highest number of species (14 & 15), individuals (275 & 607) and species of economic importance (9 & 11) of all sites (Table 9). Site 2 accounted for 60% of the total abundance and had the greatest number of species of economic importance. Site 1 accounted for just under 30% of the total abundance and had the greatest number of individuals of economic importance (Table 9). This difference was largely attributable to the high numbers of flat-tail mullet, all but one of the total occurring at that site. Site 2 was the only site where longtom (*Tylosurus gavialoides*), flathead, fantail mullet and flounder were caught, although it is probable that these species also occur in the other creeks and would be caught with greater sampling effort. Sampling over a greater time scale would be required to investigate this further. These results indicate, however, that the creeks around Horse Island provide important habitat for a diversity of fish species which have value for recreation or commerce.

3.5 Water Quality

The means and standard errors for each water quality variable are summarised in Table 10.

3.5.1 Comparison to ANZECC Guidelines

Of the variables measured during the current study, ANZECC guidelines (1992) only apply to nitrates and orthophosphates. Guidelines for most other variables are based on a minimum level of change from background or normal conditions (pH, salinity, turbidity, and temperature). Due to large diurnal fluctuations in dissolved oxygen, it is suggested that one-off measurements alone of are of limited value. Also, although there are guidelines for freshwater systems for ammonia, aluminium and iron, there is insufficient data on their toxicity to marine animals to recommend guidelines. These measurements, however, can be used for spatial comparisons and also provide baseline data which can be compared to post-construction levels to assess impacts. In particular, high concentrations of aluminium and iron indicate potential for the estuary to be affected by runoff from acid sulfate soils (Stone *et al.*, 1998).

Caution is recommended however, when applying nutrient limits for rivers and streams since some systems cope well with relatively high nutrient loads (ANZECC 1992). Rather than a set limit, the guidelines provide a concentration range above which problems have been known to occur, depending on a range of other factors, eg. low light levels, high turbidity, substrate type, etc. These limits are 0.01-0.1 mg/L for nitrates (NO_3) and 0.005-0.015 mg/L for orthophosphates, although site specific studies are recommended in order to determine the potential for nuisance aquatic plant growth. None of the sites had nitrate levels outside these limits but the mean concentration of orthophosphates were at or exceeded the maximum recommended guideline at all sites except Site 6 and Site 8.

There are no recommended concentrations of aluminium and iron for estuarine waters in ANZECC guidelines (ANZECC, 1992). However, levels of iron measured were generally low (0.09 to 0.15 mg/L) and concentrations of aluminium ranged from 0.23 to 0.43 mg/L (Table 10). Given that the levels of pH recorded were within the normal range for estuarine waters, these results indicate that at the time of sampling there was no evidence of water quality conditions attributable to run-off from acid sulphate soils. However, the presence of acid sulphate soil run-off can be ephemeral and difficult to detect. Ideally, water should be sampled immediately after the first flush of rain, which flushes acidic water into creeks and rivers. Such flushes can be accompanied by low levels of dissolved oxygen, which are likely to be directly responsible for events such as fish kills. Therefore, a specific sampling programme targeting the potential for acid sulphate soil run-off is required to adequately address this risk.

3.5.2 Comparison among Sites and Depth

Water samples for nutrients, and inorganic indicators were only taken in shallow water and therefore there is no depth comparison for these characteristics. Multivariate analyses were therefore separated into 2 sections:

- All characteristics (physico-chemical, nutrient and metals) were analysed only for surface waters among all 8 sites;
- Variables measured in situ were analysed for both depths among all 8 sites.

For both types of analyses, the similarities among samples were calculated using Euclidean distances which is the appropriate methodology for environmental variables (Appendix 1). All data were log transformed (ln(x+1) to reduce weighting given to variables with higher ranges (eg dissolved oxygen) and to increase the weighting given to those with smaller ranges (eg nitrates).

Analysis of all water quality characteristics for shallow water revealed a significant difference between sites (Global R: 0.844, $p < 0.001$). Due to limited permutations however, it is not possible to determine which pairs of sites were different and no apparent differences were noted during sampling. The MDS plot however has a very low stress value (0.1) and is therefore a good representation of the relationships between samples (Figure 5). It reveals 2 distinct groups of samples. The first group includes sites 1-3 and the second, sites 4-8. SIMPER analysis revealed that the major variable responsible for this difference between the sites is dissolved oxygen. For comparisons between Sites 1, 2 and 3 the average contribution of dissolved oxygen to the dissimilarity is only 8.6% and between Sites 4, 5, 6, 7 and 8 is 6.6%. For comparisons between these two groups of sites however, the average contribution of dissolved oxygen is 57%. Suspended solids and oxidation-reduction potential contribute the most to differences between sites within each of these 2 groups. The result that levels of dissolved oxygen contributed greatly to the differences in water quality among sites should be interpreted with caution, as the dissolved oxygen measurements were taken only at one point in time. Hence, they do not reflect the range of natural diurnal fluctuations, and are possibly influenced by the state of the tide when the measurements were taken

Analysis of *in situ* water quality characteristics for both depths revealed no significant difference between depths (Global R: 0.219 $p > 0.05$) but again showed significant difference between site groups (Global R: 0.849, $p < 0.001$). Again, due to limited permutations it is not possible to determine which sites are different.

Overall, the results from water quality sampling indicate generally good water quality in the Karuah River with respect to the variables measured. However, levels of orthophosphates at six out of the eight sites within the river are higher than guidelines recommend for the protection of estuarine ecosystems. Potential sources of elevated orthophosphate levels include releases of effluent from the sewage treatment plant upstream at Stroud, fertilisers used for pasture improve and livestock waste.

3.5.3 Quality Control

Results from blank and duplicate quality control samples for water quality samples analysed by AGAL indicated that results could be reliably interpreted.

4.0 ADDITIONAL WATER QUALITY INFORMATION

4.1 Background and Aims

In order to gain an overview of background water quality in the variety of water bodies that may be affected by the construction and operation of a new highway, additional background information on water quality was collected. The aim of this data collection was to establish background water quality conditions in order to assess the likely impact of road construction and operation. Water quality variables measured were those relevant to ecosystem health and chemicals known to be associated with road runoff.

4.2 Study Methods

Water quality measurements were taken at an additional 8 sites in the Karuah region (Figure 1 as X1-8) on 18 and 19 March 1999. General observations such as weather conditions and water depth were recorded at each site and GPS coordinates and photographs were taken for future reference. *In situ* physico-chemical variables were measured as described in Section 2.3.1 except only surface measurements were taken. In addition to *in situ* measurements, water samples were collected for analysis of total and combustible suspended solids, oils and grease, poly-aromatic hydrocarbons (PAH's), nutrients (nitrite, nitrate, TKN, NH_4, TP, and PO_4) and a selection of metals (lead, zinc, copper, chromium, iron, cadmium, nickel, manganese, and mercury). These metals were chosen for analysis because recent research has shown them to be important for assessing the impact of road works (Ball *et al.* 1997).

4.2.1 Description of Sampling Sites

For location of sampling sites, see Figure 1, locations marked X1 –X8.

Site 1 was Wallaroo swamp, a freshwater swamp to the west of the panned roadway. The swamp features grasses, , *Melaleuca*, *Casuarina* trees and shrubs . It receives run-off from the surrounding State Forest land. At the time of sampling, no free surface water was present on the surface, and hence no water quality samples were collected.

Site 2 was the un-named tidal creek that flows behind (i.e. south of) Horse island from the west. The creek was lined with mangroves and tidal movement of water was evident.

Site 3 is a farm dam on the east side of the river, approximately 150 m from the eastern river bank. At the time of sampling, cattle were observed sheltering under gum trees near the edge of the dam. The route of proposed road would cross in the immediate vicinity of this dam.

Site 4 was an intermittent, trickling freshwater creek above the tidal limits of Mosquito Creek. The sampling point was to the west of the larger Mosquito Creek. This site is in the immediate vicinity of the route of the proposed road, as indicated by the presence of pink flagging tape present at the site.

Site 5 was located in the upper reaches of Mosquito Creek, in a narrow section influenced by tidal exchange. Based on the location of pink flagging tape, the route of the proposed road will pass immediately to the north of the sampling site.

Site 6 was a dense, freshwater reed marsh located to the south of the existing Pacific Highway, just to the east of its junction with The Branch Lane. The sampling point was downstream of a culvert running below Pacific Highway to the south. The proposed new road would merge with the existing Pacific Highway at approximately this point.

Site 7 was located in the tidal creek that flows into the Karuah River immediately to the south east of the Aboriginal settlement on the western bank of the river. At the sampling point, the creek 4 to 6 m wide, shallow and lined with mangroves.

Site 8 was located in the quarry north of the existing Pacific Highway to the east of the junction with The Branch Lane. This site was close to Site 6, and in the vicinity of the junction between the proposed road and the existing Pacific Highway.

4.3 Results

General field observations and GPS readings for each of the sites are detailed in Table 11. Water quality was not sampled at Wallaroo Swamp due to the lack of free water on the surface. The means and standard errors for each water quality variable are summarised for the remaining sites in Table 12. Most of these variables have reporting limits that are indicated on the table where applicable. Reporting limits are a combination of the detection limit and the accuracy of the analytical equipment. A precautionary approach was adopted for the calculation of means. All samples for which results were less than the reporting limit were rounded up to the reporting limit value to calculate means.

4.3.1 Comparison to ANZECC Guidelines

Of the variables measured during the additional data collection, ANZECC guidelines for the for the protection of aquatic ecosystems in estuarine and freshwaters (1992) apply to:

- ammonia (freshwater only);
- nitrates (estuarine only);
- total nitrogen (freshwater only);
- total phosphorus (freshwater only);
- orthophosphates (estuarine only);
- cadmium, chromium, copper, lead, nickel and zinc (estuarine and freshwater);
- iron and mercury (freshwater only)
- Total polycyclic aromatic hydrocarbons (marine and freshwaters)

For many of the variables above the guidelines apply only to either estuarine or freshwater and cannot be used for other systems. Sites were categorised as either estuarine or fresh based on the limit given by ANZECC for freshwater of less than 1,500 $\mu S.cm^{-1}$. Freshwater sites were further categorised into lakes and reservoirs or rivers and streams as ANZECC guidelines distinguish between these categories for levels of total nitrogen and phosphorus.

Guidelines for many other variables are based on a minimum level of change from background or normal conditions (pH, salinity, turbidity, and temperature) and therefore cannot be applied to once off sampling such as the current study. However, these data supply background data against which future changes can be measured. It is suggested that one-off measurements alone of dissolved oxygen are of limited value due to large diurnal fluctuations in this variable. In other cases there is insufficient data on the toxicity of variables to recommend guidelines.

4.3.1.1 Nutrients

All of the seven sites where water quality samples were taken were found to have levels of nutrients (nitrates, ammonia, total nitrogen, orthophosphates or total phosphorus) which were within the recommended range or exceeded levels recommended in ANZECC guidelines (Table 12). Caution is

recommended however, when applying nutrient limits for rivers and streams since some systems cope well with relatively high nutrient loads (ANZECC, 1992). Rather than a set limit, the guidelines provide a concentration range above which problems have been known to occur, depending on a range of other factors, e.g. low light levels, high turbidity, substrate type, etc. In this circumstance we have taken the precautionary approach and applied the lowest recommended value in determining compliance.

4.3.1.1 Metals

All four of the freshwater sites exceeded ANZECC guidelines for iron. Lead levels exceeded ANZECC's recommended levels at two sites and was within the recommended range for the other three freshwater sites. Zinc was recorded at levels within the recommended range at all four freshwater sites (Table 12). As discussed for nutrients, the guidelines provide a concentration range above which toxicity has been known to occur depending on water hardness. Again, the lowest recommended value is used to determine compliance for all metals except cadmium. The reporting limit for cadmium lies within the guideline range and therefore, although all samples were below the upper limit it is not possible to determine whether or not they are below the lower limit.

4.4 Discussion

Values for ammonia, total nitrogen and total phosphorus at Site 3, the farm dam, exceeded ANZECC guidelines. These results are probably attributable to run-off from the surrounding land which is used to graze cattle. Levels of nutrients at other sites were above the lower guideline limits, but below the upper limit, indicating some low level of nutrient enrichment. These results are consistent with the elevated levels of nutrients, in particular orthophosphates, we recorded from the area around Horse Island in January, 1999. This suggests that some degree of nutrient enrichment is a persistent feature of the water quality in the reach of river between Horse Island and the township of Karuah. As mentioned in section 3.5.2, potential sources for nutrients include effluent from a sewage treatment plant, fertilisers used for pasture improvement and livestock waste.

Levels of iron were well above recommended levels in the dam site (Site 3), the two creek sites (Site 4 and 6) and the quarry near the junction of the proposed road and The Branch Lane(Site 8). These results may reflect naturally high background levels, and their presence may indicate past episodes of acid sulphate soil activity. However, the pH recorded at the above sites was within the recommended range, with the exception of a slightly lower value at Site 6. The largely normal pH values indicate no current problem with acid sulphate soils at the time of sampling.

Levels of lead slightly above recommended levels were recorded from Site 5 (upper Mosquito Creek), and from Site 8 (the quarry site). Levels from the two creeks (Sites 4 and 6) and the dam (Site 3) were within the recommended range. The source of lead in upper Mosquito Creek is unknown, while lead in the quarry may be a legacy of past activities there.

Although zinc was detected in the two creeks, the dam and the quarry sites, levels were within the range recommended for the protection of ecosystem health.

5.0 ASSESSMENT OF IMPACTS

5.1 Description of Proposal

The selected route of the proposed road approaches Horse Island from the west over a relatively narrow section of saltmarsh habitat (approximately 137 m wide) which contains a tidal creek. As the route passes across Horse Island to the east, it passes through a narrow section of mangroves (approximately 100 m wide) before crossing the Karuah river itself. The route crosses the eastern bank of the river in an area that has only a few mangrove trees, no saltmarsh habitat, and the banks there appear to be subject to erosion from river processes.

The concept design of the roadway in the vicinity of the river crossing, saltmarsh and mangrove habitats features a single carriageway elevated at least 10 m above the ground. The carriageway is proposed to be 22.6 m wide with spans spaced 35 m apart. The pilecaps are planned to be approximately 3 m long and 16.6 m wide for each pier location. The pile caps will extend approximately 0.5 m above ground or water level. Results from geotechnical surveys indicate that piles will be built on bedrock that is located some 10's of metres below the ground surface.

Plans for controlling run-off from the bridge section across the river include re-direction to a sedimentation basin west of SEEP 14 wetland # 743 during normal rain events. During storm events, discharge would be into the upper reaches of this wetland, then possibly northwards towards the river. At this point in the design phase, specific details regarding staging areas, locations of stockpiles, types of equipment to be used, construction methods or timing have yet to be resolved.

5.2 Impacts on the Saltmarsh Habitat

5.2.1 Impacts Due to Construction

The main impact of the construction of the proposed road across the saltmarsh habitat will be the loss of habitat in the areas where the bridge piles are located. Assuming that six spans of approximately 35 m length are built over the saltmarsh, requiring 5 piles to be placed on the saltmarsh itself, the area of permanent habitat loss would be approximately 255 m^2. This area represents approximately 0.021% of the saltmarsh habitat present in SEPP 14 Wetland # 743 (approximately 1.2 km^2). Additionally, areas of the saltmarsh immediately surrounding each pier will be damaged during construction, but would be expected to recover, given appropriate post-construction mitigation measures. Given that a 4 m perimeter around each pier would be affected, this area is estimated to be 1120 m^2. The area that would be damaged by the construction of a temporary road to allow machinery access should be limited to the roadway itself, to be built to the north of and parallel to the proposed road. Given that the road embankment is 10 m wide and crosses approximately 137 m of saltmarsh habitat, the estimated area of damage is 1370 m^2.

In summary, the concept design for the roadway and plans for machinery access would result in an estimated area of 255 m^2 of permanent loss and an additional 2490 m^2 of saltmarsh that would be damaged during construction, but expected to recover given adequate implementation of post-construction mitigation measures.

The construction of bridge piles in the saltmarsh could also have indirect effects on the ecology of the saltmarsh. The machinery required to construct the piles has the potential to change the surface topography of the saltmarsh, which could alter the distribution and abundance of saltmarsh plants. For instance, the compaction of saltmarsh soil due to machinery could alter water and nutrient flow and limit the ability of plants to regenerate in affected areas. Given that the piers will extend down some tens of metres to bedrock, the presence of the piles in the saltmarsh may alter the flow of water

across and through the saltmarsh. Such changes in water flow may also alter the abundance and distribution of saltmarsh plants. However, further studies would be required to determine the extent to which the piles may change the flow of water in the saltmarsh.

The 1996 Local Environmental Plan identified acid sulfate soils as potential problems for development at Karuah. The drainage of low-lying land has caused problems for oyster growers along Tilligerry Creek in Port Stephens in the past (MHL 1999). Tests on soil samples carried out during the EIS for the Karuah Sewerage Treatment Plant (ERM Mitchell McCotter, 1997) also found evidence of acid sulphate soils at Karuah. Assuming that the excavations for the piles would be filled and capped, and appropriate sedimentation and erosion control measures are implemented, it would appear that there is little chance of developing water quality problems associated with run-off from acid sulphate soils.

5.2.3 Long-Term Impacts

The presence of the roadway above the saltmarsh will cast a shadow on the saltmarsh below it. While the duration and extent of the shadow will change with the season and time of day, its greatest effect, if any, is likely to be seen directly below the roadway. However, the planned height of the roadway, (approximately 10 -12 m) and the relatively narrow width of road casting the shadow (approximately 22.6 m) will minimise the area of saltmarsh affected by shading and reduce the intensity of the shade directly below the roadway. One indication that shading is affecting the saltmarsh community would be any increase in the abundance of species of algae tolerant to shade immediately below the roadway. Although there are other roadways that cross over saltmarsh habitat, we can find no information regarding the tolerance of saltmarsh plants to shading by roads or other structures. This is in keeping with the general paucity of information on the ecology of saltmarsh plants in Australia. Monitoring this aspect of the potential effects of roadways on natural habitats would fill a gap in this information.

Because the design of the roadway includes provision for the re-direction of run-off to a sedimentation basin it is unlikely that the saltmarsh will be affected in the long term by chemicals that accumulate on roadways.

5.3 Impacts on the Mangrove Habitat

5.3.1 Construction Impacts

The main impact of the construction of the road across the mangrove habitat will be the loss of habitat in the areas where the bridge piles are located. The route chosen crosses the mangrove forest at its narrowest point, approximately 100 m wide. Assuming four spans of approximately 35 m length are built over the forest, requiring 3 pairs of piles to be placed within the mangrove habitat, the area of permanent habitat loss would be approximately 153 m^2. This area represents a small proportion of the mangrove habitat present in SEPP 14 Wetland # 743 (Figure 1), but the actual area of the habitat is difficult to estimate without extensive ground-truthing. The areas surrounding the pier will also be disturbed during construction. Given that a four–metre perimeter is required around each pier for construction, the area disturbed by construction is estimated to be 672 m^2. The construction of a road embankment to access the construction areas is estimated to be 1000 m^2., given that the road is 10 m wide on traverses 100 m of mangrove habitat. Areas disturbed by machine access, however, are likely to recover in the long term (in the order of years) given appropriate post-construction mitigation, whereas the areas occupied by the piles are lost permanently as mangrove habitat.

The construction of bridge piles in the mangrove habitat could also have indirect effects on the ecology of the mangrove forest. The machinery required to construct the piles has the potential to change the surface topography of the mangroves, which could alter flow of water through the forest.

Such small-scale changes in surface contour and water flow can alter the local distribution and abundance of plants and animals (e.g Warren and Underwood, 1986). Given that appropriate ameliorative measures will be taken, we would expect such changes to be undetectable within a time frame of years.

Mangrove habitats contain a high proportion of mud, and disturbances to mud surfaces can increase the turbidity of water both locally and in the river. Large or long-term increases in turbidity can affect the movement patterns of fish and mobile invertebrates, and should be minimised. As in the saltmarsh habitat, it would appear that there is little chance of developing water quality problems associated with run-off from acid sulphate soils because the excavations for the piles would be filled and capped.

5.3.2 Long-Term Impacts

The mangrove habitat below the road will be shaded for a short period of the day around midday. Based on studies of shading in other mangrove habitats we would predict that mangrove seedlings would continue to germinate under reduced light conditions, but fail to survive to the reproductive stage of development (Clarke & Allaway, 1993). This prediction should be interpreted with caution, however, as the study on which it is based examined the effects of shading on mangroves caused by natural sources (such as canopy trees) rather than artificial structures. The total area likely to be affected by shading is less than 2,260 m^2, assuming that the length of road bridge over the mangrove habitat is approximately 100 m long and the road is 22.6 m wide. However, the edges of this area are unlikely to be affected by shading, while the central strip is likely to be affected to a greater degree. Quantification of the degree and extent of shading could be determined by modelling light behaviour in a scale-model replica.

To the best of our knowledge, there are no published data on shading of mangroves by artificial structures that would allow a quantitative prediction to be made regarding the likely magnitude of the impact at the Karuah bridge site. The light compensation point, the level of light at which the energy gained during photosynthesis is equal to that required for respiration, has been calculated for *Avicennia marina* but not for *Aegiceras corniculatum* which is also present in the forest that will be shaded. As for the shading issue in the saltmarsh, this project represents an opportunity to monitor such impacts, allowing future predictions to be made with greater precision.

The presence of the bridge piers could alter the pattern of water flow in the mangrove forest, depending on their placement within the forest. Water flowing around the piers could cause local scouring, which in turn could alter the distribution of plants and animals on the scale of metres around the piers. To the best of our knowledge, there are no published studies that would provide a quantitative basis for predictions relevant to the Karuah site, however other studies have demonstrated the importance of small-scale changes in water flow and surface topography to the ecology of forest biota (Warren and Underwood, 1986; Coleman 1998).

Because the design of the roadway includes provision for the re-direction of run-off to a sedimentation basin it is unlikely that the mangrove forest will be affected in the long term by chemicals that accumulate on roadways.

5.4 Impacts on Fish, Mobile Invertebrates and Oysters

An important feature of the wetland habitat near Horse Island is the presence of tidal creeks which drain into the Karuah River. This study showed that 25 species of fish and five species of mobile invertebrates use creek habitats, including some with recreational and commercial importance. The creeks near Horse Island had a greater diversity and number of fish than other creeks sampled, and are clearly important habitats for local fish communities. Damage to these creeks due to construction activities could affect the size and health of local fish communities. Because fish can and do move

between creek, riverine and other estuarine habitats, disturbance to the tidal creeks that reduced their quality as habitat could have a flow-on effect to the ecology of the greater Port Stephens estuary. However, as other rivers also flow into the estuary and contain fish habitat, it is not possible to predict the magnitude of this potential flow-on effect with respect to the size or composition of fish populations.

The construction of piles within the river is likely to cause an increase in turbidity in the water during excavation. Due to the tidal nature of the river, it is likely that plumes of turbid water will be moved up and down the river from the construction site, and would be present for some time after construction ceases. The retention time of the turbidity plume will be related closely to the retention time of water in that particular section of the river. Input from river hydrologists is required to estimate the likely retention time of plumes in the river..

Mobile animals such as fish and prawns may avoid a turbidity plume by moving away from it, but sedentary animals such as oysters will be unable to escape its effects. The most likely response by oysters to a plume of turbid water would be to cease feeding. However, oysters are adapted to natural periods of turbid water, and could be expected to survive given that the increase in turbid water was of short duration, comparable to natural event such as those present after a storm event.

If the location of the bridge pile is such that eddies around it cause erosion from the bank or river bottom, then the turbidity plume may be a more permanent feature of the water quality under the bridge. Such a long-term increase in turbidity could make the leases affected unviable. In this case, the oyster lease would need to relocated away from the bridge piles.

6.0 MITIGATION OF IMPACTS

Mitigation of impacts of road construction and operation on and over wetland habitats should be included in a larger environmental management plan which includes the recommendations of other specialists such as those assessing impacts on terrestrial ecology. The EMP would outline specific procedures to mitigate the impacts identified for the wetland habitats in detail, and would present detailed designs for monitoring programs which encompass the design and planning, construction and post-construction phases of the project. It is understood that RTA will undertake a separate study to address the issue of compensation for wetland areas permanently lost due to road construction.

Issues and considerations for the wetland habitats at Karuah include:

6.1 Design Phase

- A significant advantage of the concept design roadway is the decision to bridge the wetland area, rather than to build across it on landfill. The bridge design minimises disturbance to the wetland habitats, and enables the wetlands to retain crucial aspects of their function.
- The longest spans that are feasible and within cost parameters should be used across wetland habitats to minimise the permanent loss in saltmarsh and mangrove habitats. Dual carriageway designs were considered, as they would decrease the potential effects of shading in wetland habitats, but the single roadway concept design was selected because it offers a better balance between habitat loss due to the number and footprint size of piers required and the amount of shadow cast by the road structure.
- Spans should be placed so that no piles are on the creek banks or in the creeks flowing through the saltmarsh or mangrove habitats, thus avoiding any disturbance to these important habitats. The concept design has taken this issue into consideration, and would avoid the creeks flowing through the saltmarsh habitat and their banks.
- Holes in the saltmarsh left by geotechnical survey should be filled with sand to minimise their impact on water flow in the saltmarsh. If possible, the material removed should be replaced. If not available, the fill sand should be similar in grain size characteristics to the soil removed, and free of chemical contaminants.

6.2 Construction Phase

6.2.1 Construction Roads

- Ideally, the construction of access paths or roads for construction vehicles through or along the saltmarsh and mangrove forest should be avoided. However, it is not possible to move heavy machinery to construction sites without building some type of temporary road, and the absence of a construction road could possibly do more damage to the habitat than a well-constructed one. The placement of construction roads should take the shortest route across wetland habitats, in this case immediately to the north of and adjacent to the position of the bridges where the wetland habitat is at its narrowest.
- Prior to laying the construction road, it is feasible to first remove the top layer of sediment (approximately 10 cm) and store it off site during construction. This biologically active sediment should be maintained such that characteristics of exposure to light, water content and salinity mimic those in the native habitat. River water should be used to water the sediment, sourced from the saltmarsh creeks or the river adjacent to the mangrove forest. The schedule of watering (frequency and timing) should correspond to that of the rising tide in the

creeks or the river. Although this technique is relatively new, it is entirely feasible and, if implemented with care, may shorten the time required for recovery from the disturbances caused by construction.

- A flexible barrier such as geotextile should be laid on the surface of the saltmarsh before road building material is added. This should minimise contamination of wetland sediments from road building material and diminish the effect of soil compaction by the machinery.
- The construction road across the saltmarsh should be designed so that it bridges the creeks that flow through the saltmarsh habitat, as these have been identified as having important ecological function for this wetland. Culverts should be placed over the creeks to allow fish passage in accordance with NSW Fisheries policy.

6.2.2 Mitigation of Other Construction Impacts

- Any stockpiles of materials adjacent to wetlands should be contained or bunded to avoid run-off into the wetlands.
- Spoil from pile excavations should not be disposed of near water or wetland habitats. If the sulphate content of the excavated material proves to be acceptably low, then it should be retained and used after construction to re-level areas around the piles and along construction roads.
- Retention devices such as silt curtains should be used around excavations for piles to avoid the movement of sediment and water into the creek or river.
- Damage to creek banks from any source should be avoided.

6.3 Post-Construction Phase

- The level of the wetland surface around the piers should be assessed, and, if required, returned to its original level using native material (if possible) or other suitable fill.
- The sediment stripped from the surface prior to construction should be replaced around the piers and along the construction road. Monitoring of the habitat would determine if additional replanting is required.
- The roadway has incorporated control measures for run-off from the road that direct run-off away from the wetlands and the river. The efficacy of these devices should be assessed after construction, during and after under rainfall events of various magnitudes.

7.0 RECOMMENDATIONS FOR MONITORING

The likely effects of the road on the aquatic ecology of the wetland habitats should be monitored using several components of the biota for which baseline information has been established.

Monitoring prior to construction should be undertaken to:

- Establish small scale (in the order of centimetres) elevation in the saltmarsh, focussing on the construction area.
- Establish small-scale distribution of algae in saltmarsh transect immediately below roadway and at several nearby reference areas that will not be shaded by the bridge.
- Record d salinity, pH and acid sulphate soil content of saltmarsh and mangrove sediments.
- Establish natural levels of light present in areas to be shaded by bridge and nearby reference areas.
- Repeat transect monitoring in wetland habitats to establish levels of variation present in biotic variables due to seasonal changes. This monitoring would allow a refinement of background levels of natural variation in abundance and distribution of biota that would assist in establishing the magnitude of the impact of road construction, if any on biotic communities. While the results of this study demonstrated significant differences in biotic communities at the level of site, it is possible, given an appropriate sampling design, to isolate changes due to the impact of road construction from background or natural variations attributable to differences between sites or seasons. Such a design would incorporate the comparison of biotic variables before and after road construction at the impact site as well as the same comparisons for wetland habitats in unaffected (control) areas. To be effective, this design must incorporate data from at least two sampling times before construction begins.

Monitoring during construction should be undertaken for:

- Water quality. During construction water quality monitoring should focus on levels of turbidity and pH in the context of background levels in similar habitats elsewhere in the river, including the main river and in smaller creeks. The locations established in this study could form a starting point for monitoring water quality during construction. Given that the landscape characteristics indicate a potential for acid sulphate soils (Stone *et al.*, 1998), and that there is visual evidence indicating their presence in the area (Plate 30), it is recommended that the potential for run-off from acid sulphate soils be investigated further. The design for such investigations should provide for sampling water immediately after the first flush of rain.
- Continued quantitative surveys of "damage" in mangroves, to determine compliance with the EMP during construction.
- Visual assessment of condition of creek and creek banks in saltmarsh habitat.

Monitoring after construction should be undertaken for:

- Mangrove condition, including density of seedling, pneumatophores and survivorship of seedling, with the aim of quantifying the effects of shading by the road bridge. The design of the monitoring programme should include reference mangrove forests within the Karuah River foreshores that are subject to varying degrees of natural shading, and mangroves in other locations that are subject to shading by roads.
- Diversity and density of saltmarsh plants (including extent of algae). Areas monitored should include those shaded by the road bridge and nearby reference areas in full sun.

- Water quality monitoring after construction should focus on those components that are known to be present in run-off from roads such as heavy metals and oil and grease. Some of the water quality indicators could be recorded using remote data loggers to reduce the overall cost of the program.
- Fish and mobile invertebrates in the creeks and rivers should be monitored using non-destructive techniques to the extent possible.

Further mitigation measures would be developed based on the outcome of the above monitoring program.

8.0 ACKNOWLEDGEMENTS

This report was written by Peggy O'Donnell (BSc, BA, PhD), Marcel Green (BAppSc), and Jane Harris (BSc, M Env. Stud.) and reviewed by Marcus Lincoln Smith (BA, BSc Hons, MSc, PhD). Marcel Green, Tim Cooper, Richard Holliday, Elton Robinson and Sarah Waterworth conducted the field studies. Michelle Yerman (BSc) sorted mangrove samples and Jane Harris did the faunal identifications. Michelle Yerman and Elton Robinson (BAppSc) sorted samples of fish and Marcel Green did the identifications. Jane Harris, Peggy O'Donnell and Marcel Green did statistical analyses, and produced tables, figures and appendices. Ingrid Berthold (BSc) assisted with figures and tables. For more detail on qualifications of staff see Appendix 5.

John Verdich, local oyster grower, provided us with information about oyster production within Karuah River and NSW Fisheries Port Stephens assisted us with recreational and commercial fishing. The many landowners are thanked for allowing us unimpeded access through their land during our field studies.

9.0 REFERENCES

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

ANZECC (1992). *Australian water quality guidelines for fresh and marine waters.* National water quality management strategy, Australia.

Ball, J. E., Jenks, R., Aubourg, D. (1997). An assessment of the availability of pollutant constituents on road surfaces. *Science of the Total Environment.* **209**, 99. 243-254.

Bishop, K.A. (1995). *Review of existing water quality and land/water use data from the Karuah River catchment: prerequisite for the development of strategic water quality monitoring* Study undertaken for the River Management Subcommittee of the Karuah and Great Lakes Total Catchment Management Committee.

Chapman, H.F., Dale, P.E.R., and Kay, B.H. (1998). A method for assessing the effects of runneling on salt marsh grapsid crab populations. *Journal of the American Mosquito Control Association* **14**, pp. 61-68.

Clarke, K.R. (1993) Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, **18**, pp. 117-143.

Clarke, K.R., and Ainsworth, M. (1993). A method of linking multivariate community structure to environmental variables. *Marine Ecology Progress Series* **92**, pp. 205-219.

Clarke, K.R., Warwick, R.M. (1994) *Change in marine communities: An approach to statistical analysis and interpretation.* Plymouth Marine Laboratory. Natural Environmental Research Council, U.K. 144pp.

Clarke, P.J., and Allaway, W.G. (1993). The regeneration niche of the grey mangrove (*Avicennia marina*): effects of salinity, light and sediment factors on establishment, growth and survival in the field. *Oecologia*, **93**, pp 548-556.

Coleman, P.S.J. (1998). Changes in a mangrove/samphire community, North Arm Creek, South Australia. *Transactions of the Royal Society of S. Australia* **122**, pp 173-178.

ERM Mitchell McCotter (1997). Environmental Impact Statement Volume 1. Karuah Sewerage Scheme. Prepared for Hunter Water Corporation, Department of Land and Water Conservation.

Fisheries Management Act 1994. New South Wales Government. Published by NSW Government Printer.

Great Lakes Council (1996). *Local Environmental Plan – Heritage.* Great Lakes Council.

Manly Hydraulics Laboratory (1999). *Port Stephens/Myall Lakes Estuary Processes Study.* Report prepared for Port Stephens Council and Great Lakes Council, Report No. MHL913.

New South Wales National Parks and Wildlife Service (1999a). *Wildlife Atlas Database Clarence Town* Location *1:25,000 Map Sheet* Map # 9232-1-N .

New South Wales National Parks and Wildlife Service (1999b). *Wildlife Atlas Database Karuah* Location *1:25,000 Map Sheet* Map # 9232-1-S.

Skilleter, G.A. (1996). Validation of rapid assessment of damage in urban mangrove forests and relationships with molluscan assemblages. *Journal of the Marine Biological Association of the United Kingdom.* **76**, pp. 701-716.

Stone, Y., Ahern, C.R., and Blunden, B. (1998). *Acid Sulfate Soil Manual 1998*. Prepared for: NSW Government. New South Wales Acid Sulfate Soils Management Advisory Committee (ASSMAC), Wollongbar, NSW.

Threatened Species Conservation Act 1995 (TSC Act). New South Wales Government.

Underwood, A.J. (1981). Techniques of analysis of variance in experimental marine biology and ecology. *Oceanography and Marine Biology: an Annual Review* **19**, pp. 513-605.

Warren, J.H., and Underwood, A.J. (1986). Effects of burrowing crabs on the topography of mangrove swamps in New South Wales. *Journal of Experimental Marine Biology and Ecology,* **102**, pp. 223-235.

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

Winer, B.J. (1971). *Statistical Principles in Experimental Design*. McGraw-Hill, Inc., USA, 907 pp.

Winer, B.J., Brown, D.R., and Michels, K.M. (1991). *Statistical Principles in Experimental Design*. McGraw-Hill, New York, USA, 1057 pp.

Report to:

Ove Arup & Partners

Wetlands Compensation Package Proposal

For the Pacific Highway Upgrade at Karuah

Stage 1

FINAL

October 1999

Report prepared by:

The Ecology Lab Pty Ltd

25/28-34 Roseberry Street

Balgowlah, NSW

Australia 2093

Phone: (02) 9907-9399

Fax: (02) 9907-9386

E-mail: ecolab@ozemail.com.au

Table of Contents

1.0 Introduction 1
1.1 Background and Aims 1
2.0 Study Methods 2
3.0 Results 3
Western River Bank Habitats 3
3.1 SEPP 14 No744 – Lizzies Creek 3
3.2 SEPP 14 No 743 3
3.3 SEPP 14 No 778 3
3.4 SEPP No 780 4
3.5 SEPP 14 No 779 4
3.6 SEPP No 781 – Swan Island 4
3.7 SEPP No 786 – Reedy Creek 4
3.8 SEPP Nos 785 and 784 5
Eastern River Bank Habitats 5
3.9 SEPP 14 No 742 5
3.10 SEPP 14 No 743a 5
3.11 SEPP 14 No 776 5
Mosquito Creek 5
Unnamed creek 5
South-eastern Boundary 6
3.12 SEPP14 No 777 – Yalimbah Creek 7
4.0 Recommendations for Remediation 8
4.1 Damage by Oyster Lease Debris 8
4.2 SEPP 14 No 778 8
4.3 Area Available for Rehabilitation 9
5.0 Recommendations for Stage 2 12
6.0 Acknowledgements 13
7.0 References 14
Figures 15
Plates 18

1.0 INTRODUCTION

1.1 Background and Aims

As part of an extensive program of upgrade for the Pacific Highway, a new bridge over the Karuah River is proposed to be built approximately 3 km to the north of the existing bridge. The preferred route for the upgrade crosses the river at Horse Island, and traverses two sections of wetland protected under State Environmental Planning Policy No. 14 (SEPP14). The sections of road that traverse the wetlands would be built on bridges to reduce habitat loss. This document summarises work done by The Ecology Lab Pty Ltd on behalf of Ove Arup & Partners to formulate proposals for wetland compensation associated with the permanent loss and shading of wetland habitat due to the construction of bridges in and over designated SEPP 14 wetlands.

NSW Fisheries policy regarding the resumption of wetlands is "no net loss", requiring compensation for unavoidable loss of habitat by the creation of new habitat in the ratio of 2:1, to account for the indirect as well as direct impacts of the development (Fisheries NSW, 1998). In addition, the Department of Urban Affairs and Planning (DUAP) has developed, but not yet implemented, a draft "compensatory wetlands policy". In the draft policy, compensation would be required for wetland area destroyed by development using a ratio of 10:1 to the wetland habitat lost.

With these policies in mind, The Ecology Lab Pty Ltd undertook visual assessments of wetlands adjacent to the Karuah River with the aim of highlighting any that could be considered candidates for rehabilitation by the proponent. Where wetlands areas showed signs of disturbance or damage, the type and extent of the damage was quantified. This report summarises the findings of the investigations and presents preliminary options for rehabilitation of the nominated wetland areas.

2.0 STUDY METHODS

Those areas of wetland which had previously been identified as having the potential for rehabilitation were revisited. Inspections of wetland habitats were made on 22/6/99 and 20/8/99. At each of these sites:

1. The type of damage was described in detail,
2. Photographs were taken of the disturbed area,
3. The area of the disturbance was measured, and
4. Consideration was made of what actions would be required to restore these areas to healthy wetland habitats.

In addition, other wetlands in the area were examined for disturbance for possible inclusion into the compensation package.

3.0 RESULTS

The wetland habitats investigated are listed firstly along the west bank of the Karuah River from north to south, then on the east bank of the river from north to south.

Western River Bank Habitats

3.1 SEPP 14 No744 – Lizzies Creek

There appeared to be very little damage along the downstream end of Lizzies Creek near the property of MH and CP Grant. This area was dominated by fringing grey mangroves with saltmarsh and Casuarina away from the rivers edge. There was no evidence of damage on the banks of the creek near the confluence with the Karuah River.

3.2 SEPP 14 No 743

Detailed descriptions of this wetland are given in the aquatic ecology specialist report for the EIS (TEL 1999). In brief, this large wetland has extensive areas of mangrove and saltmarsh habitat, through which several mangrove-lined creeks run. With the exception of the remains of a log bridge across the creek to the south-west of Horse Island, the wetland is in good condition. Very little rubbish was observed, which was of the type that could float in on high tide.

3.3 SEPP 14 No 778

This SEPP 14 wetland is adjacent to the township of Karuah and is divided by Mustons Road which runs north from the Pacific Highway (Figure 1). The section of the wetland to the west of the road is apparently freshwater habitat suggesting that there is very little or no flow of water under the road (Plate 1). This section of the wetland appears however to be relatively healthy and is lined by Casuarina and eucalypt trees and shrubs on the banks to the north and south. A large proportion of the wetland itself is covered by standing water, most of which is covered with native fern (*Azolla* sp.). Raised areas contain bracken, rushes (*Juncus* sp), cumbungi (*Typha* sp.) and mixed grasses (Plate 1). Numerous wetland birds were sighted in the wetland including ducks, ibis and black swan.

The wetland on the eastern side of Mustons Road is flushed by the small creek that flows into the river and is dominated by grey mangroves (*Avicennia marina*), with both salt couch (*Sporobolus virginicus*) and samphire (*Sarcocornia quinqueflora*) on its edges (Plate 2). A dirt lane runs to the east from Mustons Road to the end of Franklin St along the southern edge of the wetland (Plate 2). It is approximately 200m long, appears to have been recently repaired and was in frequent use during our observations. The wetland adjacent to the lane on both sides has apparently been damaged by its construction. To the south, there is only a small area of wetland, dominated by grey mangrove with small patches of salt couch and scattered samphire (Plate 2). This wetland is 19 m across at the widest point and is backed by a narrow stand of Casuarina. Although there is a small pipe to allow flushing between the northern and southern sides of the lane, it currently appears to function inadequately (Plate 3 and 4). The waterbody on the south of the lane is stagnant and rust-coloured (Plate

5). The colour of the stagnant water suggests that oxidised iron is present, which in turn may indicate the presence of acid sulphate soils (Stone *et al.*, 1998).

To the north of the road, there is a large patch of bare mud that appears to have once supported saltmarsh and mangroves, based on the presence of mangrove tree stumps and patches of dead samphire (Plate 6). In addition, the surface mud of the area is a similar colour to the road surface and may have runoff the road either during or since construction. The cause of this expanse of bare mud however is not clear. Beyond the bare patch, the mangroves and saltmarsh on the northern side of the lane appear robust and extensive.

On 20/8/99, Mustons Gully was navigated from the Karuah River. We observed erosion on the northern bank about 50m upstream from the river, near the edge of the unnamed cul de sac to the north of the wetland. (Plate 7). There was also a makeshift boat ramp from the road down the hill to the creek. It has no built structures, but the mud adjacent to the river bank was compacted (Plate 8). Further along creek were three small areas where rubbish from oyster leases had been dumped:

1. South side of creek, consisting of sticks and shells. Area approximately 10 m^2.
2. North side of creek, consisting mainly of oyster racks. Area approximately 8 m^2.
3. South side of creek, consisting of oyster sticks and shells. Area approximately 9 m^2.

In addition, we observed on small tributary off creek about 10m away a dumped, apparently unused dingy.

3.4 SEPP No 780

This wetland is a small island in the western margin of the river between SEPP No 779 and SEPP No 781 (Swan Island)(Figure 1). It was entirely covered in mangrove habitat with trees ranging from 1 to 2 m high. No damage to the habitat was observed, and no significant rubbish was sighted.

3.5 SEPP 14 No 779

This wetland was located on the western bank of the river to the north-west of Swan Island. The habitat was dominated by dense mangrove habitat. It appeared to be in healthy condition and no significant rubbish was observed.

3.6 SEPP No 781 – Swan Island

The northern tip of the island had a large area covered in oyster debris. Remnants of a building suggest it may have once been the site of oyster cleaning sheds (Plate 9). The bulk of the debris is oyster sticks piled high with shells. Also present were pylons from an old building, old rusted machinery, ½ an old water tank, drums, and miscellaneous rubbish (Plate 10). The entire damaged area was approximately 1300 m^2. Healthy mangrove habitat surrounded the damaged area and was backed by saltmarsh with scattered mangroves.

3.7 SEPP No 786 – Reedy Creek

On the first tributary on the southern bank of Reedy Creek we observed a very large pile of oyster lease debris on the bank near the mouth (Plate 11). It was comprised mainly of sticks

and shells and was approximately 8 m by 30 m by 2 m high (240 m^2). Another tributary on the northern bank further upstream also had a small dump site (32°39.59S, 151°56.22E)(Plate 12). The debris included rolls of chicken wire, oyster sticks and shells. The area of this pile was approximately 15m by 4 m by 1 m high (60m^2). No further damage was observed further upstream in Reedy Creek or any of its tributaries.

3.8 SEPP Nos 785 and 784

These small islands to the south of Swan Island consisted mainly of mangrove habitat. They appeared to be in healthy condition and no significant rubbish was observed.

Eastern River Bank Habitats

3.9 SEPP 14 No 742

This wetland was located on the eastern side of the river where the river turns east (travelling downstream) for a short distance (Figure 1). The wetland featured dense stands of mangroves dominated by 1 ½ to 2 m high grey mangroves (*Avicennia marina)* and river mangroves *(Aegiceras corniculatum)*. It appeared to be healthy and free of rubbish.

3.10 SEPP 14 No 743a

This small wetland further downstream on the eastern side of the river was very similar in structure to SEPP 14 No 742 described above. Similarly, it appeared to be healthy with no evidence of damage.

3.11 SEPP 14 No 776

Mosquito Creek

Mosquito Creek runs into the eastern side of the river in the northern section of the wetland. Although it was a large and accessible creek, it appeared to have had relatively less rubbish dumped than the unnamed creek described below. The banks of the creek were lined with mature mangrove trees extending back into wetlands with mangrove trees and saplings, saltmarsh and Casuarina trees. There were only two obvious piles of debris along the length of this creek.

- Pile 1. Upstream on northern side of creek, it covered approximately 110 m of the creek edge and was 20 m across with a maximum height of 1½ m (Plate 13).
- Pile 2. On the southern side of creek the pile extended for 40m along the creek edge, although only about half this length was piled high with debris and the other half was only scattered. It had a maximum height of 1m and extended about 6m back from the creek edge (Plate 14).

Unamed creek

This creek is located on the eastern side of the river approximately 1 km north of the bridge (Figure 1). It was quite narrow and the entrance was surrounded with oyster leases. The

creek continued upstream to the north-east with very steep banks and apparently healthy wetland habitats. There was no evidence of disturbance in the upstream end of the creek as far as it was navigable. Nearer the mouth, however, there were numerous piles of rubbish consisting of oyster lease debris including, sticks, racks, oyster shells, metal drums and miscellaneous rubbish. Photos were taken of each of the piles and their approximate sizes were as follows:

- Pile 1. This dump was on a small drainage on the south side of the creek and was approximately 20 x 20m, with a maximum height of 2m. It consisted predominantly of sticks and racks and shells (Plate 15).
- Pile 2. Also on a small drainage on the south side of the creek, it extended 25m along the creek edge and back 12m, with a maximum height of 2m. Further back into the wetland from this pile there was approximately 10m x 10m of scattered sticks and shell and a couple of car batteries (Plate 16).
- Pile 3. Located on the northern side of the creek opposite Pile 2 it contained racks, sticks, some plastic and rubbish carpet. 10m x 10m and 2m high (Plate 17).
- Pile 4. Approximately 20m downstream of Pile 3 on the northern side of the creek this dump was smaller, approximately 10m x 5m and 1½m high (Plate 18).
- Pile 5. Southern side of the creek approximately 10-15m from Pile 2, mostly sticks and some light plastic apparently roofing material. Low and scattered about 20m x 20 m (Plate 19).
- Pile 6. Located near the mouth of the creek on the southern side. It extended 15m along the creek edge and 18m back into the wetland with a maximum height of ½m (Plate 20).

Although each of the above were large and obvious dumps of oyster lease rubbish, there were many other areas of small scattered debris particularly between Pile 2 and Pile 5 on the southern side of the creek. It is not clear whether this rubbish has been dumped or floated off the other piles.

South-eastern Boundary

In addition to inspections of the creeks in SEPP No 776, the south-eastern boundary of this SEPP was examined on 20/8/99. Access was gained with permission through private property which formed the boundary of the wetland. Our observations confirmed the owner's statement that his property was fully fenced off from the wetland with well maintained fences. He also weeds along the edge of his property removing fire weed and lantana, including along the highway. Over his fence the land dropped steeply (about 15 m vertical height) to the wetland. This slope was covered in Casuarina and eucalypt trees and bushes. A narrow fringe of Casuarina tress grew on the flat, giving way to saltmarsh which included *Sarcocornia* and *Sporobolus* for about 10 – 40 m, then the grey mangrove *Avicennia*. Towards the north- east the saltmarsh widened out to large expanse of *Juncus*. Damage observed included large amounts of flotsam such as bottles (glass and plastic) and other miscellaneous rubbish (Plate 22). A large stand of dead Casuarina trees was also observed (Plate 21). Except for the dead stand of Casuarina and rubbish, the wetland appeared to be in good condition.

3.12 SEPP14 No 777 – Yalimbah Creek

Yalimbah Creek runs through the middle of SEPP 14 No 777 on the southern side of the Karuah bridge. This creek was also lined with mangroves but was much wider than the other two creeks described above. There was very little visible damage along the edges of this creek, with the exception of a small jetty on the western side of the creek. This jetty is accessed by a 4WD track that crosses the wetland and then private land before joining the highway. The purpose of this jetty is unclear although an apparently man made canal runs beside it. Although it is likely that the road and associated channel would have some effect on water flows through the wetland, there were no obvious signs of damage along the creek in the area if the jetty.

The northern section of SEPP 14 No 777 was examined using access from the highway on 20/8/99. In this section the wetland was very close to the road and likely received runoff from the steep embankment on the north-western side of the highway which was bushland (Plate 23). A series of five large runoff drains direct water from the hill under the road and into the wetland. There were gross pollutant / sediment traps on all of these drains which were in reasonable condition (Plate 24).

Further south, access to Yalimbah Creek was gained by a track onto private property approximately 21m long by about 4m wide (84m^2.) Vehicle access to the creek was blocked by a padlocked gate. Efforts had been made to restrict access to the track by 4-Wheel drive vehicles, with boulders on either side of the unfenced property.

Building material rubbish was observed along the track, and there was some erosion of the bank at the end of the track.

The section of SEPP No 777 that fronts the river consisted of saltmarsh habitat (near the northern border of the SEPP 14 area) and fringing mangroves backed by saltmarsh. The habitat appeared to be healthy and no significant rubbish was observed.

4.0 RECOMMENDATIONS FOR REMEDIATION

4.1 Damage by Oyster Lease Debris

All damage by oyster lease debris was observed in mangrove habitats along creek banks. The recommended approach to rehabilitation of this type of habitat would include the following:

1. Achieve consensus among local oyster growers to cease dumping practices. This agreement should ensure that viable alternative dump sites are available and cost-effective, so that dumping ceases on a permanent basis.
2. Remove all debris to appropriate locations. Care should be taken that items such as car batteries are disposed of in the approved manner. We recommend that the rubbish removal be done using hand tools or light machinery to avoid further compaction and disturbance to the creek banks. Removal of rubbish to a barge may be the most efficient method.
3. Re-level creek bank surface to minimise depressions and elevations caused by debris. This step should be implemented using hand tools rather than heavy machinery.
4. Evaluate areas at approximately 1, 6 and 12 month intervals after rehabilitation. Evaluation should consider the effectiveness of surface re-levelling with respect to run-off and degree of recovery of flora. Because the affected areas are long, narrow and adjacent to healthy stands of mangroves, flora would be expected to recover from natural processes of ingrowth and recruitment of new mangrove seedlings. However, some areas may require revegetation to reduce the short-term effects of erosion.

4.2 SEPP 14 No 778

With the exception of the small area of oyster debris that can easily be removed along the creek banks, rehabilitation of wetlands in this SEPP 14 area is less straightforward, as the damage observed may arise from several, interrelated sources. Overall, the obvious disturbance to the area is the presence of the unsealed road at the end of Franklin Street. The age of the road is unknown, however it appears that is has been re-surfaced sometime between January and June, 1999. The road has changed the flow of water through the back section of the wetland, and probably is a source of sediment that washes off into the wetland after rain. The single pipe running beneath the lane appears insufficient to provide the required water flow, the lack of which is likely to be the main cause of dead and dying saltmarsh and mangroves plants. Based on the presence of a large area of unvegetated mud adjacent to the road, it is possible that the area has been used to dump chemicals, although a sediment sampling program would be required to confirm this.

Three types of remediation are therefore possible to rehabilitate wetlands in SEPP 14 No 778:

1. Improve flushing currently hampered by the lane. This could involve the installation of several pipes or culverts below the lane that would allow water passage to the back of the wetland.

2. Replant the large, unvegetated area to the north of the lane. Testing of the sediments for commonly dumped chemicals in this section of the wetland is recommended to ensure that replanted vegetation will grow.
3. Remove the lane entirely, level the wetland and replant the area occupied by the road. Although this option represents the most permanent approach to rehabilitation, it also would require the greatest effort. This option would require consultation with local residents, as the lane was used extensively during our field observations.

It should be noted that an additional difficulty in the long-term rehabilitation of this wetland is its proximity to housing. We observed several incidents of rubbish dumping adjacent to wetlands, but located on private property. Wetlands adjacent to housing and roads are more likely to be subject to ongoing damage by people than less accessible wetland habitats.

4.3 Area Available for Rehabilitation

The estimated area of permanent habitat loss in SEPP wetland No 743 as a consequence of the construction of the road bridges was calculated in the EIS (aquatic ecology specialist report) as 255 m^2 of saltmarsh and 153 m^2 of mangrove habitat.

The area of wetland that may be affected by shade from the bridge structure has been estimated using methodology described in a separate report (TEL, 1999). The area has been calculated as a function of the amount of time the wetland in the vicinity of the bridge is shaded. As an extensive literature search revealed no scientific research that details the amount of time mangrove and saltmarsh plants can be shaded without ill effect, the figures below present the calculated areas for various amounts of time in shade. The areas listed below do not include permanently lost habitat (given above). The footprints of the areas are presented graphically in Figure 2. Areas shaded greater than 10% of daylight hours are physically located within the 10% footprint (outlined in beige in Figure 2), and thus the figures below are independent rather than additive.

Amount of Time shaded (% of daylight hours)	Area affected (m^2)	Indicated in Figure 2 in this colour:
90	1792	Grey
75	2892	Green
50	5892	Light Green
25	8892	Yellow
10	12492	Beige

The area of wetland which would experience temporary impacts includes the area required for access roads to the construction areas and a perimeter around each of the piers. This area was calculated as 2490 m^2 in the saltmarsh and 1972 m^2 the mangrove habitat. As detailed in the EMP, areas of temporary damage would be restored and are expected to recover fully from the impacts of construction.

The total area of SEPP 14 wetland we examined which has been damaged by the dumping of oyster lease debris is approximately 5587m^2. The components of this figure are detailed in the table below.

It is more difficult to calculated the exact area of wetland which could be restored in SEPP 14 No 778 as the damage to the wetland may have several, interrelated causes. However, if effective flushing to the wetlands on the southern side of the road can be re-established, allowing for natural recovery of flora, the area of the rehabilitated wetland would be approximately 1100 m^2. If it is possible to successfully revegetate the bare patch of mud to the north of the road with wetland flora this would result in approximately 3186 m^2 of restored wetland habitat. Should removal of the road itself be a viable option, the area it occupies could be rehabilitated, resulting in 825 m^2 of wetland habitat.

The table below presents a summary to date of the area available for rehabilitation and the feasibility of rehabilitation options.

Locations with potential for rehabilitation	**Area** m^2	**Type of damage**	**Feasibility of rehabilitation**
SEPP 14 No 778 (Muston Creek)	27	Rubbish from oyster leases	Relatively easy, requires consultation / commitment from oyster farmers to cease dumping practices, inexpensive
SEPP 14 No 776 (creek banks)	3960		
SEPP 14 No 781 (Swan Island)	1300		
SEPP 14 No 786 (Reedy Creek)	300		
Total:	**5587 m^2**		
SEPP 14 No 778: (south of lane)	**1100 m^2**	Dying plants due to lack of flushing	Requiring engineering input
SEPP 14 No 778: (north of lane):	**3186 m^2**	Extensive bare areas	Requires soil testing, replanting
Total area available for rehabilitation	**9,873 m^2**		

From the above table the following can be concluded:

1. Taking a precautionary approach, and assuming that would be appropriate to compensate for the wetland habitat near the bridges that would be shaded for 50% of daylight hours (the medium value) the base area on which compensation ratios for shaded areas 5,892 m^2. Hence, the total base area on which we propose that compensation ratios

should be based is 6,300. This figure is the sum of permanently lost habitat (255 + 153 m^2) and the area shaded 50% of daylight hours (5892 m^2).

2. The area available for compensation identified in this report, 9,873 m^2, represents a potential compensation ratio of approximately 1.5: 1. Therefore, greater compensation ratios are not achievable with the potential rehabilitation of damaged or degraded areas within SEPP 14 wetlands near Karuah identified to date.

5.0 RECOMMENDATIONS

To finalise a feasible wetland compensation package, we recommend the following activities be undertaken:

- Commence dialogue with oyster farmers regarding alternative disposal sites for rubbish from oyster leases,
- Determine with NSW Fisheries, DUAP and RTA the basis for the wetland habitat compensation package and discuss the details of SEPP 14 areas available for remediation and the application of wetland compensation policies to the situation in the Karuah region,
- Consider other forms of compensation such as the purchase of land within catchments to SEPP 14 wetlands, or rehabilitation of SEPP 14 or other wetland areas outside the general Karuah area ,
- Finalise the compensation package based on agencies' requirements and an evaluation of the various compensation options in terms of the most cost effective means of achieving agreed conservation objectives.

6.0 ACKNOWLEDGEMENTS

This report was written by Dr Peggy O'Donnell and Jane Harris. Field work was done by Jane Harris, Richard Holliday and Marcel Green, Elton Robinson and Kylie Pitt.

7.0 REFERENCES

Fisheries NSW (1998). Policy and Guidelines. Aquatic Habitat Management and fish Conservation.

Department of Urban Affairs and Planning (1998). Draft Compensatory Wetlands Policy. SEPP 14: Compensating for wetlands destroyed through development.

Stone, Y., Ahern, C.R., and Blunden, B. (1998). *Acid Sulfate Soil Manual 1998*. Prepared for: NSW Government. New South Wales Acid Sulfate Soils Management Advisory Committee (ASSMAC), Wollongbar, NSW.

The Ecology Lab (1999). Aquatic Investigations for the Pacific Highway Upgrade at Karuah. Final, June 1999.

The Ecology Lab (in preparation, 1999). Methodology for the Assessment of the Impact of Shade on Wetland Habitats In Relation to the Proposed Highway Upgrade at Karuah.

FIGURES

Figure 1: Map of Karuah region showing locations of disturbed wetlands.

Figure 2: Shade contour diagrams for the bridges over SEPP 14 No 743.

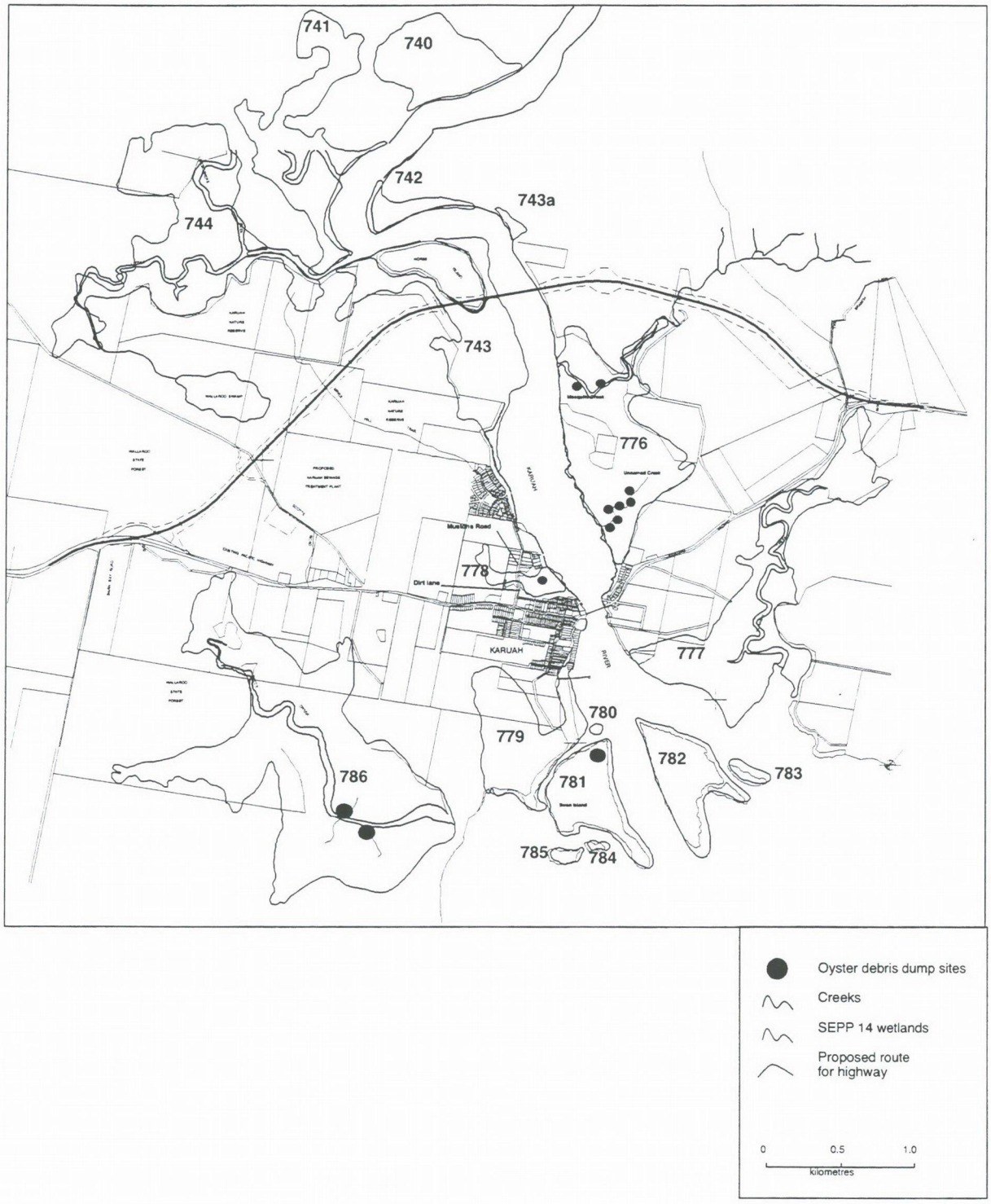
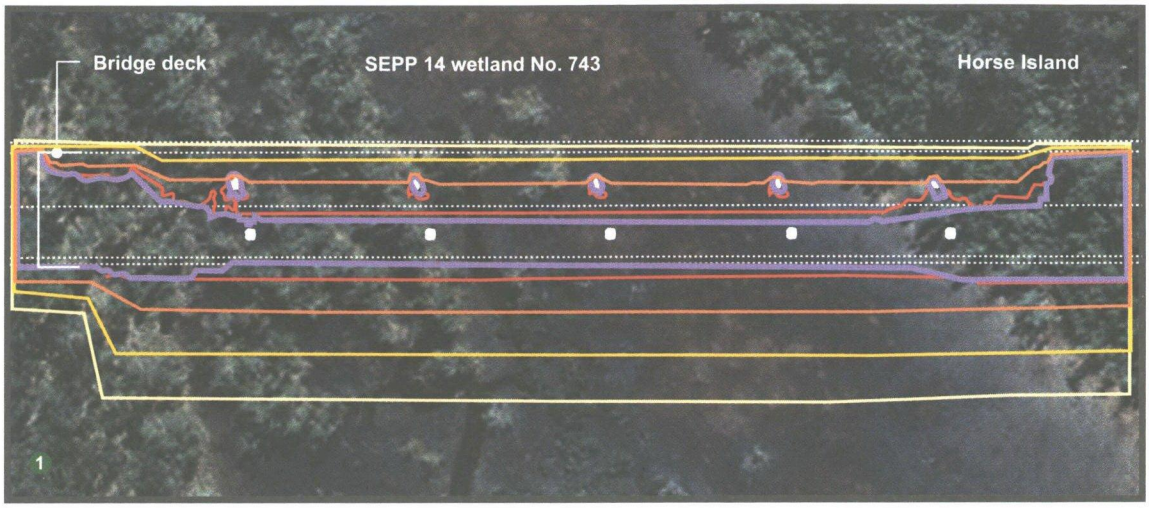
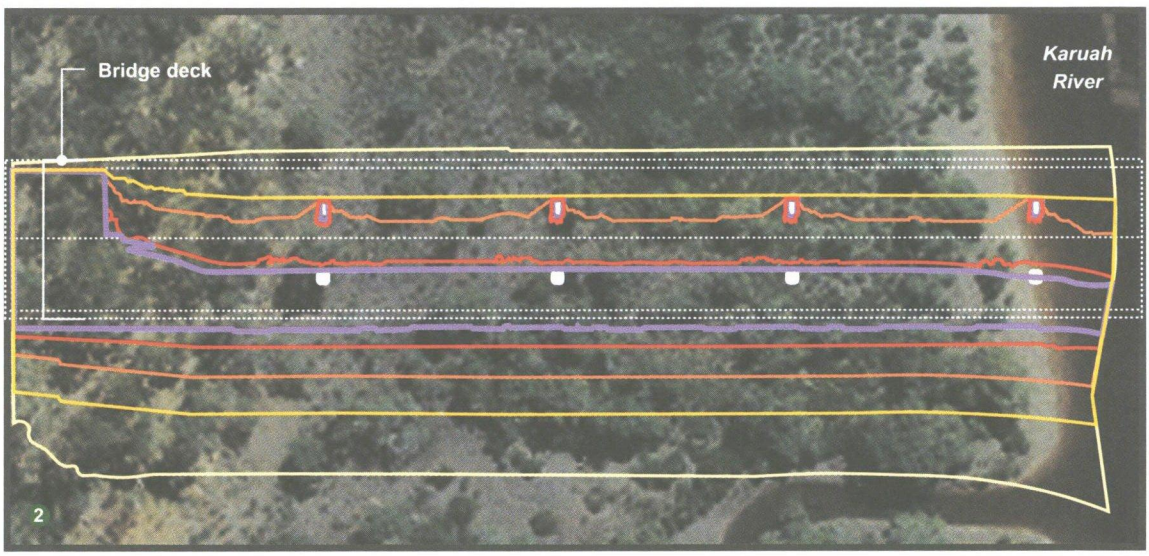


Figure 1: Map of the study area showing the proposed route of the highway, SEPP 14 wetlanc and the locations of areas with potential for rehabilitation.



Shadow contours -
bridge over SEPP 14 wetland No 743



Shadow contours -
bridge over Karuah River (western end)

10% Shade
25% Shade
50% Shade
75% Shade
90% Shade
Bridge pier

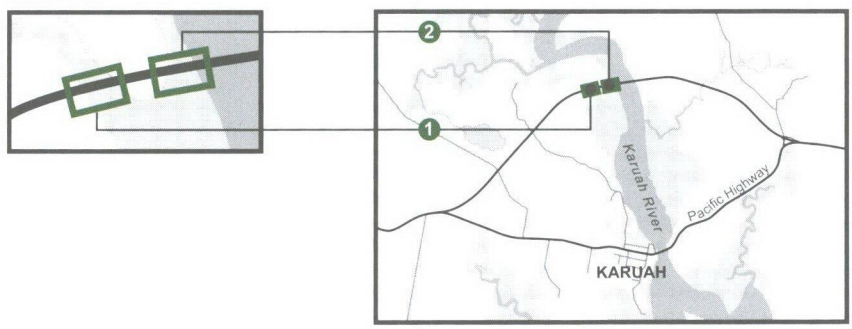


Figure 2: Shadow contour diagrams for the bridges over SEPP 14 743

PLATES

Plate 1: SEPP 14 No 778 -Freshwater wetland to the west of Mustons Road, view northeast.

Plate 2: SEPP 14 No 778 - Lane through wetland on the eastern side of Mustons Road, view west.

Plate 3: SEPP 14 No 778 -Drainage pipe under dirt lane, view west towards wetland on southern side of the lane.

Plate 4: SEPP 14 No 778 - Drainage pipe under dirt lane, view south across lane.

Plate 5: SEPP 14 No 778 - Mangroves on southern side of lane, showing stagnant rust coloured water.

Plate 6: SEPP 14 No 778 - Bare mud patch on northern side of the laneway. View south towards lane, Mustons Road to the right.

Plate 7: SEPP 14 No 778 - Erosion on creek banks near end of track. View east towards mouth of creek.

Plate 8: SEPP 14 No 778 - View of makeshift boat ramp, looking south along creek (upstream) from track down to creek.

Plate 9: SEPP 14 No 781 - Swan Island. Pile of old oyster sticks with shells. View south.

Plate 10: SEPP 14 No 781 - Swan Island. Miscellaneous rubbish in mangroves near old shed site.

Plate 11: SEPP 14 No 786 – Reedy Creek. Pile of oyster rubbish on confluence of first major tributary on the south bank of Reedy Creek. Mainly oyster stick debris.

Plate 12: SEPP 14 No 786 – Reedy Creek. Second pile of oyster rubbish in small tributary to the north of Reedy Creek. Includes oyster sticks, chicken wire and other debris.

Plate 13: SEPP 14 No 776 - Pile No 1 on north side of Mosquito Creek.

Plate 14: SEPP 14 No 776 - Pile No 2 on north side of Mosquito Creek.

Plate 15: SEPP 14 No 776 - Pile No 1 on south side of unnamed creek.

Plate 16: SEPP 14 No 776 - Pile No 2 on south side of unnamed creek.

Plate 17: SEPP 14 No 776 - Pile No 3 on north side of unnamed creek.

Plate 18: SEPP 14 No 776 - Pile No 4 on north side of unnamed creek.

Plate 19: SEPP 14 No 776 - Pile No 5 on south side of unnamed creek.

Plate 20: SEPP 14 No 776 - Pile No 6 on south side of unnamed creek.

Plate 21: SEPP 14 No 776 – Stand of dead Casuarina at back of mangroves near slope up to Derry Willis' property.

Plate 22: SEPP 14 No 776 – Large pile of flotsam at edge of Casuarina forest at back of mangroves near slope up to Derry Willis' property.

Plate 23: SEPP 14 No 777 – Drain on slope on northeastern side of highway. Water flows under the highway and into SEPP 14 No 777

Plate 24: SEPP 14 No 777 – View from road of gross pollutant and sediment traps on drains that run under the road and into SEPP 14 No 777.



Plate 1: SEPP 14 No 778 -Freshwater wetland to the west of Mustons Road, view north-east. 22/6/99.



Plate 2: SEPP 14 No 778 - Lane through wetland on the eastern side of Mustons Road, view west. 22/6/99.

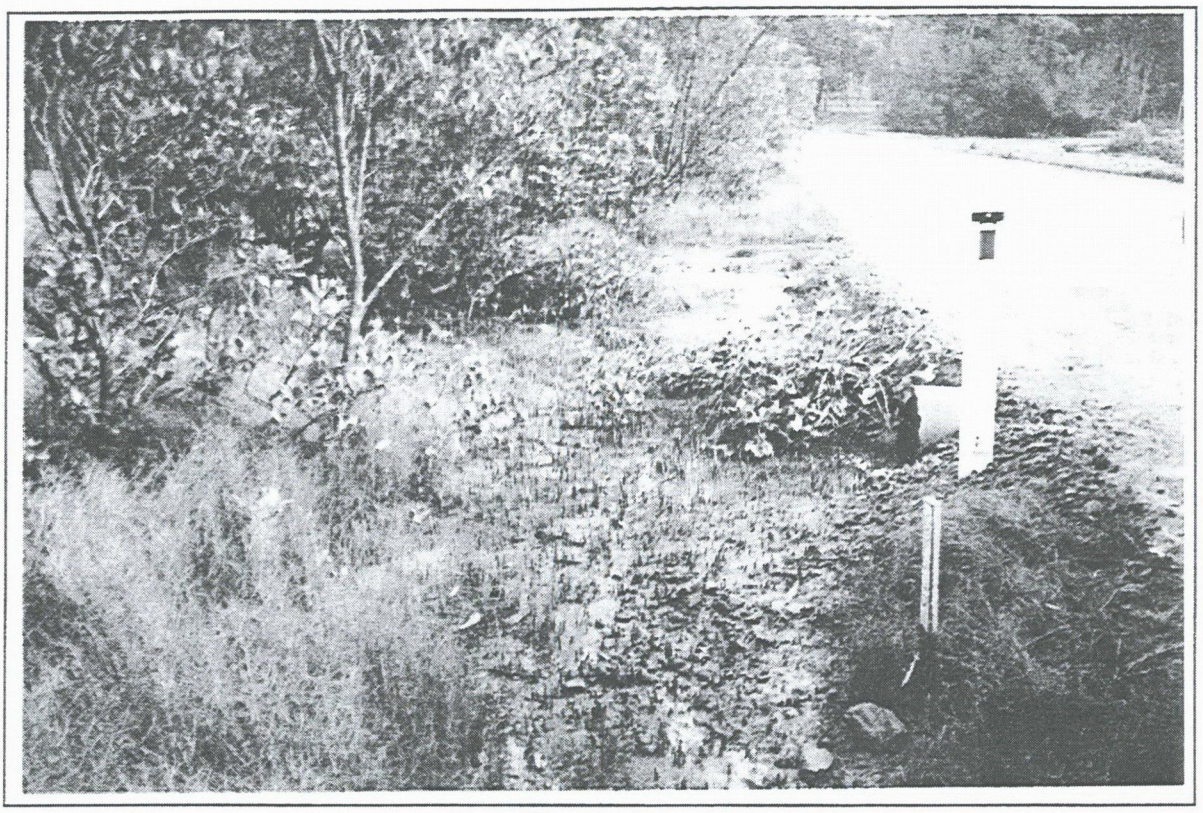


Plate 3: SEPP 14 No 778 -Drainage pipe under dirt lane, view west towards wetland on southern side of the lane. 22/6/99.

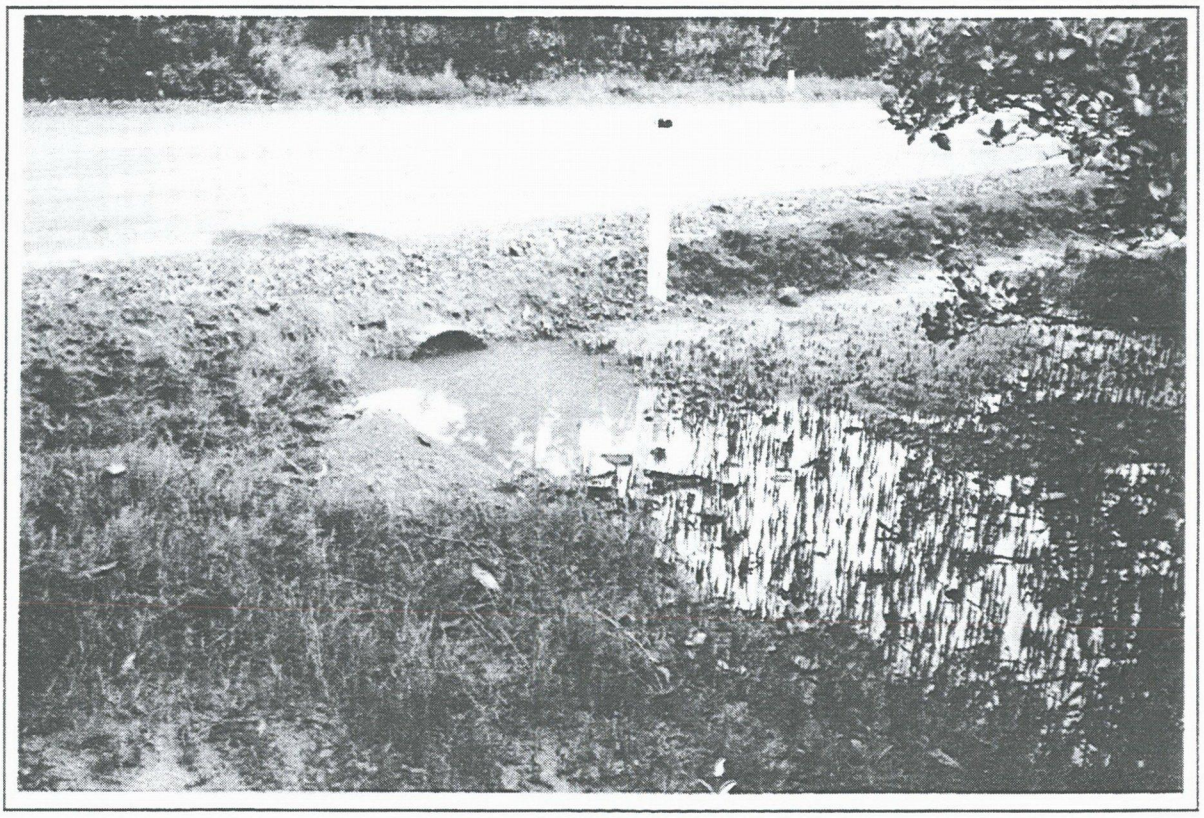


Plate 4: SEPP 14 No 778 - Drainage pipe under dirt lane, view south across lane. 22/6/99.

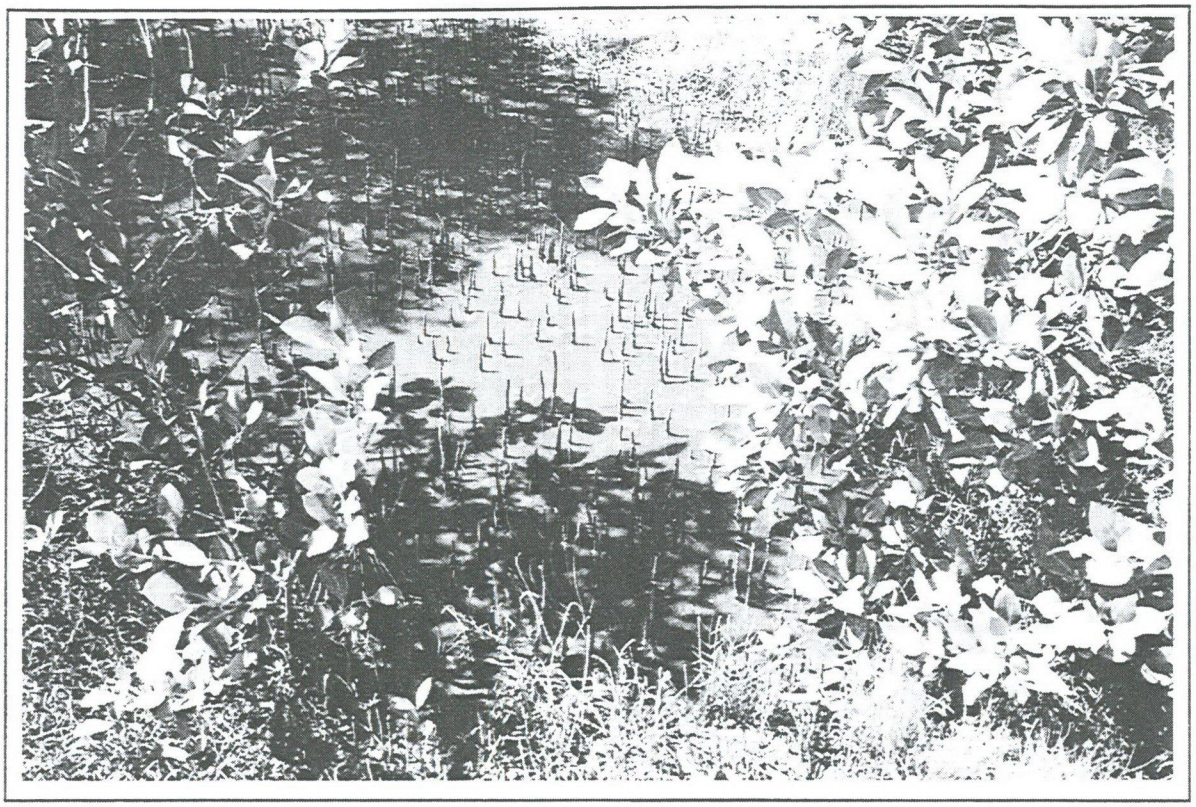


Plate 5: SEPP 14 No 778 - Mangroves on southern side of lane, showing stagnant rust coloured water. 6/1/99.

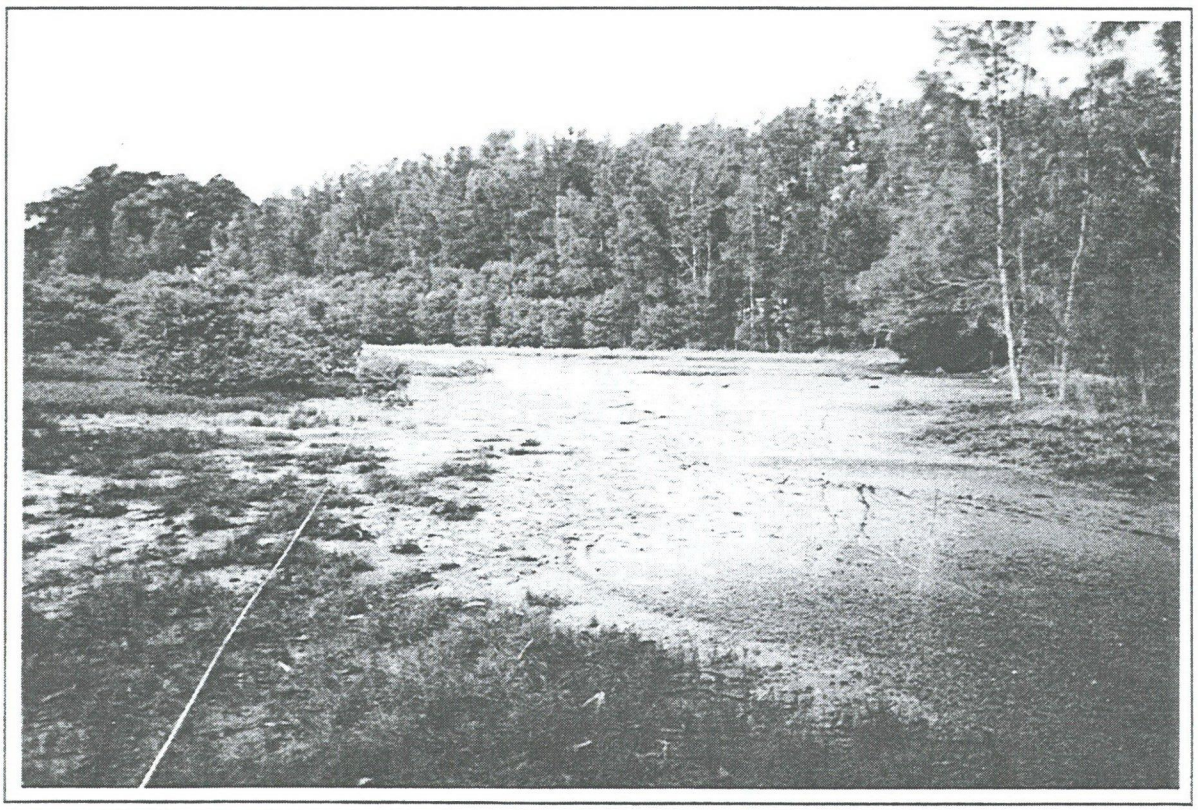


Plate 6: SEPP 14 No 778 - Bare mud patch on northern side of the laneway. View south towards lane, Mustons Road to the right. 22/6/99.



Plate 7: SEPP 14 No 778 - Erosion on creek banks near end of track. View east towards mouth of creek. 20/8/99.

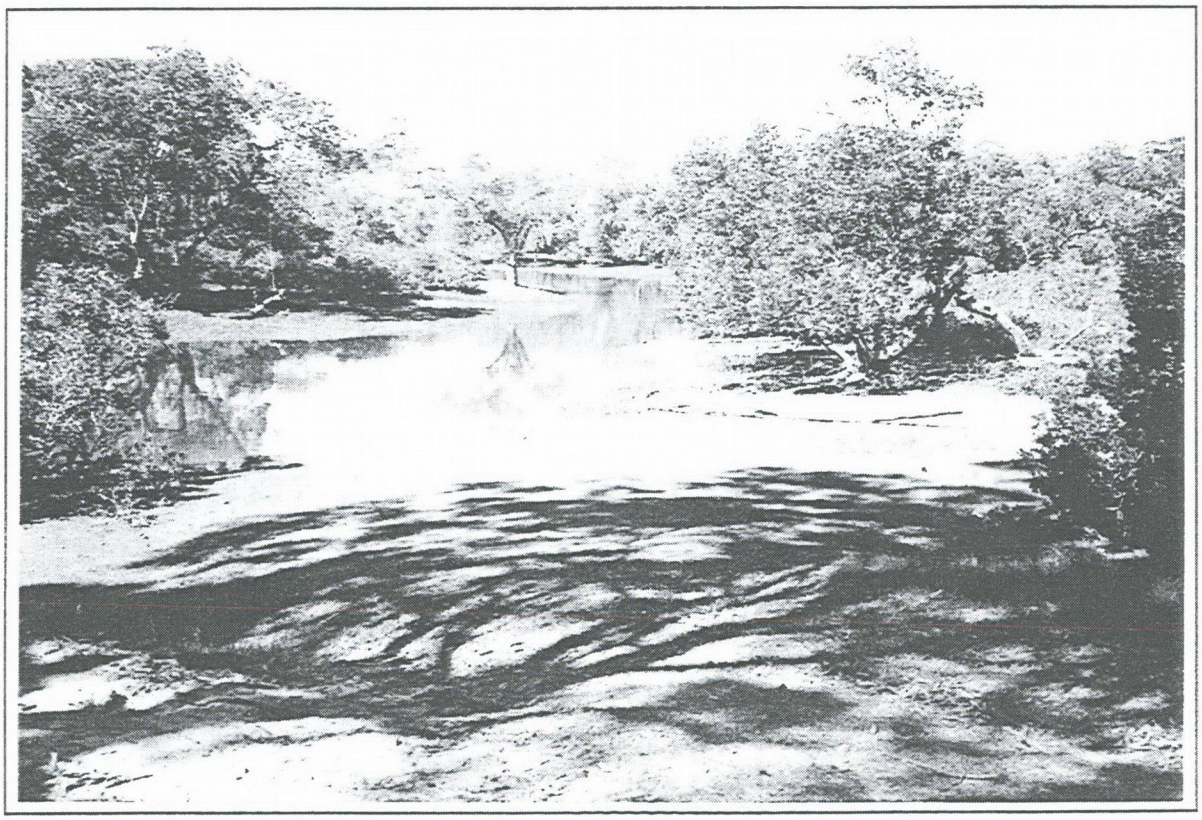


Plate 8: SEPP 14 No 778 - View of makeshift boatramp, looking south along creek (upstream) from track down to creek. 20/8/99.

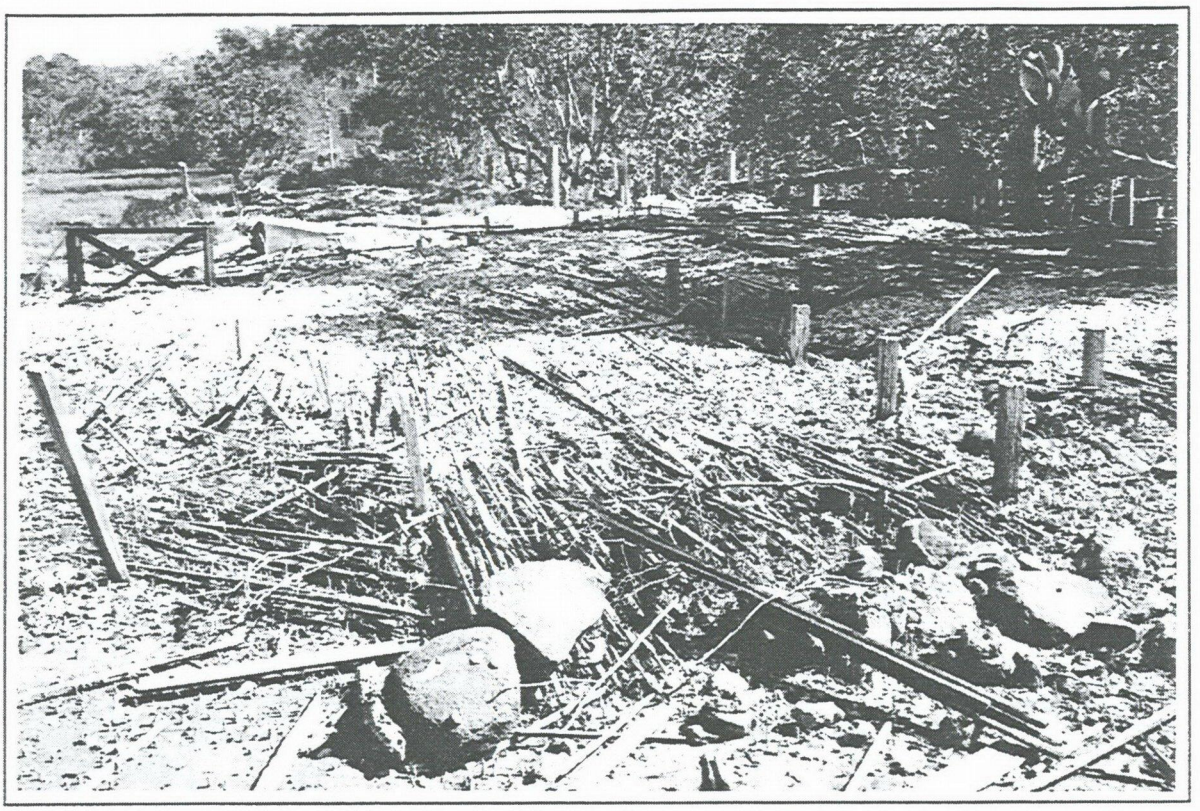


Plate 9: SEPP 14 No 781 - Swan Island. Pile of old oyster sticks with shells. View south. 20/8/99.

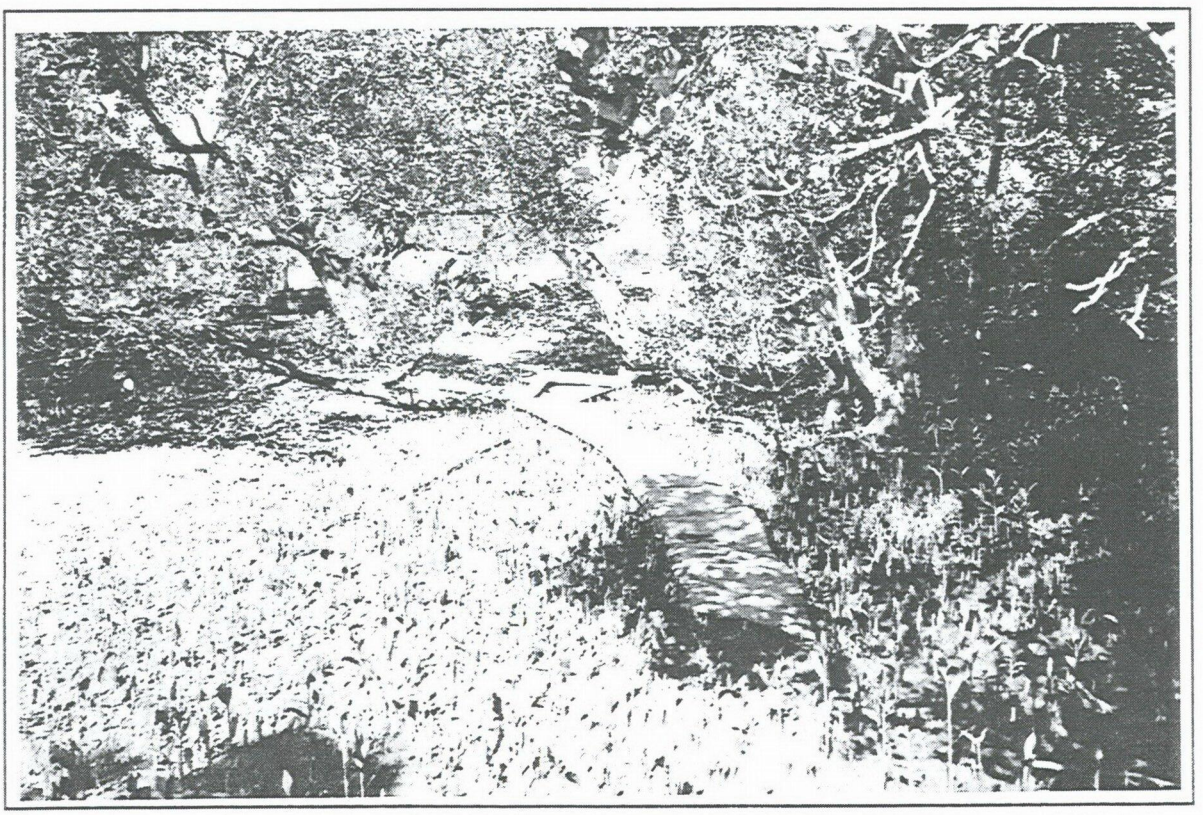


Plate 10: SEPP 14 No 7 - Swan Island. Miscellaneous rubbish in mangroves near old shed site. 20/8/99.



Plate 11: SEPP 14 No 786 - Reedy Creek. Pile of oyster rubbish on confluence of first major tributary on the south bank of Reedy Creek. Mainly oyster stick debris. 20/8/99.

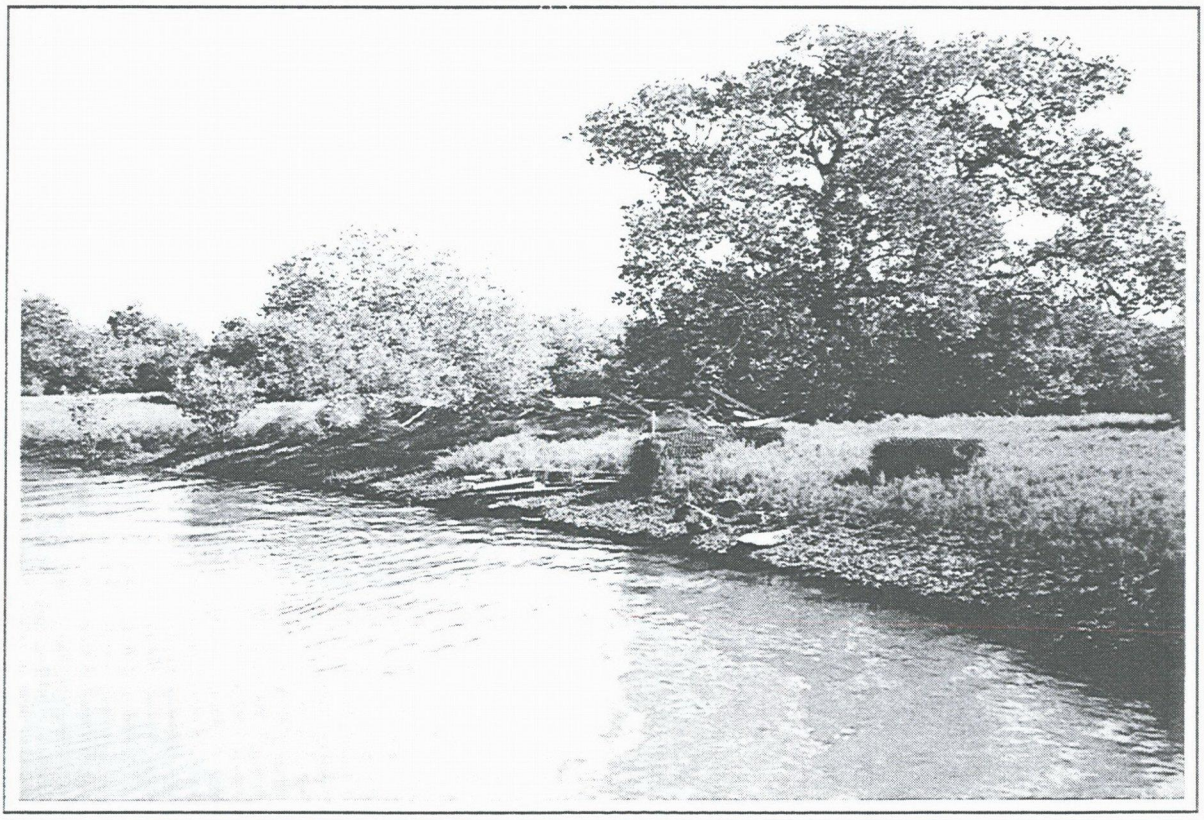


Plate 12: SEPP 14 No 786 - Reedy Creek. Second pile of oyster rubbish in small tributary to the north of Reedy Creek. Includes oyste sticks, chicken wire and other debris.. 20/8/99.



Plate 13: SEPP 14 No 776 - Pile No 1 on north side of Mosquito Creek. 22/6/99.

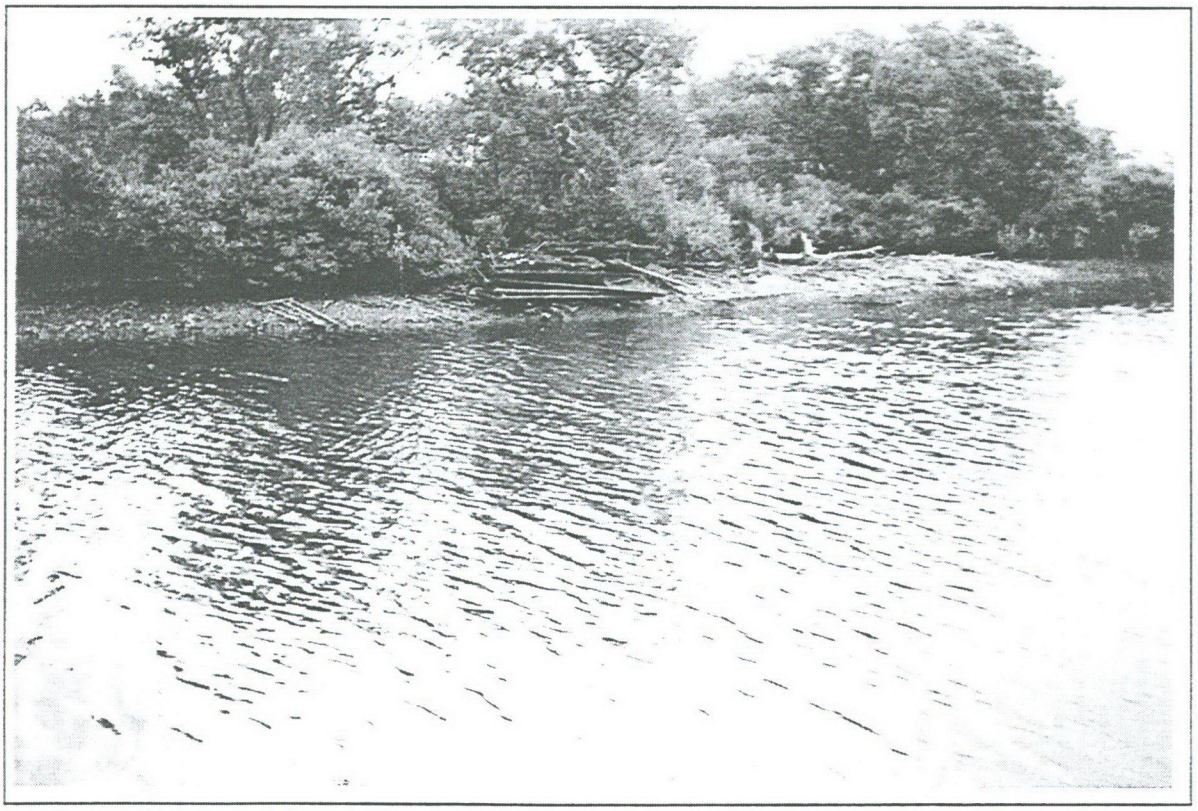


Plate 14: SEPP 14 No 776 - Pile No 2 on north side of Mosquito Creek. 22/6/99.

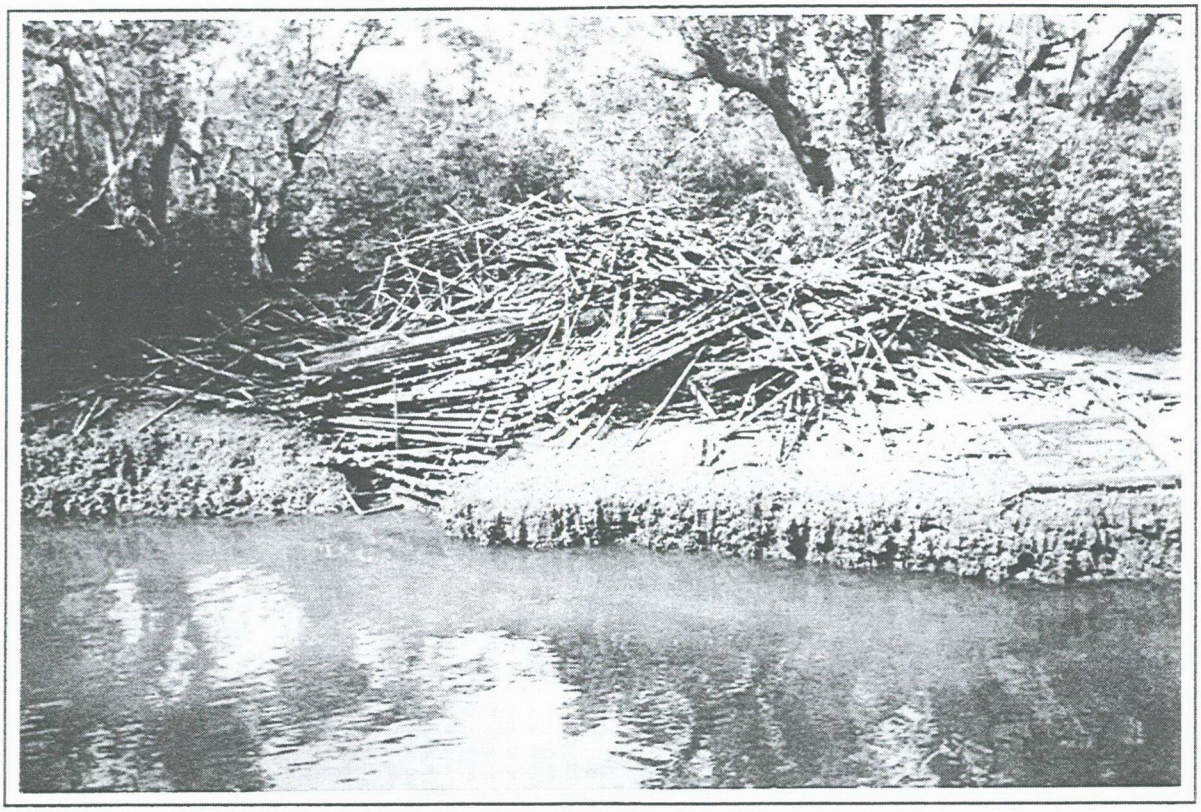


Plate 15: SEPP 14 No 776 - Pile No 1 on south side of unnamed creek. 22/6/99.

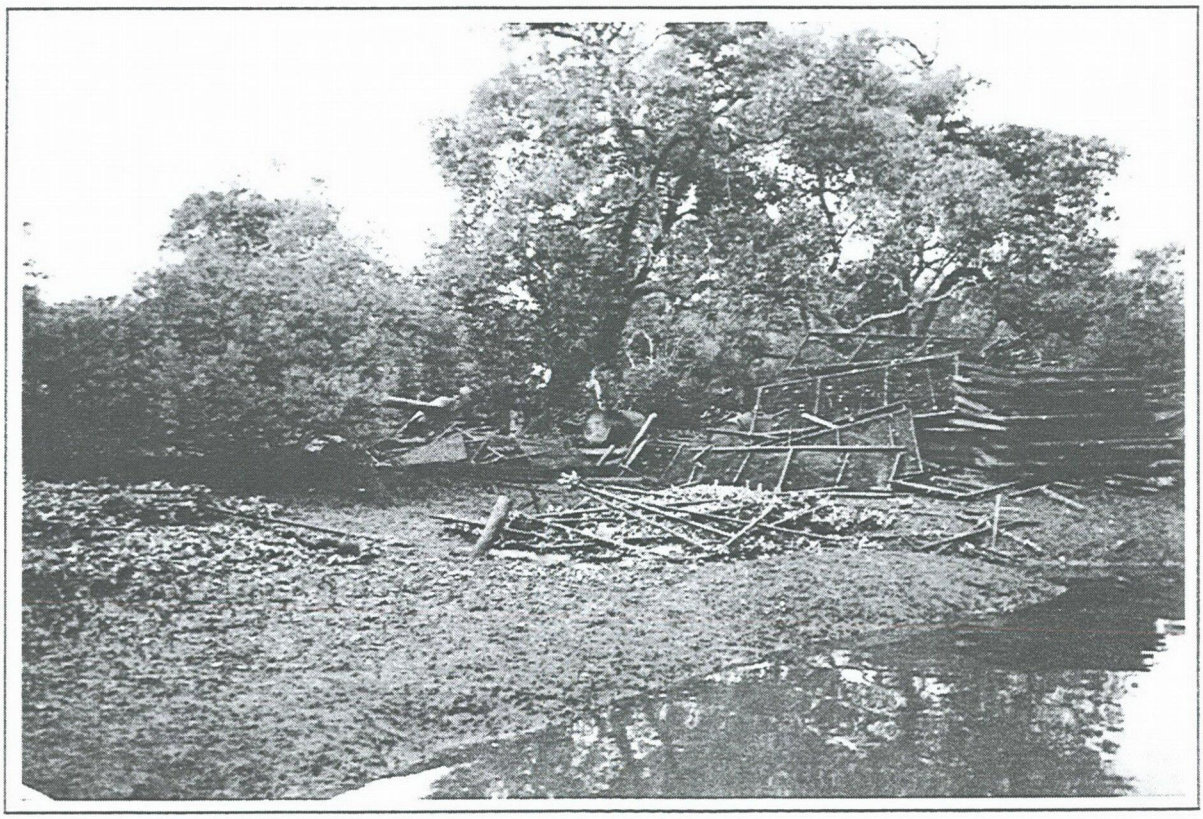


Plate 16: SEPP 14 No 776 - Pile No 2 on south side of unnamed creek. 22/6/99.



Plate 17: SEPP 14 No 776 - Pile No 3 on north side of unnamed creek. 22/6/99.



Plate 18: SEPP 14 No 776 - Pile No 4 on north side of unnamed creek. 22/6/99.



Plate 19: SEPP 14 No 776 - Pile No 5 on south side of unnamed creek. 22/6/99.

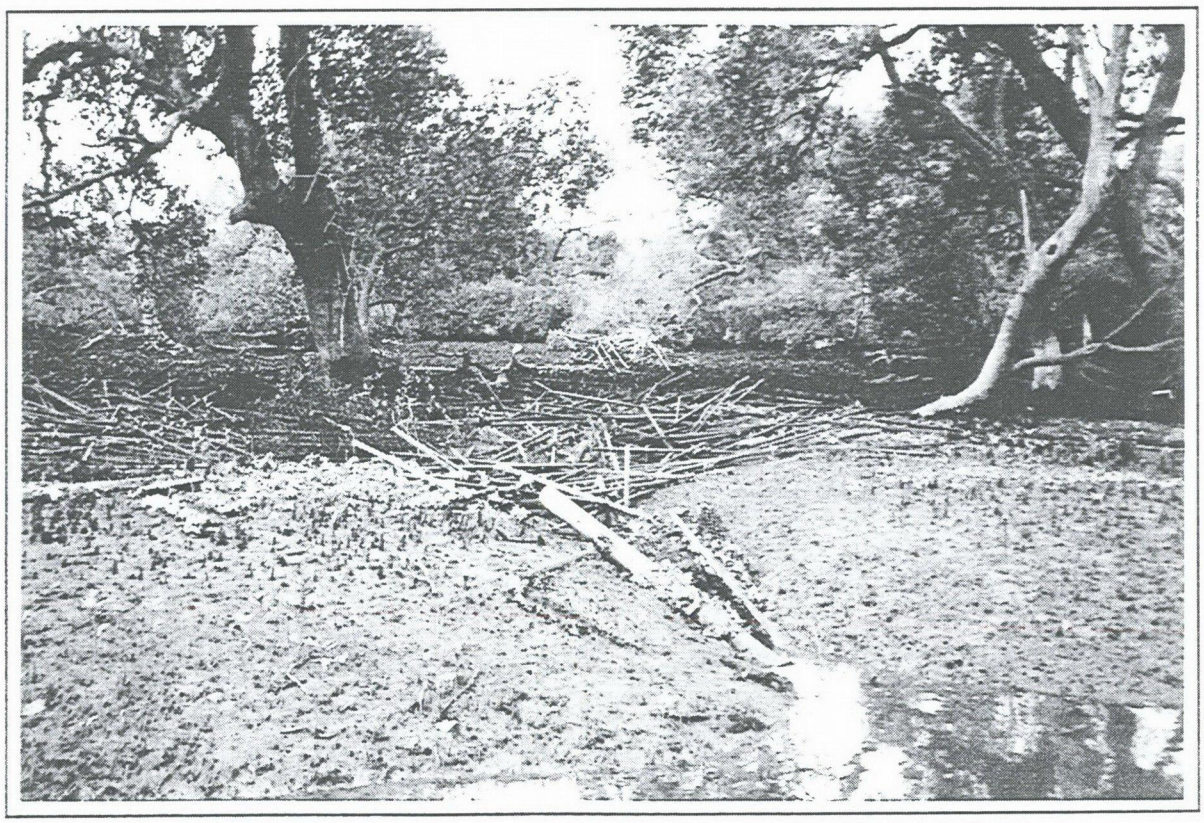


Plate 20: SEPP 14 No 776 - Pile No 6 on south side of unnamed creek. 22/6/99.

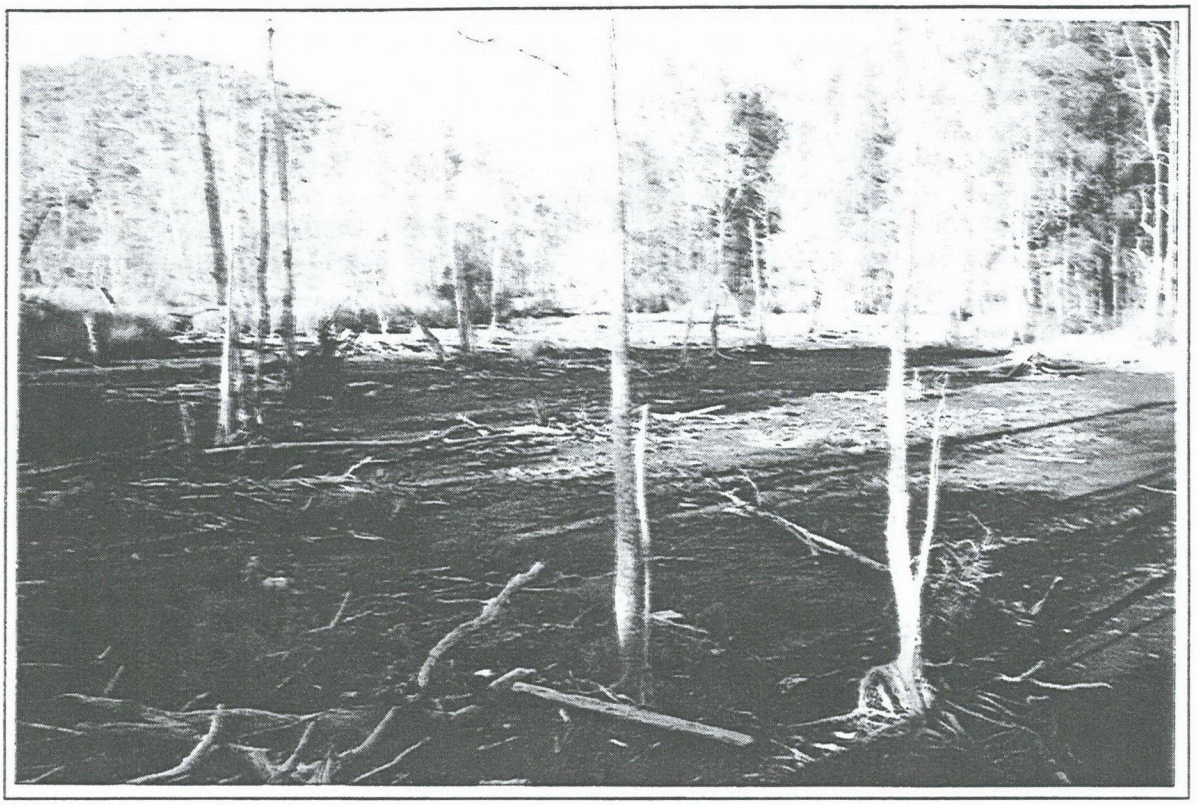


Plate 21: SEPP 14 No 776 - Stand of dead Casuarina at back of mangroves near slope up to Derry Willis' property 20/8/99.



Plate 22: SEPP 14 No 776 - Large pile of flotsam at edge of Casuarina forest at back of mangroves near slope up to Derry Willis' property. 20/8/99.



Plate 23: SEPP 14 No 777 - Drain on slope on northeastern side of highway. Water flows under the highway and into SEPP 14 No 777. 20/8/99.

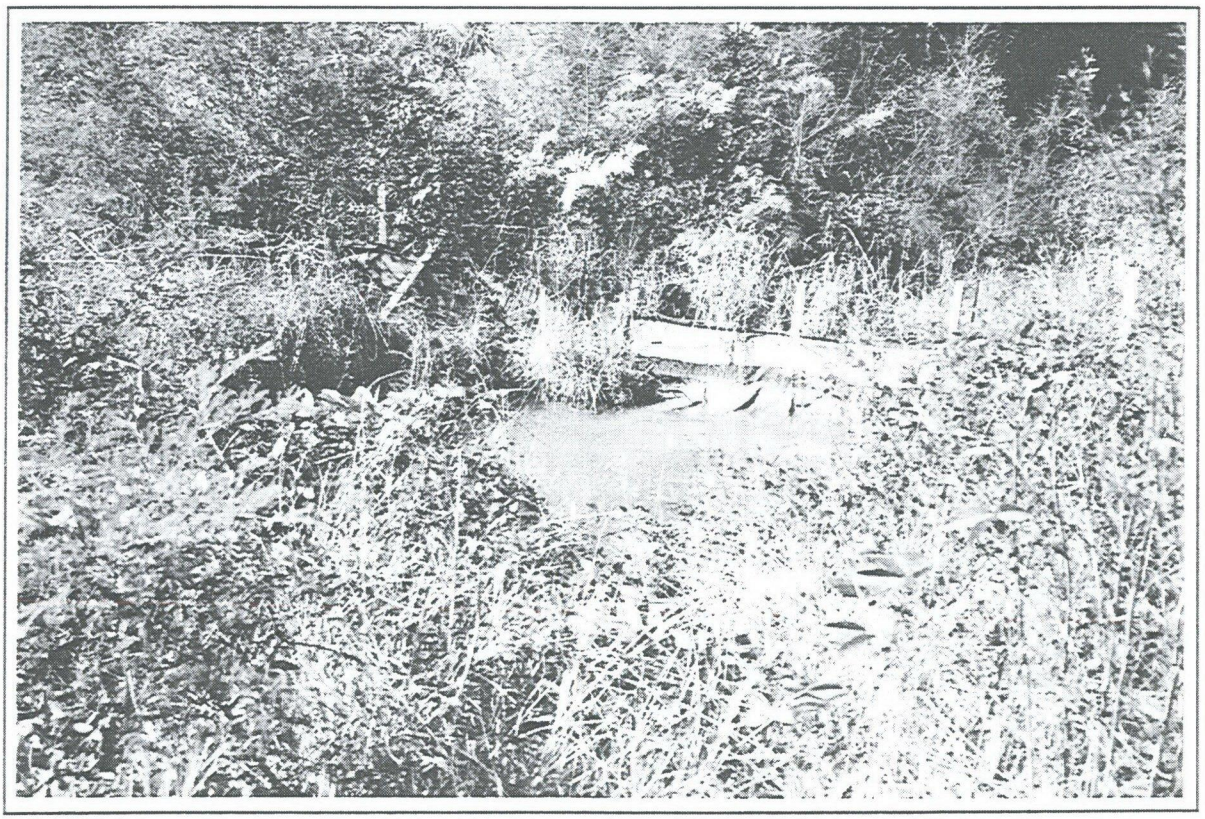


Plate 24: SEPP 14 No 777 - View south from highway of gross pollutant and sediment traps on drains which run under the road and into SEPP 14 No 777. 20/8/99.

PROPOSED UPGRADE OF PACIFIC HIGHWAY AT KARUAH

WATER QUALITY AND AQUATIC ECOLOGY BASELINE MONITORING

Prepared for: Ove Arup and Partners (for Roads and Traffic Authority)

Prepared by: WBM Oceanics Australia
126 Belford Street
PO Box 266
BROADMEADOW NSW 2292

Telephone: (02) 4940 8882
Fax: (02) 4940 8887

Document: \\C6\C6\AAC5\N0202\R003.DOC

WBM OCEANICS AUSTRALIA

DOCUMENT CONTROL SHEET

WBM Oceanics Australia
126 Belford Street
BROADMEADOW NSW 2292
AUSTRALIA

TELEPHONE: 049 40 8882
International: +6149 40 8882
FAX: 049 40 8887
International: +6149 40 8887

Original Date of Issue: 18 March, 1998

Project Manager: Greg Rogencamp

Library Ref: N0202.R1.1

Title:	Proposed Upgrade of Pacific Highway at Karuah - Water and Aquatic Ecology Baseline Monitoring
Author:	Emma-Kate Hamilton, Dr Darren Richardson, Jo Wilson, Greg Rogencamp, Tony McAlister, Jenny Pocock
Client:	Ove Arup and Partners (for Roads and Traffic Authority)
Client Contact:	Alistair Kerle
Client Reference:	

Synopsis: This report presents the results of baseline monitoring carried out for the proposed Pacific Highway upgrade at Karuah. Water quality and oyster quality/condition results are presented and assessed.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE	CHECKED BY		ISSUED BY		DISTRIBUTION - NO. OF COPIES			
						Client	Other	WBM	WBM Lib
0	3/12/97	GJR		EKH		1	0	1	0
1	18/3/98	GJR	GJR	EKH	EKH	1	0	1	0

WBM OCEANICS AUSTRALIA

CONTENTS

1 INTRODUCTION 6

1.1 General 6
1.2 Background 6
1.3 Study Objective 7

2 SITE DESCRIPTION 9

2.1 Catchment Characteristics 9
2.1.1 Physiographic Setting 9
2.1.2 Rainfall 9
2.1.3 Land Use 11
2.1.4 Vegetation 11
2.1.5 Soils 11
2.1.6 Geology Features 11
2.2 Potential Pollution Sources 12
2.2.1 Diffuse Sources of Pollution 12
2.2.2 Point Sources of Pollution 12
2.3 Sewerage System 13
2.3.1 Existing System 13
2.3.2 Proposed Sewerage System Upgrade 13
2.3.3 Caravan Park Effluent Discharge 14

3 PREVIOUS STUDIES 15

3.1 Public Works Report (July, 1989) 15
3.2 Patterson Britton Report (April, 1997) 15
3.3 Richardson, Darren (November, 1991) 16

4 EXISTING DATA 17

5 WATER QUALITY MONITORING 20

5.1 Testing Locations 20
5.2 Water Quality Parameters 22
5.2.1 Physical Parameters 22

5.2.2 Chemical Parameters 25
5.2.3 Summary of ANZECC Guidelines and Recommendations 28
5.3 Water Quality Results 28

6 OYSTER MONITORING 29

6.1 Oyster Biology and Production 29
6.1.1 General Biology 29
6.1.2 Oyster Production 29
6.2 Oyster Sampling Procedure 29
6.2.1 Tissue condition 29
6.2.2 Elemental Analyses 32
6.2.3 Microbiological Counts in Oyster Tissues 33
6.3 Oyster Tissue Condition Monitoring Results 34
6.3.1 Leydig Tissue 34
6.3.2 Local Haemocyte Infiltration 36
6.3.3 Brown Cells 37
6.3.4 Digestive Tubule Atrophy (DTA) 38
6.3.5 Other Pathologies of Interest 40
6.3.6 Diseases and Parasites 40
6.4 Analyses of Metals 41
6.4.1 Comparisons with AFSC guideline levels 41
6.4.2 Statistical Comparisons of Metal Concentrations 47
6.4.3 Metal Concentrations and Environmental Factors 49
6.5 Microbiological Counts in Oysters 51
6.5.1 Comparisons with Australian Food Standards 51
6.5.2 Rainfall and E. coli Levels 51

7 DISCUSSION 53

7.1 Water Quality Monitoring 53
7.2 Oyster Monitoring 57
7.2.1 Tissue Condition 57
7.2.2 Metals 58
7.2.3 Microbiological Counts 60

8 CONCLUSION AND RECOMMENDATIONS 62

8.1 Conclusions 62

8.2 Recommendations for monitoring during construction and operational phases63

9 REFERENCES 66

APPENDIX A: WATER QUALITY MONITORING RESULTS A-1

APPENDIX B: NEWCASTLE HERALD ARTICLE B-1

APPENDIX C: GM LABORATORIES STATEMENT C-1

APPENDIX D: RAW DATA FOR ELEMENT CONCENTRATIONS (METALS) IN OYSTER TISSUES D-1

APPENDIX E: RAW DATA FOR E. COLI COUNTS FROM OYSTER TISSUESE-1

APPENDIX F: ANOVA TABLES COMPARING MEAN CONCENTRATIONS OF METALS IN OYSTER TISSUES AMONG SITES AND TIMES F-1

APPENDIX G: CORRELATION MATRICES OF MEAN CONCENTRATIONS OF METALS AMONG SITES OVER TIME G-1

APPENDIX H: CORRELATION MATRICES COMPARING MEAN METAL CONCENTRATIONS WITH ENVIRONMENTAL PARAMETERS H-1

APPENDIX I: POWER ANALYSES I-1

LIST OF FIGURES

Figure 1-1 Locality Map 8
Figure 2-1 Daily Rainfall - Tahlee 10
Figure 2-2 Daily Rainfall - Stroud Post Office 10
Figure 5-1 Testing Locations 21
Figure 6-1 Anatomy of an oyster, showing the location of cross sections for histological examination 31
Figure 6-2 Leydig tissue scores in Sydney rock oysters collected from three sites at Karuah River in June to November 1997 (lower score equates to poorer condition). 34
Figure 6-3 Degree of diffuse haemocyte infiltration in tissues of Sydney rock oysters collected from three sites in the Karuah River in June to November 1997. 36
Figure 6-4 Average scores of local haemocyte infiltration in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997. 37
Figure 6-5 Average scores of the incidence of brown cells in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997. 38
Figure 6-6 Relative proportions of digestive tubule atrophy in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997. 39
Figure 6-7 Prevalence of the ciliate *Ancistrocoma* sp in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997. 40
Figure 6-8 Mean (error bars ± SE) concentrations of (i) total arsenic and (ii) cadmium in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997 42
Figure 6-9 Mean (error bars ± SE) concentrations of (i) chromium and (ii) cobalt in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997 43
Figure 6-10 Mean (error bars ± SE) concentrations) of (i) copper and (ii) lead in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997 44
Figure 6-11 Mean (error bars ± SE) concentrations (expressed as mg/kg) of (i) mercury and (ii) molybdenum in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997 45
Figure 6-12 Mean (error bars ± SE) concentrations (expressed as mg/kg) of (i) nickel and (ii) selenium in fresh oyster tissues, Karuah 1997 46
Figure 6-13 Mean (error bars ± SE) concentrations of Zinc (expressed as mg/kg) in fresh oyster tissues, Karuah 1997 47
Figure 6-14 Concentration of E. coli 51
Figure A-1 Temperature Plots A-2
Figure A-2 Dissolved Oxygen Plots (mg/L) A-2
Figure A-3 Dissolved Oxygen plots (% Saturation) A-2
Figure A-4 Salinity Plots A-2
Figure A-5 Conductivity Plots A-2
Figure A-6 pH Plots A-2
Figure A-7 Turbidity plots A-2
Figure A-8 Ammonia Plots A-2
Figure A-9 Oxidised Nitrogen Plots A-2
Figure A-10 Total Nitrogen Plots A-2
Figure A-11 Orthophosphorus Plots A-2
Figure A-12 Total Phosphorus Plots A-2
Figure A-13 Suspended Sediment Plots A-2
Figure A-14 Lead Plots A-2

LIST OF TABLES

Table 5-1 Summary of ANZECC Recommendations for Water Quality Parameters 28
Table 6-1 Description of the function of each tissue and scoring system used for assessment of Sydney rock oyster health (n/a = not applicable) 32
Table 6-2 Kendall's coefficient of rank correlation (τ) showing the relationship between environmental parameters and tissue developement 35
Table 6-3 Summary table of two-way ANOVA tests comparing mean metal concentrations among sites and time periods 48
Table 6-4 Summary table of post- hoc comparisons of mean metal concentrations among sites 48
Table 6-5 Summary table of significant correlations (p<0.05) of each metal type among sites 49
Table 6-6 Summary table of statistically significant correlates between metals and environmental factors 50
Table 6-7 Summary tables of regression analyses of E. coli numbers in oysters and rainfall 52
Table 7-1 Summary tables of regression analyses of conductivity and rainfall (* = significant at P<0.05) 54
Table 7-2 Metal concentrations (μg/kg) in oyster tissues from around the world 59
Table 8-1 Summary results of 'reverse' *post-hoc* power analysis 64

1 INTRODUCTION

1.1 General

WBM Oceanics Australia was commissioned by Ove Arup and Partners (acting for the Roads and Traffic Authority) to develop and carry out a water quality and aquatic ecology monitoring program for the proposed Pacific Highway upgrade at Karuah. This report details the findings of this monitoring program and presents the conclusions drawn from this study.

This report is designed to compliment a more detailed monitoring program in the future as part of the construction and operational phases of the project.

1.2 Background

Karuah is situated on the Pacific Highway, 50 km north of Newcastle (refer to Figure 1-1). The RTA is assessing an upgrade of the Pacific Highway for the section of highway presently passing through the town of Karuah. The highway currently crosses the Karuah River just north of the town centre, near the mouth of the river and its entrance to Port Stephens.

These lower reaches of the river include a number of oyster leases and this industry plays a significant role in the commerce of the local area. Protection of the oysters from potential pollutants is integral to the industry.

As part of the highway upgrade, an extensive water quality and oyster monitoring program has been undertaken by WBM Oceanics Australia. This monitoring has two primary aims.

Firstly, the monitoring will provide baseline water quality and aquatic condition data for the locality, which may be used for subsequent assessments of any possible changes to water quality resulting from the proposed highway upgrade (construction and/or operational phases).

Secondly, the data will provide a basis for predictions of the likely impacts on the aquatic environment resulting from the construction and operation of the proposed upgrade.

This monitoring program, undertaken over a period of six months, provides both detailed data on the existing quality of the surrounding environment and a foundation on which to base future quality and aquatic condition testing.

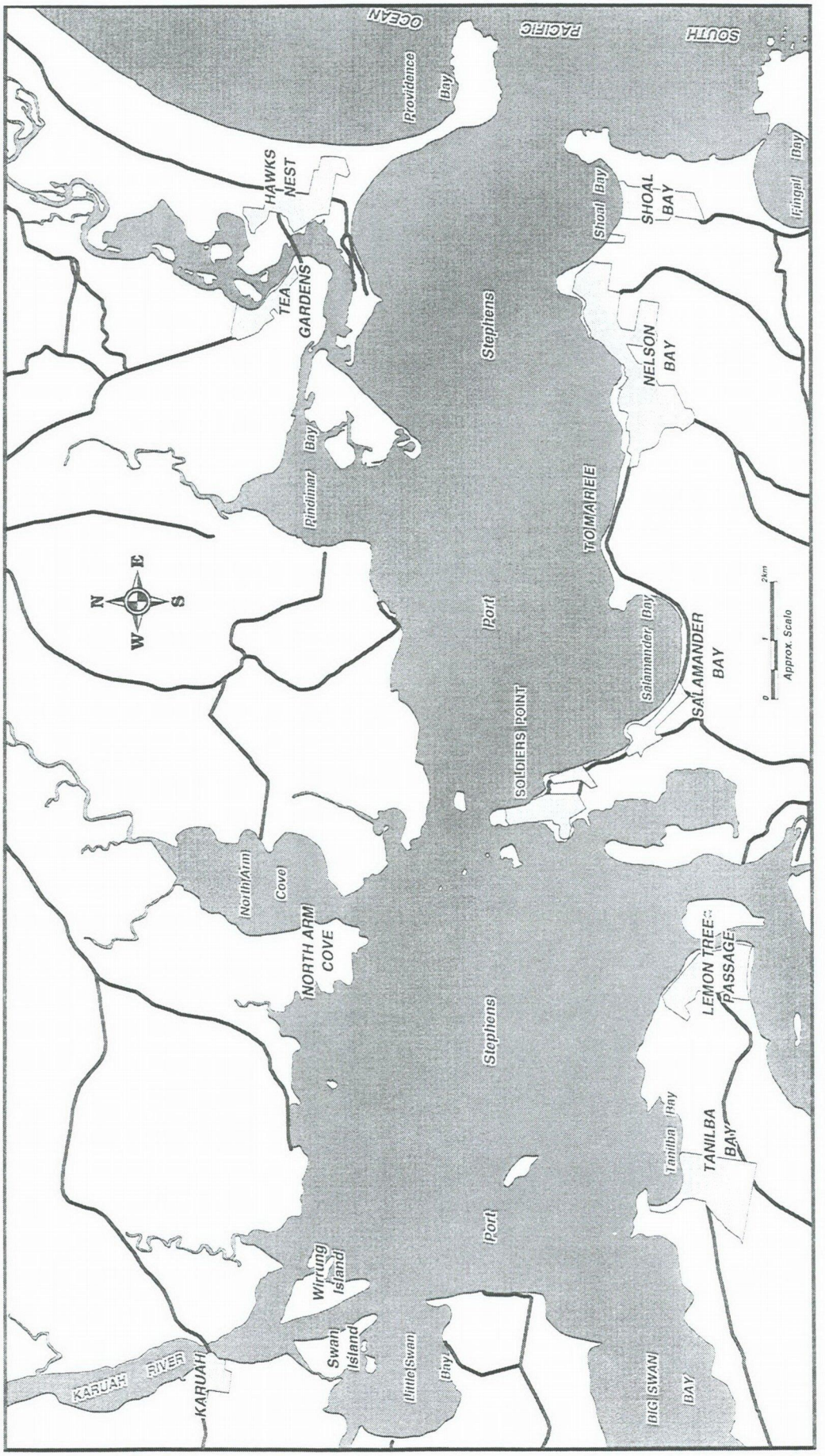
1.3 Study Objective

The objective of this study was to collect baseline water quality and oyster condition data on the Karuah River in the vicinity of the proposed upgrade of the Pacific Highway. This will enable future comparisons, particularly during the construction phase, to be made with an extensive and reliable set of baseline data.

To achieve these objectives, this study adopted the following approach:

- a search and review of existing water quality and aquatic quality data;
- collection of water quality and oyster condition data over a period of 6 months on a wet and dry day of each month. Water quality data collection included consideration of both rainfall and tidal variations; and
- analysis of this data, which produced informed conclusions on the existing water quality and oyster quality in the area.

Subsequent sections of this report describe the findings of this study.



Locality Map **Figure 1.1**

2 SITE DESCRIPTION

2.1 Catchment Characteristics

2.1.1 Physiographic Setting

The Port Stephens system is a drowned coastal valley that is bifurcated into two basins, the inner and outer basin. Rochford (1951) classified the outer basin as a 'marine zone' (ie. dominated by marine hydrological features), and the inner basin as a 'tidal' zone (ie. it is dominated by shallow mud flats and tidally dominated hydrological features) [Rochford, 1951 #783].

This study was conducted at the lower reaches of the Karuah River (refer to Figure 1-1), a major waterway draining into the Port Stephens inner basin. Previous surveys by Richardson (1991) indicated that this section of the Karuah River and the entire inner basin of Port Stephens typically has characteristics of a well mixed estuary. However, this section of the river does become stratified following heavy rainfall [Richardson, 1991 #425].

The catchment is drained by the Karuah River, running in a north-south direction. Many tributaries drain into this main river system, including Wards River in the upper north-eastern reaches of the catchment and The Branch River lower in the catchment. The bottom of the catchment is dominated by tidal mudflats and swamps, forming the upper reaches of the Port Stephens Estuary. The Karuah River catchment has an area of approximately 1500km^2.

The Karuah River initially consists of a narrow, fast flowing creek within the Chichester State Forest in the north of the catchment, eventually becoming a wide, slower flowing river at the base of the catchment. Here, it is dominated by the processes of a well-mixed estuary.

The Pacific Highway transverses the Karuah River almost at the mouth to the Port Stephens Estuary at the base of the catchment.

2.1.2 Rainfall

Daily rainfall records were sourced from two rainfall stations situated within the Karuah River catchment and close to the testing site, namely:

- the Stroud Post Office (Station number 61071); and
- Tahlee (Station Number 61072).

Tabulated rainfall data from these stations for the period of June to November, 1997 are presented in Figure 2-2 and Figure 2-3.

The wettest month during the study period was recorded in the month of May 1997 with the Tahlee Station recording 214.8mm of rainfall. The driest month within the study period was in the month of August 1997 when the Stroud Post Office recorded a total monthly rainfall of only 11.4mm.

The Tahlee rainfall station recorded the highest rainfall total over the six month study period, totalling 734mm from the months between May to November 1997 (inclusive). This was as expected, given the close proximity of the station to the coast. Stroud Post Office rainfall station recorded a total rainfall of 521mm over the same six month period.

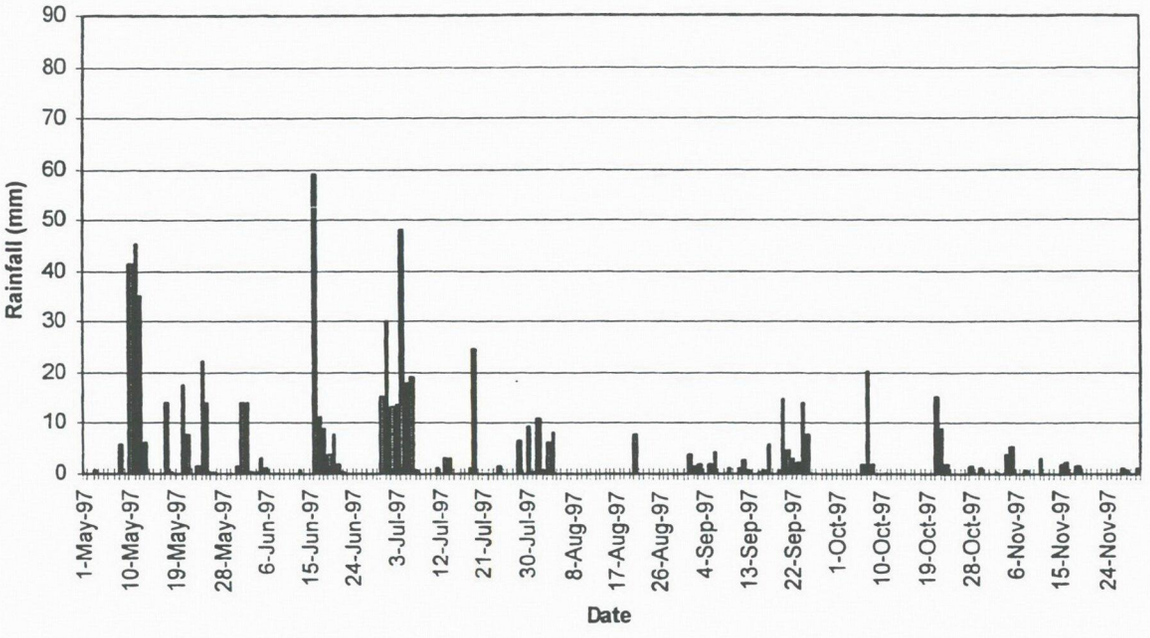


Figure 2-2 Daily Rainfall - Tahlee

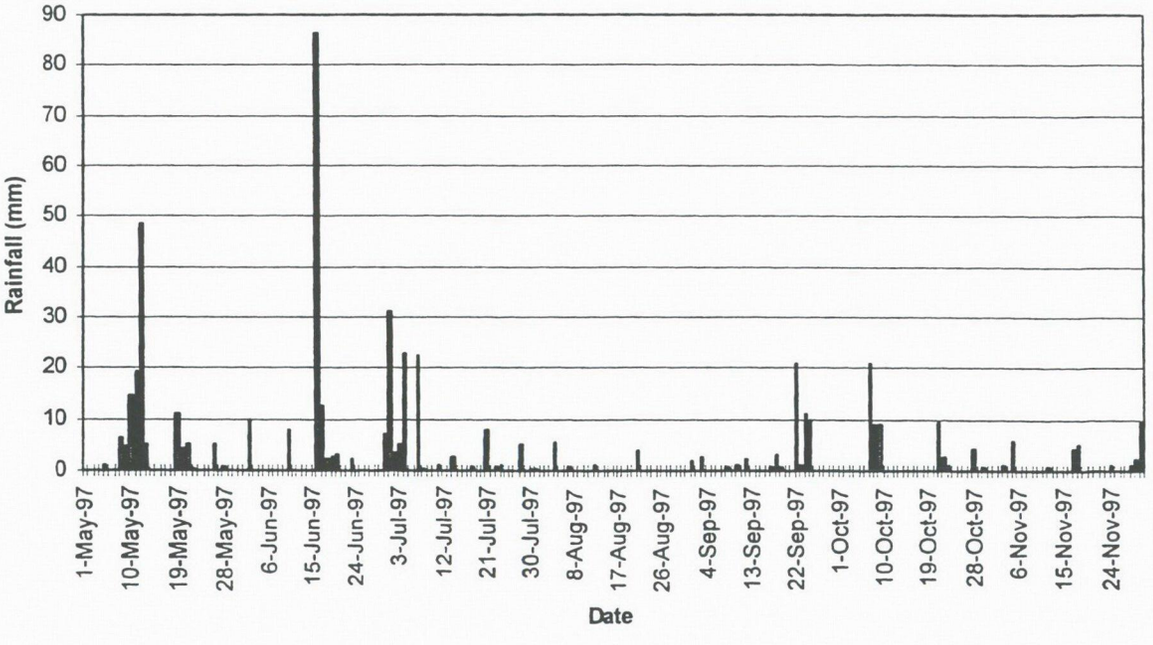


Figure 2-3 Daily Rainfall - Stroud Post Office

2.1.3 Land Use

The major commercial industry within the Karuah region is oyster farming. The outer port/basin supplies up to 70% of the NSW spat (juvenile oyster) production, whereas the inner port produces the majority of plate oysters for NSW markets.

The upper reaches of the Karuah River catchment remain largely untouched, existing in their natural state to form part of the Barrington Tops National Park and State Forests. In the lower reaches of the catchment, large areas have been cleared for agricultural purposes.

According to the Department of Mineral Resources, there are a number of existing mining or extractive industries currently operating within the catchment. These include Stratford Coal Pty Ltd leases located in the upper regions of the Karuah River catchment, and Durally Coal Pty Ltd and CIM Resources leases, both located between the Karuah and Johnson's Rivers north of Stroud.

A timber milling plant is also currently operating in the catchment, south of Stroud.

2.1.4 Vegetation

The upper reaches of the Karuah River catchment, including the Chichester State Forest and Craven State Forest, consists largely of open forest vegetation. Little of the upper catchment has been cleared, with large sections of this area recently being included in the Barrington Tops National Park.

In the lower reaches of the catchment, large areas of bushland have been cleared for rural land uses. However, substantial areas of woodland still remain.

Areas of mangroves and saltmarsh occur in the intertidal zone in the lower reaches of the Karuah River.

2.1.5 Soils

The soil types vary within the Karuah River catchment from poorly drained tidal flats with deep soils in the lower estuarine regions of the catchment, to steep hills with shallow, well-drained soils in the upper reaches of the catchment. The soils in the lower estuarine areas are subject to wave erosion and, in some areas, have the potential to become acid sulphate soils.

Broad plains on deep Pleistocene clays dominate through the middle reaches of the catchment, separating these two soil types. The soils here are deep , poorly drained, partial to seasonal water logging and highly erosive.

2.1.6 Geology Features

A number of geological features of the Karuah catchment area can be noted, based on a review of the geological maps of the Newcastle and Port Stephens area.

The upper reaches of the catchment are dominated by the Craven Coal Measures, with smaller sections of gravel, sand, silt and clay being confined to the Karuah River itself. The middle reaches of the Karuah River catchment contain Alum Mountain Volcanics and the Crawford Formations. The Wooton Beds dominate to the east and west of the Karuah River. The lower reaches of the catchment contain sediments, mostly clastics with some volcanics.

A description of these geological features are listed below.

⇒ Craven Coal Measures - conglomerate, sandstone, mudstone, arkose, carbonaceous shale, coal.

⇒ Alum Mountain Volcanics - Rhyolite, conglomerate, basalt, dacite, andesite, ignimbrite, tuff, conglomerate.

⇒ Crawford Formations - sandstone, conglomerate, mudstone, chert, tuff. Includes Issacs, Booral and Karuah Formations.

⇒ Wootton Beds - sandstone, silt stone, claystone, shale, limestone, lavas. Includes Glen William Beds.

2.2 Potential Pollution Sources

2.2.1 Diffuse Sources of Pollution

As some of the Karuah River catchment has been cleared for agriculture, acreage and urban land, numerous changes are likely to have occurred on the downstream watercourses, particularly water quality.

The changes in catchment land use would be expected to have resulted in increased sediment washoff due to sheet, rill or gully erosion. As well, they are likely to produce an increase in waste by-products (such as nutrients) which have the potential to enter the waterways through either stormwater runoff or groundwater infiltration, resulting in the degradation of downstream water quality.

There are a number of water pollution sources associated with the Pacific Highway. Large volumes of traffic pass through the township of Karuah every day, resulting in pollution due to vehicle exhaust, greases and oils. In particular, lead particles from vehicle engine emissions may be deposited throughout the catchment due to atmospheric and wind dispersion. These lead particulates will ultimately end up in the waterbody due to surface runoff and erosion.

Other diffuse sources of pollution include:

- urban areas where solids, nutrients, oils and greases accumulate;
- farms and plantation areas where high levels of fertilisers (nutrients) are applied; and
- acreage areas where septic tanks are utilised and have the potential to produce nutrient and bacterial contamination.

2.2.2 Point Sources of Pollution

Based on site visits to the catchment and inspections during regular monitoring, a number of potential point sources of pollution have been identified. These include:

- The sewer system within the township of Karuah relies on individually emptied septic systems. These septic systems are emptied by tankers on a regular basis by Port Stephens Council. As highlighted in the recent Land and Environment Court case (Section 2.3.3), there is the potential for this system to be bypassed and raw sewage to be emptied directly into the waterway. A system such as this is difficult to police, and, if bypassed, can result in the degradation of water quality within the Karuah River.

- There are a number of commercial enterprises in Karuah (eg. petrol stations) which involve underground storage of potential contaminants (eg. petrol). These storage tanks have the potential to develop leaks and thus contaminate the groundwater in the area. Due to the hydraulic interaction between the groundwater and the estuarine waters of the Karuah River, this leakage could result in contamination of the Karuah River.

2.3 Sewerage System

2.3.1 Existing System

Presently, most houses in Karuah are serviced by septic systems which are emptied on a regular basis by tankers operated by Port Stephens Council. These tankers empty the sewage into oxidation ponds, located at the western edge of the town. It is difficult to fully control such a system, as has become evident with the recent criminal conviction of a previous Karuah Caravan Park owner.

It has been recognised, however, that this present system is no longer adequate to service the forecast population growth in oncoming years. Hence, a report was produced by the NSW Public Works Department (July 1989, refer to Section 3.1) which investigated various options for upgrading the Karuah sewerage system.

2.3.2 Proposed Sewerage System Upgrade

The proposed upgrade of the current sewerage system (NSW Public Works, 1989) consists of constructing a reticulated sewerage system, with centralised treatment at a treatment works located to the west of the current Karuah township. This system will have the capacity to ultimately serve 4,000 equivalent persons. Treated effluent from the treatment works will be stored in a storage dam for re-use purposes. In overload conditions, effluent will overflow from this storage dam into Lizzies Creek via Wallaroo Swamp and subsequently into Limeburners Creek and then the Karuah River.

In the opinion of NSW Public Works, it is anticipated that, in these times of overflow, there will be sufficient dilution and dispersion within Lizzies Creek, Limeburners Creek and the Karuah River such that the water quality and oyster condition within the Karuah River will not be adversely affected by any overflows from the proposed sewerage system.

It is recommended by NSW Public Works that an extensive monitoring system should be implemented, particularly in the early stages of the operation of the proposed system, so as to closely monitor its effects on the surrounding aquatic environment. It will be necessary to collect sufficient data during these overflow events to determine the impact of this inflow on the surrounding water quality and ecology.

The need for this data is of importance to the proposed Pacific Highway upgrade as it may be difficult to distinguish impacts from the proposed sewerage treatment plant and the highway upgrade. However, the collection of rigorous baseline data and monitoring of the sewerage system overflows will allow a more informed analysis as to the cause of any changes in water quality or oyster condition.

2.3.3 Caravan Park Effluent Discharge

In November, 1997, a former operator and owner of the Karuah Caravan Park was jailed for 12 months and fined a total of $420,000 for the illegal discharge of sewage into the Karuah

River. The Land and Environment Court found the caravan park owner guilty of wilfully pumping millions of litres of sewage into the Karuah River over a period of 2½ years (from October, 1993 to April, 1996).

The incident made environmental history as the individual was only the second person in Australia to receive a jail sentence for an environmental offence. "It changed the physical, chemical and biological condition of the waters in the River," Mr Justice Lloyd said in his judgement. Refer to Appendix B for the full newspaper report (Newcastle Herald, November 8, 1997).

3 PREVIOUS STUDIES

A comprehensive search was carried out for existing studies in the Karuah area, particularly on water quality and oyster condition. Many of these studies were unavailable or irrelevant. Consequently, three of these studies were reviewed, namely:

- PUBLIC WORKS, HUNTER SEWERAGE PROJECT (July, 1989). "Karuah Sewerage Scheme Concept Report for Hunter Water Board." Report No. HSP 8914.
- PATTERSON BRITTON & PARTNERS (April, 1997). "Karuah Sewerage Project, Karuah River Water Quality Model - Preliminary Report." Document Reference J2541/R1586. Prepared for Hunter Water Corporation and Department of Land and Water Conservation in association with ERM-Mitchell McCotter.
- RICHARDSON, Darren (November, 1991). "Some Aspects of Food and Feeding in the Sydney Rock Oyster Saccostreaa Commercialis (Iredale & Roughley) in Port Stephens, NSW."

3.1 Public Works Report (July, 1989)

Karuah Sewerage Scheme Concept Report for Hunter Water Board

This report, completed by The Hunter Sewerage Project (HSP), addressed the deficiencies of the sewerage system servicing the Karuah area at the time of the study. Three strategies were considered for the upgrade of the system, which consisted of the treatment works located at three different locations.

The report suggested that considerable water quality testing and hydraulic investigations would need to be undertaken to determine the effects of a treatment works on both the quality of the river and its oyster industry.

The report did not present any statistical data, either water quality or oyster condition. Nor did it address the effect of the sewerage scheme on these parameters.

3.2 Patterson Britton Report (April, 1997)

Karuah Sewerage Project, Karuah River Water Quality Model.

This preliminary report, prepared by Patterson Britton in association with ERM Mitchell McCotter on behalf of the Hunter Water Corporation (HWC) and the NSW Department of Land and Water Conservation (DLWC), presented one component of the concept design and the Environmental Impact Statement (EIS) for the proposed sewerage scheme at Karuah.

It investigated the likely impacts of the proposed treatment plant on the water quality of the Karuah River and Limeburners Creek through the use of the water quality model AQUALM and the RMA finite element model. Total phosphorus, total nitrogen and faecal coliforms at the intersection of Limeburners Creek and Karuah River were modelled. A total of four treatment levels producing a range of effluent qualities was assessed.

Generally, the modelling indicated that high nutrient levels in the Karuah River was due to elevated background nutrient levels, with 95% of annual nutrient loads in a dry year resulting from catchment runoff.

3.3 Richardson, Darren (November, 1991)

Some Aspects of Food and Feeding in the Sydney Rock Oyster Saccostreaa Commercialis (Iredale & Roughley) in Port Stephens, NSW.

Richardson (1991, unpublished thesis) examined the water quality characteristics and feeding ecology of Sydney rock oysters (*Saccostrea commercialis*) in Port Stephens. In general, previous studies have found the Port Stephens estuary to be well-mixed during low rainfall, and partially stratified in the upper estuary following heavy rain.

This study found that water salinity, temperature and chlorophyll *a* distributions vary according to tidal stage, rainfall, and distance upstream.

Field surveys were also undertaken to determine the availability and use of various food components by oysters. Consistent with other oyster species, Sydney rock oysters were found to feed on bacteria, detritus and microalgae. Laboratory experiments were undertaken to determine the filtration rates and gut residence time of food in oysters and these were found to be strongly influenced by a variety of environmental conditions.

4 EXISTING DATA

Considerable background water quality data exists in the Karuah River, a brief summary of which follows:

Hunter Water Laboratories (May, 1997)

Hunter Water Laboratories collected a total of nine water samples during the month of April, 1997 at four sites in the Karuah area, including two in Limeburners Creek, one at the intersection of Limeburners Creek and the Karuah River and one approximately 1 km downstream of this confluence. Samples were tested for the following parameters:

⇒ pH

⇒ conductivity

⇒ dissolved oxygen

⇒ BOD_5

⇒ free ammonia as N

⇒ total kjeldahl nitrogen as N

⇒ total oxidised nitrogen

⇒ suspended solids

⇒ ortho-phosphate

⇒ total phosphate

⇒ chlorophyll *a*

⇒ faecal coliform

⇒ copper

⇒ cadmium

⇒ lead

Hunter Water Corporation (1987 - 1996)

The Hunter Water Corporation completed water quality monitoring at Booral, over 15km upstream from the township of Karuah. Samples were collected between September 1987 and May 1996 and tested for a range of nutrients, metals and microbiological parameters.

Hunter Sewerage Project (December, 1994)

A variety of physical and chemical parameters were analysed in December 1994 on behalf of the HSP in the Karuah River. Two sites, downstream of Mustons Gully and between Swan and Wirrung Islands, were chosen for assessment. Parameters tested included:

⇒ total kjeldahl nitrogen

⇒ free ammonia

⇒ total oxidised nitrogen

⇒ suspended solids

⇒ total phosphate

⇒ BOD_5

⇒ temperature

⇒ dissolved oxygen

⇒ pH

⇒ conductivity

⇒ turbidity

⇒ total coliforms

⇒ faecal coliforms

⇒ total oil and grease

⇒ algae

⇒ virus

Port Stephens Council (intermittently between 1992 - 1995)

Monitoring was undertaken by Port Stephens Council within Port Stephens at Lizzies Point at three monthly intervals between 1992 and 1995. Samples were analysed for the following parameters:

⇒ faecal coliforms

⇒ total nitrates

⇒ total phosphates

⇒ mercury

⇒ cadmium

⇒ copper

⇒ lead

Port Stephens Council (1991)

Port Stephens Council undertook sampling at two locations in the Karuah River, approximately 2 km upstream and 1 km downstream of the Karuah Bridge, during 1991. Sediment and water samples were analysed for the following parameters:

⇒ copper

⇒ cadmium

⇒ lead

⇒ zinc

⇒ iron

⇒ mercury

⇒ fluoride

⇒ cyanide

⇒ organochlorins

⇒ organophosphates

⇒ PCB's

Results

The water quality results from these Karuah River studies was considered to be generally good. A brief summary of their findings is presented below:

⇒ the Karuah River system was considered to be well aerated, with dissolved oxygen levels falling below ANZECC (Australian and New Zealand Environment and Conservation Council) recommendations on only a few occasions at limited locations;

⇒ orthophosphorus levels were regularly above ANZECC guidelines for various studies. However, since nitrogen is the limiting nutrient in estuarine waters such as that at Karuah, phosphorus concentrations will have little effect on algal populations.

⇒ nitrate concentrations were below those levels recommended by ANZECC;

⇒ ammonia concentrations generally exceeded ANZECC recommendations;

⇒ lead levels were below the guidelines set by ANZECC.

5 WATER QUALITY MONITORING

5.1 Testing Locations

Three (3) locations were chosen for the collection of samples and physical water parameter testing. These sites were located in close proximity to existing oyster leases, approximately 1km upstream of the existing bridge, at the bridge itself and 1km downstream of the bridge (refer to Figure 5-4).

The testing locations were chosen both for their location in relation to the existing Pacific Highway through Karuah, and that of the proposed highway upgrade routes.

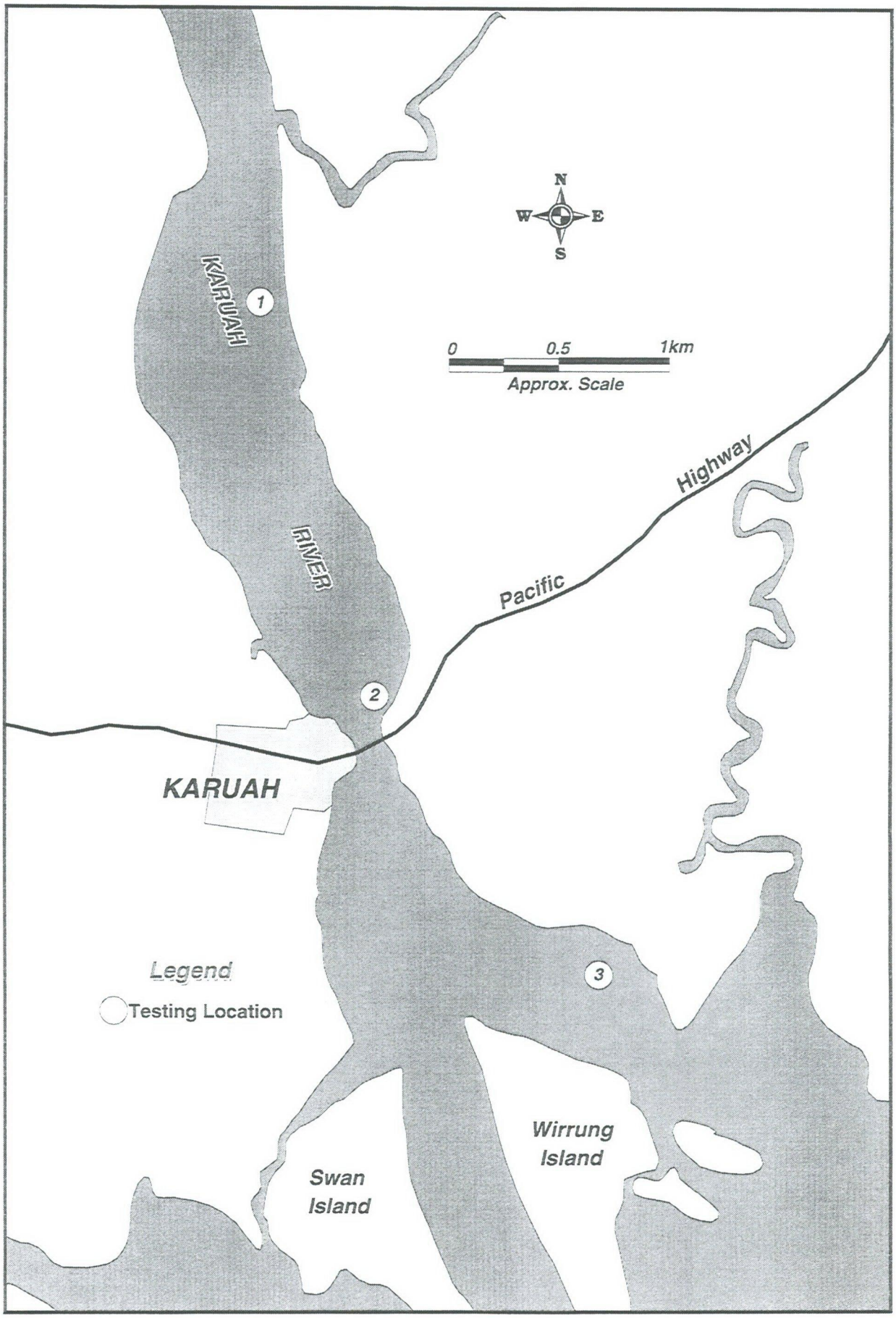
At the time of the commencement of the monitoring program, the highway route option located further west (known as Horse Island route) was not under consideration. Hence, no data was collected near this option.

All samples were collected at low tide for consistency and easy access to oyster leases. Samples were stored on ice (below 4 Degrees Celsius) and transported overnight for testing at the laboratory. Lead samples were acidified with nitric acid to preserve the sample.

On the 13th November, samples were also collected from two additional sites (sites 4 and 5), approximately 2 km downstream and 2 km upstream of the Karuah Bridge respectively. These samples were tested for lead content, the results of which are discussed in Section 7.1. Both of these sites are within the tidal influence of the Karuah River.

On the 13th January, 1998, samples were collected from two additional locations and tested for lead content. One sample was taken above the tidal limit from the bridge crossing at Booral (approximately 20 km north of Karuah), while the other sample was taken from Port Stephens itself at Lemon Tree Passage. A sample was taken from Karuah at approximately the same time (ie. at low tide) as the other samples.

The results of this testing are discussed in Section 7.1.



Testing Location **Figure 5.4**

5.2 Water Quality Parameters

Water quality parameters are an important indication of the general health and well-being of a waterbody. Water quality however, is influenced by a number of factors, including rainfall, temperature and tidal variations. Hence, to obtain an accurate indication of the existing health of the Karuah River system, a substantial water quality database is required. This database should include the measurement of both physical parameters (such as salinity, dissolved oxygen and turbidity levels) and chemical parameters (such as nutrient and heavy metal concentrations) over an extended period of time.

A brief discussion of these physical and chemical parameters, their interaction with each other, and their implication on the health of the river system follows.

ANZECC recommendations (for estuarine waters, unless otherwise stated) will also be presented and discussed. ANZECC recognise the fact that these guidelines, or recommendations, can only, at best, be broadly implemented due to the variable nature of our ecosystem.

> *"Biological systems are known to be inherently variable and this, coupled with the marked difference in sensitivity of different ecosystems and biological communities to particular pollutants and stressors, makes it essential that management must occur on an ecosystem-by-ecosystem basis."* (ANZECC, 1992).

5.2.1 Physical Parameters

The parameters tested in this baseline monitoring study included:

- temperature
- dissolved oxygen (mg/L and % Saturation)
- conductivity and salinity
- pH
- turbidity
- suspended sediment

These parameters will be discussed individually.

Temperature

Changes in temperature can have a substantial affect on an aquatic ecosystem and its health. It can have direct effects, such as altering an organism's metabolism and growth rates, reproduction and its mobility. Indirectly, it can influence the solubility of oxygen in the water which, in turn, will affect the ecosystem and the organisms living in it.

Water temperature was measured, in Degrees Celsius, at one metre intervals throughout the entire water column using a water quality probe.

Little data exist on acceptable temperature variations tolerated in aquatic environments. ANZECC provides recommendations for acceptable increases in water temperature due to artificial causes (such as the discharge of cooling water from a thermal power station).

Since no such industry is present in the Karuah River, we can attribute any increase or decrease in the mean water temperature to natural causes.

Dissolved Oxygen (DO)

Oxygen is an essential requirement for most marine organisms. Other than plants, no organism can produce its own oxygen supply.

The addition of organic material into an aquatic ecosystem leads to an increase in the activity of aerobic organisms, primarily bacteria. These bacteria, in turn, utilise more dissolved oxygen from the water as they break down and mineralise the organic material.

Dissolved oxygen levels can also be affected indirectly by the introduction of plant nutrients, leading to an increase in plant growth. Although plants (and algae) produce oxygen in the presence of sunlight, they consume oxygen overnight (when they cease to photosynthesise). Plant matter will also ultimately decompose, which is also an oxygen demanding process. Decomposition and other oxygen demanding processes typically occur in the sediments, which can result in low oxygen levels near the bed of the waterbody.

Dissolved oxygen levels can vary greatly and can be influenced by a number of parameters, including temperature, salinity and biological activity. The amount of surface aeration of a waterbody, whether through turbulence or rainfall, will also have a direct effect on dissolved oxygen levels.

Dissolved oxygen levels were measured, both in mg/L and as % saturation, at one metre intervals throughout the entire water column using a water quality probe. This was carried out to determine whether acceptable dissolved oxygen concentrations were found at all depths of the water column.

While little Australian data exists for this parameter, ANZECC recommend that dissolved oxygen levels should remain below 6 mg/L (or 80-90% saturation) for healthy waters.

Salinity and Conductivity

Conductivity is a measure of a water's ability to conduct an electric current and is sensitive to variations in dissolved solids (ie. salts). For any given waterbody, conductivity is often related to the concentrations of these total dissolved solids and major ions. Salinity is a measure of salt within the body of water. These two terms, salinity and conductivity, are often used interchangeably.

Large salinity changes have the ability to affect some organisms and, hence, the health of an aquatic system. These changes can have direct effects, through osomolarity variations and the solubility of dissolved gases, and indirect effects, by modification of the species compositions of the ecosystem. Organisms which live in estuaries are typically well adapted to large fluctuations in salinity.

Conductivity and salinity levels were measured insitu (in mS/cm and ppt respectively) at one metre intervals throughout the entire water column using a water quality probe. This demonstrates whether the water column is well mixed, or whether denser saline waters are overlying fresh surface waters, which is common in estuaries.

ANZECC offers no definite limitations or criteria on salinity and conductivity levels for marine or estuarine environments. It does recommend acceptable variations for saline discharges into fresh waters, as is often the case in catchments with significant use of irrigation.

pH

pH is an important water quality parameter as it can influence many chemical and biological processes within a waterbody. The pH is actually a measure of the hydrogen ion activity in aqueous solution, with a scale ranging from 0 to 14 (the lower end of the scale representing acidic conditions, and the upper end of the scale indicating alkaline conditions).

In natural waters, the pH level is primarily determined by the interaction of carbon dioxide, carbonate and bicarbonate ions as well as natural compounds such as fulvic acids. Variations from the natural levels of pH can often be attributed to man-made pollution sources, such as industrial effluent and the atmospheric deposition of acid-forming substances.

pH levels were measured at one metre intervals throughout the entire water column using a water quality probe.

ANZECC does not recommend acceptable pH limits in estuarine waters, such as those at Karuah. It does, however, recommend acceptable ranges for fresh and marine waters. The pH of fresh waters should be within the range from 6.5 to 9.0. The high carbonate content in marine waters buffers pH changes and, hence, these waters have a more restrictive range of variation.

Recommendations that the pH should not vary by more than 0.2 units from the normal value in marine waters have been made by ANZECC, with typical marine waters having a pH range of 8.0 to 8.3. However, it is noted that this range can be extended for biologically active coastal waters.

Turbidity

Turbidity is a measure of the amount of scattering and absorption of light by suspended particles within a body of water. Its units are NTU (nephelometric turbidity units). These suspended particles can include silts, clays, phytoplankton and other fine particles. It is essentially an indicator of water clarity.

Turbidity can vary seasonally depending on the amount of runoff within the catchment and the degree of biological activity within the body of water. By far the greatest source of suspended matter in Australian waters, and particularly estuaries, are diffuse sources such as catchment runoff and suspended material that is carried from the upper reaches of the catchment by rivers and streams. Catchments consisting of highly erosive soils with unstable creek beds can be expected to have very high turbidity levels. High turbidity levels result in reduced light penetration, often leading to reduced biological activity within the water column and on the creek bed.

Turbidity is sometimes directly correlated to total suspended solids, particularly where there are large fluctuations in suspended matter. Davies-Colley and Close (1990) found that turbidity was also closely correlated (inversely) with visual clarity.

The clarity of a waterbody (inversely related to turbidity) is measured insitu by lowering a secchi disc (a black and white circular disc attached to a cable with depths indicated) into the water and measuring the depth at which it is no longer visible. Turbidity levels were measured at one metre intervals throughout the entire water column using a water quality probe.

Suspended Sediment

Suspended solids are largely attributable to diffuse sources, such as catchment runoff, erosion of river banks in times of high flow and the re-suspension of matter from the bed of a body of water.

High suspended solid levels will lead to a reduction in the penetration of sunlight and hence may limit biological activity within the water column. Pollutants can also attach themselves to this suspended particulate matter, also resulting in a reduction in the quality of the water environment. Excess suspended sediment levels can also interfere with organisms breathing and reproductive processes.

ANZECC do not recommend any criteria on the level of suspended sediment in a waterbody, but recommend the clarity of a waterbody should not be altered by more than 10% of the seasonal mean.

5.2.2 *Chemical Parameters*

The chemical parameters tested in this baseline monitoring study included:

- ammonia (NH_3)
- oxidised nitrogen and total nitrogen (NO_x and TN)
- orthophosphorus
- total phosphorus (TP)
- lead

Nutrients

Nutrients, accompanied by sunlight, water, carbon dioxide and some trace elements, are all essential ingredients for plant growth. Sunlight and biologically available nutrient input are usually the limiting factors in this biomass production. Therefore, an increase in the supply of these factors, particularly nitrogen and/or phosphorus, can result in excessive biological activity, particularly algal growth. This nuisance growth of plants can ultimately lead to eutrophication in water systems. Excessive algal levels can also deplete dissolved oxygen levels and cause large fluctuations in pH levels, resulting in additional stresses on sensitive aquatic species. Excessive algal levels commonly cause problems in larger, slow-flowing rivers which are nutrient-enriched. Since nitrogen and phosphorus are generally the limiting factors, each of these nutrients will be considered separately.

It should be noted that ANZECC emphasise the need for site-specific studies to be undertaken for the determination of acceptable nutrient levels in an aquatic environment.

Nitrogen

Nitrogen is present in many forms in a waterbody, both in dissolved and particulate phases. Nitrogen is typically the limiting nutrient in marine and estuarine systems (ie. the availability of nitrogen limits the algal population which can be sustained in the waterway). The reverse is typically true for freshwater systems.

Plants and micro-organisms convert inorganic forms of nitrogen, such as nitrates (NO_3^-), nitrites (NO_2^-), the ammonium ion (NH_4^+) and molecular nitrogen (N_2) organic forms through biological and non-biological transformations. These processes are often complex,

and will not be dealt with in detail in this report. The most biologically available forms of nitrogen are ammonia (NH_3) and nitrate (NO_3^-). Each nitrogen component is briefly discussed below.

Ammonia - Ammonia occurs naturally in water bodies, originating from organic and inorganic nitrogen in the soil and water, excretion by biota, gas exchange with the atmosphere and by the reduction of nitrogen gas in the water by micro-organisms. Man made sources may also contribute to ammonia levels, including human waste, discharge from industry and fertiliser operations. High levels of ammonia can be toxic to the aquatic environment.

Generally, unpolluted waters will have an ammonia concentration of less than 0.1mgN/L. High ammonia levels generally indicate polluted waters, typically through human influences. Ammonia is the form most readily taken up by plants and algae.

ANZECC has a criterion of ammonia levels of less than 5 µg/L for estuarine and marine waters. This recommendation is considered to be very stringent and is rarely met in Australian estuaries.

Oxidised Nitrogen - Oxidised nitrogen includes both nitrate (NO_3^-) and nitrite (NO_2^-). Both forms are readily utilised by algae and plants. In well oxygenated waters, little nitrite is typically found.

ANZECC recommends a guideline criterion between 10-100 µg/L is appropriate for estuarine waters.

Organic Nitrogen - Organic nitrogen mainly consists of protein substances, such as amino acids, nucleic acids and urine, and the product of their biochemical transformations, such as fulvic and humic acids. Naturally occurring organic nitrogen levels tend to fluctuate seasonally, depending on the level of biological activity and catchment runoff. Consistently high organic nitrogen levels, however, may indicate pollution of the waterbody. These forms of nitrogen are not as readily taken up by algae and plants.

Total Kjeldahl Nitrogen (TKN) - The most common testing method for organic nitrogen is the Kjeldahl method which is the sum of organic nitrogen and ammonia nitrogen.

Total Nitrogen - Total nitrogen is the sum of TKN (organic nitrogen and ammonia nitrogen) and oxidised nitrogen. ANZECC does not specify a guideline for total nitrogen in estuarine or marine systems. They do however, provide a total nitrogen recommendation for rivers and streams (100-750 µg/L) above which excess algal levels have been known to occur.

The algal population however is dependant on numerous other environmental factors, such as temperature, light penetration and the concentration of other nutrients such as phosphorus. While this is not strictly the upper limit for total nitrogen levels for our study, it does provide us with a broad guideline on which to make environmental assessments.

ANZECC does make recommendations for nitrate (NO_3) concentrations in estuaries and embayments. Indicative ranges for nitrate concentrations are 10-100 µg/L.

Phosphorus

Phosphorus exists in natural waters in both particulate and dissolved forms, and is often the limiting nutrient for algal growth in fresh waters. The most biologically available form of phosphorus is orthophosphate (PO_4^{3-}). It does, however, exists in a number of other forms, most commonly polyphosphates and organically bound phosphates.

Natural sources of phosphorus include the decomposition of organic matter and the weathering of phosphorus rich rocks. Man-made sources are typically domestic wastewaters and fertiliser runoff.

ANZECC make recommendations for the desired range of total phosphorus levels in rivers and streams, namely of 10-100 µg/L. Recommendations are also presented for orthophosphate levels for estuaries and embayments. The recommended range is 5-15 µg/L.

Once again, it should be noted that these ranges are indicative only, providing values above which problems have been known to occur in other water bodies. ANZECC emphasise the need once again for site specific studies to determine acceptable limits in nutrient inputs into a particular waterbody.

Lead

Lead can be very toxic to marine organisms and elevated levels do not generally occur naturally. High lead levels can usually be attributed to some anthropogenic source, such as atmospheric lead fallout from vehicle exhausts and paint or petrol spills. However, in catchments containing lead-rich limestone deposits, natural lead levels have been known to be elevated.

Depending on the water hardness, ANZECC recommends that total lead concentrations in marine waters should not exceed 5 µg/L.

5.2.3 Summary of ANZECC Guidelines and Recommendations

Parameter	ANZECC Recommendation	Comments
Physical Parameters		
Temperature	<2°C increase	applies to artificially warm discharges only.
Dissolved Oxygen	>6 mg/L (>80-90% saturation)	for both marine and fresh waters
Salinity & conductivity	-	no recommendations made for marine or estuarine waters.
PH	<0.2 pH unit change	limit for marine waters only. No recommendations set for estuarine waters.
Turbidity/suspended particulate matter	<10% change in seasonal levels	
Chemical Parameters		
Ammonia	<5 µg/L	for both marine & estuarine waters.
Total Nitrogen	-	no recommendations made. Problems have been known to occur >100-750 µg/L in rivers & streams.
NO_3	10-100 µg/L	for estuarine waters.
Phosphorus	-	recommendation for rivers and streams of 10-100 µg/L.
Orthophosphate	5-15µg/L	recommendations made for estuaries and embayments.
Suspended sediment	-	see turbidity above.
Lead	<5µg/L	recommendations made for marine and fresh waters.

Table 5-1 Summary of ANZECC Recommendations for Water Quality Parameters

5.3 Water Quality Results

All water quality results and plots are located in Appendix A of this report. A comprehensive discussion of these results and their implications are located in Section 7.1.

6 OYSTER MONITORING

6.1 Oyster Biology and Production

6.1.1 *General Biology*

The subject of this baseline monitoring study, the Sydney rock oyster *Saccostrea commercialis* (Iredale and Roughley), is a bivalve mollusc belonging to the family Osteridae. *S. commercialis* is mostly estuarine in habitat, and typically forms a distinct band in the intertidal zone of rocky shores (Dakin and Bennett 1987). Although several oyster species occur in Australian coastal waters, *S. commercialis* accounts for around 95% of Australian commercial production of oysters (Malcolm 1987).

Oysters are filter-feeders (Jørgensen 1966, Jørgensen 1990), and feed on suspended organic material such as micro-algae, such as diatoms and flagellates, detritus and bacteria (Richardson 1991). Oysters may filter large volumes of water, with estimates ranging up to $4L.oyster^{-1}.hour^{-1}$ (Richardson 1991). During filtering, oysters may accumulate contaminants from the surrounding water column, either from ingesting contaminated food components (ie. bacteria), or up-take of metals in the soft tissue through exposure to contaminated water.

Oysters have the potential of becoming a health risk to human consumers if contaminants are accumulated by the oysters.

6.1.2 *Oyster Production*

Port Stephens estuary is of considerable fisheries importance (West, et al. 1985), particularly in relation to the production of oyster spat and plate oysters.

Oyster operations in Port Stephens involves three stages of cultivation:

- initial spat collection, involving the collection of juvenile (spat) oysters on tarred sticks or other methods. It is notable that the outer port supplies up to 70% of the NSW Sydney rock oyster spat production;
- grow-out of spat (one to two months old) to juvenile stages (one to two years old) on spat collection devices (ie. sticks); and
- adult oysters are transferred to mesh trays to 'fatten' for one or more years, and are then marketed as plate oysters. The inner port produces most of the plate oysters for NSW markets.

6.2 Oyster Sampling Procedure

6.2.1 *Tissue condition*

Histological assessment of tissue condition allows a direct assessment of the health of oysters (Wilson *et al.* 1993). A total of 360 oysters, collected from the Karuah River between June and November, were examined histologically to assess baseline levels of parasite loads and tissue condition.

Two cross sections of each oyster were examined (Figure 6-1). The first section ('A') was taken 4-7 mm posterior to the labial palps and the section included gonad, stomach, digestive gland and gills. The second section ('B') was taken through the adductor muscle and included muscle, intestine and gills (Figure 6-1).

Each histological section was examined routinely at 100x magnification and areas which showed abnormal pathology were examined at 400 and 1000x magnification.

A number of parameters were used to assess the health of each oyster. The condition of Leydig (glycogen storage) tissue, degree and type of haemocyte (blood cell) infiltration and the abundance of "brown cells" was assessed in each oyster using a simple scoring system explained below.

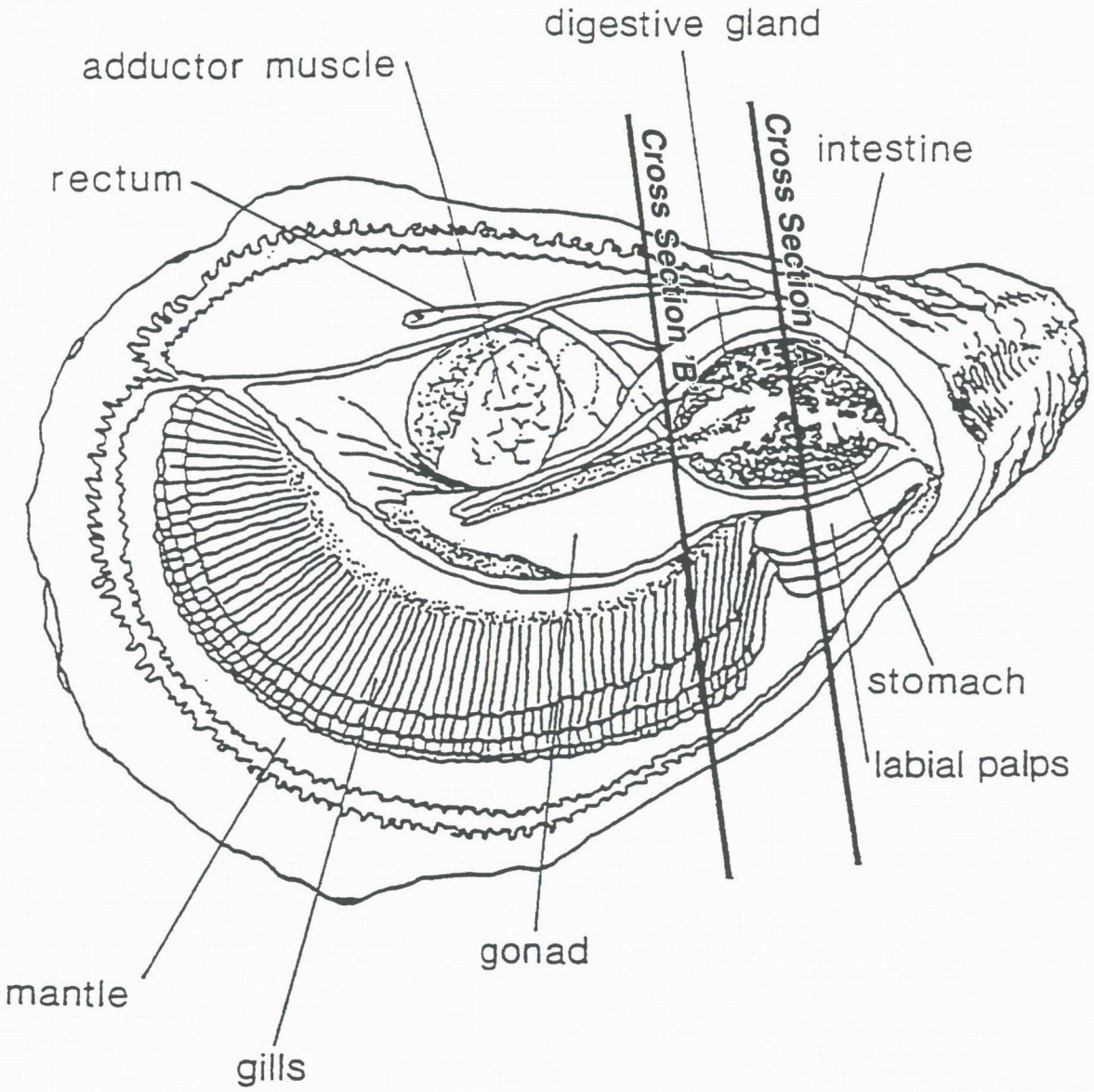
For each sample of oysters (i.e. 10 oysters collected from each site at each sampling date), a single score for each tissue type was obtained by taking the average of all scores for each sample. A value between 0 and 2 was obtained for each sample for Leydig tissue, and proportion of brown cells, and a score between 1 and 3 was obtained for scores of diffuse and local haemocyte infiltration. High scores indicate poor condition or abnormal pathology.

The condition of the digestive gland was assessed by estimating the proportion of digestive tubules with no, moderate or severe atrophy (Table 6-1). Digestive tube atrophy (DTA) was characterised by a reduction in the height of epithelial cells. For example, in an oyster with 70% of digestive tubules with no atrophy, 20% moderately atrophied and 10% severely atrophied, the score would be:

DTA 1	DTA 2	DTA 3
70	20	10

The average proportion of digestive tubules at each level of atrophy was calculated for each sample of oysters.

In addition, each oyster was examined for the presence of diseases (viruses, bacteria, protozoa), parasites and commensal organisms, and for abnormal pathology such as tissue oedema (swelling). The prevalence of these conditions in each sample of oysters from each site was calculated.



Source : Howard Smith (in Wilson et al. 1993)

Anatomy of an Oyster **Figure 6.1**

Table 6-1 Description of the function of each tissue and scoring system used for assessment of Sydney rock oyster health (n/a = not applicable)

Tissue	Function	Score			
		0	1	2	3
Leydig	glycogen storage[1]	full	partially depleted	majority of cells depleted	n/a
Diffuse haemocyte infiltration	transport of food, resorption, immune response	no infiltration	light infiltration	moderate infiltration	heavy infiltration
Local haemocyte infiltration	immune response	no infiltration	light infiltration	moderate infiltration	heavy infiltration
Brown cells	digestion of foreign material, indicator of poor condition and abnormal fat metabolism[2,3]	low numbers	moderate numbers	high numbers	n/a
Digestive Tubule Height	digestion, reduced height associated with poor condition[1,4]	n/a	normal tall epithelia	height of epithelia reduced	only basal cells and membrane remaining

Reference sources: [1] Meyers (1981); [2] Gauthier *et al.* (1990); [3] Lauckner (1983); [4] Couch (1985).

6.2.2 *Elemental Analyses*

Metals are toxic elements that have the potential to bio-accumulate through the consumption of aquatic biota. This study examined a suite of metals (described below) and other elements that are toxic at high concentrations. In this study, the suite of elements (metals and non-metals) examined will be collectively known as 'metals'.

Procedure

A total of 360 oysters were collected to assess metal concentrations in soft tissues.

Oysters were sent to the NATA certified Queensland Department of Primary Industries (DPI) Animal Research Institute Laboratory for analyses. Oysters shells were initially cleaned and then opened by cutting through the hinge. Oyster soft tissues were removed from the shell and the gut cavity was cleaned prior to analyses. The concentration of metals in oyster tissues were analysed by ICP-MS following microwave assisted digestion.

The elements/metals tested for were: Arsenic (As); Cadmium (Cd); Cobalt (Co); Chromium (Cr); Copper (Cu); Lead (Pb); Mercury (Hg); Molybdenum (Mo); Nickel (Ni); Selenium (Se); Zinc (Zn).

Statistical Analyses

General trends in the concentrations of metals were described and compared to the Australian Food Standards Code (National Food Authority 1992) maximum permitted concentrations (Standard A12) for bivalve molluscs.

Two-way analysis of variance (ANOVA) was used to test for, and identify differences in, the mean concentrations of each of the metals among times and sites, following the

procedures outlined in (Sokal and Rohlf 1981). Tukey's Least Significant Difference (LSD) test was used to make *post-hoc* mean comparisons of sites and times.

Prior to parametric tests, all data were tested for normality and homogeneity of variances using Levene's test for equality of error variances (Sokal and Rohlf 1981). If variances were heterogeneous, data were log transformed. If the transformation failed to remove the heterogeneity, significance was determined at a lower probability level of $p = 0.01$ on the untransformed data (Underwood 1981).

In cases of non-significant main effects, *post-hoc* power analysis was used to indicate if the analyses had adequate power (>0.8) to detect differences among the times and sites (Fairweather 1991). All statistical tests were performed using the software package SPSS for Windows 7.0 (SPSS 1996).

6.2.3 *Microbiological Counts in Oyster Tissues*

Analyses were preformed to determine the numbers of *Escherichia coli* (*E. coli*) in oysters. A total of 10 unopened oysters were collected from each site on each sample period. The unopened oysters were placed into a plastic 'esky' to keep samples cool, and sent to EML laboratory (NATA certified for biological testing). Samples were analysed within 24 hours of field collection.

The testing procedure used was the 'Rapid method for generic *Escherichia coli* in bivalve molluscs' which is an Australian Standard (AS1766.2.12) microbiological assessment method. Oysters from each site were cleaned, aseptically shucked (removed from the shell), and tested as a composite sample. The direct plate method was used to culture and count E. coli (counted as 'colony forming units' - or 'cfu'), specific details of this method are outlined in Australian Standard AS 1766.2.12 (1994).

Escherichia coli counts in oysters were then compared to the maximum permitted concentrations for human consumption, as outlined in *Australian Standard D1 - Fish*. The relationship between *E. coli* levels and rainfall in the preceding 24, 48, 72 hours and 7 day period prior to sampling were examined through linear regression, following the procedures outlined in Sokal and Rohlf (1981).

6.3 Oyster Tissue Condition Monitoring Results

6.3.1 *Leydig Tissue*

The scores of Leydig tissue condition for each sample collected from each of the three sites are shown in Figure 6-2. The condition of the Leydig tissue in oysters collected from all sites was generally good with scores less than 1 indicating healthy glycogen rich tissue. At site 1, Leydig tissue scores were low in samples collected in June and July and increased over the sampling period with highest scores of 0.5 recorded in October and November (Figure 6-2). At site 2, Leydig tissue scores increased over the sampling period with highest values of 0.7 recorded in November. Scores were highly variable at site 3 with highest score recorded in June and low scores recorded in July and October.

Variations in the development of Leydig tissue were significantly correlated to brown cell development (τ= 0.294, p <0.05) and the proportion of oysters with healthy digestive tubules (τ= 0.269, p <0.05), but were not correlated to any other environmental factors or other tissues (Table 6-2).

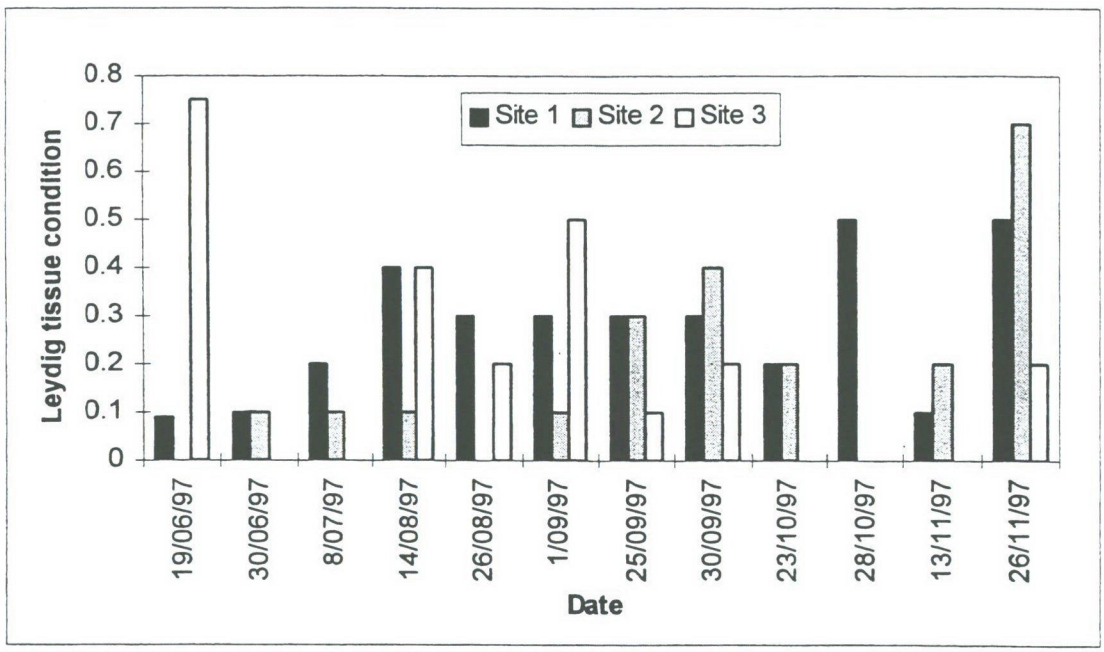


Figure 6-2 Leydig tissue scores in Sydney rock oysters collected from three sites at Karuah River in June to November 1997 (lower score equates to poorer condition).

Table 6-2 Kendall's coefficient of rank correlation (τ) showing the relationship between environmental parameters and tissue developement

	Temperature	Conductivity	Leydig tissue	Diffuse haemocytosis	Local haemocytosis	Brown tissue
Temperature	1.000					
Conductivity	0.735**	1.000				
Leydig tissue	0.185	0.135	1.000			
Diffuse haemocytosis	0.569**	0.530**	0.095	1.000		
Local haemocytosis	- 0.049	0.054	0.106	0.000	1.000	
Brown cells	- 0.076	- 0.131	0.294*	- 0.109	0.175	1.000
DTA	- 0.211	- 0.241*	- 0.269	- 0.159	- 0.190	- 0.249*

* correlation is significant at 0.05 level (2-tailed), ** correlation is significant at the 0.01 level (2 tailed)

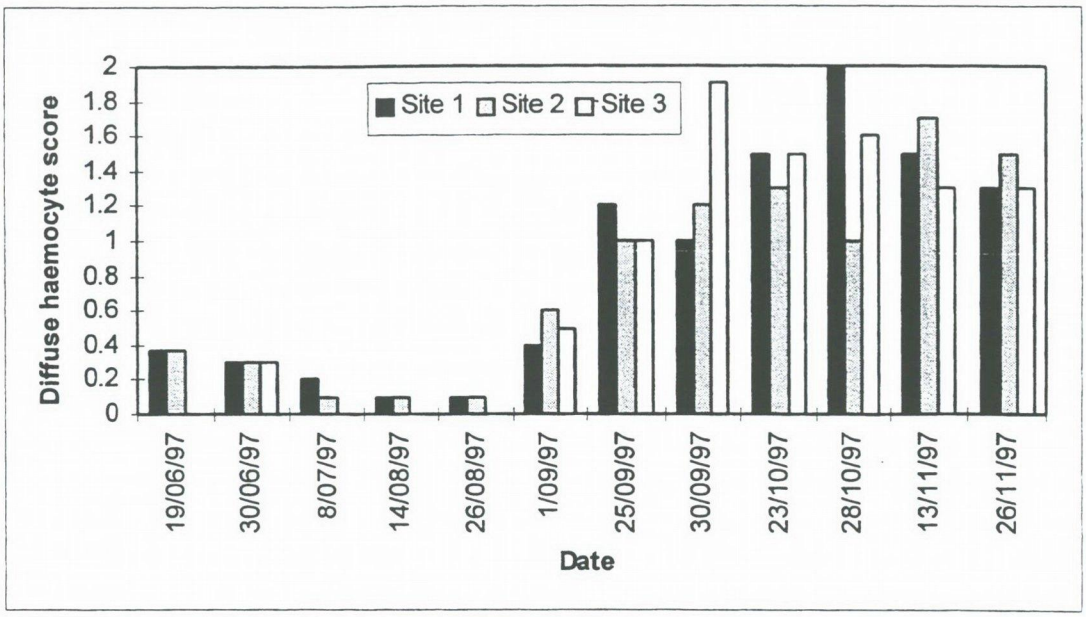


Figure 6-3 Degree of diffuse haemocyte infiltration in tissues of Sydney rock oysters collected from three sites in the Karuah River in June to November 1997.

6.3.2 *Local Haemocyte Infiltration*

The average scores for local haemocyte infiltration in oysters is shown in Figure 6-4.

The average scores for local haemocyte infiltration were less than one (1) at all sites and were highly variable over the sampling period. At all sites, scores were highest in samples collected in late August and early September. In total, 60 of the 360 oysters examined showed some evidence of moderate to heavy local haemocyte infiltration. In most cases, two to four small lesions were apparent in the section and were associated with the digestive gland or gut. Local haemocyte infiltration scores were not correlated with environmental variables or the development of other tissues (Table 6-2).

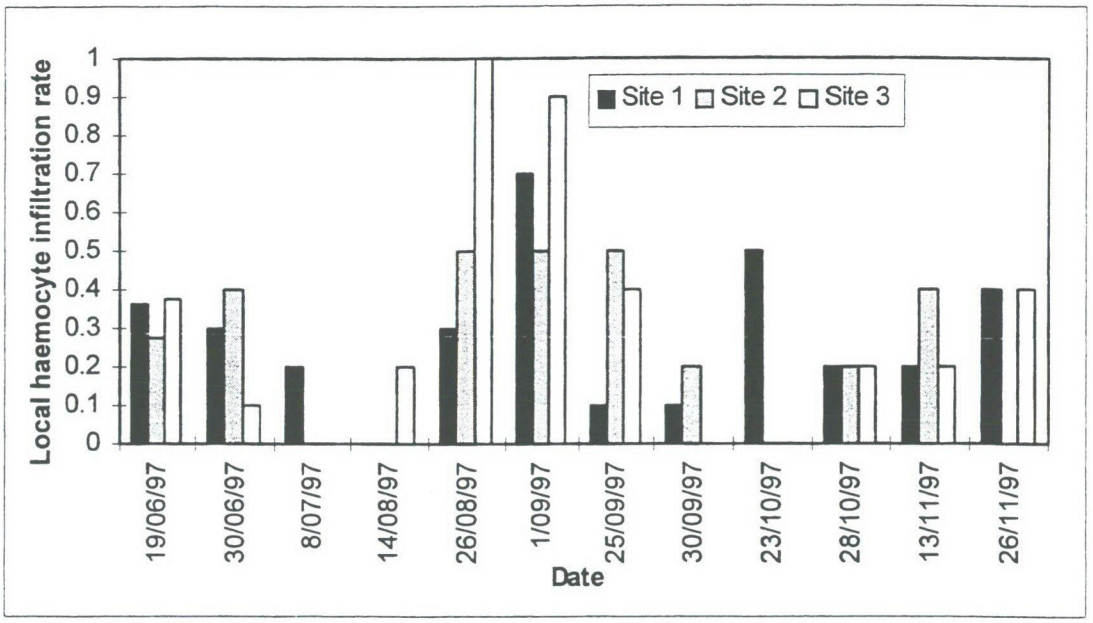


Figure 6-4 Average scores of local haemocyte infiltration in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997.

6.3.3 Brown Cells

The average scores for the abundance of brown cells in the tissues of oysters is shown in Figure 6-5.

Oysters from sites 1 and 3 had the highest incidence of brown cells in their tissues. At both sites, highest values were recorded in samples collected in June followed by samples collected in August and early September. No cause for the relatively high scores in June was detected although the slight increase in brown cell scores during August and September was coincident with increases in the scores for local haemocyte infiltration (Figure 6-4). As can be seen from Table 6-2, the incidence of brown cells was also significantly correlated with digestive tubule development and Leydig tissue development. The incidence of brown cells was low in samples collected at site 2 throughout the sampling period.

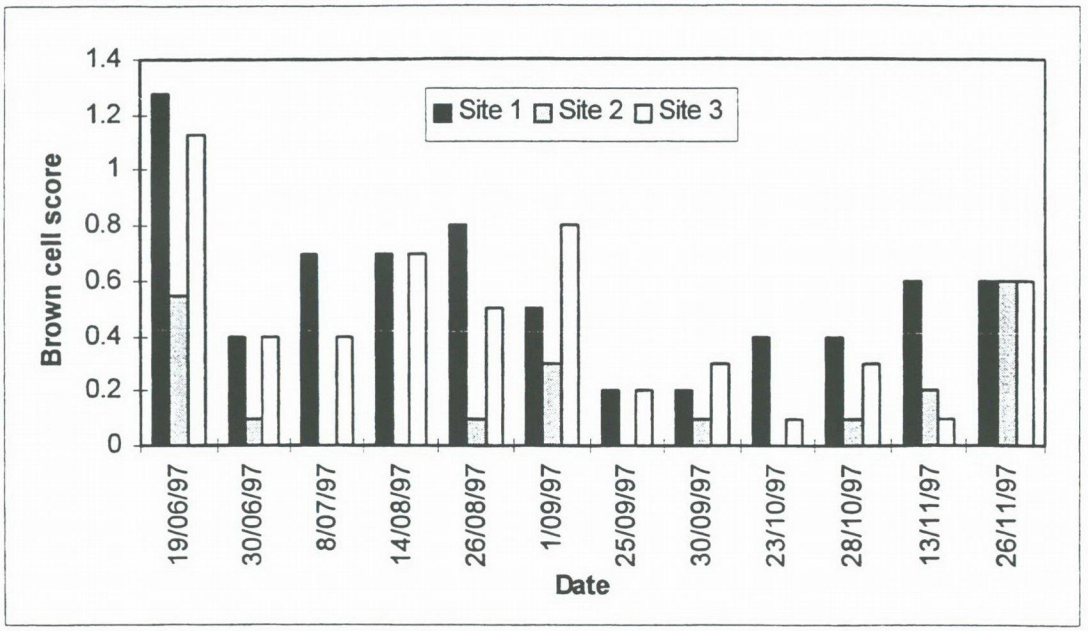


Figure 6-5 Average scores of the incidence of brown cells in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997.

6.3.4 Digestive Tubule Atrophy (DTA)

The relative proportions of each level of digestive tubule atrophy in oysters collected at each site are shown in Figure 6-6.

Site 2 showed the least amount of digestive tubule atrophy of all sites with 60 to 90% of tubules with tall healthy epithelia throughout the sampling period. Sites 1 and 3 had similar levels of digestive tubule atrophy with 40 to 70% of tubules with tall healthy epithelia. The highest incidence of severely atrophied digestive tubule epithelia (DTA 3) occurred at all sites in late September (Figure 6-6). The proportion of oysters with 'healthy' digestive tubules (DTA 1) was negatively correlated with brown cell development, Leydig tissue and conductivity (Table 6-2).

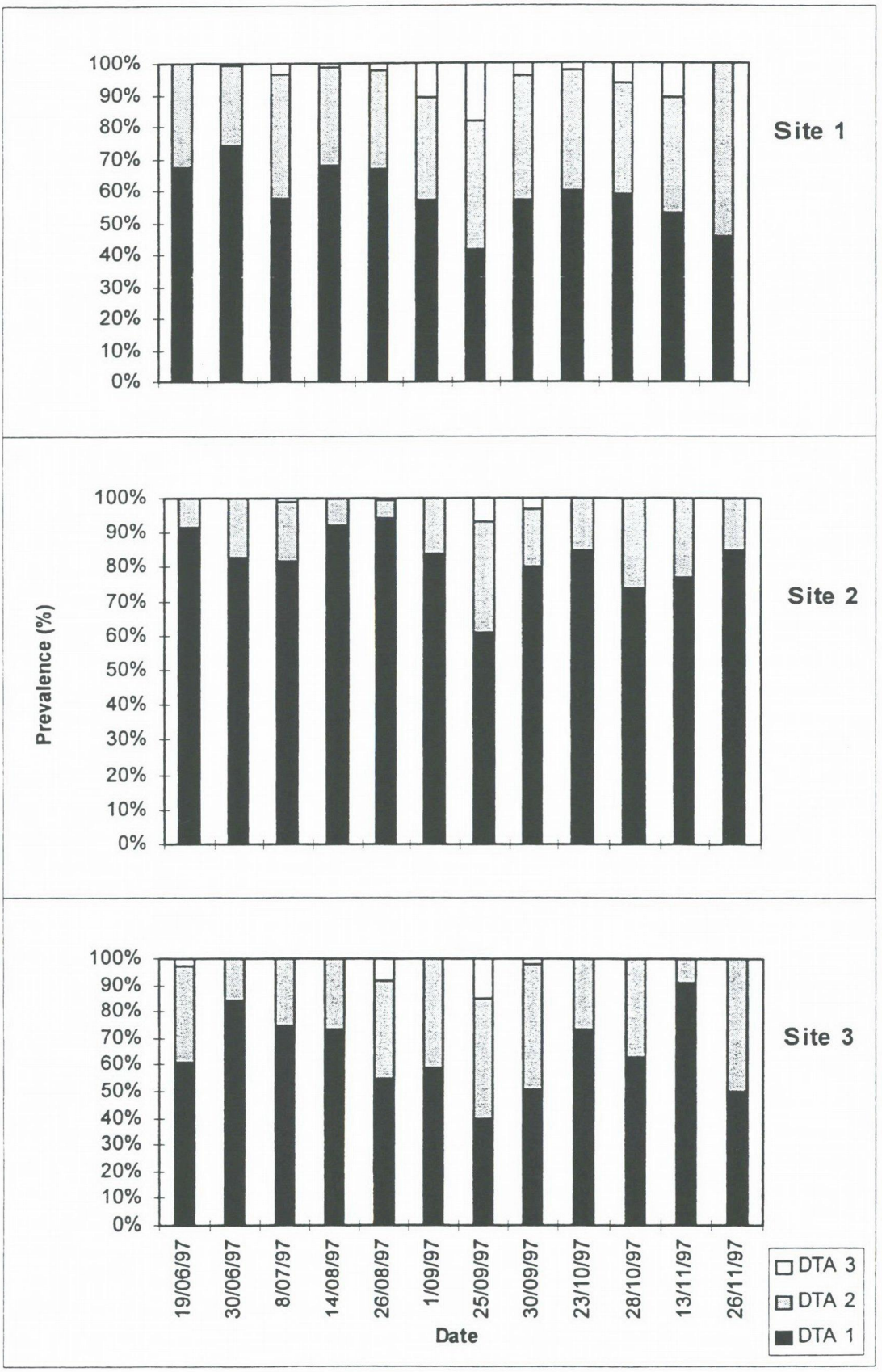


Figure 6-6 Relative proportions of digestive tubule atrophy in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997.

6.3.5 *Other Pathologies of Interest*

Oedema and inflammation of gill tissue was observed in 14 of the 360 oysters examined. Seven of these cases were recorded from the sample collected at site 3 on 27 November. This condition was characterised by "swollen" gills, large intercellular spaces, degeneration of connective tissue cells, and in some cases, was associated with haemocyte infiltration to the affected area. There was no apparent cause for this condition in any of the oysters examined, although this pathology suggests a blockage of fluid transport within the oyster which probably affects the ability of the gills to function normally.

Oedema of the mantle was observed in two oysters collected from site 3 in June.

6.3.6 *Diseases and Parasites*

No significant diseases were detected in any of the oysters sampled during this study. A total of four parasites or viruses were found during this study and all occurred at very low prevalence.

Papovavirus infection of the gonads was detected in one oyster from site 1 collected in November. A low proportion of the gametes was affected and there was no haemocytic infiltration associated with the infection.

A single trematode worm, probably of the genus *Bucephalus*, was found in the gonad of one oyster collected from site in November.

Two types of ciliate were detected in oysters collected during this study. Ciliates resembling *Ancistrocoma* sp was detected in the lumen of the digestive tubules in 26 of the 360 oysters examined (Figure 6-7). Infections were of low intensity with 1 to 10 ciliates seen in an oyster section. Ciliates of unknown taxonomy were associated with the gills of three oysters collected in June, July and September from site 3 . No haemocytic reaction was associated with the presence of either type of ciliate and neither type have been associated with disease in shellfish. However, increased prevalence or intensity of infection of these ciliates can indicate poor health in host organisms.

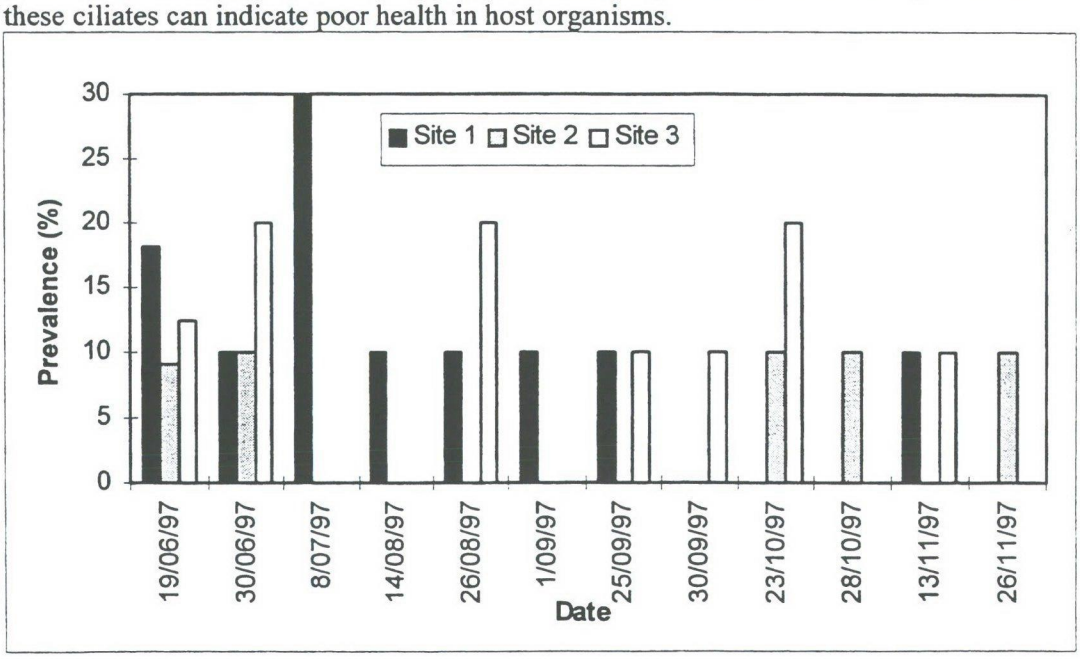


Figure 6-7 Prevalence of the ciliate *Ancistrocoma* sp in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997.

6.4 Analyses of Metals

Mean concentrations of metals in oyster tissues are presented in Figure 6-8 to Figure 6-13. The Australian Food Standards Code (National Food Authority 1992) maximum permitted concentrations of metals (Standard A12) in bivalve molluscs are also shown. With one exception (Selenium), metal concentrations were well below the maximum permitted concentrations of the Australian Standards Code (AFSC), as discussed below.

6.4.1 Comparisons with AFSC guideline levels

Arsenic (As)

Total arsenic concentrations are presented in Figure 6-8, and ranged from 1.3 to 2.5 mg/kg per sample at site 1, 1.0 to 3.3 mg/kg at site 2 and 1.2 to 2.5 mg/kg at site 3.

Arsenic occurs as several forms in natural waters, some of which are acutely toxic to biota. AFC guidelines are only available for inorganic arsenic (1.0 mg/kg). The organic fraction, which is not considered to be toxic, occurs naturally in the soft tissues of biota and comprises most of the total arsenic.

A highly conservative estimate of the inorganic arsenic fraction is a quarter of the total arsenic. On this basis, the inorganic arsenic fraction recorded during this study were much lower than guideline levels. According to the Animal Health Laboratory (H. Mawhinney pers. comm.), the total arsenic levels reported in this study are consistent with levels reported for oysters elsewhere, (including Torres Strait, an area with few anthropogenic inputs), and are of little concern.

Cadmium, Copper, Lead, Mercury and Zinc

Cadmium may be accumulated by aquatic organisms, and is acutely toxic to aquatic biota and humans (ANZECC 1992, Hartwell, et al. 1989). The mean concentrations of cadmium in oysters at each site, and the levels in all individual oyster samples (0.1-0.48 mg/kg), were consistently below the AFSC maximum permitted concentration of 2.0 mg/kg (Figure 6-8).

In all individual oysters examined, concentrations of copper (range: 5.1-64.2 µg/kg), lead (range: 0.03-0.18 µg/kg), and mercury (range: 0.008-0.07 µg/kg) were below maximum allowable concentrations of the AFSC for bivalves. Mean concentrations of zinc were below the AFSC maximum allowable concentration (1000 mg/kg), however 13 of the 360 oysters examined exceeded AFSC limits (range of zinc values in individual oysters: 138-1450 µg/kg).

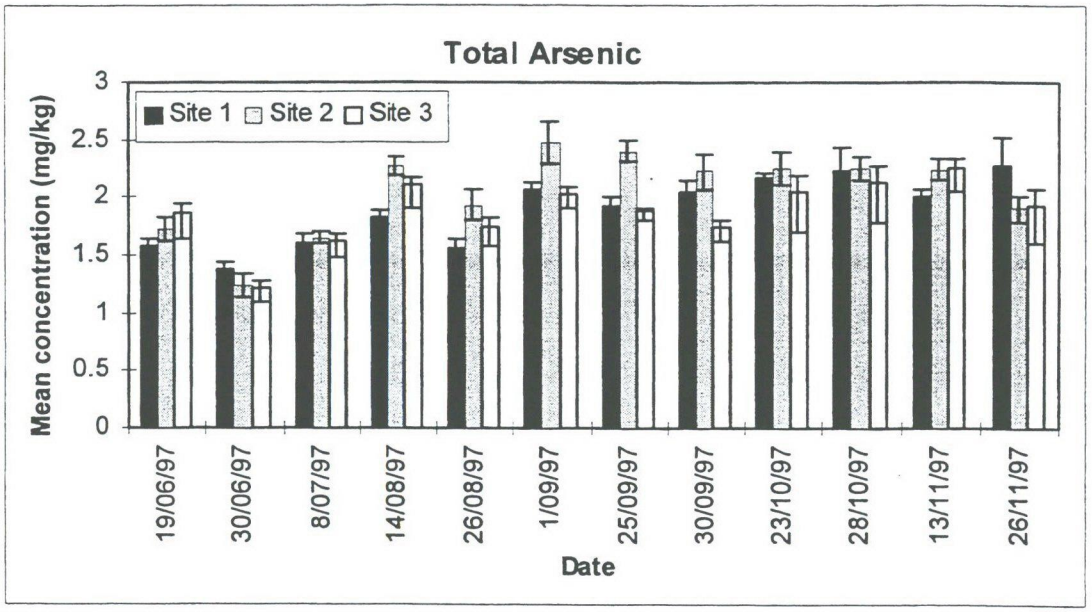
Selenium

Mean selenium concentrations were generally below maximum allowable concentrations of 1.0 mg/kg. However, mean levels of Se for the 28/10/97 sample at site 2 (1.1 mg/kg) exceeded AFSC maximum levels, and were only slightly below maximum levels on other occasions (eg. 14/8/97, 1/9/97, 30/9/97).

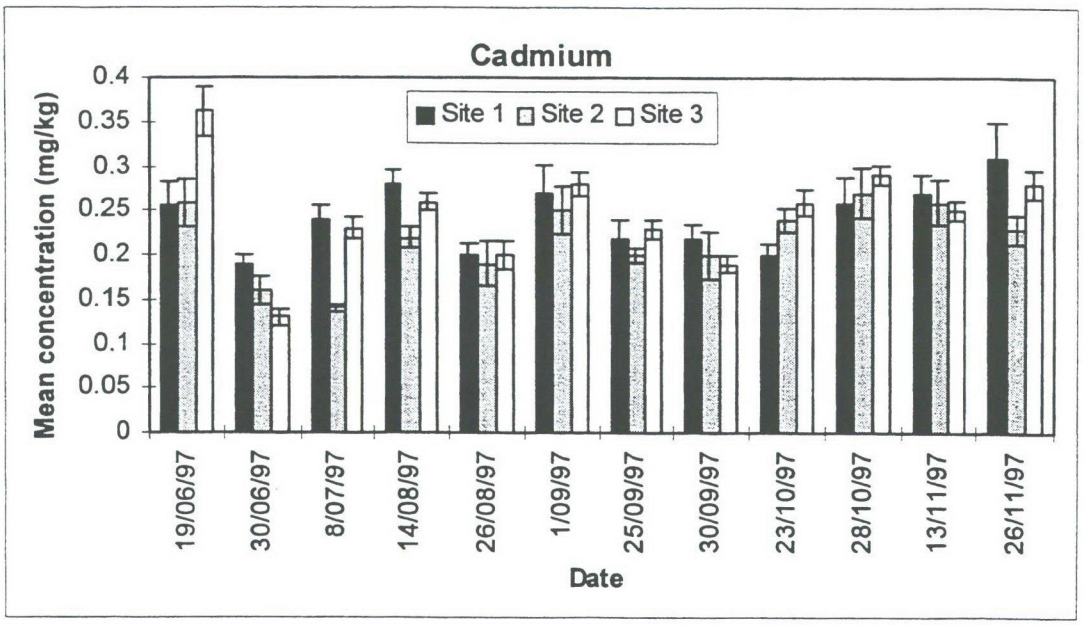
A total of 8 of the 216 oyster samples (4%) exceeded AFSC criteria, with one oyster having 1.4 mg/kg, and all others having 1.1 to 1.2 mg/kg. Five of the eight contaminated oysters were from site 2, 2 were from site 1, and one was from site 3.

Chromium, cobalt, nickel

Although all three of these metals are acutely toxic to aquatic biota and humans at high concentrations (ANZECC 1992), there are no AFSC guidelines for maximum concentrations in seafood.

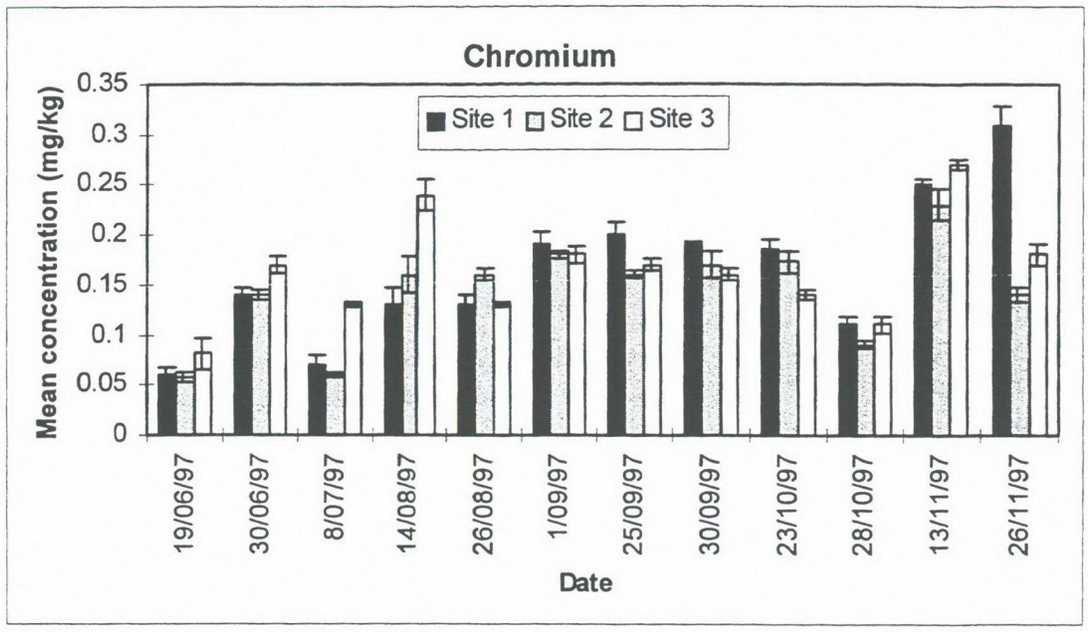


Australian Food Standards Code (NFA): no criteria for total defined arsenic, maximum permitted concentration of inorganic arsenic = 1.0 mg/kg

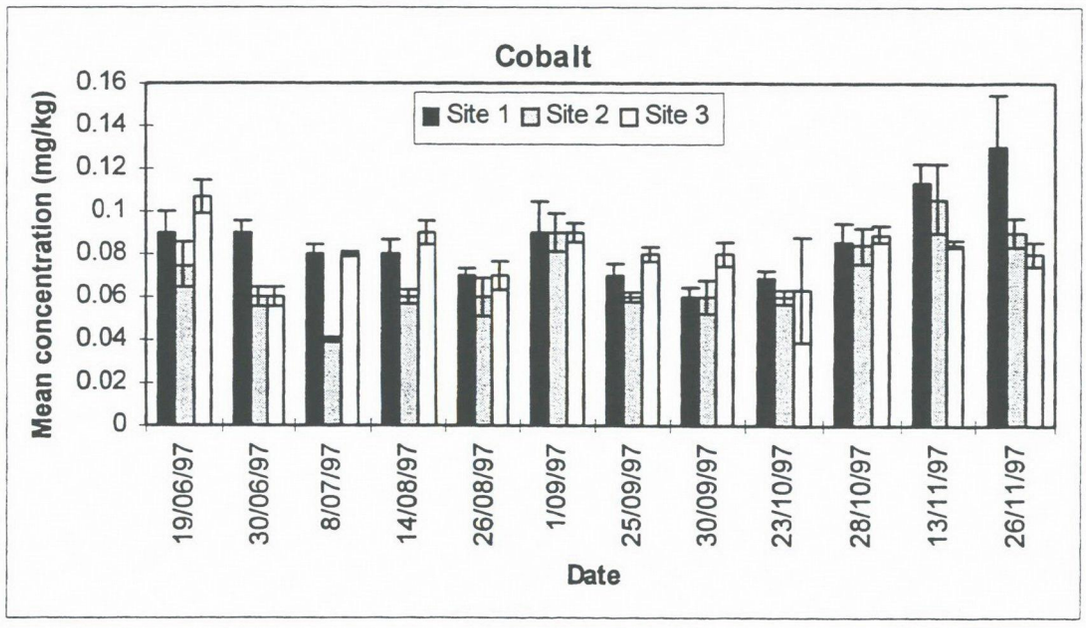


Australian Food Standards Code (NFA): maximum permitted concentration of cadmium = 2.0 mg/kg

Figure 6-8 Mean (error bars ± SE) concentrations of (i) total arsenic and (ii) cadmium in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997

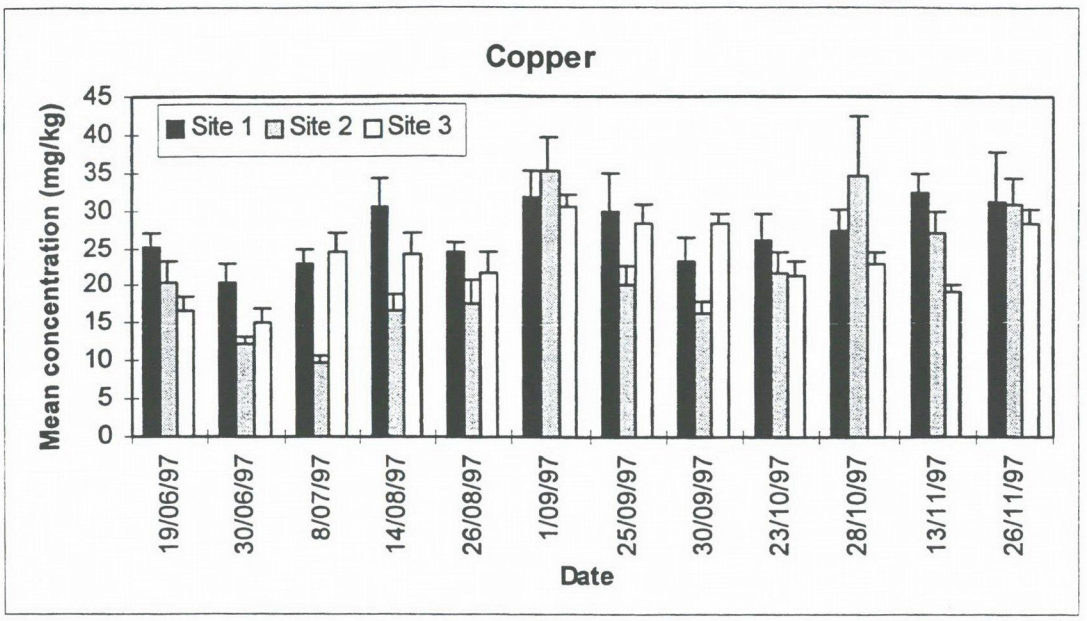


Australian Food Standards Code (NFA): no maximum permitted concentration defined

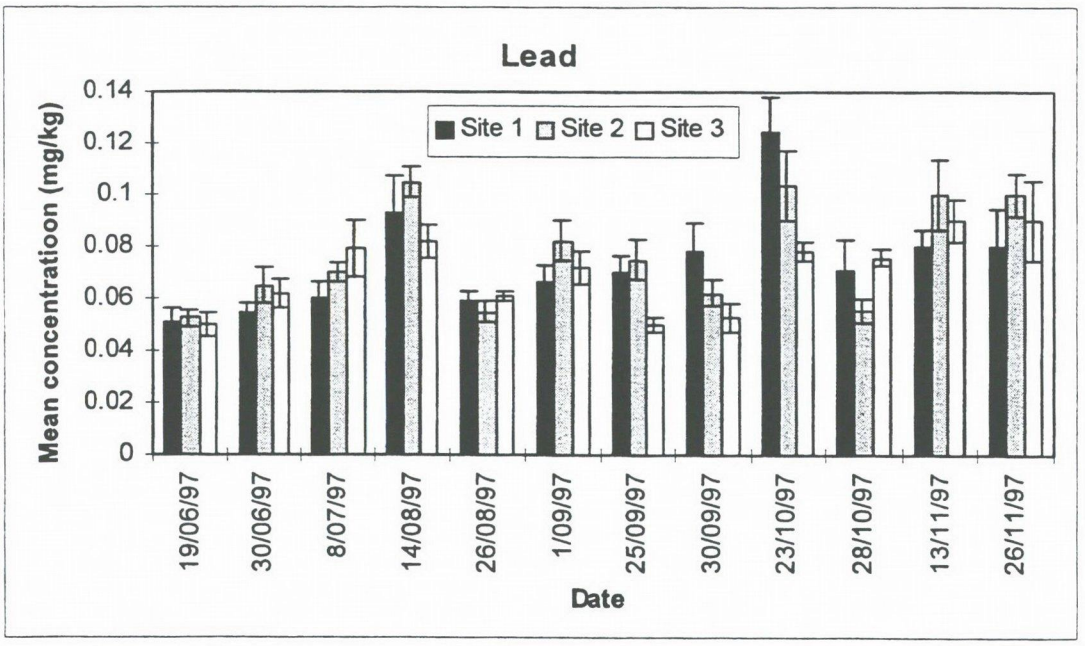


Australian Food standards Code (NFA): maximum permitted concentration = defined

Figure 6-9 Mean (error bars ± SE) concentrations of (i) chromium and (ii) cobalt in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997

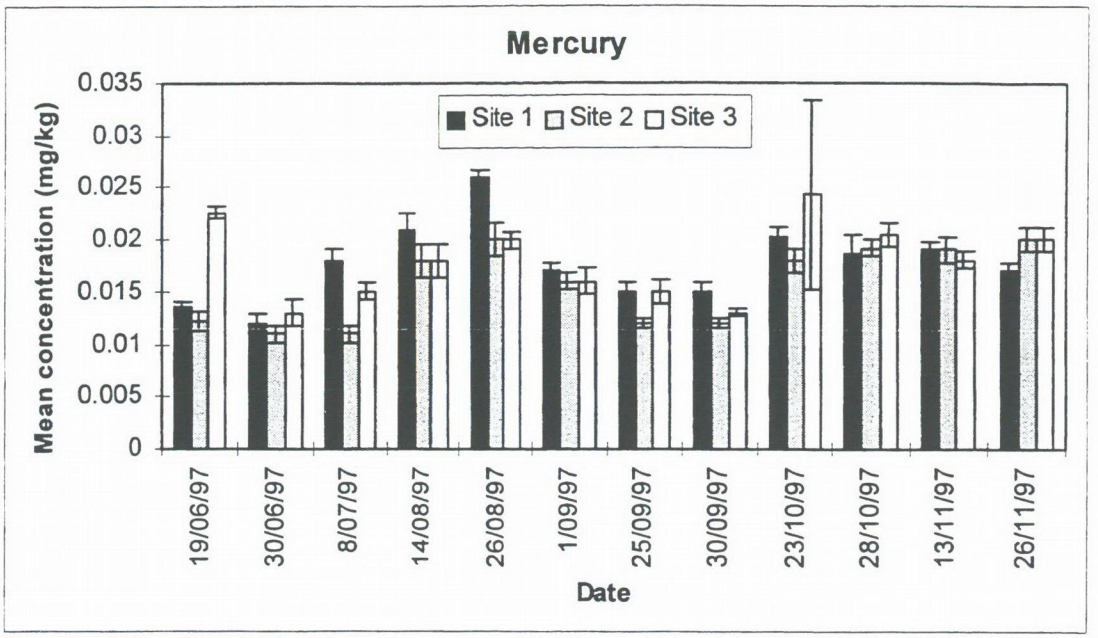


Australian Food Standards Code (NFA): maximum permitted concentration = 70.0 mg/kg

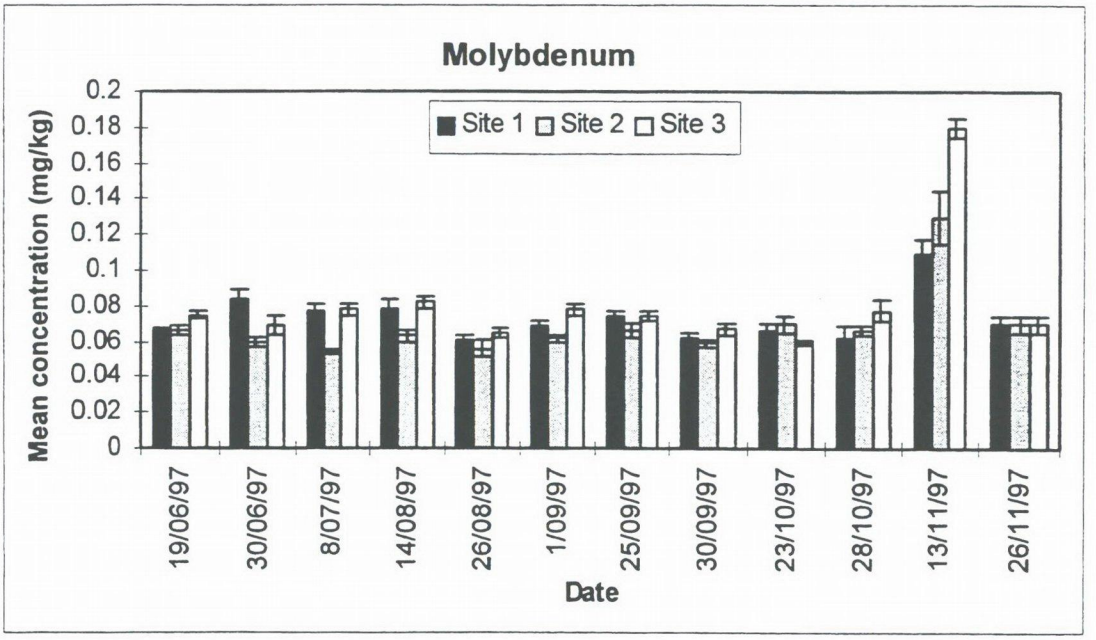


Australian Food Standards Code (NFA): maximum permitted concentration = 2.5 mg/kg

Figure 6-10 Mean (error bars ± SE) concentrations) of (i) copper and (ii) lead in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997

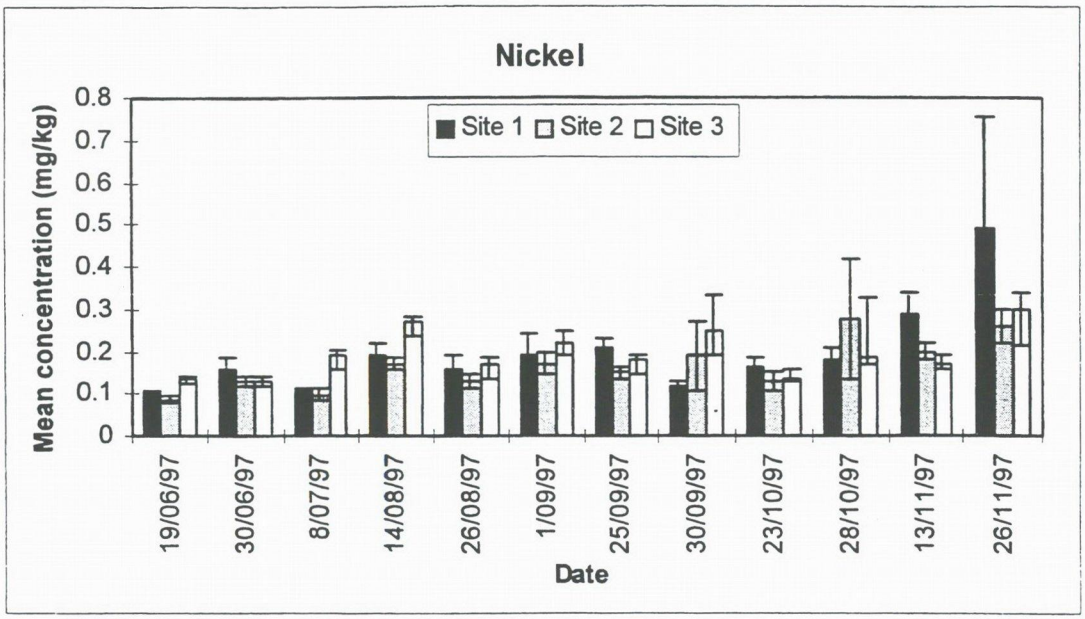


Australian Food standards Code (NFA): maximum permitted concentration = 0.5 mg/kg

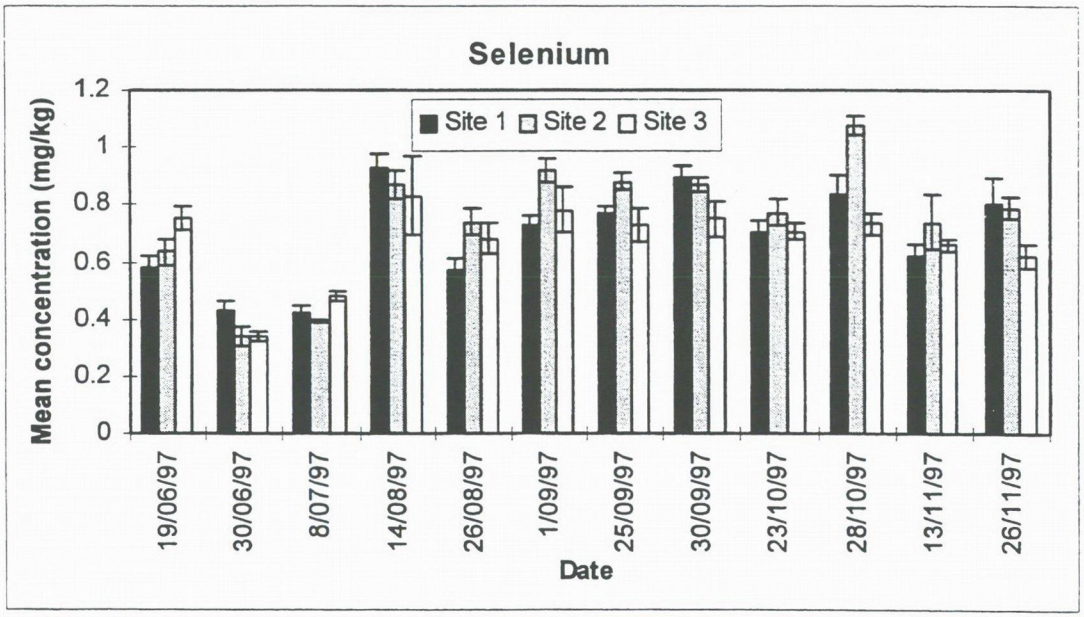


Australian Food Standards Code (NFA): maximum permitted concentration = none

Figure 6-11 Mean (error bars ± SE) concentrations (expressed as mg/kg) of (i) mercury and (ii) molybdenum in Sydney rock oysters collected from three sites in the Karuah River from June to November 1997

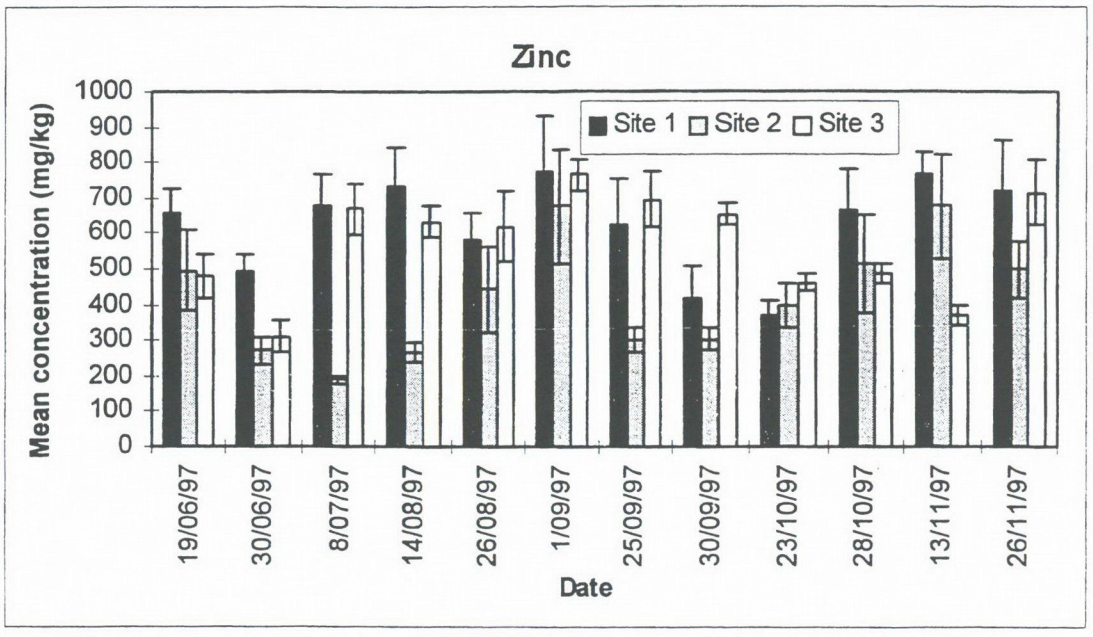


Australian Food Standards Code (NFA): maximum permitted concentration defined



Australian Food Standards Code (NFA): maximum permitted concentration = 1.0 mg/kg

Figure 6-12 Mean (error bars ± SE) concentrations (expressed as mg/kg) of (i) nickel and (ii) selenium in fresh oyster tissues, Karuah 1997



Australian Food Standards Code (NFA): maximum permitted concentration = 1000 mg/kg

Figure 6-13 Mean (error bars ± SE) concentrations of Zinc (expressed as mg/kg) in fresh oyster tissues, Karuah 1997

6.4.2 *Statistical Comparisons of Metal Concentrations*

As can be seen from Figure 6-8 to Figure 6-13, mean metal concentrations fluctuated greatly over time and among sites. ANOVA tests were undertaken to determine whether there were statistically significant differences in metals concentrations in oysters. The results of these tests are summarised in Table 6-3 and Table 6-4, and the complete ANOVA tables are presented in Appendix F.

Site Variations

The results presented in Table 6-5 indicate that the concentrations of all metals except lead (p = 0.166, β-1 = 0.17), nickel (p = 0.388, , β-1 = 0.08) and mercury (p = 0.019, , β-1 = 0.48) were highly significantly different among sites (significance measured at p<0.01 due to heterogeneity). However, the statistical power of all three non-significant results were low indicating that that there was a high probability of a type II error and an incorrect rejection of the null hypothesis, ie. there were likely to be site differences that were not detected by the ANOVA test due to high within cell variability. Caution is therefore advised when interpreting these non significant results.

Post-hoc mean comparisons indicate that none of the three sites had consistently high concentrations of all metals (Table 6-4).

Table 6-3 Summary table of two-way ANOVA tests comparing mean metal concentrations among sites and time periods

Dependent variable	Site	Time	Site Vs Time
Arsenic	8.645***	19.096***	2.124**
Cadmium	8.076***	12.135***	2.179**
Cobalt	11.441***	9.390***	2.366**
Chromium	15.653***	85.601***	12.959***
Copper	7.857**	6.811***	2.202**
Lead	1.813† (0.17)	11.526***	2.003**
Mercury	4.041* (0.48)	8.926***	1.889* (0.93)
Molybdenum	23.894***	56.094***	5.763***
Nickel	0.951† (0.08)	3.490***	0.807† (0.38)
Selenium	8.135***	30.039***	2.393**
Zinc	15.586***	4.177***	2.299***

*** $p < 0.001$; ** $p < 0.01$, * $p < 0.05$, † $p > 0.05$. The statistical power (1-β) of the test is shown in parentheses for cases with non-significant results ($p \geq 0.01$).

Table 6-4 Summary table of post- hoc comparisons of mean metal concentrations among sites

Metal	Tukey LSD (significance measured at $p < 0.01$)
As, Se	site 2 > site 1 and site 3
Cd, Co, Cr, Zn	site 1 and site 3 > site 2
Cu	site 1 > site 2 and site 3
Mo	site 3 > site 2 > site 1
Ni, Pb, Hg	none

Temporal Variations

Table 6-3 indicates that there were highly significant differences among time periods in the mean concentrations of all metals tested. As can be seen from Figure 6-8 to Figure 6-13, mean metal concentrations fluctuated greatly throughout the six month sampling period but did not demonstrate any distinct seasonal trends. No single time period had higher levels of all metal types compared to other time periods.

Time and Site Interaction

The time by site interaction was significant for all but two of the metals (nickel and mercury), indicating that direction of change for all metals was not always consistent among each site during all time periods (Figure 6-8 to Figure 6-13).

The time x site interaction was not significantly different for nickel ($p = 0.715$) and mercury ($p = 0.013$), however, the statistical power of these tests (except the site * time interaction for mercury) were very low ($1\text{-}\beta < 0.5$), again indicating that that there was a high probability of a type II error and an incorrect rejection of the null hypothesis.

Although there was considerable spatial and temporal variability, in most cases there was a significant correlation in the mean concentrations of metals among sites over time (Appendix G). This result indicates that temporal fluctuations in metals were constant among sites. The only metal type not show significant correlations was zinc, which also showed significant within-site variability.

Table 6-5 Summary table of significant correlations ($p<0.05$) of each metal type among sites

Sites	Significant Correlations
site 1 v site 2 only	Co, Cu, Mg, Ni, Pb
site 1 v site 3 only	none
site 2 v site 3 only	Mg, Pb
site 1 v site 2 v site 3	As, Cr, Se

6.4.3 *Metal Concentrations and Environmental Factors*

The results of water quality assessments indicated that lead concentrations in the water column were high in comparison to ANZECC (1992) water quality guidelines. This was determined to be a result of laboratory analysis interference (refer to Section 7.1). None the less, Pearson Product-Moment correlation analysis was used to assess the relationship between mean lead concentrations in oyster tissues and lead concentrations in the water column. The results of this analysis indicate that there was no significant correlation

between these variables ($n = 36$, $r = 0.006$, $p = 0.974$), further supporting the assumption of laboratory analysis interference.

Table 6-6 below provides a summary of statistically significant correlates between selected environmental factors and mean metal concentrations in oysters (see Appendix H for correlation matrices).

As can be seen from these results, no single environmental variable explained significantly amounts of variance in mean concentrations across all sites. Dissolved oxygen and selenium, and chromium and conductivity, were significantly correlated at both sites 1 and 2, whereas all other significant correlations were site specific. There was a high degree of collinearity among several of the environmental values (eg. between conductivity, temperature and rainfall; and conductivity and dissolved oxygen) thus other environmental parameters may also explain this variability.

Table 6-6 Summary table of statistically significant correlates between metals and environmental factors

Metal	Site 1	Site 2	Site 3
As	temp** (+)	cond* (+) and DO** (+)	-
Cd	-	48h rain* (-)	7d rainfall* (+)
Co	-	temp* (+)	-
Cr	cond** and temp (+)**	cond**, 7d rainfall**, pH** (+)	-
Cu	-	temp* (+)	DO* (+)
Mg	redox** (-)	cond* (+)	-
Ni	temp** (+)	temp** (+) cond*(+)	-
Pb	-		-
Se	DO* and cond* (+)	DO** (+) and pH* (+)	-
Zn	-	-	-

* $p < 0.05$, ** $p < 0.01$, + or - shows the direction of the correlation

6.5 Microbiological Counts in Oysters

6.5.1 *Comparisons with Australian Food Standards*

The concentrations of E. coli in oysters during each time period and site are shown in Figure 6-14 and Appendix E.

Australian Standard D1 - Fish indicates that bivalve molluscs (other than scallops) must have an *Escherichia coli* count not exceeding 2.3 E. coli per gram of the food. The results from the present study indicated that E. coli counts were usually below this level, except during the 19/6/1997 sample where counts ranged from 16 (site 1) to 52 (site 3) and 95 (site 2) colony forming units (cfu) per gram.

Escherichia coli counts in oysters were consistently below the maximum permitted level during the other eleven time periods. E. coli counts were generally < 1 cfu/gram, except during the 25/9/1997 sample period where counts ranged from 0 (site 3) to <1 (site 1) and 2 (site 2) cfu/gram.

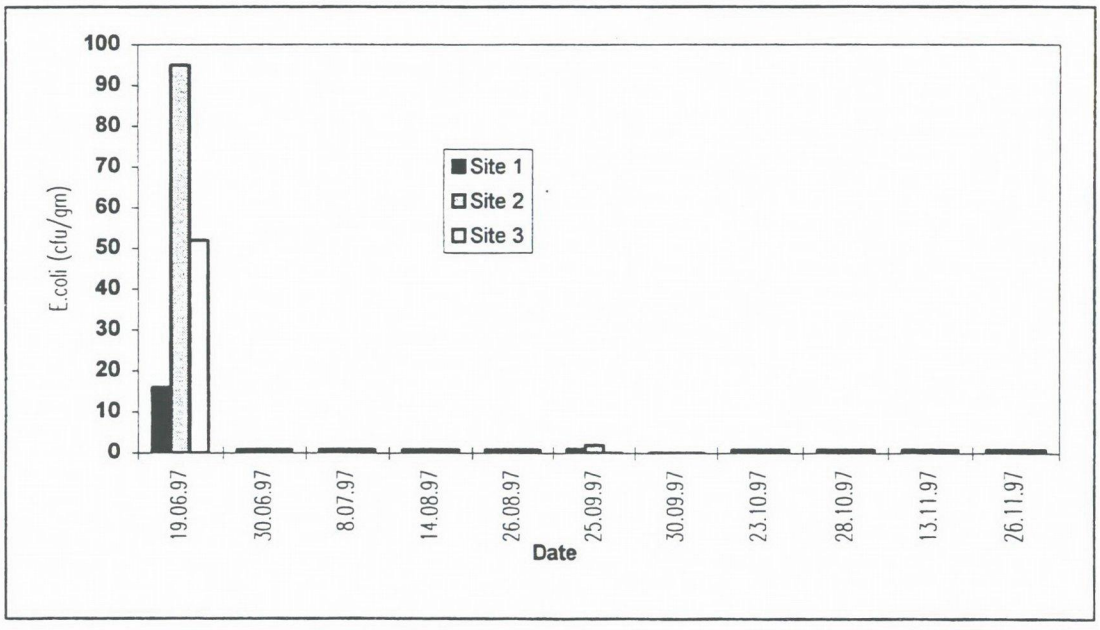


Figure 6-14 Concentration of E. coli

6.5.2 *Rainfall and E. coli Levels*

Table 6-7 presents the results of regression analyses examining the relationship between rainfall and E. coli levels at the three sites.

The results indicated that there was no significant relationships between E. coli numbers in oysters and rainfall in the preceding 24 and 48 hour observation periods. However, E. coli levels demonstrated a highly significant positive relationship with rainfall in the preceding 72 hour and 7 day observation periods. The amount of rain 72 hours immediately prior to the sampling date explained 85-87% of the variation in the numbers of E. coli over time,

wheras 50% of the variation in the numbers of E. coli was explained by the amount of the rainfall within the preceding 7 day period.

Table 6-7 Summary tables of regression analyses of E. coli numbers in oysters and rainfall

Rainfall	df	F	r^2	P
Site 1				
24 hour	1,9	0.025	0.003	0.877
48 hour	1,9	1.572	0.149	0.242
72 hour	1,9	62.372	0.874	0.0001
7 day	1,9	90.24	0.501	0.015
Rainfall	df	F	r^2	P
Site 2				
24 hour	1,9	0.031	0.003	0.864
48 hour	1,9	1.506	0.143	0.251
72 hour	1,9	61.626	0.873	0.0001
7 day	1,9	9.209	0.506	0.014
Rainfall	df	F	r^2	P
Site 3				
24 hour	1,9	0.041	0.004	0.845
48 hour	1,9	1.445	0.138	0.260
72 hour	1,9	54.849	0.859	0.0001
7 day	1,9	8.943	0.498	0.015

7 DISCUSSION

7.1 Water Quality Monitoring

Generally, the water quality in the Karuah River was considered to be good, with ANZECC guidelines rarely violated.

Seasonal trends in water quality parameters were as expected, with no major variations from these trends throughout the study period.

Water quality results for individual parameters are discussed separately below.

Temperature

Water temperature fluctuated seasonally, as expected, throughout the duration of the study, from 12.9 °C recorded in the month of June to a maximum of 27.1 °C recorded in the month of November 1997.

No significant trends were noted in temperature changes throughout the water column, with temperatures rarely differing by more than 1°C between the surface waters and those at depth.

Variations in temperature over time for depths of 0.3m, 1m, and 2m are presented in Appendix A.

Dissolved Oxygen (DO)

ANZECC recommend dissolved oxygen levels should be greater than 6 mg/L (or 80 - 90% saturation) for the maintenance of a healthy aquatic ecosystem. The DO levels at the Karuah site were never less than this recommended limit, with the minimum DO level of 6.2mg/L recorded in the month of November.

DO levels fluctuated seasonally with maximum levels of 9.5mg/L recorded in the colder, wetter months of June and July. There was a consistent fall in DO levels throughout the warmer, drier months in the latter part of the sampling period, as oxygen is less soluble in warm water.

Salinity and Conductivity

Conductivity levels ranged from 11mS/cm to 53 mS/cm from June to November, tending to increase throughout the drier months of the testing period. Waters throughout these drier months are less diluted due to minimal rainfall. Hence, an increase in conductivity or salinity levels is expected.

It can be noted that conductivity levels recorded on 19th June and 7th July appeared to be significantly lower than other levels recorded throughout the sampling period, with recordings consistently increasing down the water column. These samples were recorded following significant rainfall events, which indicates that the water may have been stratified, with the fresh, less-dense layer floating on top of the more dense salt layer of water.

The remaining monitoring results showed a well-mixed, non-stratified system, indicating the stratification was temporary during the salinity recovery period following these rainfall events.

Rainfall Versus Conductivity

The results presented in Table 7-1 indicate that there is a generally good correspondence between rainfall and river water conductivity at each site. The amount of rain in the 72 hours and 7 days immediately prior to the sampling date explained between 42 to 48% of the variation in conductivity over time. However, the amount of rainfall in the preceding 24 to 48 hour period only explained 23 to 32% of the variation in river water conductivity over time and was not statistically significant. This result indicates that there was a 3 to 7 day lag between the rainfall event/s and a corresponding decline in water conductivity.

Table 7-1 Summary tables of regression analyses of conductivity and rainfall (* = significant at P<0.05)

Rainfall	df	F	r^2	P
Site 1				
24 hour	1,10	3.964	-0.284	0.074
48 hour	1,10	3.064	-0.235	0.111
72 hour	1,10	7.773	-0.437	0.019*
7 day	1,10	9.291	-0.482	0.012*
Rainfall	df	F	r^2	P
Site 2				
24 hour	1,10	4.887	-0.328	0.052
48 hour	1,10	3.805	-0.276	0.080
72 hour	1,10	8.380	-0.456	0.016*
7 day	1,10	7.499	-0.429	0.021*
Rainfall	df	F	r^2	P
Site 3				
24 hour	1,10	3.787	-0.275	0.080
48 hour	1,10	3.348	-0.251	0.097
72 hour	1,10	7.707	-0.435	0.020*
7 day	1,10	7.713	-0.435	0.020*

pH

pH values within the study area remained fairly constant throughout the duration of the sampling period, ranging from 7.1 to 8.2. This range of 1.1 pH units would be considered typical of estuarine ecosystems.

Although ANZECC does not offer a definitive criterion on pH levels in an estuarine system, it is our opinion that this range is acceptable.

Turbidity

Turbidity levels at the three sites were generally low (<50NTU) throughout the study period. An intermittent fault in the turbidity probe was attributed as the cause of several high turbidity readings (eg. site 3, 11th September, 1997). On these occasions, both the suspended sediment concentrations analysed and a visual inspection did not support the high turbidity readings (of approximately 100 NTU).

General trends in turbidity levels reflected the trends of both suspended sediment and secchi depth (inversely), as would be expected.

There are no turbidity recommendations in the ANZECC guidelines to compare the recorded levels against.

Nutrients

Generally speaking, nutrient content of the water within the study area was considered to be acceptable. Nitrogen levels were not exceeded for those parameters for which recommendations were made by ANZECC.

One general trend noted was the increase in nitrogen levels during periods of high rainfall. As discussed previously, this trend can be attributed to an increase in surface runoff from the catchment, possible sewer overflows and/or scouring of sections of the river bank during these events. Refer to Appendix A for a plot of these graphs.

Phosphorus levels did exceed recommendations by ANZECC on a number of occasions. The majority of these occurrences were during wet periods. This increase in phosphorus levels may be attributed to catchment runoff and the possibility of sewer overflows in periods of high rainfall. The following can be noted in regard to this issue:

- these recommendations have been only marginally exceeded on infrequent occasions;
- ANZECC recommendations are not definitive, with ANZECC acknowledging the limitations of their recommendations and the need for site-specific studies to determine acceptable nutrient levels within any particular waterbody; and
- as nitrogen is typically the limiting nutrient for primary growth (plants and algae) in estuarine systems, slightly elevated phosphorus levels are not of great concern.

Based on the above, we do not believe that the phosphorus levels indicate any significant water degradation in the Karuah River.

Suspended Sediment

Suspended sediment levels (or non-filtratable residue) ranged from a minimum of 1.4 mg/L recorded on 11th September to a maximum of 36 mg/L recorded on the 12 June, 1997. As expected, these results show good correlation with the secchi index measured at the same site on the same date with secchi depths of 1.7m and 0.9m recorded respectively.

These two parameters have an inverse relationship. Hence, a low suspended sediment level indicates a waterbody with few suspended particulates and therefore high water clarity. A high secchi reading would be expected in this case.

Lead (Pb)

Laboratory results from GM Laboratories indicated that lead levels in the water samples collected from the study sites were consistently high throughout the duration of the study. Lead levels ranged from 12 µg/L to a maximum of 1000 µg/L recorded in the month of October. These results are presented in Appendix A.

These results were contrary to existing water quality data in the Karuah River reviewed by WBM Oceanics Australia. All other existing data in the area indicated lead levels in the Karuah River to be below ANZECC recommendations (ie. <5 µg/L).

Extensive investigations into the cause of these elevated lead levels were carried out by WBM Oceanics Australia staff. Literature reviews were completed and additional field work and testing was carried out to identify potential sources. Considerable consultation with experts in this contaminant were also undertaken. A number of possible sources for this lead were identified.

Additional testing, including sampling carried out above the tidal range at Booral and on Port Stephens itself, was carried out by WBM Oceanics Australia. Testing was also carried out at sites two km upstream and 2 km downstream of the Karuah Bridge. Results from this testing indicated high lead levels in all samples except those above the tidal range (ie. in fresh water). Lead levels at Booral (approximately 20 km upstream of Karuah) were recorded to be 8 µg/L, significantly less than those recorded elsewhere.

The low lead level in the freshwater sample collected led to a review and assessment of the laboratory results and testing methods used. A review of testing procedures was also completed by GM Laboratories. The results of this review discovered that the test used for lead level determination throughout the nominal six month monitoring period (using graphite furnace techniques) was not appropriate for the testing of lead in saline waters, such as those at Karuah. Interferences from other species within the water sample appears to have occurred, resulting in an artificially high lead concentration being reported. Saline waters contain a large number of ions and other species that are known to interfere with many tests. However, interference in the lead tests had not been encountered by GM Laboratories or WBM Oceanics Australia prior to this study.

Hence, lead results from the nominal six month monitoring period are not considered to be a true indication of the actual lead levels in the Karuah River. A statement completed by GM Laboratories on this matter is presented in Appendix C.

Additional testing was undertaken to more accurately determine lead levels in the Karuah River. These samples were tested using the ICP MS test, which is more reliable for testing in saline waters.

These additional tests indicated that lead levels in the study area were less than 5µg/L at all three sites. This is the detection limit for the ICP MS test. This data can be viewed in conjunction with the existing data from the Karuah River carried out in May 1997 by Hunter Water Laboratories. Results from this previous testing also indicated lead levels of less than 5 µg/L.

Hence, it can be reasonably assumed that the lead levels in the Karuah River remained below ANZECC guidelines throughout the duration of the study.

7.2 Oyster Monitoring

The Sydney rock oysters examined during this study were generally of excellent health, as indicated by low parasite loads and good tissue condition. With only a few exceptions, metal concentrations and E. coli counts were generally low, and oysters were of acceptable eating quality. Overall, there is little evidence to suggest that the existing Karuah River bridge and associated road traffic has significant impacts on the health and quality of Sydney rock oyster in adjacent waters.

7.2.1 Tissue Condition

Tissue condition was the only oyster health parameter to show consistent differences among sites. Oysters from the existing bridge location (Site 2) had the lowest scores of local haemocyte infiltration, digestive tubule atrophy and prevalence of ciliates, indicating that these oysters were in better health than oysters from the upstream (Site 1) and downstream (Site 3) areas. Tissue condition and parasite loads were similar for sites 1 and 3, although gill ciliates, papovavirus infection and *Bucephalus* were only recorded from the upstream proposed bridge crossing location (Site 3). The factors determining these site specific variations are unknown, but may be related to fine scale variability in the environmental conditions at each site.

Values for tissue condition indices were highly variable over the six month sampling period, partly reflecting seasonal changes in metabolic processes, and environmental variables such as salinity and turbidity. In general, trends in the temporal variability of tissue condition were similar to results obtained for other oyster species, as described below.

Average diffuse haemocyte infiltration scores in Sydney rock oyster tissues were observed to increase with increasing water temperature. Diffuse haemocytosis is generally associated with spent gonads, as the haemocytes are involved in resorption of unspent gonad material. Haemocytes also aid in the digestion and transport of food and act as a defensive mechanism against parasites and pathogens (Wilson *et al.* 1993). Both the reproductive activity and metabolic processes of oysters are known to increase with increasing temperature (Walne 1972; Ansell 1974), hence the correlation with water temperature may reflect seasonal changes in these biological processes. The increase in diffuse haemocyte infiltration over time is also consistent with an increase in food availability, as phytoplankton productivity in temperate estuaries generally increases during the spring and summer period (Jørgensen 1966; Harris 1978; Knox 1986).

Local haemocyte infiltration showed no trends over time, and was not correlated with environmental variables or development of other tissue types. Local haemocyte infiltration in oysters is often associated with the presence of a disease or parasite. However, careful and thorough examination of areas of intense haemocyte infiltration in oysters collected during this study did not reveal any apparent cause for this abnormal pathology. Chitinous material was associated with one lesions and it is possible that the lesion were caused by mechanical damage due to the presence of parasitic copepods (*Pseudomyicola* spp). Similar lesions associated with the presence of *Pseudomyicola* spp were present the gut region of Pacific oysters (*Crassostrea gigas*) in Tasmania (Wilson, 1993).

The digestive tubule epithelium of oysters showed no consistent trends over time. Reduced epithelial height in digestive tubules is an indicator of physiological stress and/or may be caused by a number of factors including reduced feeding activity linked to reduced salinity (Quayle 1988). Consistent with Quayle (1988), there was a strong negative correlation

between conductivity and digestive tubule atrophy, which appears to indicate that feeding was reduced at low salinities, leading to the reduction in digestive tubule epithelium height (see also Wilson *et al.* 1993).

Digestive tubule epithemium height was also correlated with the number of brown cells, agreeing with results reported for Pacific oysters (*Crassostrea gigas*) in Tasmanian waters (Wilson *et al.* 1993), and the American oyster (*C. virginica)* in American estuaries (Gauthier *et al.* 1990). A possible explanation for this trend is that as the digestive tubule epithemium becomes reduced at low salinities, brown cells increase to aid in the digestion of waste cellular material (Wilson *et al.* 1993).

High numbers of brown cells have been suggested to be an indicator of poor health in oysters (Wilson 1993; Wilson *et al.* 1993), however the number of brown cells observed in this study were similar to those reported for 'healthy' Pacific rock oysters from Tasmanian waters, indicating that Sydney rock oysters were of excellent health.

No significant diseases were detected in any of the oysters sampled during this study, and pathogens and parasites were uncommon, indicating that oysters were in good health. Monitoring is required to determine whether these components increase in prevalence in association with bridge construction activities.

7.2.2 Metals

The metals analysed in this study all occur naturally in marine environments. Several of the metals tested, including chromium, cobalt, nickel, copper, molybdenum, selenium and zinc are essential for metabolism in living organisms, however all of these metals (except molybdenum) are toxic to biota at high concentrations (Wood 1974; Förstner and Wittman 1983). The elements lead, cadmium and mercury have no apparent beneficial biological function, and may be acutely toxic at even low concentrations (Hartwell *et al.* 1989; Gabarino *et al.* 1995).

A summary of metal levels in oysters from around the world is presented in Table 7-2. The Sydney rock oysters from Karuah had much lower concentrations of most metals, and by world standards, Karuah oysters are relatively clean and free of serious metal contamination. This result is likely to reflect the lack of heavy industry and intensive urbanisation in the catchment.

Table 7-2 Metal concentrations (μg/kg) in oyster tissues from around the world

Species	Locality	As	Cd	Co	Cr	Cu	Hg	Pb	Ni	Se	Zn
Saccostrea commercialis	Karuah[1]	0.95-3.3	0.1-0.48	0.03-0.25	0.04-0.38	5.10-64.2	0.01-0.07	0.03-0.18	0.06-1.8	0.27-1.40	138-1450
S. commercialis	Moreton Bay[2]	-	0.56-1.93	-	-	14.4-29.5	-	0.05-0.20	-	0.57-1.28	135-544
S. commercialis	NSW[3]	0.3-3.4	0.1-1.0	-	-	3-48	-	0.3-1.3	-	-	80-665
C. gigas	Washington[4]	-	-	0.10-0.20	0.10-0.30	7.8-37.5	-	0.1-4.5	-	-	86-344
C. gigas	U.K., Menai Straits[4]	-	4.0-6.0	1.0-2.0	-	200-340	-	7-12	2.0-5.0	-	1830-2750
Ostrea sinulata	N.Z.[4]	-	10-43	-	2-6	21-53	-	6-14	1-3	-	850-1500
C. virginica	Texas[3]	1.3	3.2	-	-	161	0.05	0.8	-		322
C. virginica	Virginia[4]	-	0.05-1.61	-	<0.1-3.3	3.7-78.3	-	<0.1-1.8	-	-	140-3800
C. virginica	USA, Atlantic[4]	-	0.1-7.8	0.06-0.2	0.04-3.4	7-517	-	0.1-2.3	0.08-1.8	-	180-4120
C. echinata	Townsville[4]	-	1.1-1.9	0.4-0.9	0.3-<0.8	178-250	-	<0.6-<1.0	<0.4-1.3	-	503-1011

Sources: 1 = this study, 2 = White & Beumer (1997), 3 = references in Förstner & Wittmann (1983), 4 = references and data in Burdon-Jones *et al.* (1975)

Selenium was the only metal to be consistently above AFSC criteria. The major source of selenium in the aquatic environment is from weathering of rocks (ANZECC 1992), particularly in areas containing coal deposits (AWACS 1995); a feature of the Hunter Valley region. A number of anthropogenic sources may also contribute to loads in the natural waters, including burning of fossil fuels (particularly coal), cement production and smelting of copper (Förstner and Wittmann 1983). It is not presently known whether air-borne emissions from heavy industry in other parts of the Hunter Valley (eg. coal burning from power stations in Lake Macquarie, WBM Oceanics Australia 1996) reach Port Stephens, and would require further investigations to do so.

The data reported here indicate that there is considerable spatial variability in the concentrations of metals, even among oysters collected from the same culture tray, although none of the sites had consistently high metal concentrations during all time periods. A high degree of temporal variability was also observed, and was apparently independent to any seasonal effects.

Burdon-Jones (1975) listed a number of factors that influence the uptake of metals by marine organisms, including: the bio-availability, quantity and physio-chemical properties of the metal, the ambient water quality conditions (eg. temperature, conductivity and concentrations of metal), the type and number of ligands available for chelation, the mechanisms for transport and storage and the stability of the complex formed.

In this study, there were no consistent correlations between mean metal concentrations in oyster tissues and ambient water quality parameters at each site. Temporal fluctuations in most metals were relatively constant among sites (as indicated by the significant correlations in metals among sites), suggesting that factors influencing the uptake of metals were also consistent among sites. This result is similar to the results of the water quality section, which demonstrated that the three sites had relatively similar water quality characteristics.

There was a poor correlation between lead in the water column and lead concentrations in oyster tissues ($r < 0.1$; $p >> 0.05$). This has been attributed to the laboratory error in the laboratory analysis (refer to Section 7.1). The low levels found in both the Hunter Water Laboratory data and the ICP MS testing (both < 5 µg/L) support the low lead levels found in the oyster tissue.

7.2.3 *Microbiological Counts*

Escherichia coli (E. coli) counts in oysters were generally low except during one sampling period when levels were much higher than Australian Food Standards. There are insufficient data to determine the source/s of E. coli contamination. It is probable that these elevated E. coli levels were from stormwater runoff from the surrounding catchment. Although the catchment is largely rural, localised land based pollution sources such as septic tanks, earthen pits and animal (cattle, dogs, cats) faeces may enter Karuah River through stormwater runoff. Oysters may then filter E. coli from the surrounding water column and eventually accumulate E. coli in their gut.

Similar to metal concentrations in oyster tissues, numbers of E. coli in oysters varied greatly over time. A significant amount of variation in the number of E. coli in oysters over time was explained by the amount of rainfall. There was a strong correlation between E. coli levels and the total amount of rainfall recorded 72 hours, a weaker correlation for rainfall in 7 day period prior to sampling, but no correlation between the amount of rainfall recorded in the preceding 24 hour and 48 hour periods and E. coli levels. These results indicate that

there was a 3 day lag between the rainfall event/s in the catchment and E. coli numbers in oysters.

This lag may be attributed to hydrological conditions of the catchment. Regressions models suggested that there was a 3 to 7 day lag period between the rainfall event/s and reduced salinities in the Karuah River, corresponding with the time lag for E. coli levels. Since the Karuah catchment is largely non-urbanised, much of the rainfall may soak into the ground before eventually reaching the river through ground-water flows, resulting in the observed lag. This is an important consideration for the timing of sampling during the construction and post-construction phases of the project (see Recommendations in Section 8.2).

8 CONCLUSION AND RECOMMENDATIONS

8.1 Conclusions

This study provides baseline results for a monitoring program examining the water quality and oyster quality/health of oysters located at Karuah, Port Stephens. The results of this baseline study can be compared with the results of subsequent studies to determine whether the construction and operation of the a new bridge at Karuah, associated with the upgrade of the Pacific highway, has a significant impact on water quality and oyster health.

In summary, the main findings of the study were:

a) Comparisons of Values with Health Criteria and other Studies

- water quality results compared well with existing data of the site and previous studies.
- water quality parameters tested rarely exceeded ANZECC guidelines and recommendations. These exceedances were not considered to be a cause of concern.
- with the exception of selenium, metal concentrations in oyster tissues were below Australian Food Standard Maximum Permitted Levels. Elevated selenium levels in natural waters may be due to natural weathering of selenium bearing rocks in the catchment (eg. coal), or possibly aerial inputs from heavy industry located outside the catchment;
- the oysters examined from all sites were generally of good health which was indicated by low parasite loads and good tissue condition;
- comparisons with data from other studies of metal concentrations in oysters from around the world indicate that the Karuah river oysters were generally 'clean', and free of serious metal contamination;
- faecal coliforms (E. coli) levels in oyster tissues were generally below maximum permitted levels and acceptable for human consumption, except during one sampling period following heavy rain.

b) Spatial Variability

- overall, the three sample sites had relatively similar water quality and oyster quality/health characteristics;
- histological assessments indicated that site 2 (located at the present site of the Karuah River bridge and Pacific Highway crossing) had healthier oysters than sites located upstream (proposed future bridge crossing) and downstream of the site; and
- water quality, metal concentrations in soft tissues oysters and E. coli in oyster tissues showed no consistent variations among the three sites.

c) *Temporal Variability*

- water quality proved to be subject to seasonal variation
- results indicate that there was a 3 to 7 day lag between the rainfall event/s and a corresponding decline in water conductivity.
- water quality generally declined following rainfall events, with noticeable increases in nutrient and suspended sediment levels.
- values for oyster condition indices were highly variable over time and may reflect variations in environmental conditions and seasonal changes in biological processes (eg. reproduction, feeding and metabolism);
- metal concentrations in oysters were also highly variable over time, but typically varied consistently among and between sites over time, ie. fluctuations in the concentrations of metals usually varied across two or three of the sites;
- there was a significant positive relationship between rainfall and E. coli levels in oyster tissues. However, E. coli levels were generally low and relatively consistent over time.

8.2 Recommendations for monitoring during construction and operational phases

Number and Location of Control Sites

Site 3 was considered a valid reference site as:

- the results of water quality and oyster analyses indicate that the three current sample sites have very similar water quality characteristics thus direct comparisons among sites were considered valid;
- the magnitude of any impacts associated with bridge development would have to be very large to impact on site 3, due to the significant dilution of waters inside the inner basin, and the relatively large distance of site 3 from sites 1 and 2.

However, given that there is minor potential for site 3 to be affected by very large impacts in the Karuah River (due to tidal exchange of waters), and the fact the 'control' effect was not replicated, it is recommended that a second control site be located in an area with similar environmental conditions, but outside the area of influence of bridge works. Big Swan Bay, located to the north of Wirrung Island, is a possible control area, depending on availability of commercial oyster leases at this location.

It is recommended that sites 1 to 3 be retained in future monitoring studies.

Variables to be Measured

It is recommended that all water quality and oyster quality/health variables measured in this study be sampled in future studies.

Analysis of lead should be determined by ICP MS in order to prevent interference from other species in the water.

Number of samples per site

- Water quality - retain the sampling strategy of the present study.

- Oyster tissue condition/health - a sample size of 10 oysters per site (compared to 6 in the present study) is recommended to account for the high levels of variability in tissue condition among individual oysters.
- E. coli in oysters - the 'Rapid method for generic *Escherichia coli* in bivalve molluscs' testing procedure (AS1766.2.12) requires a minimum of 10 oysters per site for analyses, thus 10 oysters is the recommended sample size.
- Metals in oysters - Power analysis was performed to determine the sample size required to achieve statistically reliable results (ie. a power (1-β) of 0.8 with p = 0.05; Fairweather 1991). Table 8-1 summarises the results of these analyses, and Appendix I provides details of the analyses and a discussion of power. At a sample size of 6 oysters per site (the sample size used in this study), a critical effect size of 0.4 is achieved when comparing 36 means (ie. 12 sample periods x 3 sites). This indicates that medium to large changes in metal concentrations would be detected by the present sampling strategy. Smaller changes in metal concentrations would be detected with greater replication (ie. 9 oysters per site), whereas only very large changes would be detected with 4 oysters per site.

In this study, statistically significant differences in mean concentrations were detected over time and space. Due to the high laboratory costs associated with tissue metal analyses, and the relatively good detectable effect size, it is recommended that the present sample size of 6 oysters per site be retained.

Table 8-1 Summary results of 'reverse' *post-hoc* power analysis

No. of means	Effect size (F)	Required no. of samples*
36	0.5	4
	0.4	6
	0.3	9
24	0.5	5
	0.4	7
	0.3	10 (β-1 = 0.75)

* except where indicated, β-1 = 0.8 and p = 0.05

Sample timing

The present study indicated that most variables measured varied greatly over time, even between sample periods separated by less than a week. It is recommended that:

- the total number of sampling periods be reduced from 12 to 9 (4-5 wet weather and 4-5 dry weather samples). This would provide 36 means for comparisons, given that 4 sites would be sampled. Fewer sample periods (and subsequently means) will result in lower power of tests.

- since there is more than a 3 day lag between rainfall and reduced salinities in the river, water quality and oyster sampling should be undertaken 3 days after a rainfall event for wet weather sampling.

- comparisons of the results of this study with results from construction and operational phases should be conducted at the same time of the year to account for the confounding influence of seasonal variability, particularly in oyster condition (related to reproductive cycles and feeding biology).

9 REFERENCES

Ansell, A. D. (1974) Seasonal changes in biochemical composition of the bivalve *Abra alba* from the Clyde Sea. *Marine Biology*, **25:** 13-20.

ANZECC (1992) Australian Water Quality Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council, Kingston.

AWACS (1995) Lake Macquarie Estuary Process Study. AWACS, prepared for Lake Macquarie City Council, Report 94/25.

Burdon-Jones, C., Denton, G. R. W., Jones, G. B. and McPhie, K. A. (1975) Long-Term Sub-Lethal Effects of Metals on Marine Organisms - Part 1. Base Line Survey. Department of Marine Biology, James Cook University, Townsville. 1975.

Couch J. A. (1985) Prospective study of infectious and noninfectious diseases in oysters and fishes in three Gulf of Mexico estuaries. *Diseases of Aquatic Organisms* **1**: 59-82.

Dakin, W. J. and Bennett, I. (1987) Australian Seashores. Angus & Robertson Publishers, North Ryde. 411 pp.

Fairweather, P. G. (1991) Statistical power and design requirements for environmental monitoring. *Australian Journal of Marine and Freshwater Research*, **42**: 555-567.

Gabarino, J. R., Hayes, H. C., Roth, D. A., Antweiler, R. C., Brinton, T. I. and taylor, H. E. (1995) Heavy Metals in the Mississippi River. *In*: R. H. Meade, Contaminants in the Mississippi River, U.S. Geological Survey Circular, Reston.

Gauthier J. D., Soniat T. M. and Rogers J. S. (1990) A parasitological survey of oysters along salinity gradients in coastal Louisiana. *Journal of the World Aquaculture Society* **21**: 105-115.

Harris, G. P. (1978) Photosynthesis, productivity and growth: the physiological ecology of phytoplankton. *Ergebisse der Limonologie*, **10**: 1-163.

Hartwell, S. I., Jin, J. H., Cherry, D. S. and Cairns, J. (1989) Toxicity versus avoidance response of golden shiner *Notemigonus crysoleucas*, to five metals. *Journal of Fish Biology*, **35**: 447-456.

Jørgensen, C. B. (1966) Biology of Suspension Feeding. Pergamon Press Ltd., Oxford. 357 pp.

Jørgensen, C. B. (1990) Bivalve Filter Feeding: Hydrodynamics, Bioenergetics, Physiology, and Ecology. Olsen & Olsen Publishers, Fredensborg, Denmark. 140 pp.

Knox, G. A. (1986) Estuarine Ecosystems: A Systems Approach - Volume 1. CRC Press, Florida. 380 pp.

Lauckner G. (1983) Diseases of Mollusca: Bivalvia. In: O Kinne (Ed) Diseases of Marine Animals vol II: Bivalvia to Scaphopoda. Biologische Anastalt Helgoland, Hamburg. pp 477-879.

Malcolm, W. B. (1987) The Sydney rock oyster. *Agfacts*, **F3.1.1**: 12.

Meyers T. R. (1981) Endemic diseases of cultured shellfish of Long Island, New York: adult and juvenile American oysters (*Crassostrea virginica*) and hard clams (*Mercenaria mercenaria*). *Aquaculture* **22**: 305-330.

National Food Authority (1992) Australian Food Standards Code. National Food Authority, Canberra. July 1992.

National Shellfish Sanitation Program (1995) Manual of Operations Part 1 Sanitation of Shellfish Growing Areas.

Prosi, F. and Goldberg, E. D. (1983) Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin. 486 pp.

Quayle D. B. (1988) Pacific oyster culture in British Columbia. *Canadian Bulletin of Fisheries and Aquatic Sciences* **218**: 1-214.

Richardson, D. L. (1991) Some Aspects of Food and Feeding in the Sydney Rock Oyster *Saccostrea commercialis* (Iredale & Roughley) in Port Stephens, N.S.W. Honours Thesis, Centre for Coastal Management, University of New England 117 pp.

Rochford, D. J. (1951) Studies in Australian estuarine hydrology - I. Introductory and comparative features. *Australian Journal of Marine and Freshwater Research*, **2**: 1-117.

Sokal, R. R. and Rohlf, F. J. (1981) Biometery, The Principles and Practice of Statistics in Biological Research. W. H. Freeman and Co., New York. 858 pp.

SPSS (1996) SPSS for Windows, Base System. SPSS Inc, Chicago. 828 pp.

Underwood, A. J. (1981) Techniques of analysis of variance in experimental marine biology and ecology. *Oceanography and Marine Biology Annual Review*, **19**: 513-605.

Walne, P. R. (1972) The influence of current speed, body size and water temperature on the filtration rate of five species of bivalves. *Journal of the Marine Biological Association of the United Kingdom*, **52**: 345-374.

WBM Oceanics Australia (1996) Lake Macquarie Estuary Management Study - Report on Lake Management Issues. WBM Oceanics Australia prepared for Lake Macquarie City Council, 9487. Brisbane. December 1996.

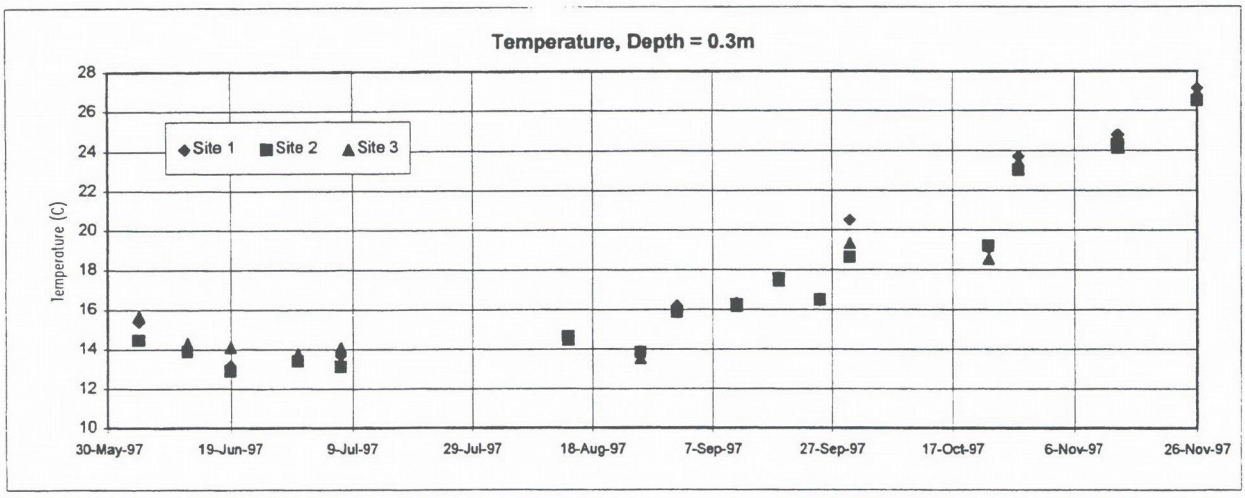
West, R. J., Thorogood, C., Walford, T. and Williams, R. J. (1985) An estuarine inventory for New South Wales, Australia. Fishery Bulletin 2. Department of Agriculture New South Wales.

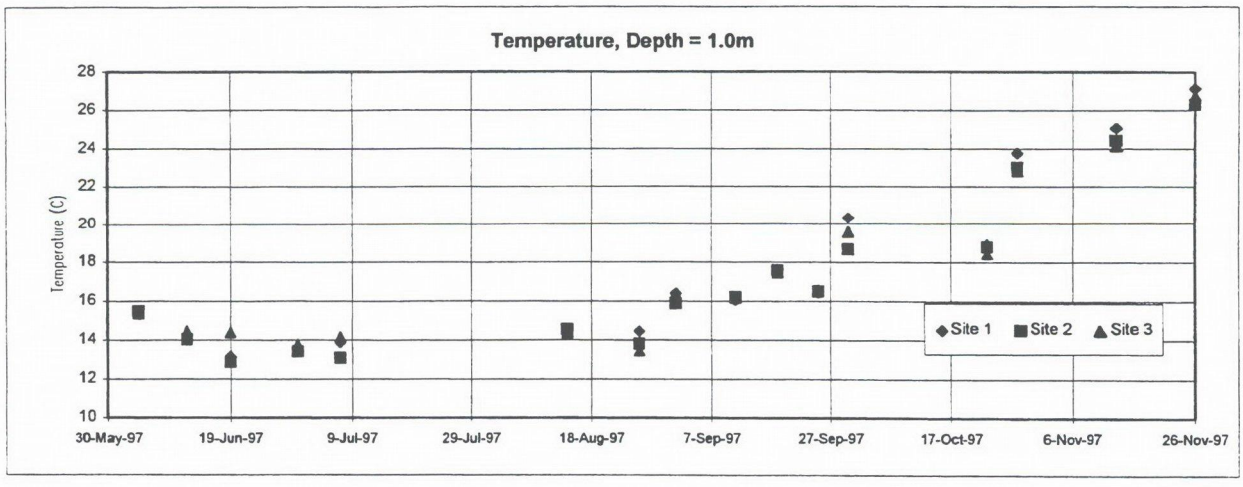
Wilson J. R. (1993) The health status of two species of Tasmanian farmed shellfish. Masters Thesis. University of Tasmania at Launceston. 189pp.

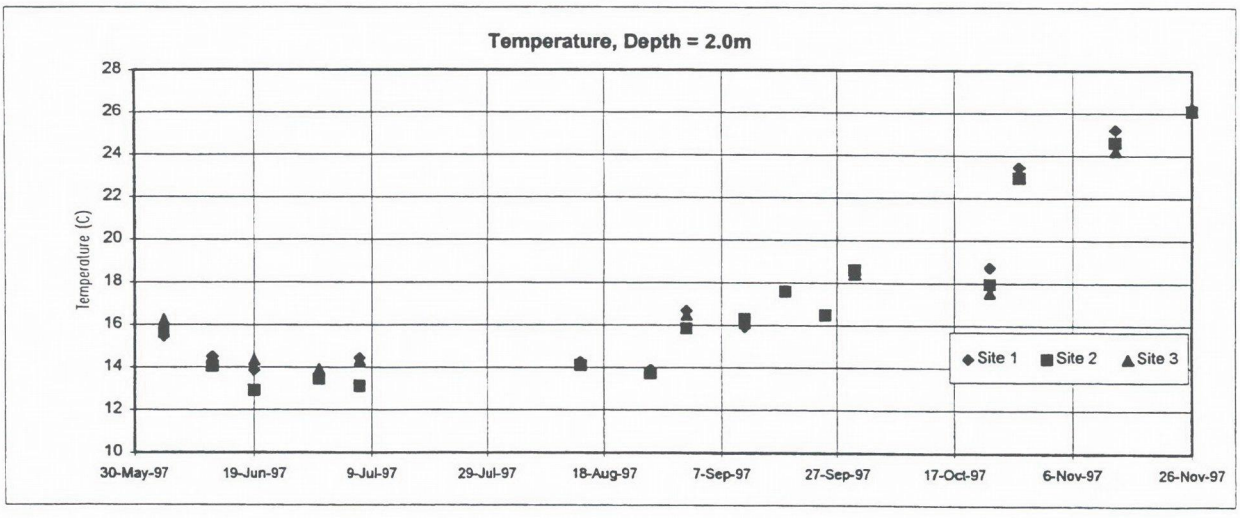
Wilson, J. R., Handlinger, J. and Sumner, C. E. (1993) The Health Status of Tasmania's Bivalve Shellfish. Sea Fisheries Division - Department of Primary Industry and Fisheries, Tasmania, Technical Report: 47. 1993.

Wood, J. M. (1974) Biological cycles for toxic elements in the environment. *Science*, **183**: 1049-1052.

APPENDIX A: WATER QUALITY MONITORING RESULTS







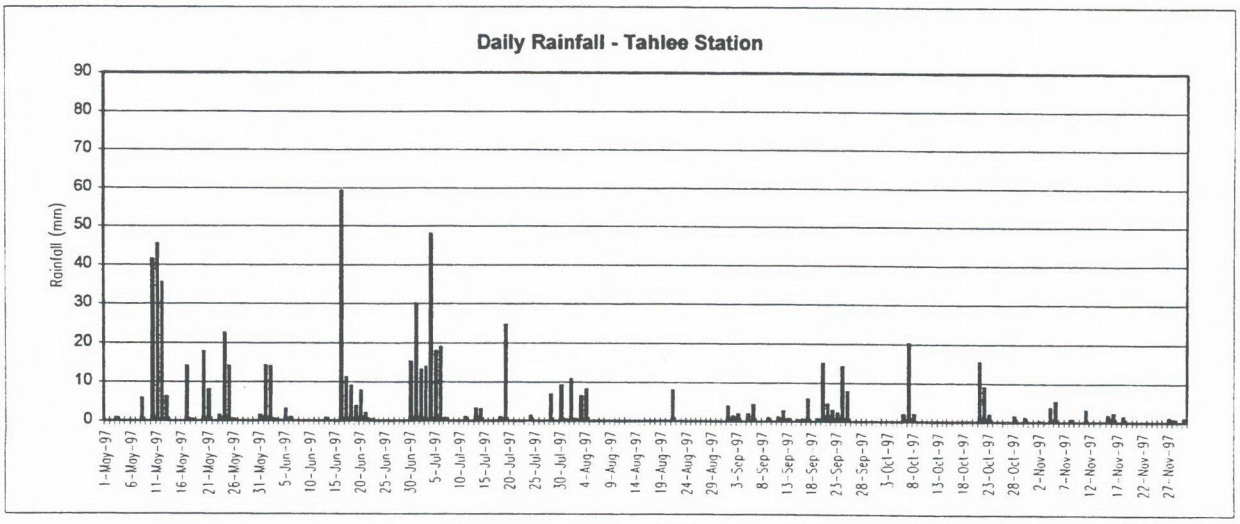
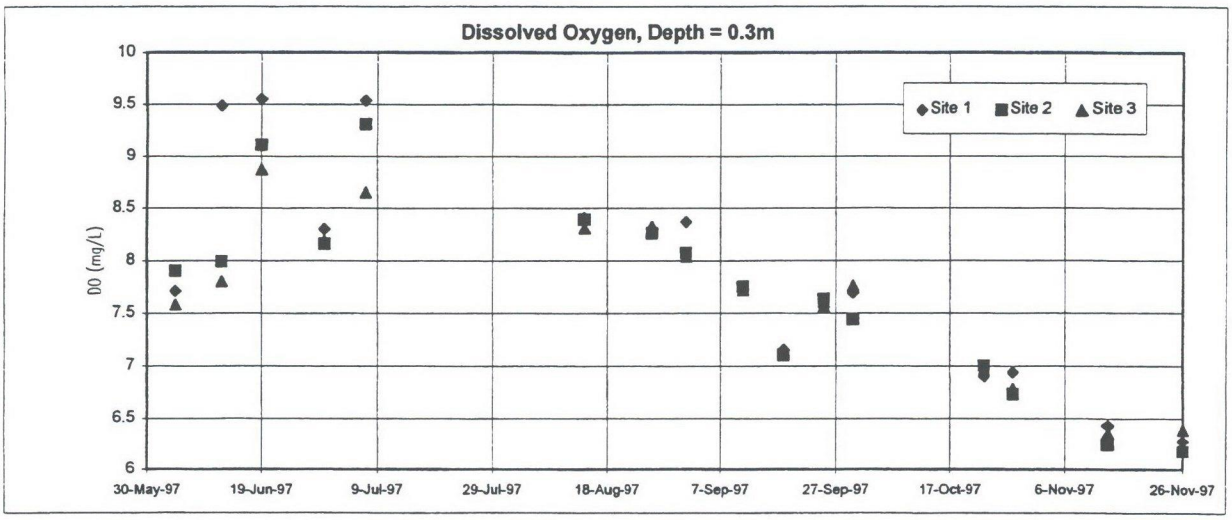
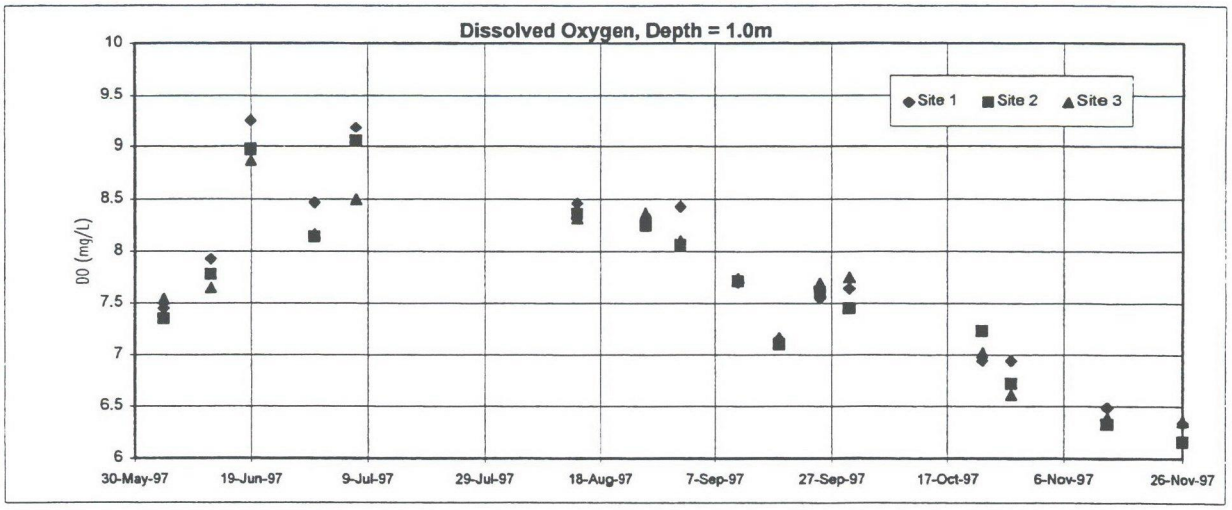
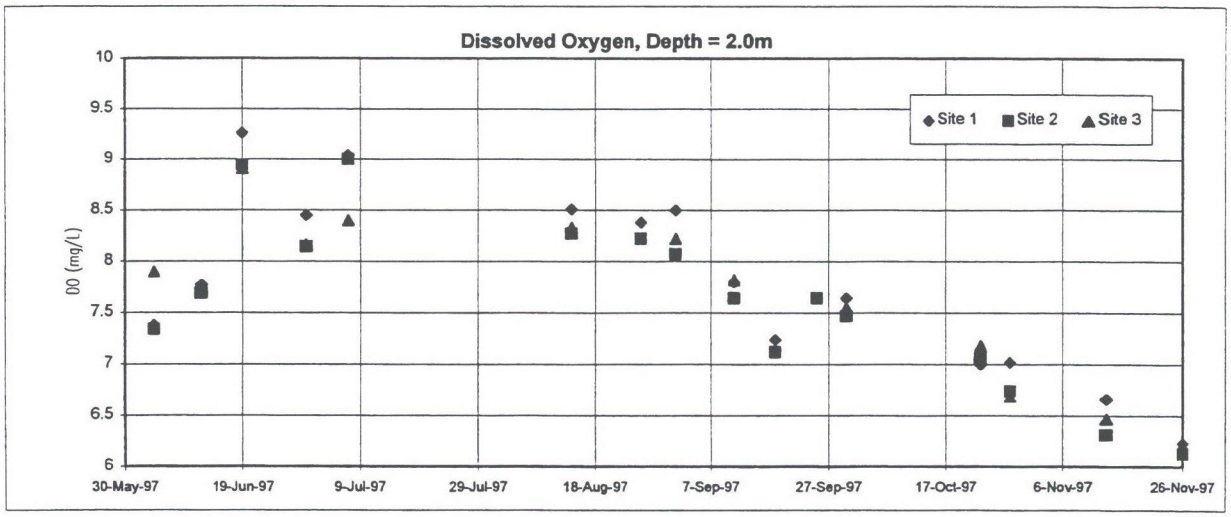


Figure A-1 Temperature Plots







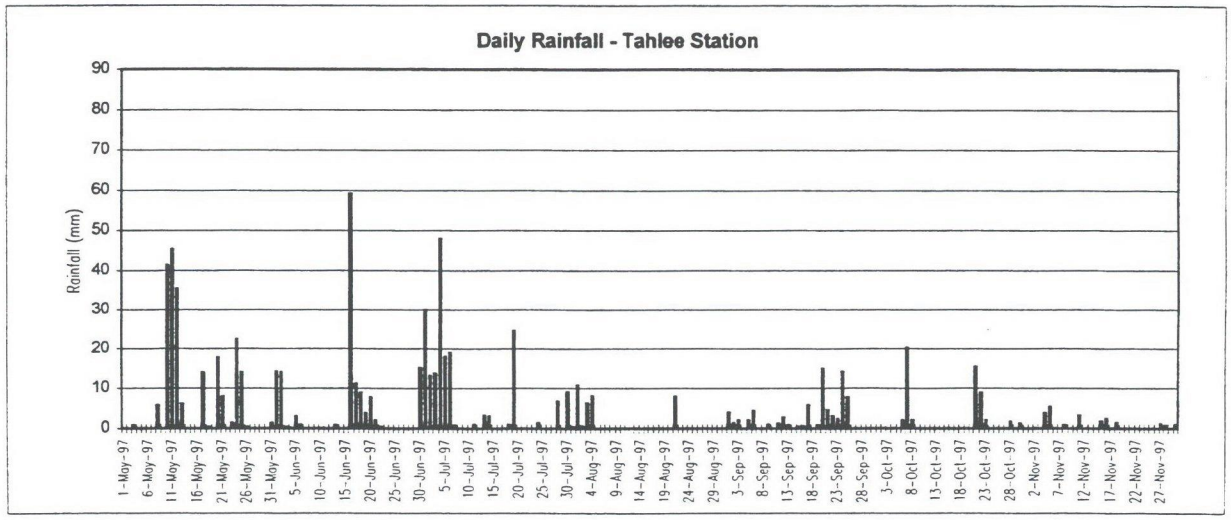
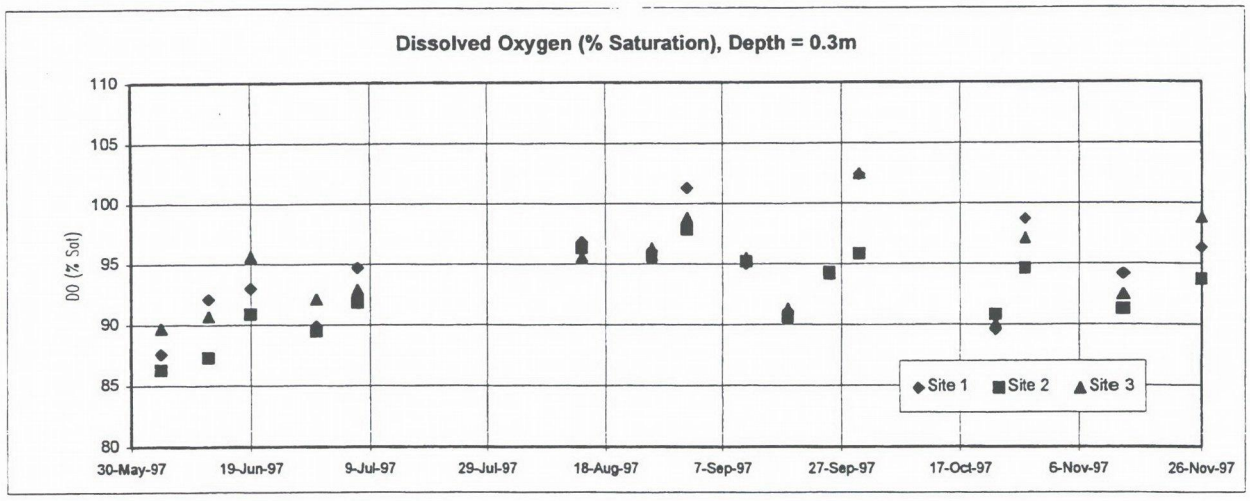
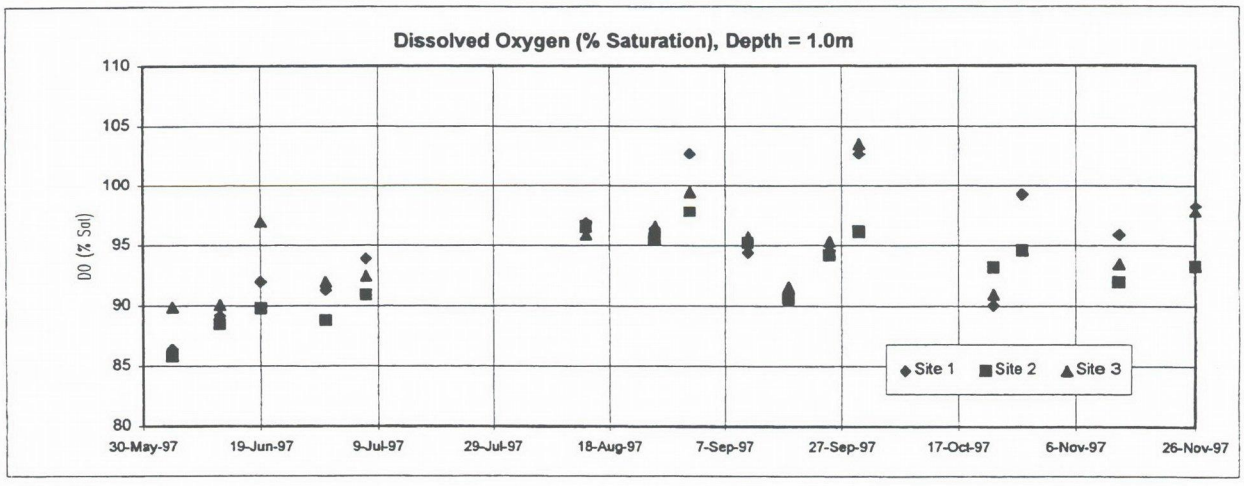
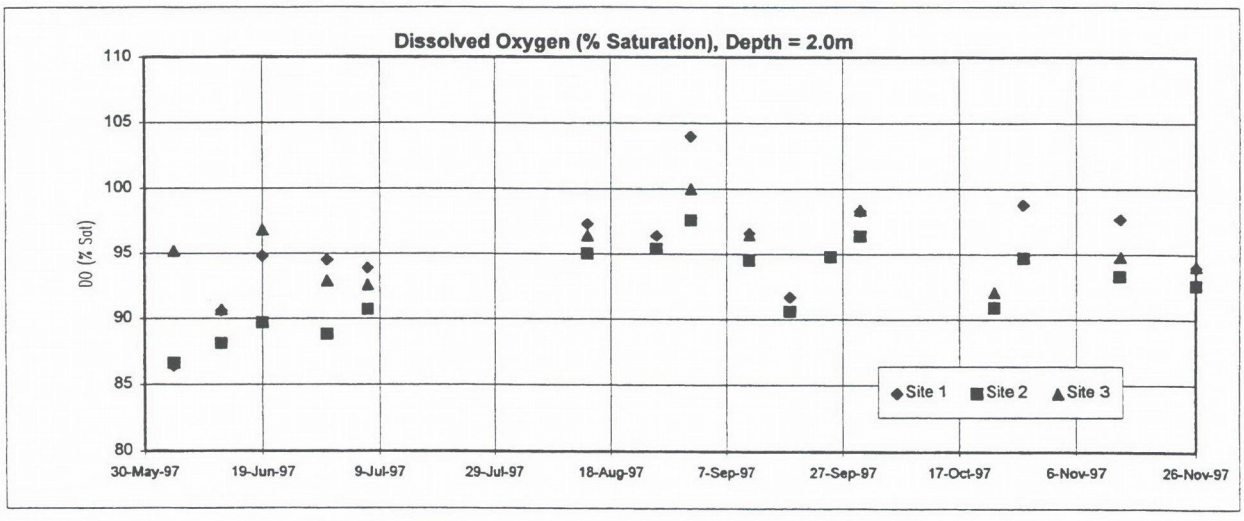


Figure A-2 Dissolved Oxygen Plots







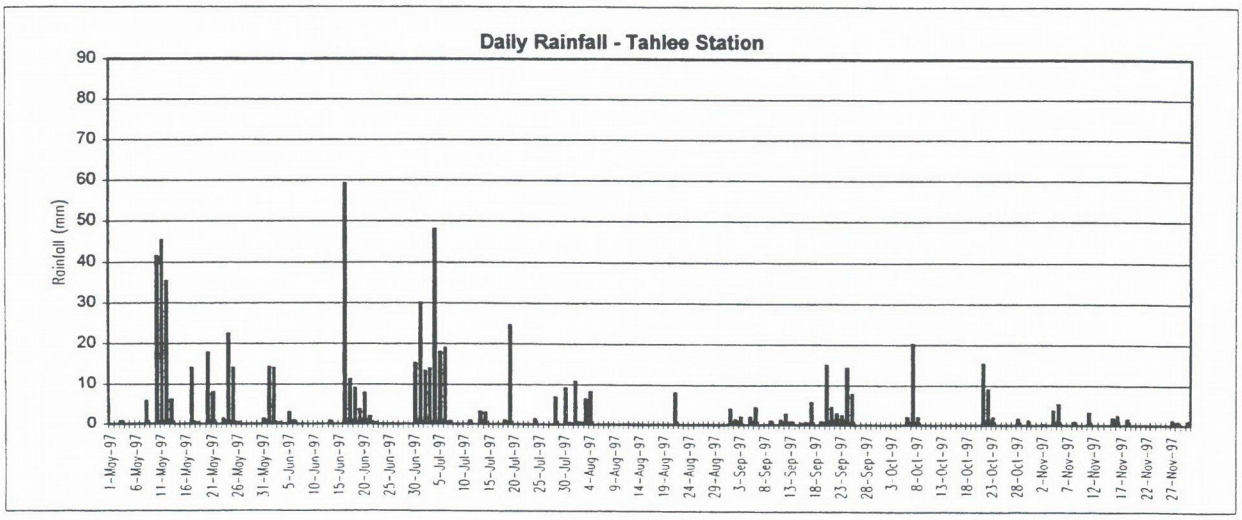
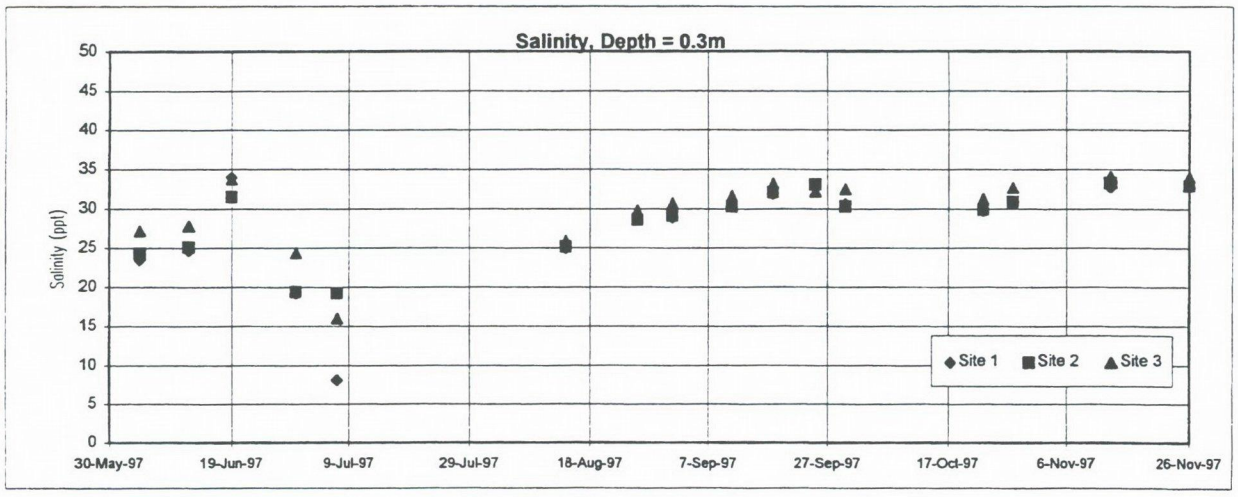
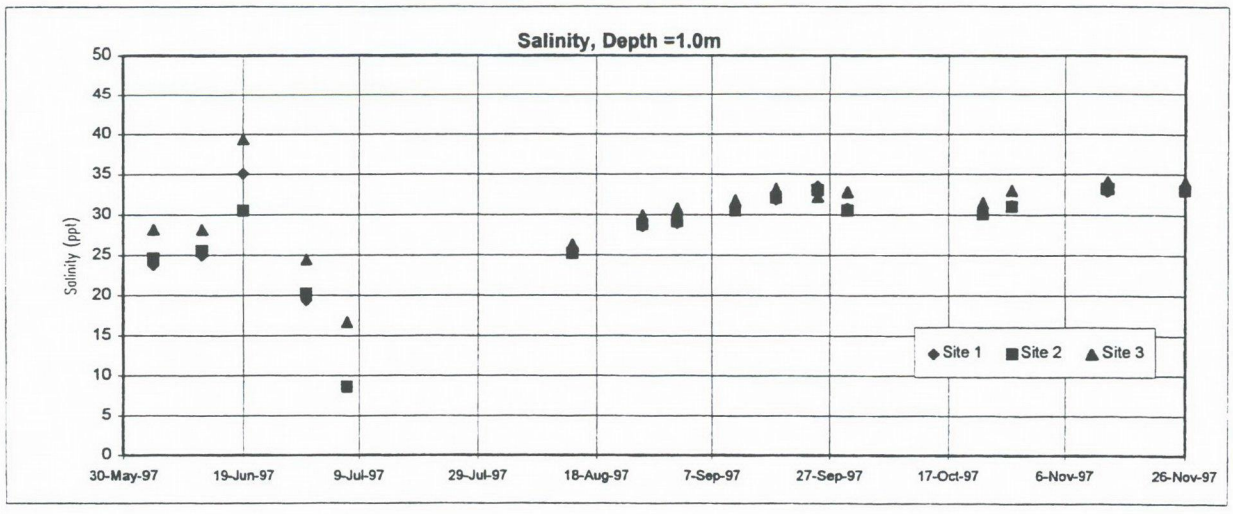
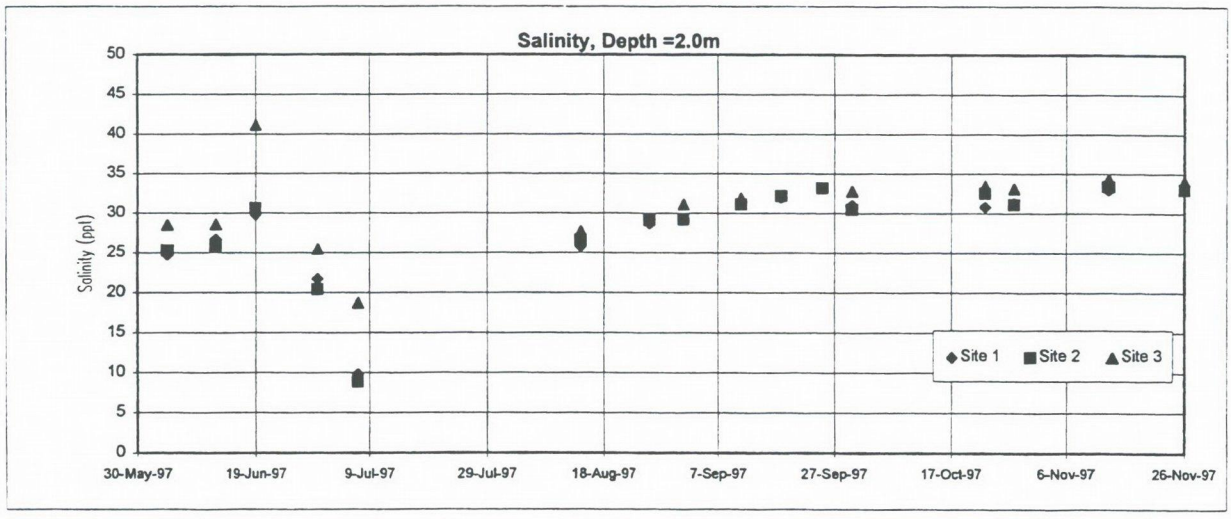


Figure A-3 Dissolved Oxygen Plots (% Saturation)







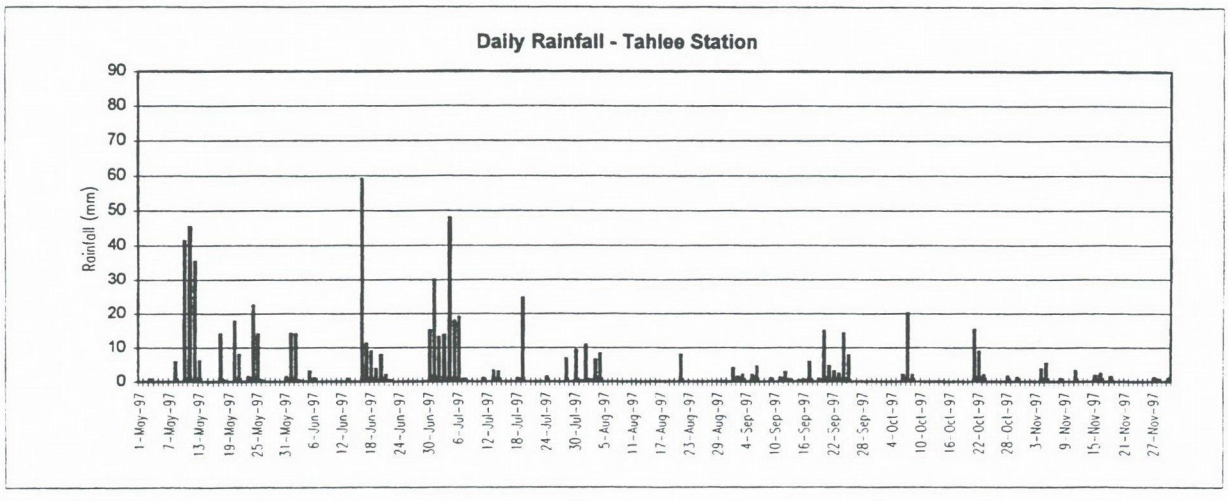
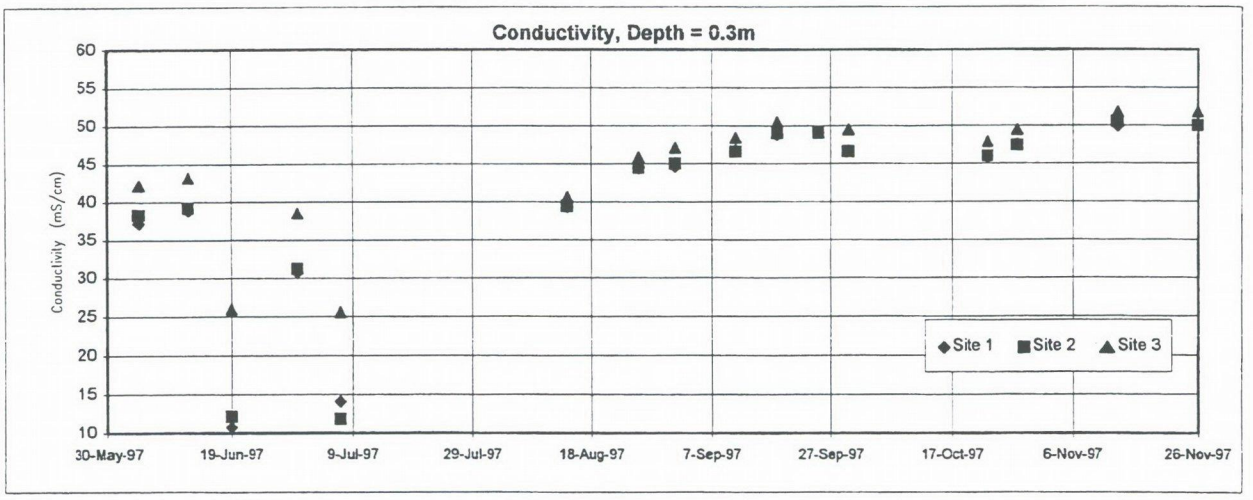
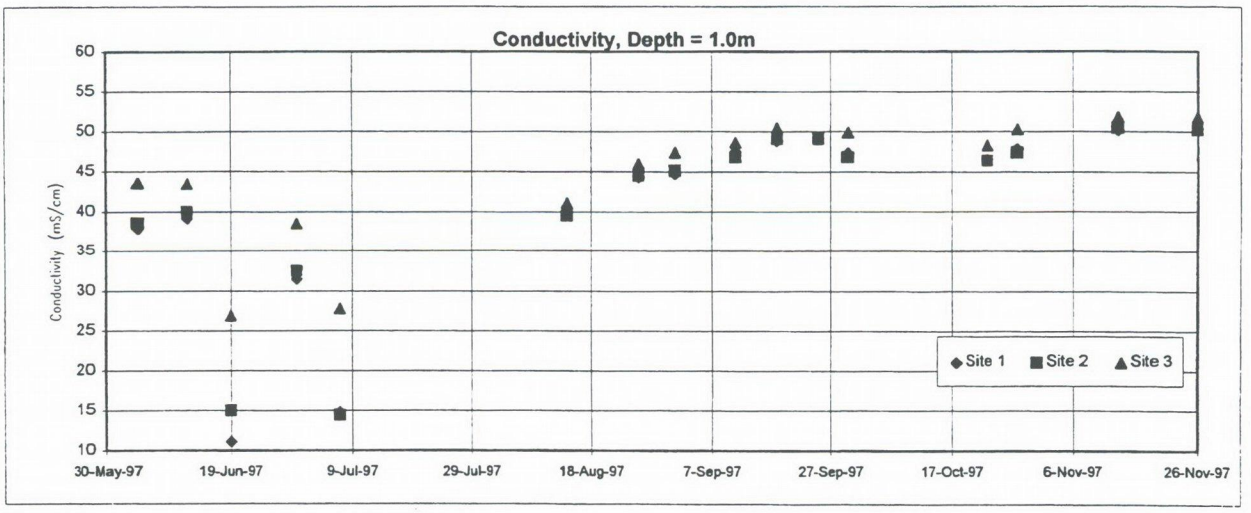
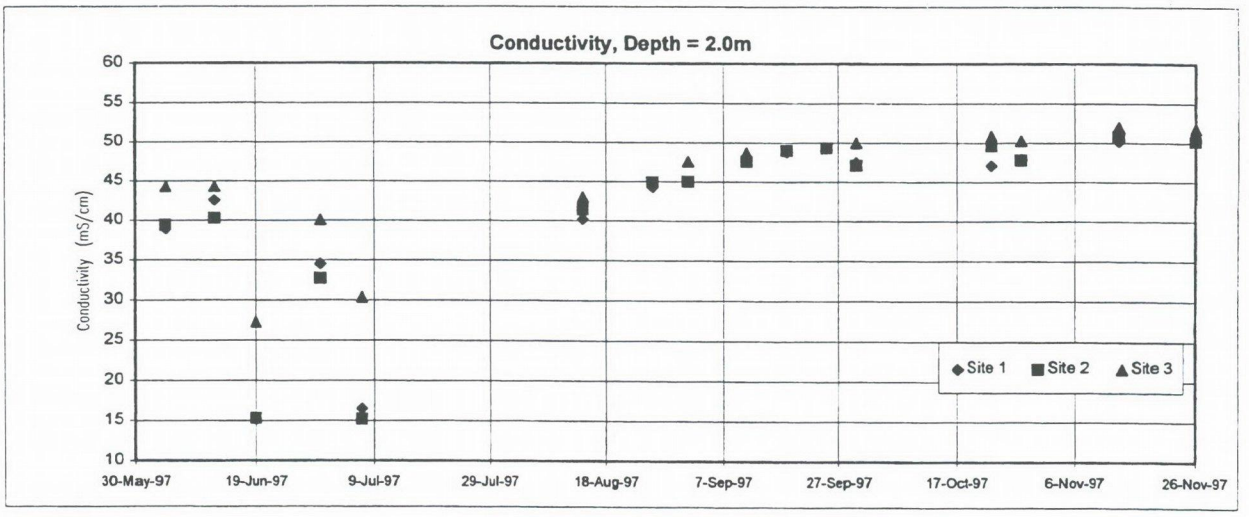


Figure A-4 Salinity Plots







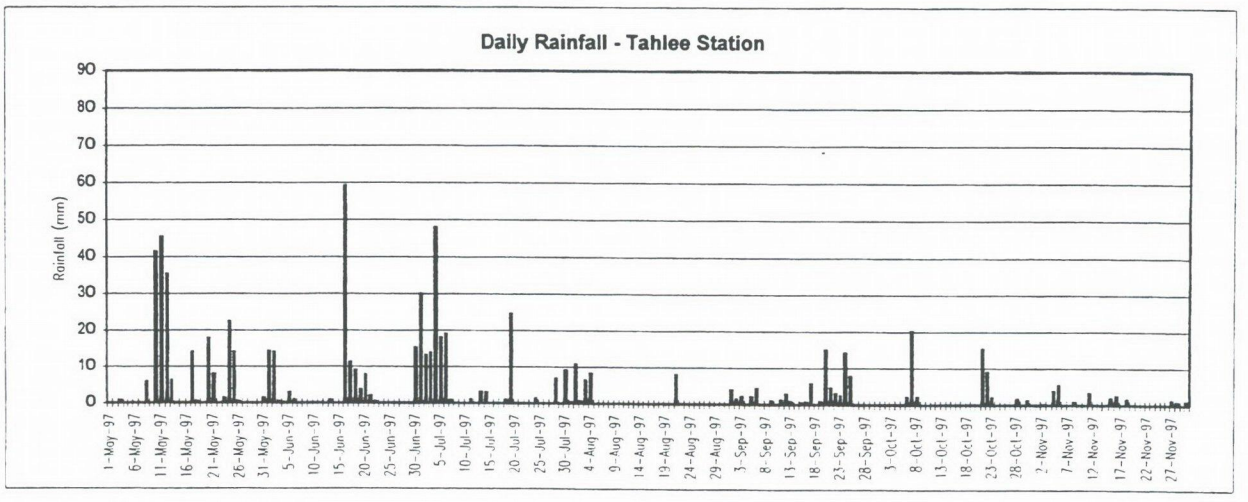
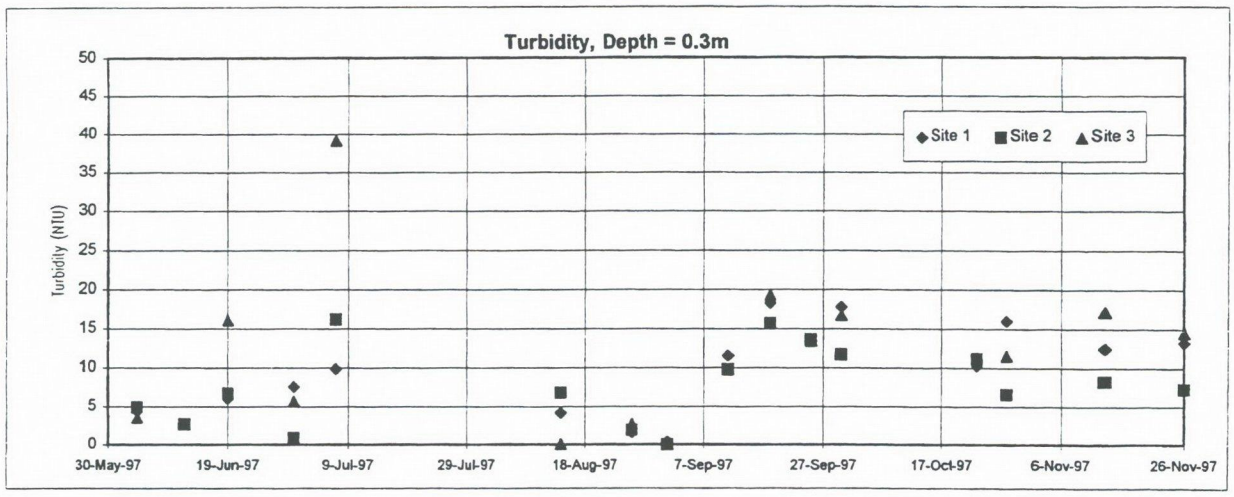
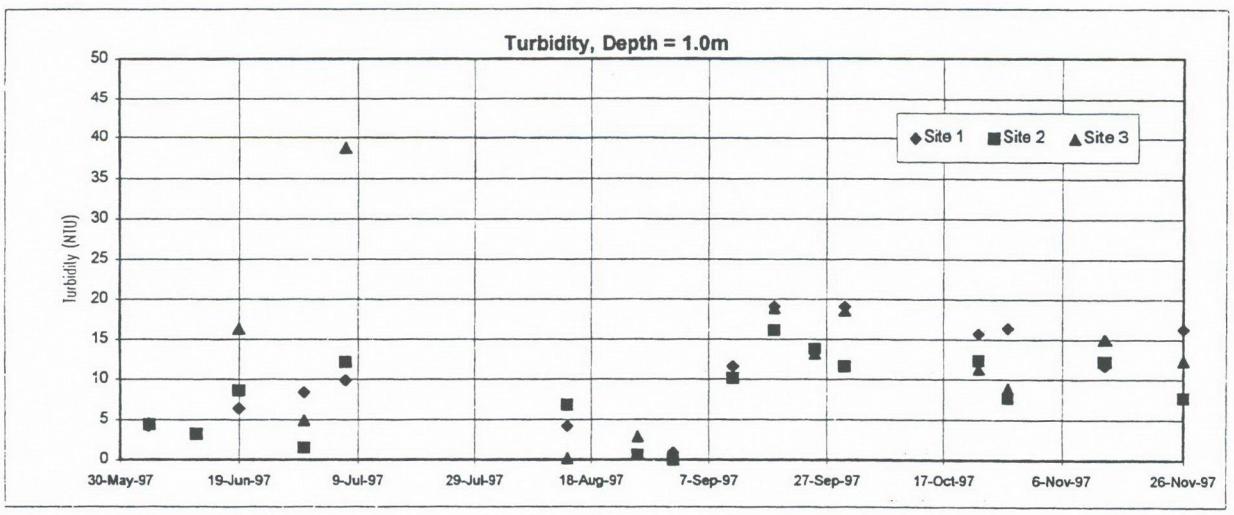
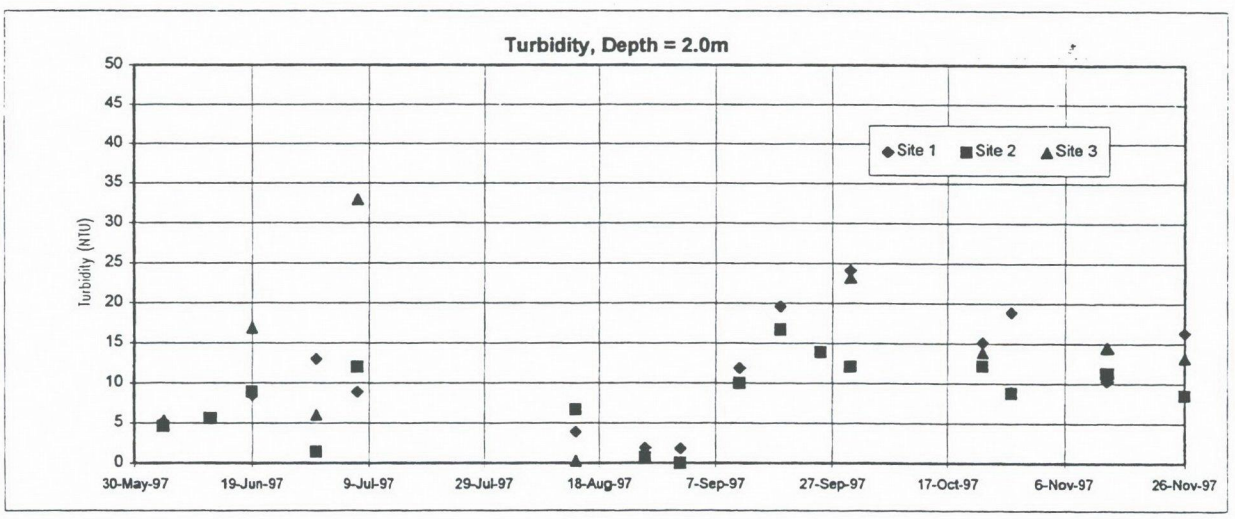


Figure A-5 Conductivity Plots







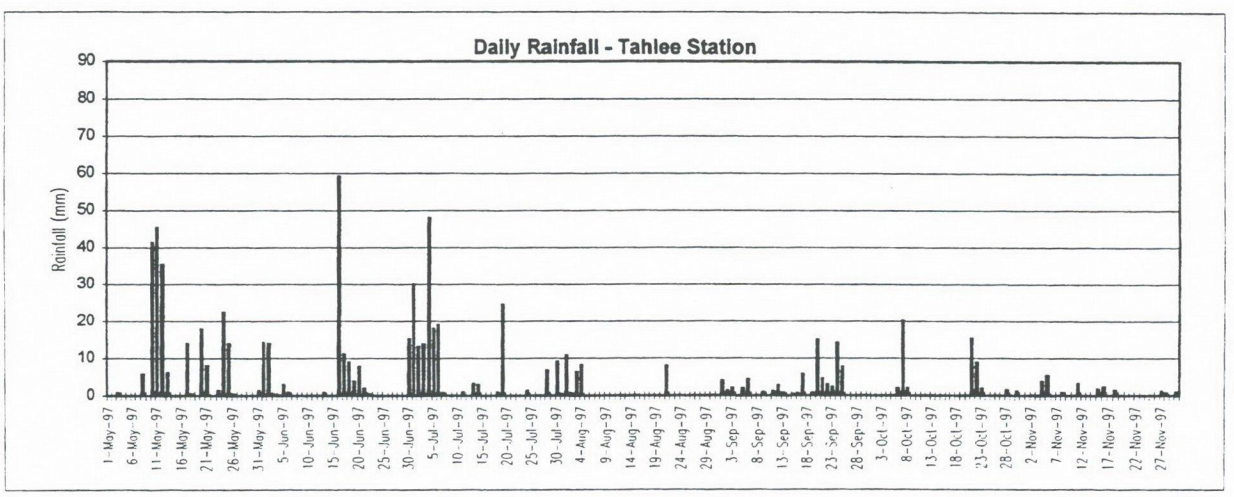


Figure A-7 Turbidity Plots

Figure A-8 Ammonia (mgN/L)

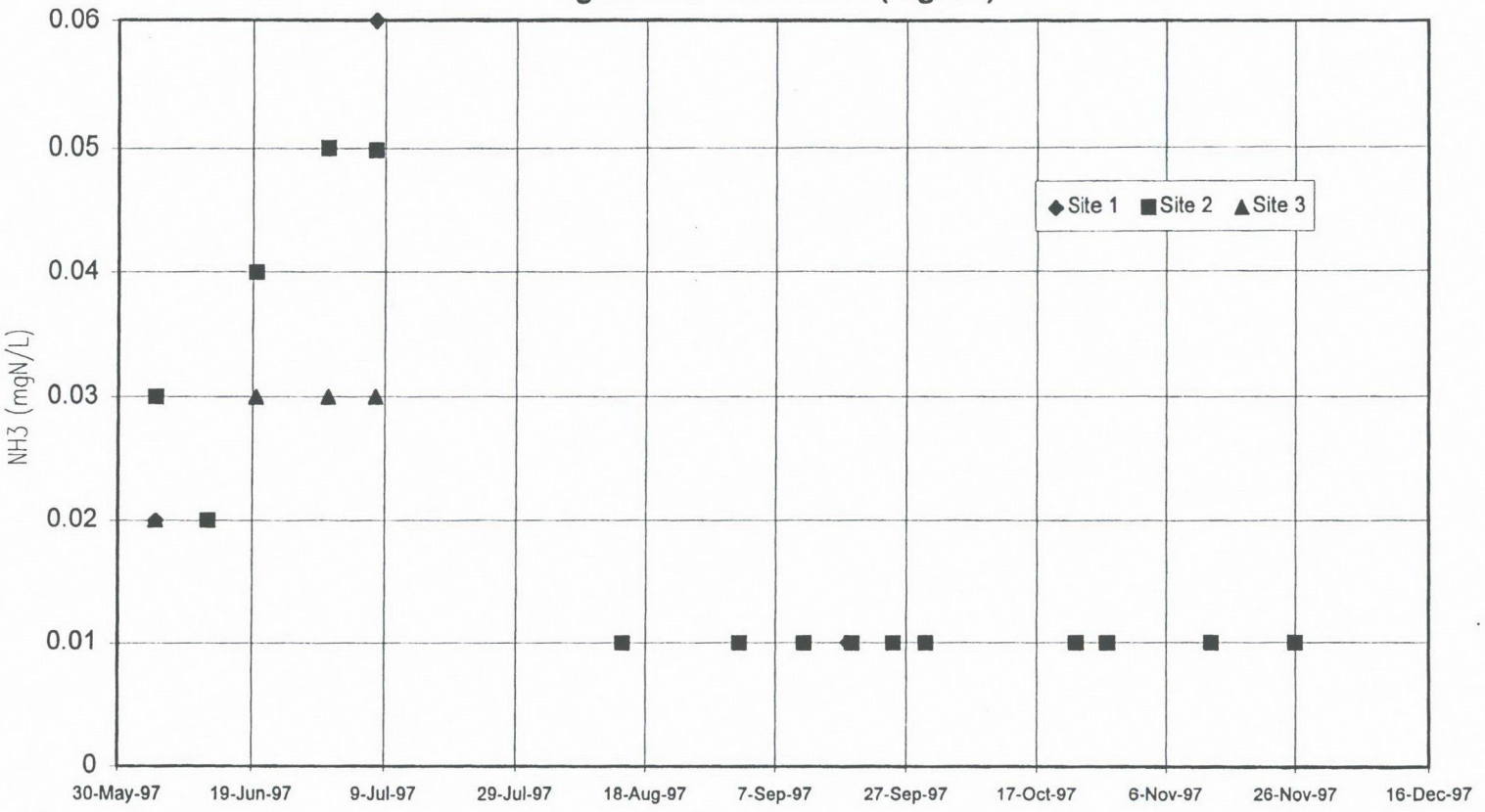


Figure A-9 Oxidised Nitrogen (ugN/L)

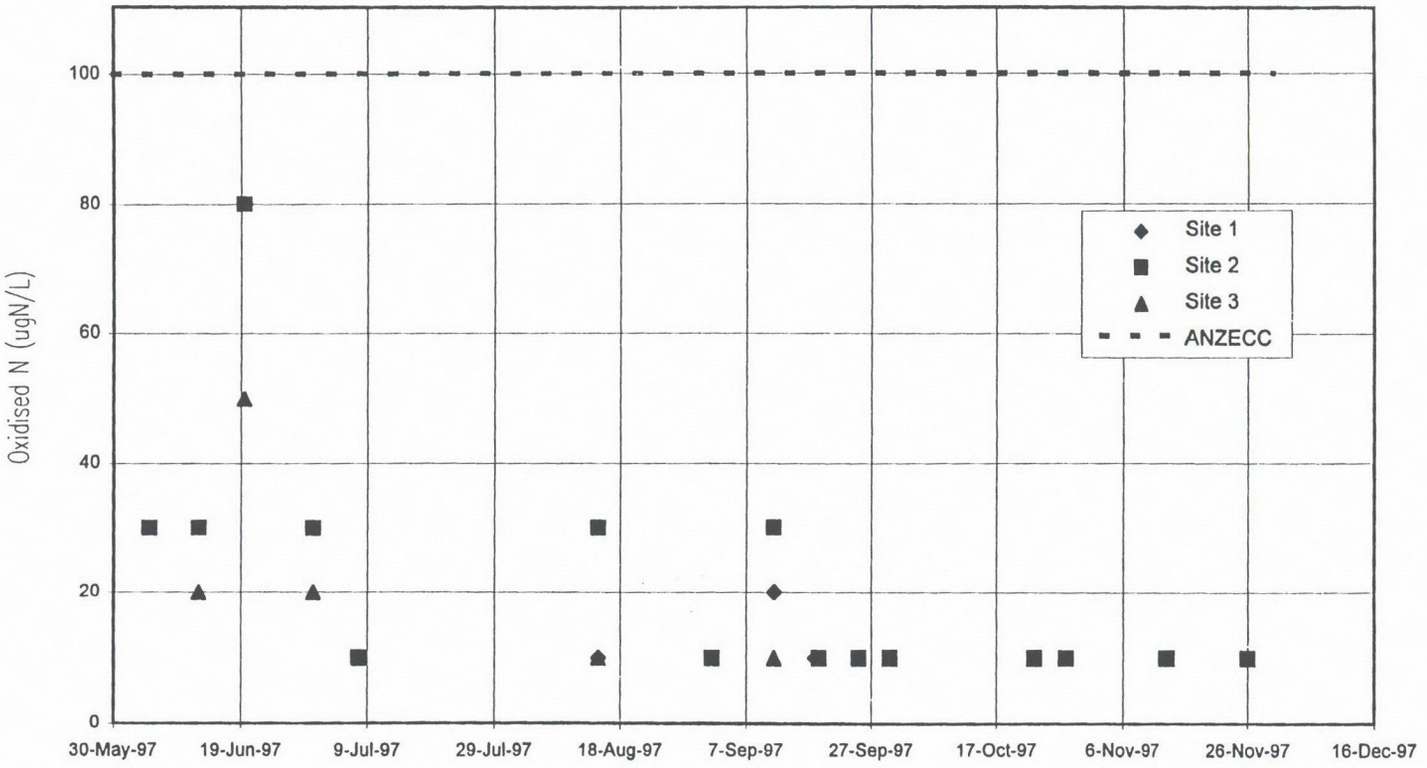


Figure A-10 Total Nitrogen (ugN/L)

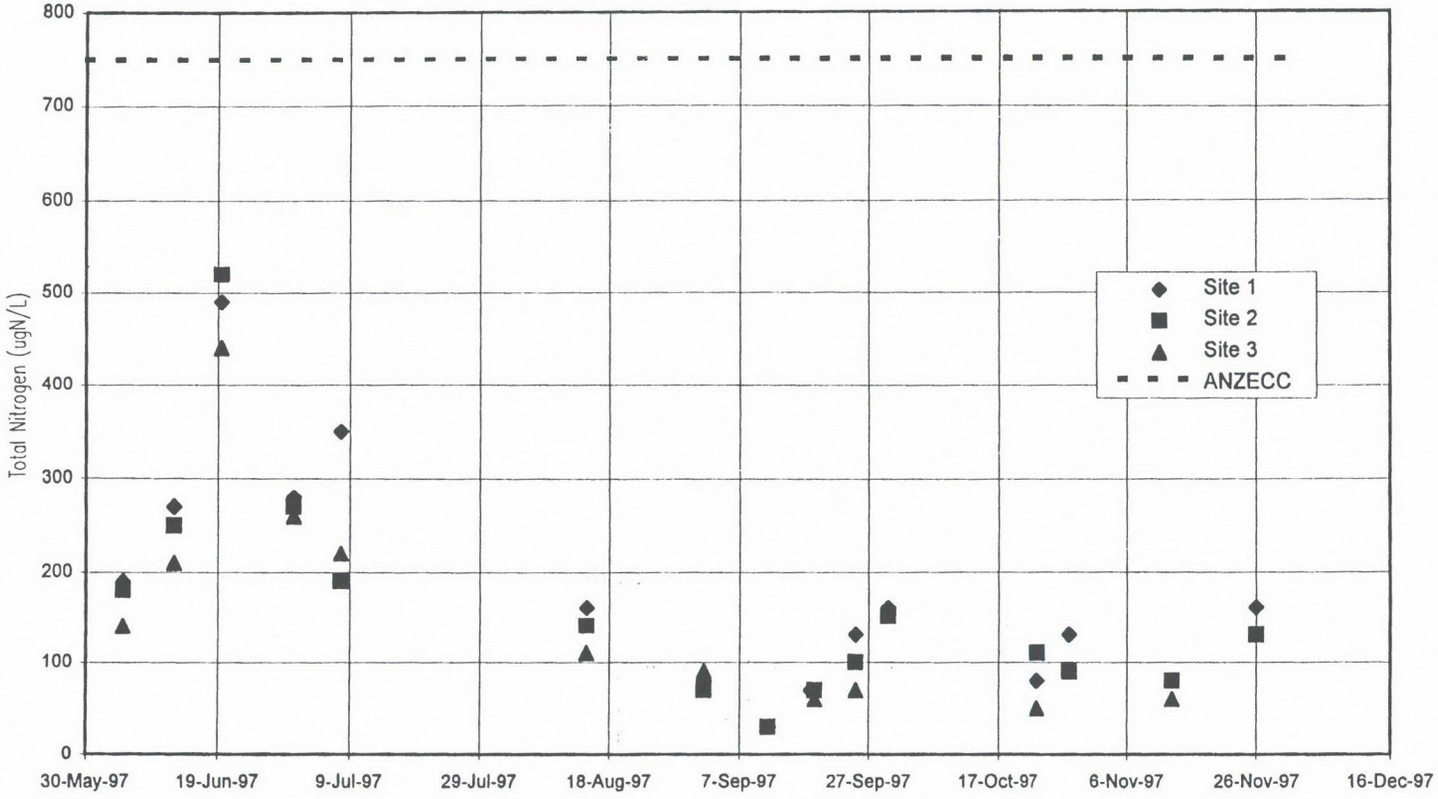


Figure A-11 Orthophosphate (mgP/L)

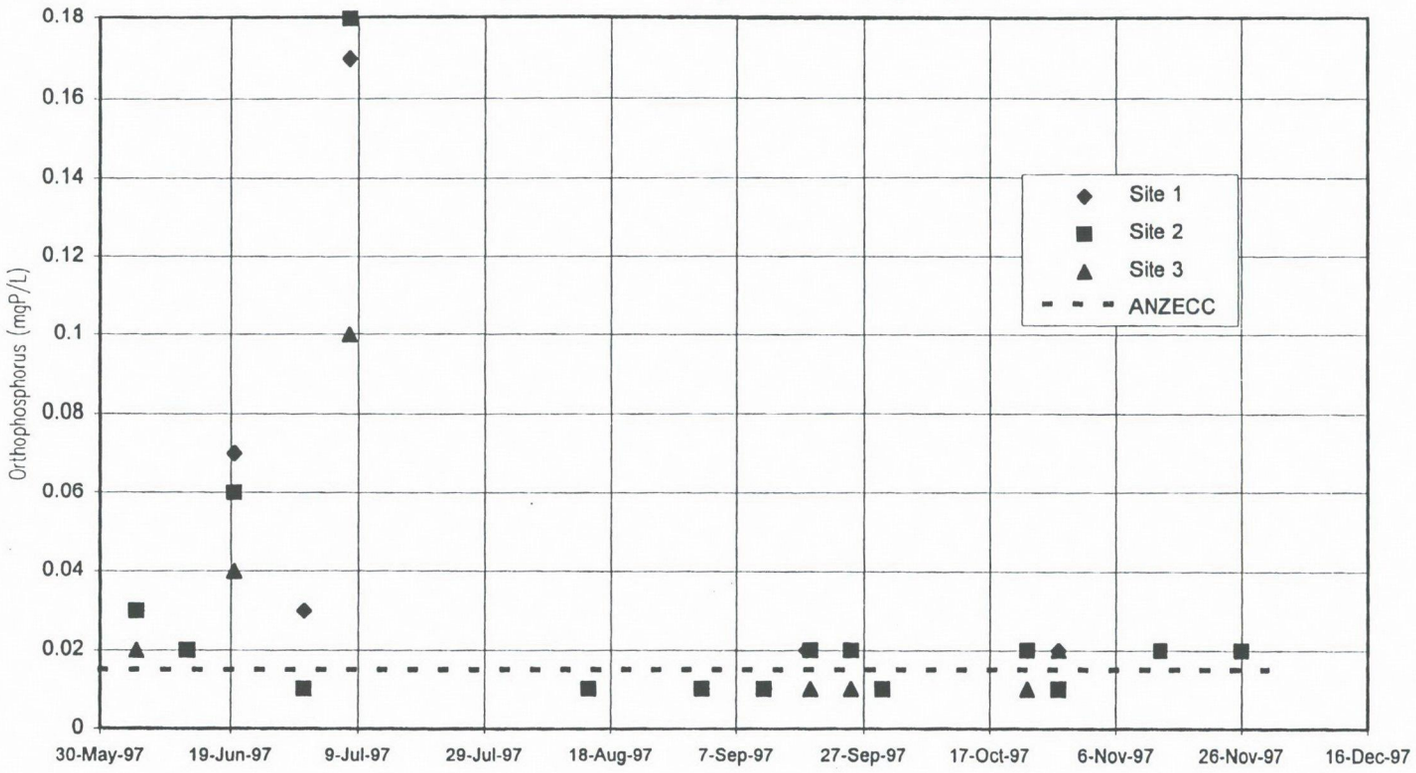


Figure A-12 Total Phosphorus (mgP/L)

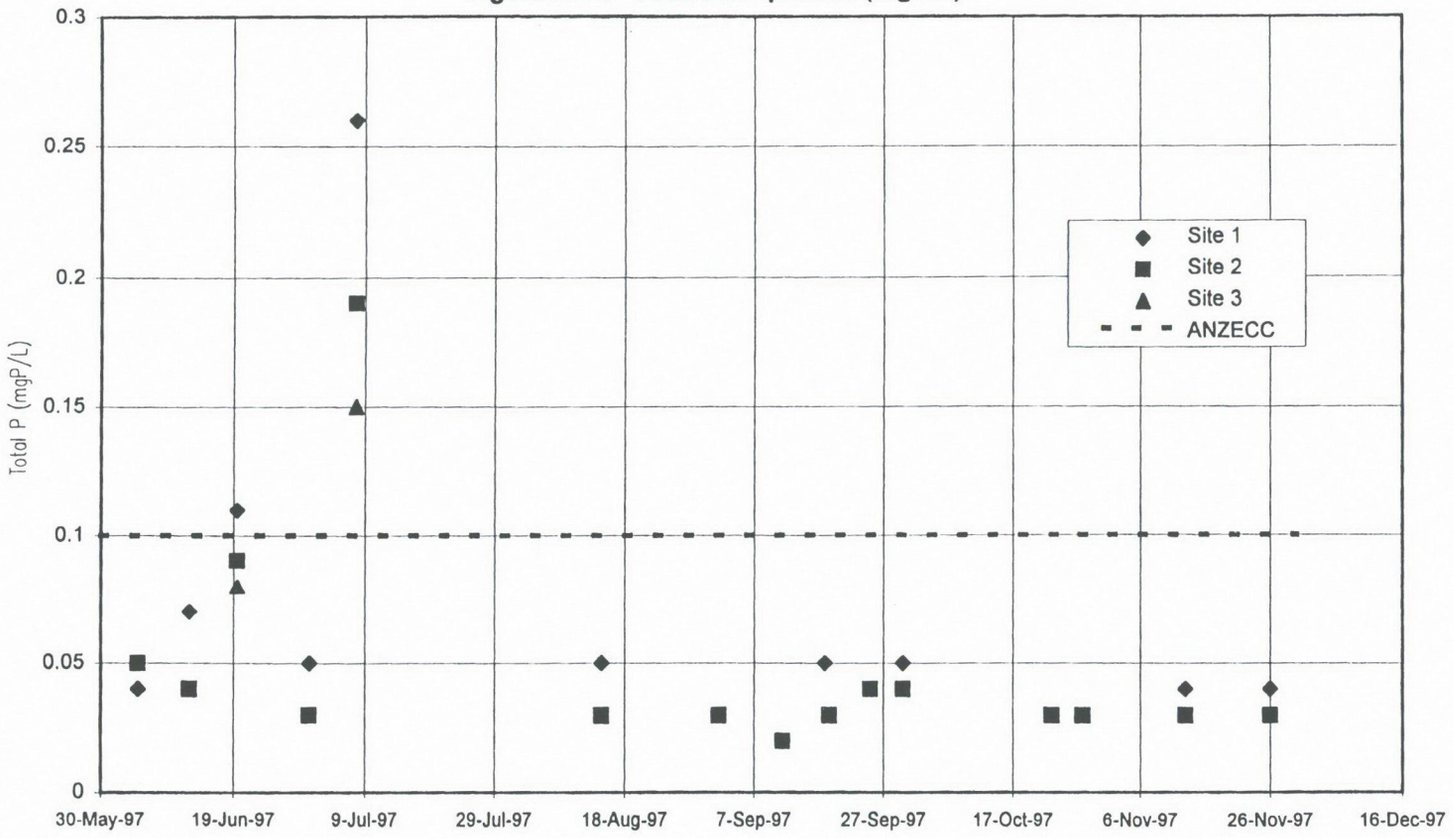


Figure A-13 Suspended Sediment (mg/L)

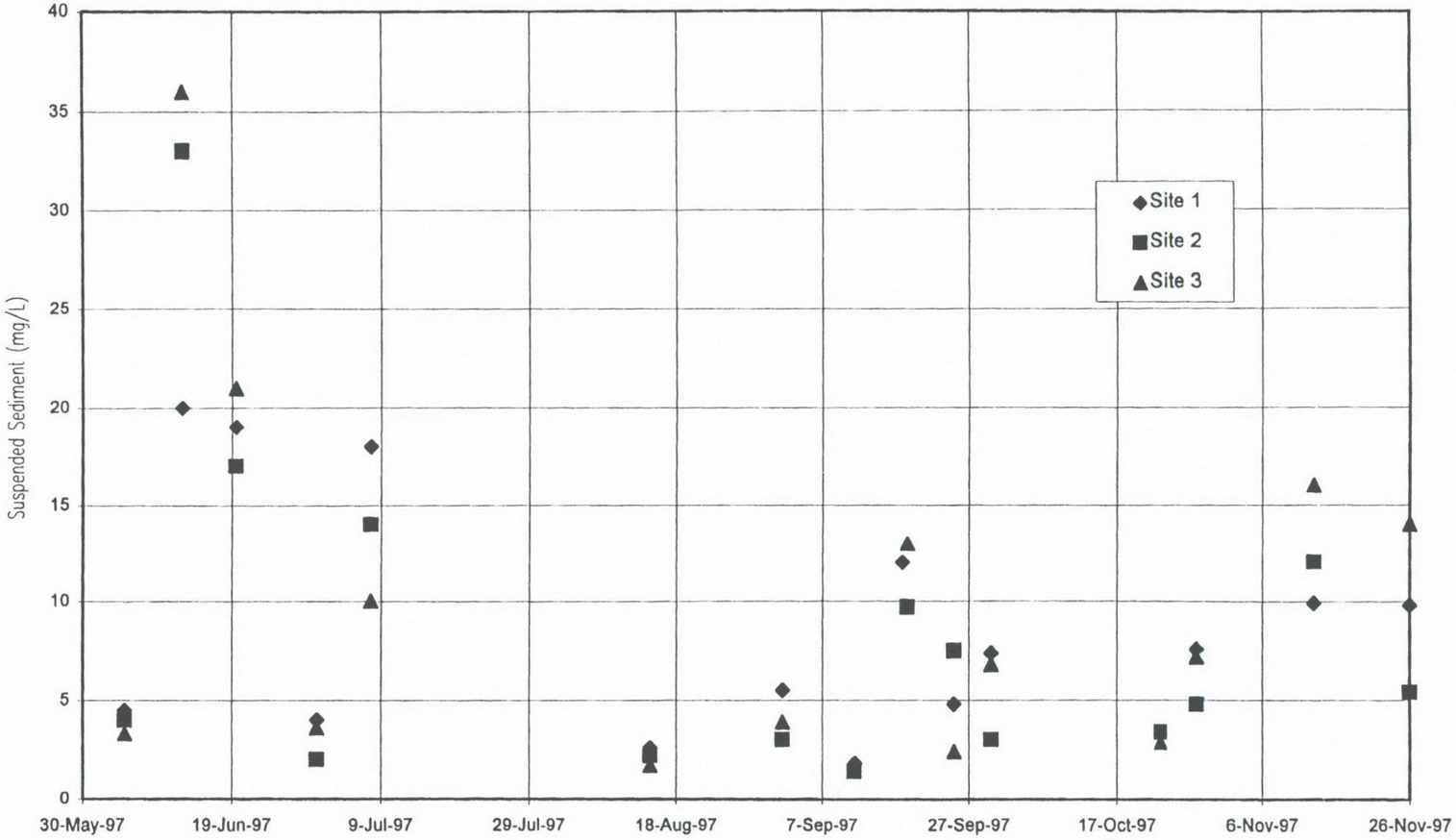


Figure A-14 Lead (ug/L)

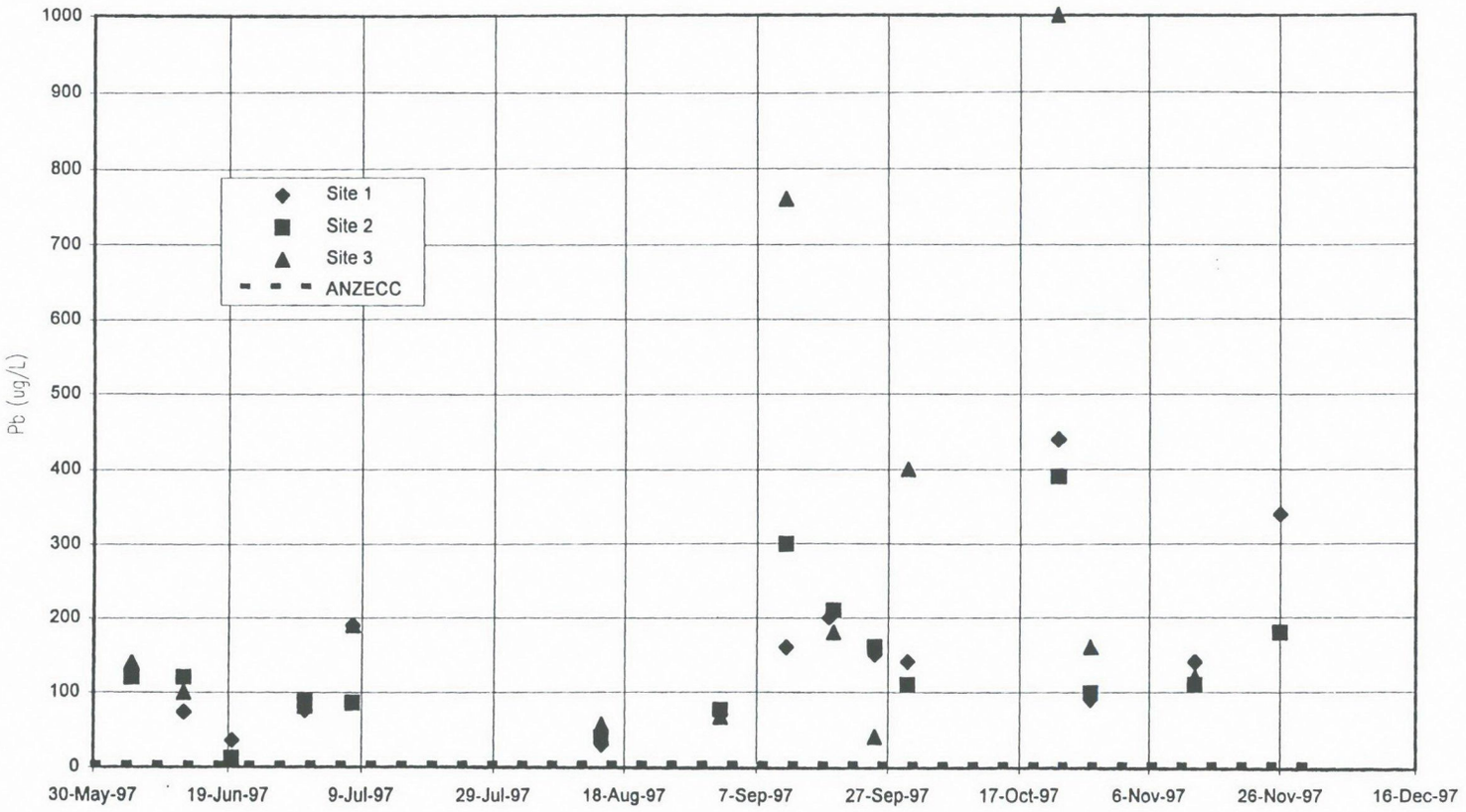


Table A-1 : GM Laboratory Results

Date	Station	Ammonia NH3	Lead Pb	Orthophosphorus PO4	Oxidised N NOx	Total Phosphorus T-P	SS/NFR	Total Nitrogen T-N	VSS
		mgN/L	ug/L	mgP/L	ugN/L	mgP/L	mg/L	ugN/L	mg/L
04-Jun-97	1	0.02	130	0.03	30	0.04	4.5	190	2
04-Jun-97	2	0.03	120	0.03	30	0.05	4	180	2
04-Jun-97	3	0.02	140	0.02	30	0.05	3.3	140	<1
12-Jun-97	1	0.02	74	0.02	30	0.07	20	270	8
12-Jun-97	2	0.02	120	0.02	30	0.04	33	250	11
12-Jun-97	3	0.02	100	0.02	20	0.04	36	210	12
19-Jun-97	1	0.04	36	0.07	80	0.11	19	490	3
19-Jun-97	2	0.04	12	0.06	80	0.09	17	520	4
19-Jun-97	3	0.03	13	0.04	50	0.08	21	440	5
30-Jun-97	1	0.05	76	0.03	30	0.05	4	280	2
30-Jun-97	2	0.05	88	0.01	30	0.03	2	270	1
30-Jun-97	3	0.03	82	0.01	20	0.03	3.6	260	2
07-Jul-97	1	0.06	190	0.17	10	0.26	18	350	4
07-Jul-97	2	0.05	86	0.18	10	0.19	14	190	3
07-Jul-97	3	0.03	190	0.1	10	0.15	10	220	2
14-Aug-97	1	0.01	30	<0.01	<10	0.05	2.6	160	<1
14-Aug-97	2	0.01	40	<0.01	30	0.03	2.2	140	<1
14-Aug-97	3	0.01	57	<0.01	10	0.03	1.7	110	<1
26-Aug-97	1	<0.01	58	0.01	<10	0.03	2.9	120	1
26-Aug-97	2	<0.01	82	0.01	<10	0.02	2.5	110	1
26-Aug-97	3	<0.01	200	0.01	<10	0.02	4.7	110	1
01-Sep-97	1	<0.01	70	<0.01	<10	0.03	5.5	80	1
01-Sep-97	2	<0.01	77	<0.01	<10	0.03	3	70	1
01-Sep-97	3	<0.01	67	<0.01	<10	0.03	3.9	90	2
11-Sep-97	1	<0.01	160	0.01	20	0.02	1.8	<30	<1
11-Sep-97	2	<0.01	300	0.01	30	0.02	1.4	<30	1
11-Sep-97	3	<0.01	760	0.01	<10	0.02	1.6	<30	<1
18-Sep-97	1	<0.01	200	0.02	<10	0.05	12	70	2
18-Sep-97	2	<0.01	210	0.02	<10	0.03	9.7	70	2
18-Sep-97	3	<0.01	180	0.01	<10	0.03	13	60	2
25-Sep-97	1	<0.01	150	0.02	<10	0.04	4.8	130	1
25-Sep-97	2	<0.01	160	0.02	<10	0.04	7.5	100	2
25-Sep-97	3	<0.01	40	0.01	<10	0.04	2.4	70	<1
30-Sep-97	1	<0.01	140	<0.01	<10	0.05	7.4	160	1
30-Sep-97	2	<0.01	110	<0.01	<10	0.04	3	150	<1
30-Sep-97	3	<0.01	400	<0.01	<10	0.04	6.8	160	2
23-Oct-97	1	<0.01	440	0.02	<10	0.03	3.3	80	1
23-Oct-97	2	<0.01	390	0.02	<10	0.03	3.4	110	1
23-Oct-97	3	<0.01	1000	0.01	<10	0.03	2.9	50	1
28-Oct-97	1	0.01	90	0.02	<10	0.03	7.6	130	2
28-Oct-97	2	<0.01	99	0.01	<10	0.03	4.8	90	1
28-Oct-97	3	<0.01	160	0.02	<10	0.03	7.2	90	2
13-Nov-97	1	<0.01	140	0.02	<10	0.04	9.9	80	2
13-Nov-97	2	<0.01	110	0.02	<10	0.03	12	80	2
13-Nov-97	3	<0.01	120	0.02	<10	0.03	16	60	2
13-Nov-97	4		240						
13-Nov-97	5		130						
26-Nov-97	1	<0.01	340	0.02	<10	0.04	9.8	160	1
26-Nov-97	2	<0.01	180	0.02	<10	0.03	5.4	130	2
26-Nov-97	3	<0.01	180	0.02	<10	0.03	14	130	3

APPENDIX B: NEWCASTLE HERALD ARTICLE

Karuah river polluter jailed

By SCOTT TUCKER
Staff Reporter

A KARUAH caravan park owner has been jailed for 12 months and ordered to pay $420,000 after being convicted by the Land and Environment Court of pumping millions of litres of sewage into the Karuah River.

Mr Charles Gardner's jail sentence was only the second handed down in Australia for an environmental crime, and the first in NSW, sending a tough message to polluters.

The court heard the offences occurred between about October 16, 1993, and April 1, 1996, while Mr Gardner owned and operated a caravan and relocatable home park called the Karuah Jetty Village.

An average of 128,710 litres of sewage generated in the park was pumped into the river each week through a system of hidden underground pipes and valves specifically installed for that purpose.

By dumping the sewage Mr Gardner saved more than $138,000 on sewage removal fees estimated to cost $852 a week, but jeopardised oyster plots, river and community health.

Mr Justice Lloyd, making history in the NSW Land and Environment Court, sent Mr Gardner to jail for his deception.

'It changed the physical, chemical and biological condition of the waters of the river,' he said in his judgment.

'There was a mass of evidence relating to smells in the village emanating from the discharge which thereby degraded the aesthetic factors relating to human surroundings.'

Mr Justice Lloyd found that of greatest concern were sediments found near the park outlet pipes which had been pounded with viruses for a number of years.

Nearby water suffered viral contamination which posed a 'grave health risk', particularly to nearby oyster leases during tidal periods.

'You went to great lengths to hide the effluent disposal system,' Mr Justice Lloyd said.

'You made numerous self-serving and deceptive statements to residents of the village and to this court in evidence as to your pumping activities and the purpose which the system served.'

The court found that Mr Gardner knew the health risk posed by his dumping activities yet pursued them with the sole purpose of saving money.

His senior counsel, Mr A.J. Bellanto QC, said Mr Gardner was of previous good character, was unlikely to re-offend and should therefore not be sent to jail.

Mr Justice Lloyd said it was the most serious environmental crime he had heard, the crime was committed over a lengthy period and large amounts of effluent had been wilfully discharged.

Continued on Page 2
Editorial, Page 10



Mr Gardner

Karuah man jailed for polluting river

Continued from Page 1

He told Mr Gardner he could have faced an even stiffer penalty if his case had been heard before the Supreme Court.

In sentencing Mr Gardner to 12-months jail, a $250,000 fine and $170,000 in court costs, Justice Lloyd said there must be an element of 'just desserts'.

'The sentence must be proportionate to the gravity of the crime,' he said.

The executive director of operations with the Environment Protection Authority, Mr Brian Gilligan, said the sentence was a very significant decision that sent a powerful message to other polluters.

'The judgment obviously makes the point that by doing what he did Mr Gardner placed at risk the environment, public health and key elements of the local and regional economy, in this case the oyster industry and the Port Stephens area and its tourism industry,' he said.

'The fact that Mr Gardner sought to hide what he was doing sends a clear message that polluters will get caught.'

Mr Gilligan said the danger of such pollution, and the effects it could have on public health and local economies, was made obvious during the Wallis Lake oyster scare.

'I think that's still vivid in people's memories and therefore when the judge has said in this case that there was a grave risk to public health people knew what he meant,' he said.

The only other person to have been jailed for environmental offences was a West Australian man who was imprisoned for 12 weeks in 1995 for discharging 22,000 litres of zinc plating waste into waters.

APPENDIX C: GM LABORATORIES STATEMENT

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 9564 1697
Phone: (02) 9564 1033

16 FEB 1998

11th February 1998

WBM Pty Ltd
126 Belford Street
Broadmeadow NSW 2292

Attention Greg Rogencamp

Dear Greg,

Since discussions between Jenny Pocock and Michael Irwin regarding Batch number 22634 and the Lead results reported from that batch an internal investigation has been carried out. Samples from this batch were reanalysed for lead by Graphite Furnace and reproduced results of 300µg/L and confirmed the original reported number. The same sample was run in parallel by ICP AES and produced a result of <0.05mg/L which was more in line with the expectations of the environment from where the samples were taken. Further investigations revealed that saline waters have an interfering effect on metals analysis by Graphite Furnace and in this instance has produced a falsely high result.

The corrective action taken is that all metals methods using Graphite Furnace techniques have now had the scope of the test amended to read "Not applicable to saline waters". Further, our quality system has been amended so that the standard operating procedures for all Graphite Furnace methods now include a step to check the conductivity of the sample before analysis begins. Should this level be high then a different technique will be required.

In my opinion samples reported in batch 22634 and previous batches for this project where lead has been analysed in saline waters, it would be reasonable to assume that lead levels would be below 0.05mg/L. Samples from previous batches have been disposed of and so reanalysis cannot be performed.

Attached is a copy of our internal paperwork for your information.

Yours Sincerely,

Grant Leslie.

Grant Leslie
Sales and Customer Service Manager.

APPENDIX D: RAW DATA FOR ELEMENT CONCENTRATIONS (METALS) IN OYSTER TISSUES

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
19/06/97	1	1.4	0.18	0.073	0.041	25.5	0.013	0.060	0.089	0.48	573	0.037
19/06/97	1	1.6	0.22	0.061	0.049	19.5	0.011	0.061	0.110	0.62	228	0.071
19/06/97	1	1.5	0.28	0.120	0.057	29.3	0.015	0.071	0.100	0.53	645	0.040
19/06/97	1	1.8	0.26	0.090	0.084	27.6	0.015	0.067	0.110	0.70	655	0.056
19/06/97	1	1.7	0.37	0.120	0.073	20.2	0.014	0.074	0.100	0.52	606	0.043
19/06/97	1	1.5	0.23	0.080	0.056	28.8	0.013	0.061	0.100	0.65	688	0.060
19/06/97	2	2.0	0.16	0.050	0.063	16.0	0.009	0.058	0.093	0.83	196	0.059
19/06/97	2	1.8	0.26	0.060	0.046	18.2	0.012	0.074	0.066	0.62	377	0.052
19/06/97	2	1.5	0.36	0.120	0.067	25.1	0.014	0.064	0.085	0.61	843	0.051
19/06/97	2	1.8	0.28	0.093	0.062	32.7	0.016	0.064	0.068	0.58	857	0.056
19/06/97	2	1.3	0.24	0.063	0.042	14.5	0.011	0.062	0.093	0.50	334	0.039
19/06/97	2	1.9	0.25	0.064	0.062	18.5	0.011	0.074	0.110	0.67	370	0.056
19/06/97	3	2.0	0.39	0.120	0.050	17.5	0.023	0.086	0.170	0.83	409	0.049
19/06/97	3	1.5	0.36	0.082	0.046	23.0	0.023	0.074	0.140	0.57	523	0.070
19/06/97	3	1.8	0.45	0.089	0.075	18.2	0.021	0.069	0.140	0.69	652	0.052
19/06/97	3	2.0	0.26	0.130	0.076	10.2	0.020	0.070	0.100	0.83	215	0.034
19/06/97	3	1.8	0.41	0.110	0.084	15.6	0.023	0.076	0.160	0.83	500	0.051
19/06/97	3	2.1	0.30	0.110	0.150	16.1	0.025	0.074	0.100	0.77	561	0.044
30/06/97	1	1.6	0.18	0.079	0.160	15.7	0.010	0.073	0.170	0.48	335	0.059
30/06/97	1	1.6	0.17	0.075	0.160	15.9	0.010	0.069	0.160	0.45	346	0.063
30/06/97	1	1.3	0.24	0.096	0.120	24.5	0.013	0.082	0.130	0.35	628	0.056
30/06/97	1	1.2	0.19	0.077	0.130	31.7	0.016	0.069	0.160	0.56	593	0.044
30/06/97	1	1.5	0.18	0.082	0.120	17.0	0.012	0.100	0.120	0.38	436	0.058
30/06/97	1	1.2	0.19	0.110	0.150	16.8	0.012	0.089	0.270	0.38	428	0.063
30/06/97	1	1.4	0.17	0.078	0.130	17.1	0.011	0.093	0.110	0.40	551	0.052
30/06/97	2	1.1	0.19	0.068	0.130	15.4	0.014	0.068	0.150	0.35	355	0.056
30/06/97	2	1.6	0.15	0.052	0.150	12.1	0.011	0.059	0.140	0.48	173	0.096
30/06/97	2	1.2	0.20	0.065	0.140	13.1	0.011	0.061	0.100	0.29	357	0.050
30/06/97	2	1.1	0.13	0.050	0.150	11.8	0.014	0.061	0.160	0.30	215	0.057
30/06/97	2	1.0	0.16	0.069	0.130	11.8	0.009	0.056	0.140	0.27	351	0.062
30/06/97	2	1.5	0.10	0.039	0.130	9.3	0.009	0.046	0.088	0.34	181	0.071
30/06/97	3	1.2	0.14	0.069	0.180	15.5	0.013	0.069	0.130	0.28	288	0.067
30/06/97	3	1.3	0.13	0.063	0.150	12.1	0.016	0.080	0.130	0.41	352	0.052

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
30/06/97	3	1.2	0.15	0.073	0.210	19.3	0.013	0.085	0.170	0.34	355	0.083
30/06/97	3	1.3	0.16	0.074	0.160	20.9	0.014	0.059	0.140	0.32	474	0.052
30/06/97	3	1.3	0.12	0.046	0.150	8.7	0.009	0.067	0.110	0.38	152	0.068
30/06/97	3	1.0	0.10	0.051	0.180	13.3	0.010	0.054	0.110	0.31	246	0.051
8/07/97	1	1.7	0.31	0.091	0.053	31.8	0.021	0.088	0.120	0.40	918	0.085
8/07/97	1	1.3	0.22	0.089	0.051	23.1	0.017	0.060	0.087	0.38	590	0.043
8/07/97	1	1.4	0.22	0.069	0.065	18.8	0.016	0.077	0.091	0.45	481	0.055
8/07/97	1	1.7	0.21	0.074	0.089	18.2	0.014	0.079	0.110	0.34	531	0.065
8/07/97	1	1.7	0.25	0.098	0.087	22.3	0.023	0.073	0.130	0.46	1010	0.049
8/07/97	1	1.8	0.24	0.071	0.100	23.3	0.016	0.083	0.092	0.51	536	0.057
8/07/97	2	1.6	0.15	0.042	0.048	9.0	0.014	0.057	0.056	0.39	194	0.073
8/07/97	2	1.6	0.14	0.040	0.061	8.8	0.010	0.048	0.066	0.39	208	0.062
8/07/97	2	1.7	0.13	0.044	0.068	9.0	0.012	0.056	0.160	0.40	138	0.074
8/07/97	2	1.5	0.15	0.048	0.065	6.8	0.012	0.058	0.120	0.39	170	0.059
8/07/97	2	1.8	0.12	0.039	0.071	14.2	0.008	0.050	0.092	0.37	227	0.069
8/07/97	2	1.7	0.14	0.050	0.068	10.0	0.009	0.055	0.093	0.39	195	0.086
8/07/97	3	1.8	0.25	0.084	0.120	34.4	0.018	0.073	0.120	0.46	976	0.052
8/07/97	3	1.7	0.18	0.078	0.130	18.9	0.013	0.070	0.140	0.40	563	0.110
8/07/97	3	1.4	0.23	0.078	0.120	18.2	0.013	0.093	0.260	0.53	460	0.063
8/07/97	3	1.6	0.24	0.075	0.140	26.7	0.015	0.082	0.230	0.46	605	0.110
8/07/97	3	1.5	0.26	0.081	0.130	25.0	0.016	0.068	0.120	0.49	733	0.057
8/07/97	3	1.7	0.24	0.075	0.120	24.9	0.015	0.082	0.290	0.52	674	0.079
14/08/97	1	1.8	0.29	0.100	0.110	33.3	0.024	0.074	0.150	0.77	953	0.085
14/08/97	1	1.6	0.32	0.088	0.120	33.9	0.023	0.084	0.180	1.10	895	0.090
14/08/97	1	2.0	0.27	0.094	0.160	35.3	0.020	0.100	0.310	0.96	824	0.076
14/08/97	1	2.0	0.27	0.068	0.200	11.6	0.017	0.077	0.220	0.89	225	0.160
14/08/97	1	1.8	0.21	0.058	0.087	33.0	0.024	0.065	0.110	0.93	620	0.082
14/08/97	1	1.8	0.32	0.085	0.096	35.5	0.016	0.071	0.140	0.93	885	0.062
14/08/97	2	2.0	0.20	0.061	0.110	16.4	0.015	0.062	0.170	0.86	292	0.098
14/08/97	2	2.4	0.22	0.066	0.120	16.8	0.016	0.064	0.210	0.88	282	0.110
14/08/97	2	2.5	0.24	0.066	0.180	11.7	0.015	0.075	0.180	1.10	192	0.130
14/08/97	2	2.1	0.19	0.050	0.130	16.8	0.024	0.068	0.160	0.85	285	0.110
14/08/97	2	2.3	0.27	0.071	0.230	26.3	0.019	0.055	0.110	0.78	349	0.097

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
14/08/97	2	2.3	0.21	0.050	0.170	12.8	0.016	0.052	0.190	0.77	203	0.086
14/08/97	3	2.2	0.24	0.094	0.200	20.9	0.025	0.082	0.310	0.73	513	0.071
14/08/97	3	2.0	0.23	0.061	0.200	23.4	0.018	0.081	0.180	0.94	666	0.072
14/08/97	3	1.9	0.25	0.100	0.280	17.6	0.016	0.100	0.350	0.41	483	0.110
14/08/97	3	1.9	0.29	0.086	0.250	30.2	0.013	0.074	0.200	0.64	767	0.082
14/08/97	3	2.3	0.26	0.087	0.240	17.7	0.016	0.076	0.240	0.87	702	0.083
14/08/97	3	2.3	0.29	0.098	0.280	35.5	0.017	0.080	0.350	1.40	663	0.072
20/08/97	1	1.8	0.21	0.070	0.120	28.1	0.027	0.054	0.140	0.47	769	0.044
20/08/97	1	1.8	0.26	0.084	0.160	24.6	0.026	0.056	0.130	0.72	486	0.063
20/08/97	1	1.3	0.19	0.056	0.160	19.4	0.023	0.065	0.120	0.54	522	0.071
20/08/97	1	1.5	0.17	0.068	0.120	25.9	0.024	0.061	0.310	0.50	806	0.065
20/08/97	1	1.5	0.21	0.064	0.110	22.4	0.027	0.062	0.130	0.66	564	0.062
20/08/97	1	1.5	0.18	0.067	0.130	27.1	0.026	0.065	0.140	0.53	363	0.048
20/08/97	2	2.3	0.17	0.044	0.150	13.5	0.020	0.054	0.100	0.80	199	0.055
20/08/97	2	1.9	0.29	0.083	0.170	28.7	0.022	0.066	0.140	0.86	849	0.042
20/08/97	2	2.3	0.14	0.047	0.160	8.7	0.017	0.049	0.140	0.74	183	0.069
20/08/97	2	1.9	0.21	0.070	0.180	20.7	0.022	0.064	0.190	0.79	662	0.050
20/08/97	2	1.5	0.12	0.031	0.140	9.7	0.013	0.034	0.086	0.54	178	0.046
20/08/97	2	1.7	0.23	0.078	0.140	23.6	0.023	0.068	0.110	0.69	581	0.068
20/08/97	3	1.8	0.20	0.086	0.120	25.8	0.023	0.067	0.290	0.85	852	0.062
20/08/97	3	1.6	0.23	0.065	0.130	18.6	0.018	0.059	0.120	0.75	517	0.059
20/08/97	3	1.9	0.13	0.034	0.130	11.0	0.016	0.058	0.068	0.54	179	0.070
20/08/97	3	1.9	0.22	0.075	0.140	24.9	0.020	0.072	0.180	0.77	706	0.057
20/08/97	3	1.8	0.21	0.069	0.120	19.8	0.020	0.064	0.230	0.65	659	0.055
20/08/97	3	1.5	0.22	0.065	0.130	30.0	0.021	0.070	0.140	0.51	792	0.064
1/09/97	1	2.0	0.21	0.057	0.160	21.4	0.018	0.056	0.110	0.73	382	0.086
1/09/97	1	1.9	0.26	0.077	0.180	38.2	0.018	0.074	0.140	0.75	772	0.049
1/09/97	1	2.3	0.18	0.052	0.170	21.2	0.013	0.066	0.110	0.84	352	0.083
1/09/97	1	2.1	0.25	0.110	0.240	33.3	0.017	0.070	0.440	0.75	751	0.058
1/09/97	1	2.1	0.40	0.140	0.200	38.4	0.016	0.071	0.200	0.63	1370	0.065
1/09/97	1	2.0	0.30	0.110	0.170	38.8	0.020	0.075	0.150	0.70	1030	0.052
1/09/97	2	2.5	0.20	0.075	0.180	30.1	0.014	0.054	0.120	0.80	409	0.092
1/09/97	2	2.8	0.21	0.120	0.190	56.4	0.018	0.063	0.290	0.93	663	0.086

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
1/09/97	2	3.3	0.20	0.075	0.200	33.6	0.017	0.060	0.140	1.00	551	0.081
1/09/97	2	2.0	0.28	0.084	0.180	40.1	0.015	0.060	0.200	0.83	889	0.060
1/09/97	2	2.1	0.38	0.110	0.180	37.8	0.019	0.068	0.160	1.10	1450	0.052
1/09/97	2	2.1	0.23	0.075	0.180	24.6	0.013	0.068	0.180	0.86	418	0.100
1/09/97	2	2.5	0.26	0.057	0.170	23.0	0.013	0.060	0.100	0.90	346	0.100
1/09/97	3	2.2	0.28	0.090	0.200	32.4	0.021	0.083	0.160	0.90	823	0.060
1/09/97	3	2.1	0.30	0.100	0.160	25.6	0.015	0.085	0.180	0.65	572	0.088
1/09/97	3	1.9	0.32	0.088	0.190	29.8	0.017	0.084	0.170	1.00	727	0.096
1/09/97	3	1.9	0.23	0.096	0.170	34.4	0.015	0.075	0.340	0.59	855	0.062
1/09/97	3	2.0	0.30	0.078	0.180	32.5	0.016	0.078	0.240	0.58	746	0.064
1/09/97	3	2.1	0.25	0.068	0.150	29.3	0.014	0.063	0.200	0.96	867	0.062
25/09/97	1	1.8	0.22	0.078	0.180	42.5	0.014	0.069	0.180	0.69	1010	0.056
25/09/97	1	1.7	0.25	0.073	0.180	24.8	0.013	0.078	0.220	0.72	669	0.064
25/09/97	1	1.9	0.20	0.073	0.180	33.3	0.016	0.080	0.190	0.81	663	0.059
25/09/97	1	2.2	0.17	0.058	0.220	16.5	0.015	0.072	0.210	0.86	259	0.090
25/09/97	1	1.9	0.17	0.053	0.190	16.2	0.014	0.068	0.150	0.74	237	0.090
25/09/97	1	2.1	0.30	0.090	0.260	45.8	0.019	0.084	0.310	0.80	904	0.061
25/09/97	2	2.2	0.22	0.054	0.150	18.1	0.013	0.058	0.150	0.85	336	0.068
25/09/97	2	2.6	0.19	0.051	0.170	18.7	0.012	0.068	0.200	0.97	258	0.068
25/09/97	2	2.7	0.18	0.058	0.170	17.4	0.012	0.082	0.150	0.94	247	0.059
25/09/97	2	2.3	0.24	0.051	0.170	16.7	0.010	0.054	0.150	0.80	272	0.064
25/09/97	2	2.5	0.18	0.065	0.170	32.8	0.014	0.074	0.170	0.89	449	0.110
25/09/97	2	2.1	0.20	0.063	0.150	17.8	0.013	0.057	0.096	0.83	250	0.082
25/09/97	3	2.0	0.24	0.082	0.180	35.4	0.018	0.084	0.120	0.78	717	0.060
25/09/97	3	1.9	0.20	0.068	0.180	21.0	0.013	0.067	0.180	0.89	607	0.048
25/09/97	3	1.9	0.24	0.088	0.170	29.2	0.016	0.067	0.120	0.62	702	0.047
25/09/97	3	1.8	0.21	0.069	0.150	22.2	0.012	0.071	0.330	0.56	450	0.044
25/09/97	3	1.9	0.20	0.080	0.150	35.8	0.016	0.074	0.130	0.89	1020	0.045
25/09/97	3	1.8	0.26	0.082	0.160	26.0	0.012	0.078	0.170	0.65	677	0.054
30/09/97	1	2.1	0.25	0.058	0.190	22.3	0.018	0.066	0.110	0.90	371	0.110
30/09/97	1	1.7	0.24	0.082	0.190	33.9	0.015	0.067	0.140	1.00	714	0.061
30/09/97	1	1.9	0.19	0.055	0.190	10.7	0.016	0.055	0.110	0.82	196	0.074
30/09/97	1	2.5	0.17	0.057	0.200	21.1	0.012	0.056	0.110	1.00	323	0.073

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
30/09/97	1	2.0	0.25	0.071	0.190	29.5	0.014	0.056	0.150	0.70	640	0.042
30/09/97	1	2.1	0.22	0.062	0.200	21.6	0.016	0.074	0.120	0.93	264	0.110
30/09/97	2	2.2	0.18	0.050	0.160	11.2	0.012	0.064	0.097	0.87	181	0.071
30/09/97	2	2.0	0.34	0.100	0.140	15.6	0.014	0.050	0.590	0.89	383	0.042
30/09/97	2	2.0	0.17	0.046	0.130	15.5	0.011	0.059	0.096	0.88	253	0.056
30/09/97	2	2.0	0.18	0.051	0.160	14.7	0.012	0.055	0.160	0.76	311	0.065
30/09/97	2	3.0	0.17	0.054	0.210	20.0	0.012	0.061	0.096	0.93	327	0.064
30/09/97	2	2.1	0.17	0.059	0.190	21.8	0.011	0.063	0.100	0.89	368	0.074
30/09/97	3	1.6	0.20	0.075	0.150	23.3	0.013	0.062	0.180	0.90	542	0.047
30/09/97	3	1.9	0.19	0.074	0.170	30.8	0.015	0.071	0.150	0.83	608	0.049
30/09/97	3	1.9	0.21	0.057	0.140	29.4	0.013	0.063	0.110	0.60	721	0.044
30/09/97	3	1.8	0.22	0.088	0.170	27.9	0.014	0.076	0.240	0.75	638	0.075
30/09/97	3	1.6	0.18	0.100	0.180	27.4	0.013	0.069	0.330	0.53	749	0.062
30/09/97	3	1.7	0.16	0.079	0.170	31.1	0.012	0.058	0.480	0.87	656	0.042
23/10/97	1	2.3	0.17	0.059	0.180	22.4	0.017	0.056	0.170	0.79	293	0.088
23/10/97	1	2.3	0.17	0.057	0.190	24.0	0.018	0.059	0.170	0.81	306	0.095
23/10/97	1	2.2	0.22	0.084	0.210	22.4	0.021	0.078	0.270	0.79	331	0.120
23/10/97	1	2.1	0.22	0.065	0.210	16.8	0.024	0.085	0.170	0.71	252	0.180
23/10/97	1	2.1	0.23	0.065	0.160	17.2	0.028	0.086	0.150	0.75	255	0.160
23/10/97	1	2.0	0.24	0.072	0.170	32.9	0.021	0.059	0.095	0.55	469	0.120
23/10/97	1	2.3	0.26	0.072	0.170	24.0	0.019	0.058	0.130	0.62	332	0.140
23/10/97	1	2.1	0.19	0.067	0.180	38.6	0.020	0.061	0.140	0.78	533	0.100
23/10/97	2	2.4	0.26	0.066	0.190	18.9	0.021	0.078	0.120	0.87	305	0.140
23/10/97	2	2.7	0.25	0.068	0.200	19.1	0.018	0.068	0.230	0.81	318	0.120
23/10/97	2	2.3	0.22	0.059	0.190	20.8	0.022	0.061	0.150	0.79	407	0.097
23/10/97	2	2.0	0.26	0.075	0.160	26.5	0.018	0.079	0.120	0.81	691	0.100
23/10/97	2	1.7	0.18	0.054	0.130	14.1	0.013	0.050	0.071	0.55	401	0.045
23/10/97	2	2.4	0.24	0.050	0.170	31.8	0.016	0.065	0.096	0.81	269	0.120
23/10/97	3	1.5	0.26	0.063	0.130	16.8	0.015	0.070	0.130	0.74	365	0.085
23/10/97	3	2.0	0.31	0.058	0.120	19.5	0.014	0.064	0.130	0.65	522	0.073
23/10/97	3	1.9	0.29	0.053	0.140	29.2	0.018	0.065	0.140	0.68	514	0.090
23/10/97	3	2.5	0.23	0.070	0.150	19.9	0.014	0.062	0.130	0.81	479	0.065
23/10/97	3	2.3	0.22	0.054	0.150	23.0	0.015	0.065	0.120	0.61	440	0.082

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
23/10/97	3	2.1	0.26	0.063	0.150	20.0	0.070	0.063	0.140	0.74	448	0.074
28/10/97	1	2.8	0.27	0.071	0.110	24.2	0.023	0.082	0.160	1.00	344	0.110
28/10/97	1	1.9	0.34	0.110	0.096	35.9	0.019	0.055	0.190	0.67	952	0.052
28/10/97	1	1.5	0.15	0.065	0.065	19.8	0.011	0.036	0.072	0.69	579	0.030
28/10/97	1	2.7	0.21	0.063	0.130	26.7	0.017	0.067	0.170	1.00	443	0.097
28/10/97	1	2.4	0.29	0.110	0.120	24.0	0.020	0.066	0.280	0.81	1040	0.069
28/10/97	1	2.0	0.27	0.094	0.110	34.6	0.022	0.069	0.200	0.87	644	0.066
28/10/97	2	2.1	0.40	0.110	0.080	54.8	0.025	0.063	0.200	1.10	1200	0.044
28/10/97	2	2.7	0.25	0.082	0.110	64.2	0.020	0.077	0.210	1.20	331	0.075
28/10/97	2	2.1	0.25	0.072	0.091	25.5	0.019	0.059	0.100	0.95	443	0.050
28/10/97	2	2.0	0.23	0.110	0.086	20.7	0.015	0.069	0.970	1.10	382	0.047
28/10/97	2	2.3	0.27	0.066	0.086	20.2	0.016	0.061	0.110	1.00	391	0.052
28/10/97	2	2.3	0.21	0.065	0.091	21.8	0.020	0.071	0.075	1.10	340	0.065
28/10/97	3	1.9	0.25	0.079	0.130	18.7	0.018	0.062	0.220	0.76	459	0.082
28/10/97	3	1.9	0.30	0.098	0.140	28.1	0.022	0.073	0.260	0.69	576	0.070
28/10/97	3	2.4	0.28	0.099	0.100	27.6	0.024	0.092	0.190	0.75	430	0.084
28/10/97	3	2.0	0.27	0.077	0.096	20.7	0.023	0.069	0.130	0.64	433	0.067
28/10/97	3	2.7	0.31	0.096	0.097	21.1	0.019	0.100	0.160	0.88	452	0.070
28/10/97	3	1.9	0.32	0.087	0.110	21.7	0.017	0.069	0.160	0.68	567	0.082
13/11/97	1	2.1	0.25	0.100	0.230	28.7	0.020	0.091	0.150	0.57	656	0.057
13/11/97	1	1.9	0.28	0.130	0.240	36.2	0.020	0.120	0.450	0.51	945	0.095
13/11/97	1	1.8	0.36	0.150	0.260	41.1	0.020	0.140	0.390	0.69	895	0.089
13/11/97	1	2.2	0.26	0.092	0.260	28.9	0.018	0.100	0.180	0.52	600	0.069
13/11/97	1	2.2	0.25	0.100	0.270	34.3	0.021	0.100	0.210	0.77	859	0.081
13/11/97	1	1.8	0.22	0.110	0.250	25.2	0.017	0.100	0.330	0.64	644	0.059
13/11/97	2	2.3	0.22	0.093	0.230	21.3	0.020	0.170	0.210	0.70	311	0.140
13/11/97	2	1.9	0.17	0.061	0.180	17.2	0.014	0.074	0.110	0.48	298	0.130
13/11/97	2	2.4	0.33	0.099	0.220	30.9	0.022	0.100	0.160	0.84	1010	0.072
13/11/97	2	2.1	0.28	0.110	0.230	33.6	0.018	0.120	0.240	0.52	969	0.053
13/11/97	2	2.5	0.31	0.180	0.300	34.0	0.022	0.160	0.200	1.10	1030	0.089
13/11/97	2	2.2	0.24	0.093	0.210	26.1	0.019	0.150	0.260	0.77	444	0.094
13/11/97	3	2.2	0.24	0.088	0.270	18.9	0.021	0.180	0.160	0.70	453	0.082
13/11/97	3	2.0	0.24	0.083	0.250	18.7	0.017	0.160	0.160	0.66	360	0.090

Date	Site	As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Se	Zn	Pb
13/11/97	3	2.3	0.28	0.086	0.270	20.5	0.018	0.170	0.160	0.70	345	0.110
13/11/97	3	2.1	0.21	0.089	0.280	21.7	0.018	0.180	0.160	0.62	371	0.110
13/11/97	3	2.6	0.28	0.083	0.260	20.0	0.018	0.180	0.240	0.70	427	0.063
13/11/97	3	2.3	0.24	0.082	0.270	16.2	0.016	0.200	0.150	0.57	264	0.077
26/11/97	1	2.5	0.23	0.094	0.290	27.7	0.020	0.082	0.290	0.87	405	0.082
26/11/97	1	2.8	0.30	0.097	0.320	39.8	0.018	0.068	0.210	0.73	987	0.097
26/11/97	1	2.5	0.33	0.120	0.290	31.2	0.017	0.056	0.120	1.20	1040	0.040
26/11/97	1	1.2	0.48	0.250	0.240	5.1	0.016	0.058	1.800	0.52	312	0.043
26/11/97	1	2.5	0.26	0.100	0.310	28.2	0.017	0.085	0.290	0.84	470	0.110
26/11/97	1	2.2	0.23	0.130	0.380	54.3	0.016	0.069	0.230	0.61	1100	0.130
26/11/97	2	1.9	0.28	0.098	0.130	41.7	0.028	0.091	0.230	0.75	789	0.130
26/11/97	2	1.9	0.18	0.078	0.120	33.3	0.022	0.060	0.280	0.69	494	0.086
26/11/97	2	1.8	0.21	0.096	0.150	26.0	0.024	0.072	0.220	0.84	354	0.100
26/11/97	2	2.4	0.25	0.120	0.130	34.6	0.022	0.076	0.200	0.93	602	0.120
26/11/97	2	1.8	0.19	0.072	0.120	16.1	0.019	0.058	0.450	0.70	248	0.085
26/11/97	2	1.6	0.25	0.097	0.170	32.7	0.027	0.078	0.180	0.84	503	0.092
26/11/97	3	1.8	0.29	0.065	0.140	28.0	0.023	0.072	0.120	0.65	632	0.060
26/11/97	3	2.5	0.23	0.074	0.190	20.5	0.016	0.072	0.420	0.80	346	0.095
26/11/97	3	1.8	0.25	0.069	0.180	32.7	0.022	0.063	0.120	0.57	884	0.068
26/11/97	3	1.6	0.26	0.095	0.160	32.7	0.019	0.060	0.110	0.48	773	0.071
26/11/97	3	2.1	0.34	0.096	0.210	30.2	0.019	0.062	0.470	0.60	1020	0.160
26/11/97	3	1.8	0.28	0.076	0.210	26.5	0.018	0.091	0.580	0.62	638	0.110

APPENDIX E: RAW DATA FOR E. COLI COUNTS FROM OYSTER TISSUES

E. Coli Counts (Colony Forming Units/gm)

	Site 1	Site 2	Site 3
19/06/97	16	95	52
30/06/97	<1	<1	<1
8/07/97	<1	<1	<1
14/08/97	<1	<1	<1
26/08/97	<1	<1	<1
25/09/97	1	2	0
30/09/97	0	0	0
23/10/97	<1	<1	<1
28/10/97	<1	<1	<1
13/11/97	<1	<1	<1
26/11/97	<1	<1	<1

APPENDIX F: ANOVA TABLES COMPARING MEAN CONCENTRATIONS OF METALS IN OYSTER TISSUES AMONG SITES AND TIMES

Arsenic

Tests of Between-Subjects Effects

Dependent Variable: AS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	20.289[b]	35	.580	7.860	.000	.603	275.104	1.000
Intercept	815.119	1	815.119	11052.2	.000	.984	11052.161	1.000
SITE	1.275	2	.638	8.645	.000	.087	17.291	.888
DATE	15.492	11	1.408	19.096	.000	.537	210.054	1.000
SITE * DATE	3.446	22	.157	2.124	.004	.205	46.721	.962
Error	13.349	181	7.4E-02					
Total	850.573	217						
Corrected Total	33.639	216						

a. Computed using alpha = .01

b. R Squared = .603 (Adjusted R Squared = .526)

Post Hoc Tests

SITE

Multiple Comparisons

Dependent Variable: AS

LSD

(I) SITE	(J) SITE	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.1625*	.045	.000	-.2799	-5.E-02
	3.00	5.694E-03	.045	.900	-.1121	.1235
2.00	1.00	.1625*	.045	.000	4.5E-02	.2799
	3.00	.1682*	.045	.000	5.1E-02	.2856
3.00	1.00	-5.69E-03	.045	.900	-.1235	.1121
	2.00	-.1682*	.045	.000	-.2856	-5.E-02

*. The mean difference is significant at the .01 level.

Tests of Between-Subjects Effects

Dependent Variable: CR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	.699[b]	35	2.0E-02	35.208	.000	.872	1232.280	1.000
Intercept	5.290	1	5.290	9320.492	.000	.981	9320.492	1.000
SITE	1.9E-02	2	9.4E-03	16.547	.000	.155	33.094	.997
DATE	.522	11	4.7E-02	83.642	.000	.836	920.063	1.000
SITE * DATE	.159	22	7.2E-03	12.730	.000	.607	280.067	1.000
Error	.103	181	5.7E-04					
Total	6.096	217						
Corrected Total	.802	216						

a. Computed using alpha = .01

b. R Squared = .872 (Adjusted R Squared = .847)

Post Hoc Tests

SITE

Multiple Comparisons

Dependent Variable: CR

LSD

(I) SITE	(J) SITE	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.957E-02*	.004	.000	9.3E-03	3.0E-02
	3.00	1.250E-04	.004	.975	-1.E-02	1.0E-02
2.00	1.00	-1.96E-02*	.004	.000	-3.E-02	-9.E-03
	3.00	-1.94E-02*	.004	.000	-3.E-02	-9.E-03
3.00	1.00	-1.25E-04	.004	.975	-1.E-02	1.0E-02
	2.00	1.945E-02*	.004	.000	9.1E-03	3.0E-02

*. The mean difference is significant at the .01 level.

Copper

Tests of Between-Subjects Effects

Dependent Variable: CU

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	8150.801[b]	35	232.880	3.973	.000	.436	139.072	1.000
Intercept	126949	1	126949	2166.047	.000	.923	2166.047	1.000
SITE	920.994	2	460.497	7.857	.001	.080	15.714	.950
DATE	4391.001	11	399.182	6.811	.000	.294	74.921	1.000
SITE * DATE	2838.806	22	129.037	2.202	.002	.212	48.437	.994
Error	10549.5	180	58.608					
Total	145649	216						
Corrected Total	18700.3	215						

a. Computed using alpha = .05

b. R Squared = .436 (Adjusted R Squared = .326)

Lead

Tests of Between-Subjects Effects

Dependent Variable: PB

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	7.2E-02[b]	35	2.1E-03	4.985	.000	.492	174.482	1.000
Intercept	1.178	1	1.178	2847.583	.000	.941	2847.583	1.000
SITE	1.5E-03	2	7.5E-04	1.813	.166	.020	3.626	.173
DATE	5.2E-02	11	4.8E-03	11.526	.000	.413	126.790	1.000
SITE * DATE	1.8E-02	22	8.3E-04	2.003	.007	.197	44.066	.946
Error	7.4E-02	180	4.1E-04					
Total	1.325	216						
Corrected Total	.147	215						

a. Computed using alpha = .01

b. R Squared = .492 (Adjusted R Squared = .393)

Post Hoc Tests

SITE

Homogeneous Subsets

PB

Student-Newman-Keuls[a,b]

SITE	N	Subset 1
3.00	72	7.0E-02
1.00	72	7.4E-02
2.00	72	7.7E-02
Sig.		.142

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. Alpha = .01.

Tests of Between-Subjects Effects

Dependent Variable: HG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	3.1E-03[b]	35	8.8E-05	4.223	.000	.451	147.813	1.000
Intercept	6.4E-02	1	6.4E-02	3057.949	.000	.944	3057.949	1.000
SITE	1.7E-04	2	8.4E-05	4.041	.019	.043	8.082	.479
DATE	2.1E-03	11	1.9E-04	8.926	.000	.353	98.183	1.000
SITE * DATE	8.7E-04	22	3.9E-05	1.889	.013	.188	41.548	.926
Error	3.8E-03	180	2.1E-05					
Total	7.1E-02	216						
Corrected Total	6.8E-03	215						

a. Computed using alpha = .01

b. R Squared = .451 (Adjusted R Squared = .344)

Post Hoc Tests

SITE

Homogeneous Subsets

HG

Student-Newman-Keuls[a,b]

SITE	N	Subset 1
2.00	72	1.6E-02
3.00	72	1.8E-02
1.00	72	1.8E-02
Sig.		.035

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. Alpha = .01.

Molydenum

Tests of Between-Subjects Effects

Dependent Variable: MO

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	.107[b]	35	3.1E-03	22.618	.000	.815	791.614	1.000
Intercept	1.193	1	1.193	8784.818	.000	.980	8784.818	1.000
SITE	6.5E-03	2	3.2E-03	23.894	.000	.210	47.787	1.000
DATE	8.4E-02	11	7.6E-03	56.094	.000	.774	617.035	1.000
SITE * DATE	1.7E-02	22	7.8E-04	5.763	.000	.413	126.792	1.000
Error	2.4E-02	180	1.4E-04					
Total	1.325	216						
Corrected Total	.132	215						

a. Computed using alpha = .01

b. R Squared = .815 (Adjusted R Squared = .779)

Post Hoc Tests

SITE

Homogeneous Subsets

MO

Student-Newman-Keuls[a,b]

SITE	N
2.00	72
1.00	72
3.00	72

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. There are no homogeneous subsets for alpha = .01.

Nickel

Tests of Between-Subjects Effects

Dependent Variable: NI

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	1.210[b]	35	3.5E-02	1.659	.018	.244	58.050	.965
Intercept	7.384	1	7.384	354.215	.000	.663	354.215	1.000
SITE	4.0E-02	2	2.0E-02	.951	.388	.010	1.901	.077
DATE	.800	11	7.3E-02	3.490	.000	.176	38.395	.974
SITE * DATE	.370	22	1.7E-02	.807	.715	.090	17.754	.381
Error	3.752	180	2.1E-02					
Total	12.347	216						
Corrected Total	4.962	215						

a. Computed using alpha = .01

b. R Squared = .244 (Adjusted R Squared = .097)

Post Hoc Tests

SITE

Homogeneous Subsets

NI

Student-Newman-Keuls[a,b]

SITE	N	Subset 1
2.00	72	.1657
1.00	72	.1944
3.00	72	.1946
Sig.		.455

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. Alpha = .01.

Tests of Between-Subjects Effects

Dependent Variable: SE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	6.332[b]	35	.181	11.410	.000	.689	399.355	1.000
Intercept	107.118	1	107.118	6755.658	.000	.974	6755.658	1.000
SITE	.258	2	.129	8.135	.000	.083	16.270	.863
DATE	5.239	11	.476	30.039	.000	.647	330.434	1.000
SITE * DATE	.835	22	3.8E-02	2.393	.001	.226	52.651	.983
Error	2.854	180	1.6E-02					
Total	116.304	216						
Corrected Total	9.186	215						

a. Computed using alpha = .01

b. R Squared = .689 (Adjusted R Squared = .629)

Post Hoc Tests

SITE

Homogeneous Subsets

SE

Student-Newman-Keuls[a,b]

SITE	N	Subset 1
3.00	72	.6712
1.00	72	.6894
2.00	72	
Sig.		.386

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. Alpha = .01.

Zinc

Tests of Between-Subjects Effects

Dependent Variable: ZN

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	5859170[b]	35	167405	3.648	.000	.415	127.686	1.000
Intercept	6.2E+07	1	6.2E+07	1358.013	.000	.883	1358.013	1.000
SITE	1430415	2	715207	15.586	.000	.148	31.172	.995
DATE	2108218	11	191656	4.177	.000	.203	45.943	.993
SITE * DATE	2320537	22	105479	2.299	.001	.219	50.570	.977
Error	8259725	180	45887.4					
Total	7.6E+07	216						
Corrected Total	1.4E+07	215						

a. Computed using alpha = .01

b. R Squared = .415 (Adjusted R Squared = .301)

Post Hoc Tests

SITE

Homogeneous Subsets

ZN

Student-Newman-Keuls[a,b]

SITE	N	Subset 1
2.00	72	
3.00	72	571.0000
1.00	72	615.4306
Sig.		.213

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares

a. Uses Harmonic Mean Sample Size = 72.000.

b. Alpha = .01.

APPENDIX G: CORRELATION MATRICES OF MEAN CONCENTRATIONS OF METALS AMONG SITES OVER TIME

Correlations

		AS1	AS2	AS3
Pearson Correlation	AS1	1.000	.730**	.720**
	AS2	.730**	1.000	.808**
	AS3	.720**	.808**	1.000
Sig. (2-tailed)	AS1	.	.007	.008
	AS2	.007	.	.001
	AS3	.008	.001	.
N	AS1	12	12	12
	AS2	12	12	12
	AS3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		CD1	CD2	CD3
Pearson Correlation	CD1	1.000	.515	.643*
	CD2	.515	1.000	.741**
	CD3	.643*	.741**	1.000
Sig. (2-tailed)	CD1	.	.087	.024
	CD2	.087	.	.006
	CD3	.024	.006	.
N	CD1	12	12	12
	CD2	12	12	12
	CD3	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		CO1	CO2	CO3
Pearson Correlation	CO1	1.000	.721**	.214
	CO2	.721**	1.000	.383
	CO3	.214	.383	1.000
Sig. (2-tailed)	CO1	.	.008	.505
	CO2	.008	.	.220
	CO3	.505	.220	.
N	CO1	12	12	12
	CO2	12	12	12
	CO3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		CR1	CR2	CR3
Pearson Correlation	CR1	1.000	.704*	.589*
	CR2	.704*	1.000	.766**
	CR3	.589*	.766**	1.000
Sig. (2-tailed)	CR1	.	.011	.044
	CR2	.011	.	.004
	CR3	.044	.004	.
N	CR1	12	12	12
	CR2	12	12	12
	CR3	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		CU1	CU2	CU3
Pearson Correlation	CU1	1.000	.716**	.462
	CU2	.716**	1.000	.348
	CU3	.462	.348	1.000
Sig. (2-tailed)	CU1	.	.009	.131
	CU2	.009	.	.268
	CU3	.131	.268	.
N	CU1	12	12	12
	CU2	12	12	12
	CU3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		MG1	MG2	MG3
Pearson Correlation	MG1	1.000	.736**	.431
	MG2	.736**	1.000	.598*
	MG3	.431	.598*	1.000
Sig. (2-tailed)	MG1	.	.006	.162
	MG2	.006	.	.040
	MG3	.162	.040	.
N	MG1	12	12	12
	MG2	12	12	12
	MG3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		NI1	NI2	NI3
Pearson Correlation	NI1	1.000	.649*	.550
	NI2	.649*	1.000	.576
	NI3	.550	.576	1.000
Sig. (2-tailed)	NI1	.	.023	.064
	NI2	.023	.	.050
	NI3	.064	.050	.
N	NI1	12	12	12
	NI2	12	12	12
	NI3	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		PB1	PB2	PB3
Pearson Correlation	PB1	1.000	.749**	.457
	PB2	.749**	1.000	.725**
	PB3	.457	.725**	1.000
Sig. (2-tailed)	PB1	.	.005	.135
	PB2	.005	.	.008
	PB3	.135	.008	.
N	PB1	12	12	12
	PB2	12	12	12
	PB3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		SE1	SE2	SE3
Pearson Correlation	SE1	1.000	.871**	.770**
	SE2	.871**	1.000	.840**
	SE3	.770**	.840**	1.000
Sig. (2-tailed)	SE1	.	.000	.003
	SE2	.000	.	.001
	SE3	.003	.001	.
N	SE1	12	12	12
	SE2	12	12	12
	SE3	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		ZN1	ZN2	ZN3
Pearson Correlation	ZN1	1.000	.461	.295
	ZN2	.461	1.000	-.078
	ZN3	.295	-.078	1.000
Sig. (2-tailed)	ZN1	.	.132	.352
	ZN2	.132	.	.810
	ZN3	.352	.810	.
N	ZN1	12	12	12
	ZN2	12	12	12
	ZN3	12	12	12

APPENDIX H: CORRELATION MATRICES COMPARING MEAN METAL CONCENTRATIONS WITH ENVIRONMENTAL PARAMETERS

Correlations

		BROWN	COND	DIFFUSE	LEYDIG	LOCAL	TEMP
Pearson Correlation	BROWN	1.000	-.343*	-.243	.442**	.256	-.134
	COND	-.343*	1.000	.588**	.175	.136	.643**
	DIFFUSE	-.243	.588**	1.000	.145	-.133	.820**
	LEYDIG	.442**	.175	.145	1.000	.123	.192
	LOCAL	.256	.136	-.133	.123	1.000	-.134
	TEMP	-.134	.643**	.820**	.192	-.134	1.000
Sig. (2-tailed)	BROWN	.	.040	.153	.007	.132	.437
	COND	.040	.	.000	.307	.430	.000
	DIFFUSE	.153	.000	.	.399	.441	.000
	LEYDIG	.007	.307	.399	.	.474	.261
	LOCAL	.132	.430	.441	.474	.	.435
	TEMP	.437	.000	.000	.261	.435	.
N	BROWN	36	36	36	36	36	36
	COND	36	36	36	36	36	36
	DIFFUSE	36	36	36	36	36	36
	LEYDIG	36	36	36	36	36	36
	LOCAL	36	36	36	36	36	36
	TEMP	36	36	36	36	36	36

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX I: POWER ANALYSES

Analysis of the power of statistical tests used in environmental biomonitoring have only recently attracted the attention of ecologists (Fairweather 1991).

Power is inversely related to the probability of making a Type II error (ie. low power indicates a high probability of a Type II error). In the context of environmental monitoring, a Type II error is made when it is concluded that no environmental impacts has occurred even through one has.

"Power procedures are concerned with the statistical significance of the null hypothesis, and they lend little insight, on their own into workings of nature. Power analyses are, however, essential to designing sensitive tests and correctly interpreting their results. The most compelling reason for considering power is that Type II errors can be more costly than Type I errors for environmental management. This is because the commitment of time, energy and people to fighting a false alarm (a Type I error) may continue only in the short term until the mistake is discovered. In contrast, the cost of not doing something when in fact it should be done (a Type II error) will have both short-term and long-term costs (eg. ensuing environmental degradation and the eventual cost of its rectification). Low power can be disastrous for environmental monitoring programmes." (Fairwather 1991, p55).

In a hypothesis-testing framework, two conclusions may be drawn from a monitoring study: ie. There is, or there is not, an impact. However, it is possible that either of these conclusions may be wrong. If it is falsely believed that there is an impact (a "false alarm"), a Type I error is made. The probability of this error being made is determined by the significance or confidence level of a that has been set for the test (eg. the conclusion is wrong 1 in 20 times for $a = 0.05$). In contrast, a Type II error involves the false conclusion that there is no impact, when in fact there is one. The probability of a Type II error being made is determined by the value of b, and the statistical power of the test is $1-b$ (Sokal and Rohlf 1981, Fairweather 1991). High power (close to 1) thus indicates a lower risk of a Type II error, and the power of any test that is done should be as large as possible to minimise the risk of a Type II error. According to Fairweather (1991) and Cohen (in Hintz 1991), the emerging convention is that power should preferably be equal to at least 0.8.

8 Flora and fauna



Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

October 1999

Gunninah Environmental Consultants

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

October 1999

Project Team:

F Dominic Fanning
Jayne Tipping
Amelia Hurren
Rebecca Hayes
Felicity Hargraves
Samantha Lloyd
Steve Chamberlain
Clare de Lacey
Matthew Chambers
Anne Carey
Alex Cowdery

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

Flora & Fauna Assessment

October 1999

TABLE of CONTENTS

			Page
SECTION A		INTRODUCTION & METHODS	1
1		INTRODUCTION	1
	1.1	Background	1
	1.2	Aims	1
2		METHODS - FIELD INVESTIGATIONS & LITERATURE REVIEW	2
	2.1	Flora	2
	2.2	Fauna	3
SECTION B		THE EXISTING ENVIRONMENT	5
3		GENERAL FEATURES	5
4		FLORA	5
	4.1	Vegetation Communities	5
		4.1.1 Vegetation Communities	5
		4.1.2 Woodland/Open Forest Communities	6
		4.1.3 Cleared Pasture/Highly Modified Woodland	8
	4.2	Flora Species of Conservation Concern	8
		4.2.1 Species Recorded in the Study Area	9
		4.2.2 Species Recorded in the Surrounding Area	11
5		FAUNA	12
	5.1	Fauna Habitats	12
		5.1.1 Woodland/Open Forest Habitats	12
		5.1.2 Riverine & Wetland Habitats	13
		5.1.3 Highly Modified Woodland/Cleared Pasture Habitats	14
	5.2	Native Fauna Recorded	15
		5.2.1 Birds	15
		5.2.2 Mammals	16
		5.2.3 Reptiles	18
		5.2.4 Amphibians	18
	5.3	Fauna Species of Conservation Concern	18
		5.3.1 Threatened Fauna Recorded in the Study Area	19
		5.3.2 Threatened Fauna Known from the Surrounding Area	23
SECTION C		IMPACTS AND AMELIORATION	27
6		POTENTIAL IMPACTS OF THE PROPOSAL	27
	6.1	Habitat Removal	28
	6.2	Flora	28
	6.3	Fauna	29
	6.4	Barrier Formation	31
	6.5	Wildlife Corridors	33
	6.6	Habitat Fragmentation	33
	6.7	Wildlife Mortality	34
	6.8	Disturbance and Degradation of Adjacent Habitat	34
	6.9	Alteration of Hydrologic Regimes	35
	6.10	SEPP 14 - Coastal Wetlands	36

6.11 SEPP 44/Koala Habitat Protection 36
6.12 Karuah Nature Reserve 37
6.13 Cumulative Impacts 38

7 SIGNIFICANCE OF POTENTIAL IMPACTS 39

8 ENVIRONMENTAL MANAGEMENT AND IMPACT AMELIORATION 39

8.1 General Measures 39

8.2 Specific Measures 40
8.2.1 Flora 41
8.2.2 Fauna 41
8.2.3 SEPP14 Wetlands 42

BIBLIOGRAPHY 43

APPENDICES

1 Vegetation Communities
2 Flora Species Recorded
3 Fauna Survey Methods
4 Fauna Species Recorded
5 Migratory Bird Species
6 Details of Fauna Recorded
7 Assessment of Significance Pursuant to Section 5A of the EP&A Act

TABLES

1 Flora species listed under the TSC Act and those of regional conservation concern, recorded during field investigations conducted along the proposed Horse Island Route for the Pacific Highway upgrade at Karuah.
2 National conservation status codes for Rare Or Threatened Australian Plants (ROTAP) species (Briggs & Leigh 1996).
3 Locations of threatened fauna species recorded during field surveys along the proposed Horse Island Route option and in the surrounding area.
4 Threatened fauna and flora species recorded during the field investigation in the Karuah Upgrade study area.

FIGURES

1 General location of the proposed Karuah Bypass (Horse Island Route) of the Pacific Highway.
2 Location of study area of the Proposed Karuah Bypass (Horse Island Route), and surrounding land uses.
3 Aerial map of Karuah including study area of Proposed Karuah Bypass (Horse Island Route).
4 SEPP 14 Wetlands in the vicinity of the Proposed Karuah Bypass (Horse Island Route).
5 Aerial photograph of Karuah outlining the study area of the Proposed Karuah Bypass (Horse Island Route), and the location of flora survey sites and transects.
6 Topographic map of Karuah outlining the Proposed Bypass (Horse Island Route) study area and the location of fauna survey sites and transects.
7a Topographic map of the western section of the Proposed Karuah Bypass (Horse Island Route) and the vegetation communities present within the study area.
7b Topographic map of the eastern section of the Proposed Karuah Bypass (Horse Island Route) and the vegetation communities present within the study area.
8 Topographic map of the proposed Karuah Bypass (Horse Island Route) and the location of subject flora and fauna species identified from field surveys.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

October 1999

SECTION A INTRODUCTION & METHODS

1 INTRODUCTION

1.1 Background

The NSW Roads & Traffic Authority (RTA) proposes to upgrade the Pacific Highway (State Highway 10) at Karuah on the mid-north coast of NSW (Figure 1), as part of a project to provide a high-grade freeway between Sydney and Brisbane.

Several options were considered with regard to the proposed roadworks, including either the upgrading of the existing Highway through Karuah, or a bypass of the town to the north. The RTA had identified a 'main study area' for the route options assessment process (Figure 2 & 3), which was investigated by Gunninah Environmental Consultants (Gunninah) in 1997 (Gunninah 1997a).

An additional route, the proposed Horse Island option (located approximately 3km north of the main study area - Figure 2), was subsequently suggested by local residents as a possible alternative route for the proposed Pacific Highway upgrade at this locality. A preliminary desk-top study was subsequently conducted (Gunninah 1997d), followed by the completion of a Preliminary Flora & Fauna Assessment of the route in April 1998 (Gunninah 1998a).

The Preliminary Flora & Fauna Assessment detailed a broad investigation of the proposed Horse Island Route option and surrounding area, to determine the conservation value of the landscape and natural features to be traversed by the proposed alignment, and to provide input into the route selection process. The report was prepared on the basis of published information regarding native flora and fauna and their habitats in the general area, and some dedicated flora and fauna surveys along the proposed Horse Island alignment and in the surrounding area (as documented in this report).

Following consideration of the various route options for the proposed Pacific Highway Upgrade at Karuah, the Horse Island Route option was selected as the 'preferred option'. Further detailed investigations of the route have been conducted to more comprehensively document the existing environment and to ascertain the likely or potential impacts of the activity on native flora and fauna[1].

1.2 Aims

The aims of the biological investigation and this Flora & Fauna Assessment report are:

- to describe the flora and vegetation communities present along the proposed Horse Island Route alignment, and to assess their condition;

[1] This document concentrates on the field investigations which have been conducted on the native biota and habitats along the Horse Island Route, which is defined as the 'study area'. The report also includes consideration of biological investigations for the route selection process, and includes surveys conducted up to mid-1998 specifically for the Horse Island Route. However, this report, for completeness, has also included the more detailed vegetation community investigations conducted in late 1998. Conversely, this report does not incorporate the detailed additional investigations conducted pursuant to the NP&WS Director-General's Requirements for the Species Impact Statement (SIS), which has been subsequently prepared for the project by Gunninah Environmental Consultants. The SIS was initiated prior to the completion of the final edits to this report, and the SIS focuses on those threatened and other biota identified as of relevance pursuant to the *NSW Threatened Species Conservation Act 1995* and the Director-General's Requirements for the SISs.



Karuah FFA
Project No. 98071

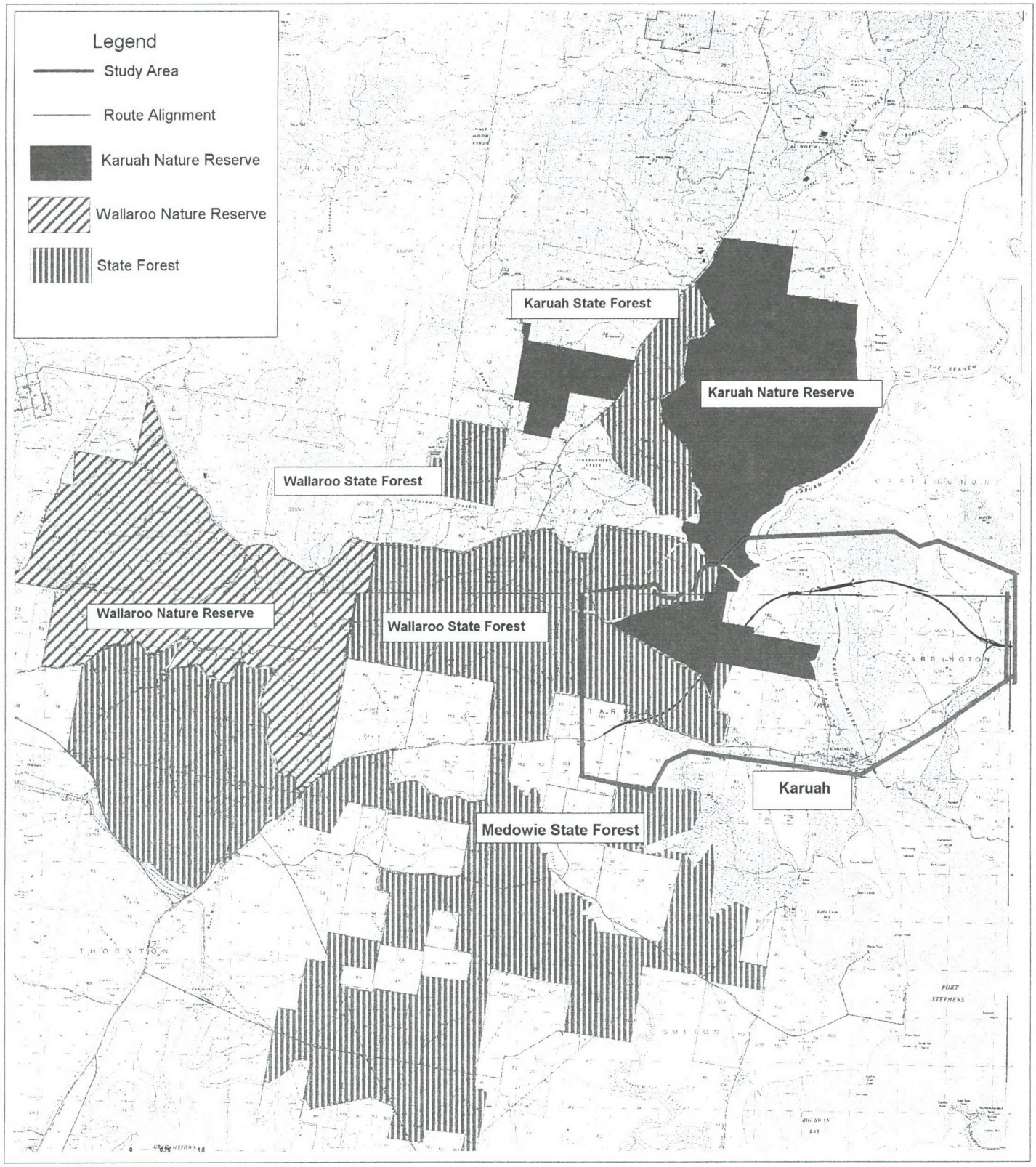
Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 7770

0 30
Kilometres

Figure 1 **General location of the Proposed Karuah Bypass (Horse Island Route) of the Pacific Highway.**

N

Version 6 8th October 1999



Karuah FFA
Project No. 98071

Gunninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 770

N

0 1.5 3
Kilometres

Figure 2 Location of study area of the Proposed Karuah Bypass (Horse Island Route), and surrounding land uses.

Version: 4 8th October 1999



Karuah FFA
Project No. 98071

Gunninah Environmental Consultants

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

Figure 3 **Aerial map of Karuah including study area of Proposed Karuah Bypass (Horse Island Route).**

Version 3 6th October 1999

- to describe the fauna habitats present along the alignment and assess their condition, and to determine the fauna assemblage likely to occur;
- to determine the conservation significance of native biota identified along the alignment or considered likely to occur;
- to determine the potential for adverse impacts to be imposed on native biota and habitats by the proposed Horse Island bypass of the Pacific Highway at Karuah;
- to consider the significance of potential impacts arising from the proposed roadworks with respect to Section 5A (s.5A) of the *NSW Environmental Planning & Assessment Act 1979* (EP&A Act), as modified by the *NSW Threatened Species Conservation Act 1995* (TSC Act);
- to determine the requirement for a Species Impact Statement (SIS) to be prepared; and
- to recommend environmental management and impact amelioration measures which should be applied along the proposed alignment to reduce potential impacts which could be imposed on native biota and their habitats.

2 METHODS - FIELD INVESTIGATIONS & LITERATURE REVIEW

The Horse Island Route study area (Figure 3) is defined as that area specifically surveyed for the Horse Island alignment. The study area includes those areas of vegetation likely to be affected by the proposed Karuah Bypass (Horse Island Route), as well as adjacent vegetation in State Forests and Nature Reserves, on private land, and cleared agricultural lands.

Information from other investigations conducted in the immediate vicinity or at sites which overlap the Horse Island Route study area (Gunninah 1997b, c) have been consulted for relevant records of the native biota and habitats, and particularly for records of threatened species. Previous investigations in the Karuah area, which partially overlap the Karuah Bypass (Horse Island Route) study area, include:

- the route selection studies for the Karuah Bypass (Gunninah 1997a, d, 1998a);
- the Karuah Quarry - at the eastern end of the alignment (Ecotone 1995; Gunninah 1997c);
- the Karuah sewerage treatment works (not completed) - near the western end of the alignment (ERM Mitchell McCotter) and
- the Raymond Terrace to Karuah upgrade of the Pacific Highway (Gunninah 1997b).

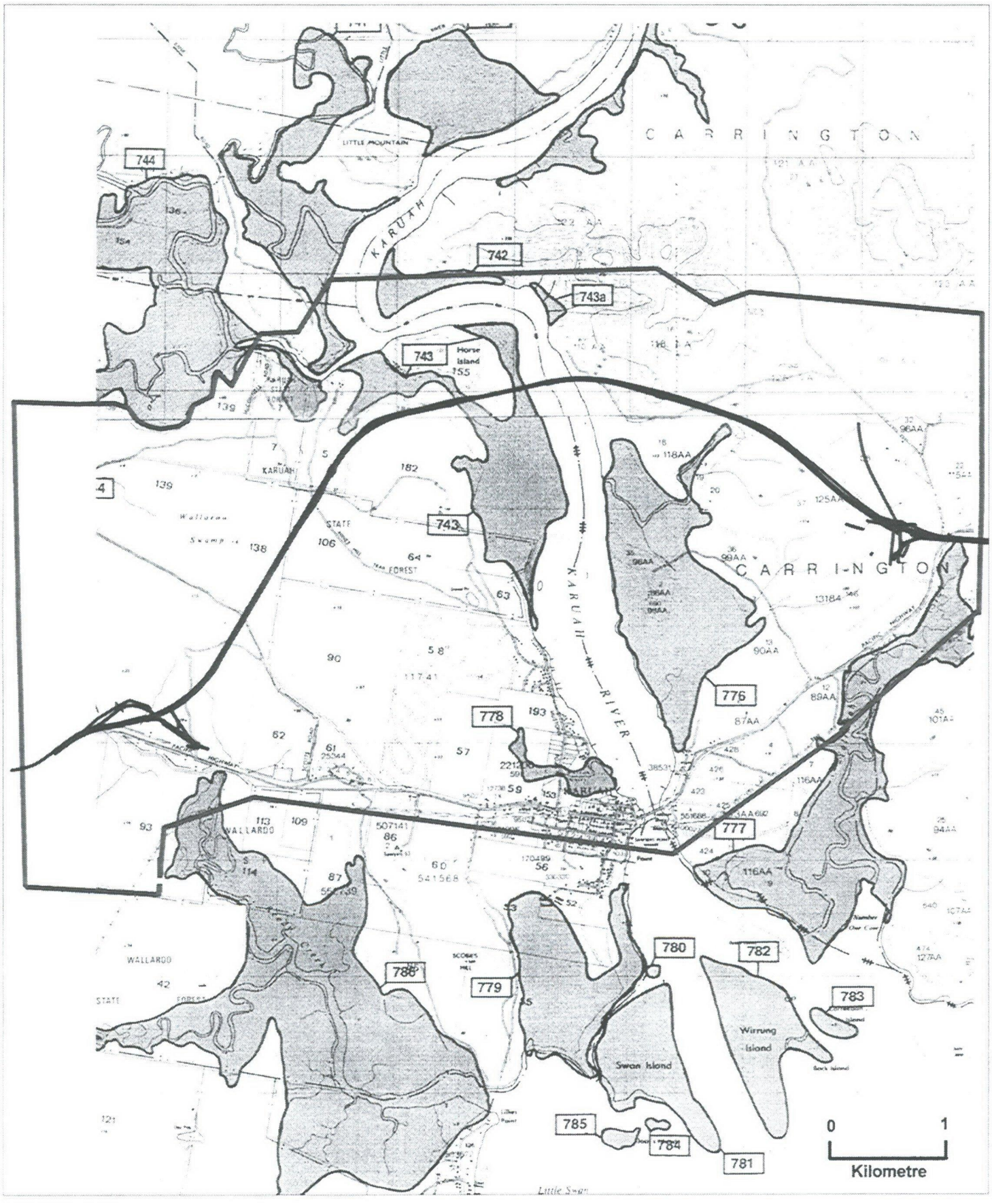
These investigations provide information regarding vegetation, fauna habitats and plant and animal assemblages of the area, with particular emphasis on threatened and endangered species.

Preliminary appraisal of the study area, and the extent of vegetation communities and natural features (such as wetlands) present, was conducted using aerial photography, topographic maps and *State Environmental Planning Policy No.14 - Coastal Wetlands* (SEPP 14) maps (Figure 4). The preliminary appraisal was followed by more detailed flora and fauna surveys.

2.1 Flora

A general botanical survey of the study area was conducted on the 22nd and 23rd of December 1997 (Appendix 3), involving walked surveys according to the Random Meander technique (Cropper 1993).

In addition, detailed surveys were conducted in November 1998 (10th to 13th inclusive), involving fourteen extensive random surveys (Cropper 1993) and thirty dedicated quadrats



Karuah FFA

Project No. 98071

Gunninah Environmental Consultants

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

Figure 4 **SEPP 14 Wetlands within the vicinity of the Proposed Karuah Bypass (Horse Island Route).**

Version 6 8th October 1999

along the alignment (Figure 5). The vegetation quadrats are standard 20m x 20m (*ie* 400m^2) and were intensively surveyed (all plant species present recorded).

All vegetation communities present were described, mapped (Appendix 1; Figure 7a & 7b), 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 2). 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). 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.

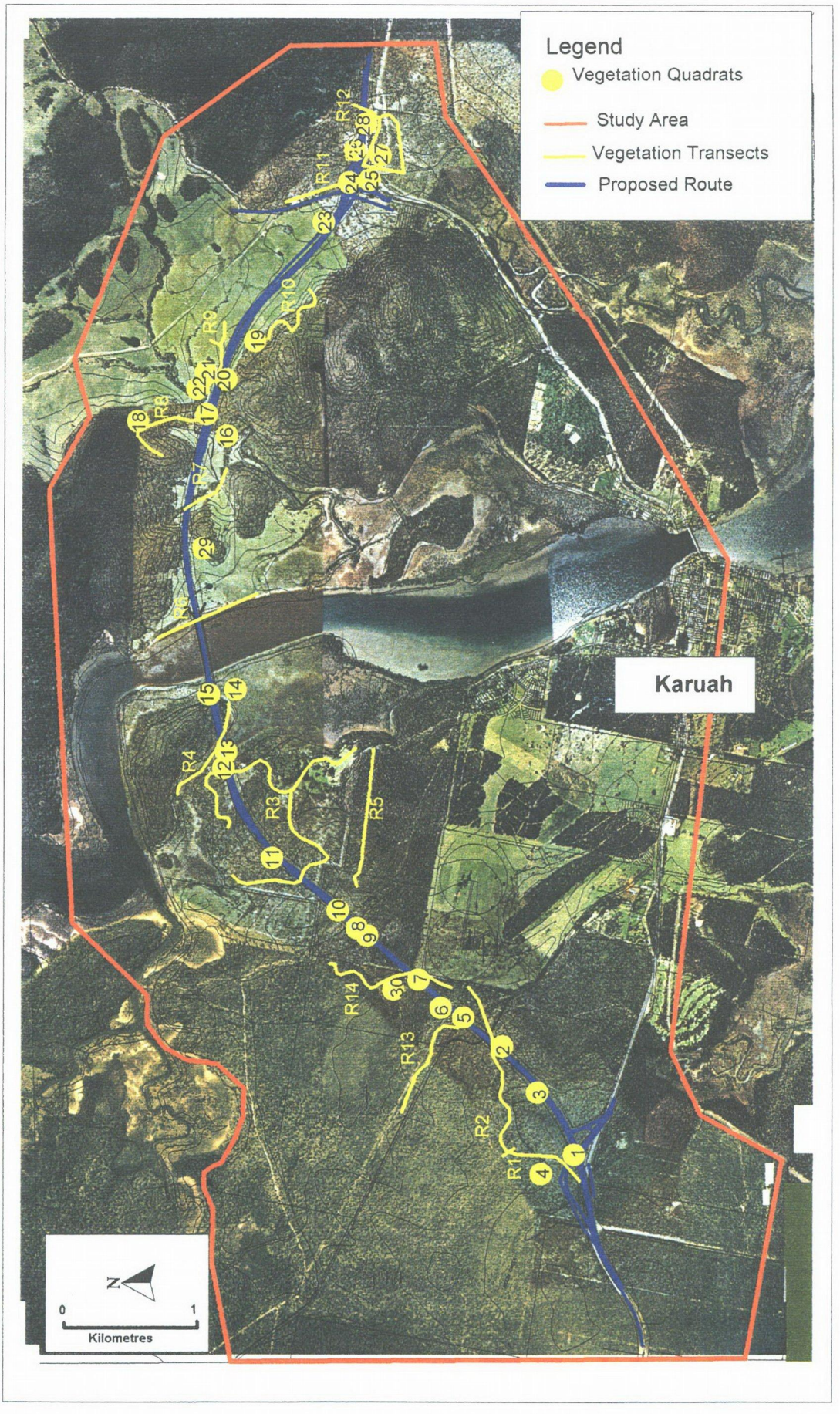
Targeted surveys were conducted in woodland/open forest communities in the study area for *Tetratheca juncea*, a threatened species which has been recorded recently in the surrounding area (Ecotone 1995; Gunninah 1997a, c). Broad-scale searches were conducted during the initial study area inspection (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.

2.2 Fauna

Field investigations for native fauna were conducted throughout all habitats in the study area between the 26th of February and the 6th of March 1998, involving ten person-days. Fauna survey methods are outlined below, with a more detailed description of specific techniques used, survey effort and survey locations provided in Appendix 3 and Figure 6. Weather conditions throughout the fauna survey are also provided in Appendix 3. An inventory of all fauna species recorded during the field surveys is provided in Appendix 4.

A combination of standard fauna survey techniques was employed throughout the study area, including both diurnal and nocturnal survey methods. Diurnal investigations involved avifauna surveys (including specific waterbird surveys in wetland habitats), Koala surveys (including scat and scratch searches, and direct observations) and dedicated searches for herpetofauna in areas of suitable habitat. Evening investigations included mammal trapping, spotlighting surveys for mammals and other nocturnal fauna, use of call playback to detect owl species, surveys for microchiropteran bats using Anabat II ultra-sonic call detectors and harp traps, and riparian/wetland searches for herpetofauna (Appendix 3; Figure 6).

The proposed Horse Island Route and the surrounding area were divided into three broad areas for the purposes of diurnal and nocturnal herpetofaunal searches: Sector 1 including the western section of the proposed alignment (from the existing Pacific Highway to approximately 1km past Wallaroo Swamp), Sector 2 including the central part of the route (from 1km past Wallaroo Swamp to the Karuah River crossing, including Horse Island), and Sector 3 covering the remaining eastern section of the route (from the Karuah River to the existing Highway).



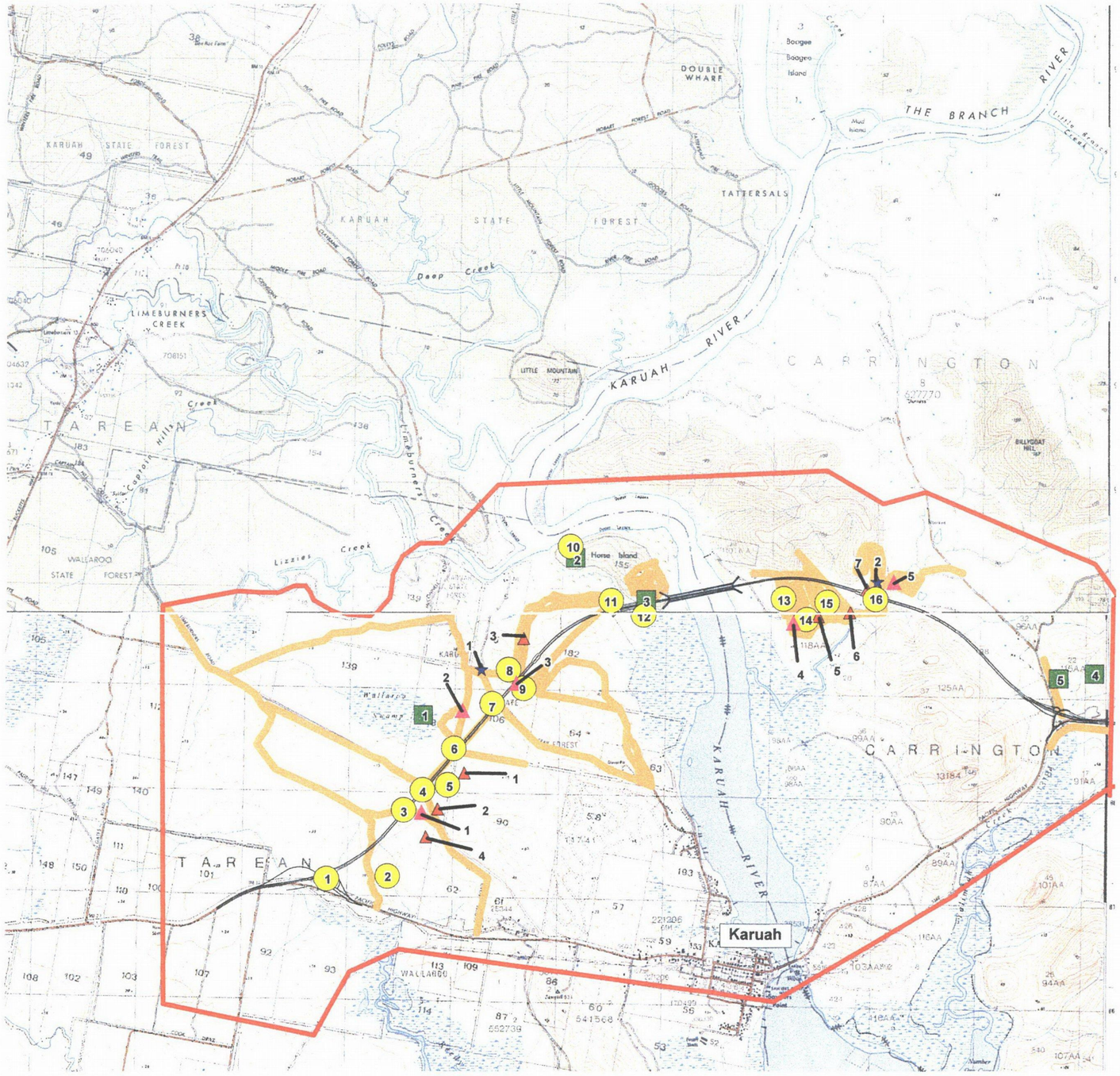
Karuah FFA
Project no. 98071

Gunninah Environmental Consultants

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

Figure 5 **Aerial map of Karuah outlining the study area of the Proposed Karuah Bypass (Horse Island Route) and the location of flora survey sites and transects.**

Version: 3 8th October 1999



Legend

- Koala Plot
- Nocturnal playback
- Harp Trap
- Anabat recordings
- Elliot/cage/hair tube trapping
- Study area
- Spotlighting
- Proposed Horse Island Route

Karuah FFA

Project No. 98071

Gunninah Environmental Consultants

Phone: (02) 9906 5436 Fax: (02) 9906 770

Figure 6

Topographic map of Karuah outlining the Proposed Bypass (Horse Island Route) study area and the location of fauna survey sites and transects.

N

0 1

Kilometre

Trapping surveys for mammalian fauna were conducted in areas of suitable habitat, with special attention paid to detecting the presence of several species of threatened fauna which are known from the general area. However, it is recognised that trapping was not undertaken in all vegetation communities and further trapping in all vegetation communities was undertaken for the SIS (Gunninah 1999c). Harp traps were erected at various locations (in suitable flyways) for the capture and identification of microchiropteran bats. Small native terrestrial mammals (including dasyurids and rodents) and arboreal mammals (such as the Brush-tailed Phascogale) were searched for using ground-based and tree-mounted Elliott traps. Cage traps were deployed to survey for medium-sized terrestrial fauna such as bandicoots and quolls, and arboreal mammals (such as the Common Brushtail Possum). Hair tubes were also deployed as an additional means of detecting native mammals in the area (Appendix 3; Figure 6).

General habitat details were also noted during the diurnal field investigations. Particular attention was paid to the possible presence of features or resources which could be of potential significance for native fauna, and for threatened fauna known from the vicinity, in particular the Koala, Squirrel Glider, Brush-tailed Phascogale, Tiger Quoll and several microchiropteran bat and avifauna species. General habitat searches included investigations of trees and tree-hollows for evidence of the presence of arboreal mammals (*eg* scratches, sap incisions, dreys, nests, evidence of foraging), and general searches for indirect evidence of native fauna (such as scats, prints, white-wash, remains [feathers, bones, fur], scents, burrows and diggings).

Further to standard survey techniques, records of fauna species from previous fauna studies conducted in the surrounding area (Ecotone 1995; Gunninah 1997a, b, c) were collated. Records of threatened fauna species or migratory birds of international conservation concern that occur in the mid-north coast region and which could possibly occur in the study area were obtained from the NP&WS Wildlife Atlas and the Birds Australia database[2]. In the case of the NP&WS Wildlife Atlas, generally only those threatened species recorded within a 10km radius of the study area were considered relevant for consideration.

[2] Database obtained from Birds Australia, formerly the Royal Australasian Ornithologists Union.

3 GENERAL FEATURES

Karuah is surrounded by extensive tracts of forest and woodland, much of which is located within Karuah, Wallaroo and Medowie State Forests (Figure 2 & 3) or recent additions to the Karuah Nature Reserve (NR). There are also many natural wetlands in the vicinity, the majority of which are protected under SEPP 14. These comprise both freshwater and estuarine (mangrove and saltmarsh) communities, and are located along the Karuah River and other major creeklines in the area (Figure 4). The wetland and woodland and forest communities occurring along the proposed Horse Island Route are representative of the communities present in the surrounding area (DF *pers obs*).

The proposed Horse Island Route is approximately 9.4km long and is located north of the existing Pacific Highway at Karuah. The proposed alignment deviates from the existing Highway 4.5km west of Karuah, crosses the Karuah River at Horse Island (3.5km to the north of the current Highway crossing), and re-aligns with the Pacific Highway 4km east of Karuah, as indicated in (Figures 1 & 2).

The majority of the western portion of the proposed alignment traverses substantial tracts of open forest/woodland within Wallaroo and Karuah State Forests (SFs) and a small portion of the recently gazetted Karuah NR (Figure 2). The route then passes eastwards through an area of semi-cleared and forested private land to the south of Horse Island. The proposed alignment crosses the Karuah River at the southern-most end of Horse Island, traversing SEPP 14 wetlands (#743) surrounding the Island and along the western bank of the Karuah River (Figure 4). After crossing the River, the eastern portion of the alignment traverses cleared pasture and areas of forested private land.

SEPP 14 wetlands, associated with Reedy Creek (#786) and Yalimbah Creek (#777), also occur to the south of the existing Pacific Highway, near the western and eastern ends of the proposed Horse island alignment respectively (Figures 4).

4 FLORA

4.1 Vegetation Communities

An outline of the main vegetation communities recorded along the proposed Horse Island Route option is provided below, with a detailed description of the vegetation communities recorded along the proposed alignment and in the general study area provided in Appendix 1. The location and extent of wetlands and of the vegetation communities is indicated in Figure 6, and an inventory of all plant species recorded during the field investigations is provided in Appendix 2.

Ten vegetation communities have been identified and described along the Horse Island alignment of the Karuah Bypass, representing three main vegetation types:

- estuarine and freshwater wetlands;
- dry woodland and open forest communities; and
- cleared pasture or highly modified.

4.1.1 Estuarine and Freshwater Wetland Communities

Wetland communities and vegetation which is regularly or occasionally inundated along the Horse Island Route alignment and in the vicinity includes:

- freshwater wetlands - sedgeland;

- low forest/closed low forest (paperbark swamps);
- mangrove open scrub; and
- saltmarsh.

A significant feature of the proposed Horse Island Route is the presence of wetland communities mapped and protected under SEPP 14. These communities comprise estuarine mangrove forest and saltmarsh communities within the intertidal zone along the western bank of the Karuah River and surrounding Horse Island, and fringing sedgeland/rushland and swamp forest (Figure 4). The wetland communities generally appear relatively intact, with only minimal levels of disturbance in areas adjacent to private property.

The wetland communities present display a number of zones of differing structure and floristic characteristics, depending on elevation, tidal patterns, degrees of salinity and the varying salt tolerance of flora species (Benson 1986). Mangrove open scrub occurs along the seaward side of the estuarine mudflats which are regularly inundated, and in shallows along inlets and creeklines. This community mainly comprises Grey Mangrove *Avicennia marina* var *australasica*, with occasional isolated individual River Mangrove *Aegiceras corniculatum*. Understorey and groundcover species are absent until the transition with saltmarsh communities.

Saltmarsh communities generally occur behind the mangrove scrub community in areas which are inundated by salt water during very high tides or periods of flooding. This community comprises predominantly halophytic shrub and herb species, including *Sarcocornia quinqueflora* and *Suaeda australis*. Salt-tolerant species from adjacent sedgeland communities are also present, including Sea Rush *Junks krausii*, *Baumea juncea*, *Trichoglin striata*, *Cotula coronopiflora* and *Bolboschoenus caldwellii*.

The saltmarsh communities are commonly bordered by sedgeland/rushland species in areas which only experience occasional inundation. Typical species include the salt-tolerant species listed above, as well as Prickly Couch *Zoysia macrantha*, *Isolepis nodosus* and *Sporobolus virginicus* var *minor*. Other less frequently occurring species include *Phragmites australis* and *Selliera radicans*.

A fringing band of low open swamp forest to 15m in height occurs on low-lying banks and creek flats in adjacent areas. The upper canopy is characterised by Swamp Oak *Casuarina glauca* and Cabbage Gum *Eucalyptus amplifolia*, with occasional Swamp Mahogany *E robusta* and Rough-barked Apple *Angophora floribunda*. Where upper canopy species are sparse or absent, there is a dense mid-canopy of Prickly-leaved Paperbark *Melaleuca styphelioides* and Snow-in-Summer *M linariifolia*, with an understorey of Ball Honeymyrtle *Melaleuca nodosa* and Sydney Golden Wattle *Acacia longifolia*.

Freshwater sedgeland communities also occur throughout Wallaroo Swamp, which is located adjacent to the western portion of the proposed alignment (Figure 3). Wallaroo Swamp is a temporarily inundated wetland, and is not classified under SEPP 14. The sedgeland community is characterised by a diverse range of sedge and rush species, including *Schoenoplectus mucronatus*, Jointed Twig-rush *Baumea articulata*, Cumbungi *Typha orientalis*, Dirty Dora *Cyperus difformis*, Saw-sedge *Gahnia melanocarpa*, Spiny-headed Mat-rush *Lomandra longifolia* and a range of *Juncus* species. The swamp supports a fringing band of dense *Melaleuca* spp with occasional Cabbage Gum *E amplifolia* and Swamp Oak *Casuarina glauca* and a variety of shrub species. The vegetation communities present exhibit minimal disturbance apart from the presence of some exotic species along the surrounding forest edges.

4.1.2 Woodland/Open Forest Communities

Open forest and woodland communities dominate most of the Horse Island Route, particularly west of the Karuah River. East of the Karuah River, open forest and woodland communities are more fragmented as a result of previous agricultural activities, with the less disturbed forest and woodland vegetation generally occurring on slopes and ridges.

Stands of vegetation within Wallaroo and Karuah SFs, and the Karuah NR, and on private lands along the proposed alignment and in the general study area comprise a mosaic of variously disturbed woodland and open forest communities.
The four main communities recorded along the proposed alignment, in order of greatest extent, are:

1a Dry Spotted Gum Open Forest;

1b 'Moist' Spotted Gum Open Forest;

2 Smooth-barked Apple/Sydney Peppermint Open Forest;

3 Dry Woodland/Open Forest (dominated by Smooth-barked Apple, Brown Stringybark and Bastard Mahogany); and

4 'Moist' Open Forest (dominated by Cabbage Gum, White Stringybark and Rough-barked Apple).

Spotted Gum Open Forest (Community 1) is the most widespread community along the proposed alignment and in the general study area, and includes both drier and moister vegetation types (Figure 7a & 7b). Extensive stands occur on the higher slopes and ridges to the east of the Karuah River, and in Karuah SF, the northern area of Wallaroo SF and on private land to the west. Horse Island also supports this community type. The drier vegetation type is more extensive (Figure 7a & 7b) than moister Spotted Gum Open Forest.

Woodland/Open Forest dominated by Smooth-barked Apple and Brown Stringybark (Community 3) occurs on ridges and gentle slopes in the southern portion of Wallaroo SF, merging with Smooth-barked Apple/Sydney Peppermint Open Forest on the gently sloping terrain surrounding Reedy Creek (Community 2).

Open forest dominated by White Stringybark, Forest Red Gum and Cabbage Gum (Community 4) occurs around Wallaroo Swamp in the northern portion of Wallaroo SF, and along minor creeklines in cleared pasture on the eastern side of the River. Small stands of this community are also associated with a creekline at the eastern end of the proposed alignment (Figure 7a & 7b).

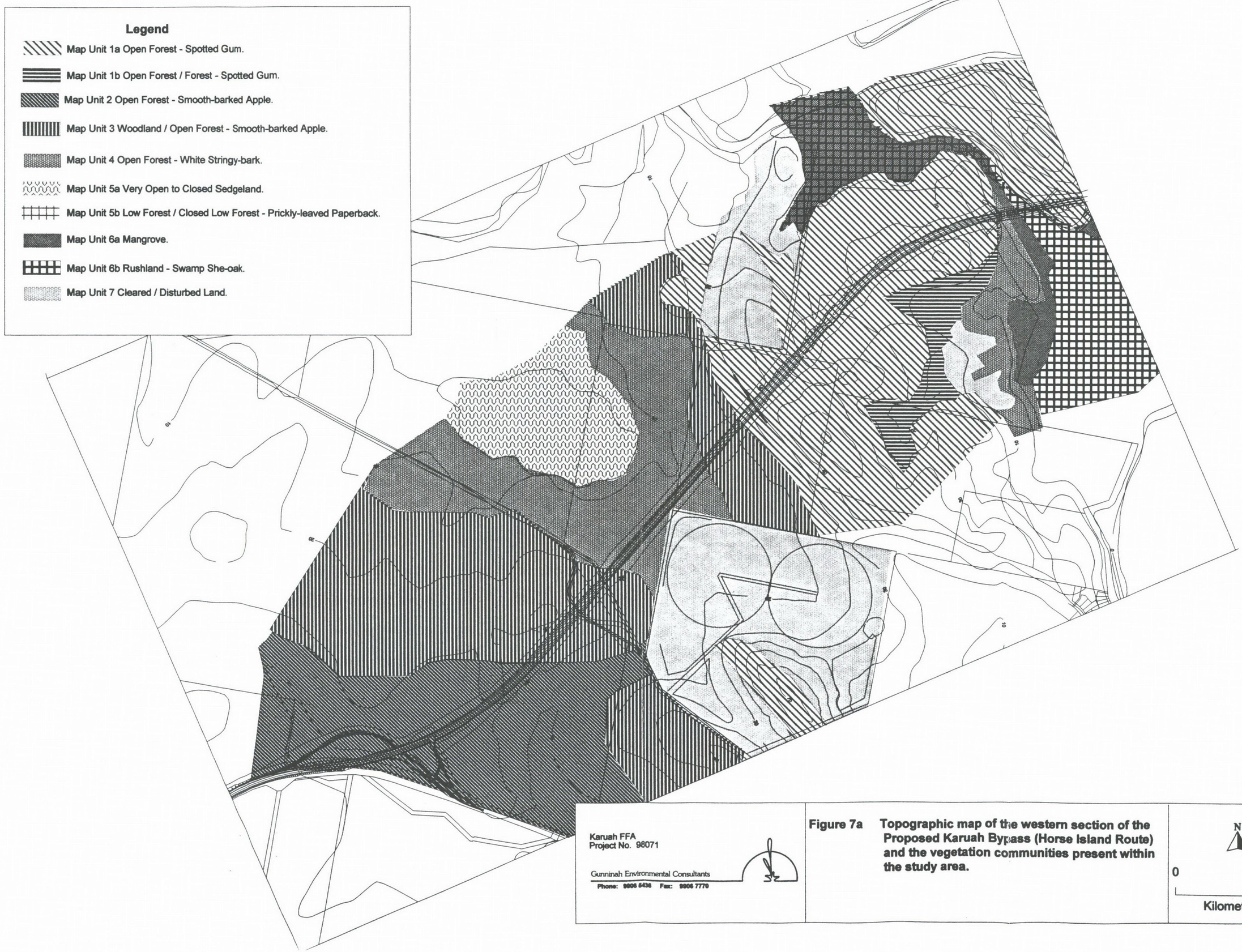
Most of the open forest and woodland communities in the study area have been disturbed to at least some extent through logging, clearing, grazing, burning and refuse dumping, and much of the vegetation exhibits varied levels of modification.

The Woodland/Open Forest communities surrounding Wallaroo Swamp (Community 4) and Spotted Gum Open Forest (Community 1) within the northern portions of Wallaroo SF, Wallaroo NR and Karuah SF appear relatively intact, despite past logging activities. Conversely, adjacent stands of Spotted Gum Open Forest on private lands to the southwest of Horse Island have been modified considerably through substantial clearing and logging activities. Similar stands on Horse Island have also been previously logged, although the southern portion of the Island supports some mature upper canopy species. Extensive stands of Spotted Gum Open Forest to the east of the River are also relatively intact, supporting a mixture of mature and young upper canopy species, despite some obvious disturbance.

Open Forest and Woodland communities (Communities 2 & 3) in the southern portion of Wallaroo SF predominantly comprise young and regenerating upper canopy species, and support few mature specimens. However, the vegetation communities are relatively intact, apart from some clearing, rubbish dumping and fire disturbance along the edge of Community 3.

In general, where the vegetation communities within the study area form relatively continuous stands, the upper canopy consists predominantly of semi-mature and juvenile species with few mature specimens. A mid-canopy of varying density and diversity is present in most communities, and is particularly well represented in moister communities associated with drainage lines and in communities surrounding Wallaroo Swamp.

The diversity and density of the understorey varies greatly throughout the various communities, although a large number of the shrub species recorded are common to all of the woodland and forest communities in the general area. The understorey ranges from fragmented and weed-infested in the more disturbed areas, to diverse and well-developed in



Karuah FFA
Project No. 98071

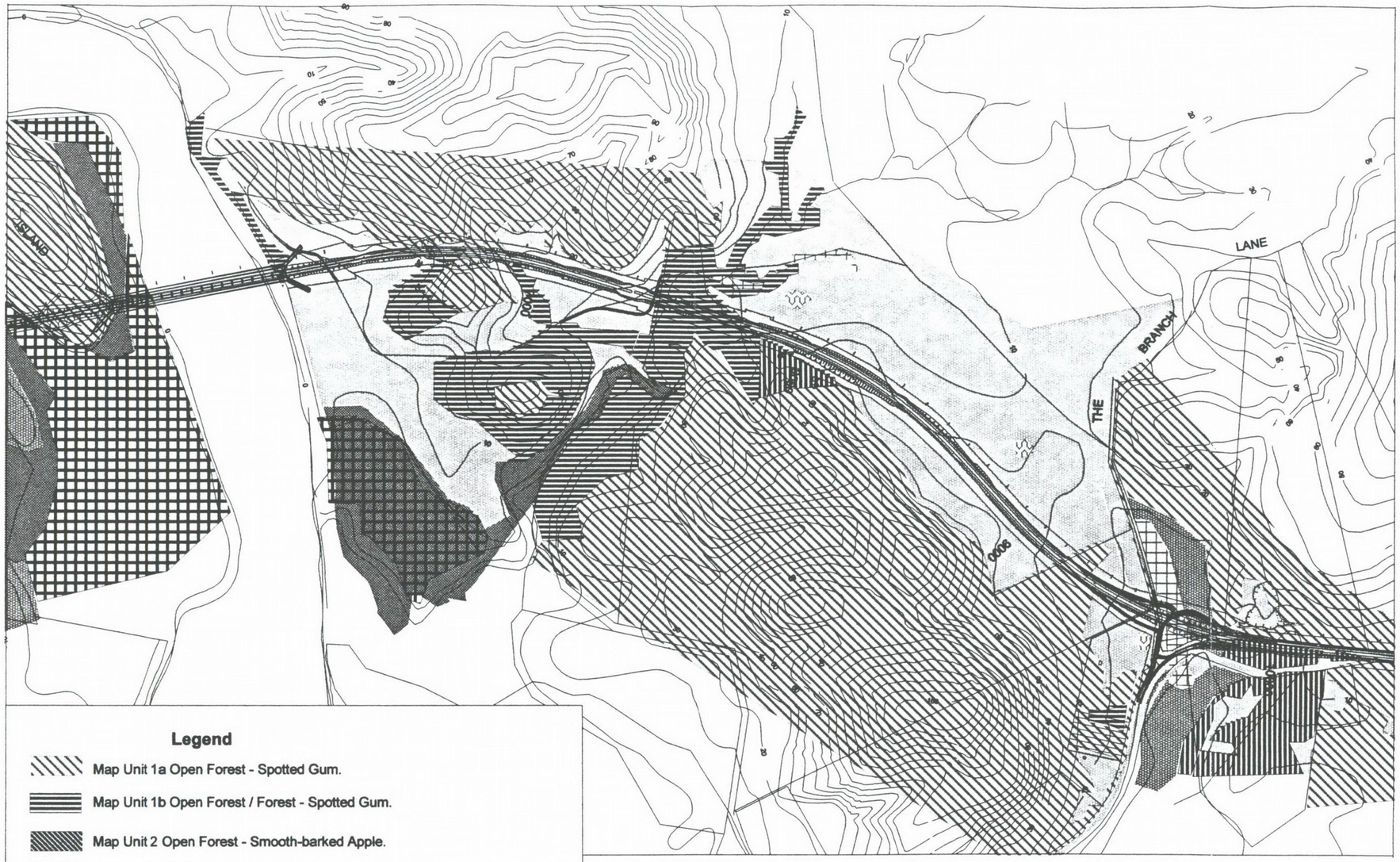
Gunninah Environmental Consultants
Phone: 9906 5436 Fax: 9906 7770

Figure 7a **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 FFA
Project No. 98071

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

Figure 7b **Topographic map of the eastern section of the Proposed Karuah Bypass (Horse Island Route) and the vegetation communities present within the study area.**

Version 6 October 13 1999

N

0 0.5

Kilometres

the more intact communities. Vegetation communities in the southern area of Wallaroo SF in particular, support a well-developed and diverse shrub layer.

The groundcover varies according to the level of disturbance to the shrub and canopy layers, becoming more diverse in open areas. Groundcover density and diversity is relatively high in Communities 2 & 3 in the southwestern portion of the study area, whilst in the east and north, weed species become more common, probably as a consequence of past clearing for grazing and agriculture.

Weed-infestation in most of the forest and woodland communities is generally limited to track-side verges and the edges of communities abutting cleared land. Areas of exposed soil and current grazing activities have contributed to extensive weed infestations within adjacent creeklines, particularly in sites to the east of the Karuah River.

4.1.3 Cleared Pasture/Highly Modified Woodland

This community type (Community 7) is characteristic of the majority of the eastern portion of the proposed Horse Island Route (Figure 7a & 7b), which consists predominantly of cleared grazing land supporting introduced pasture species with scattered stands of native upper canopy, shrub layer and groundcover species. Commonly represented upper canopy species include Grey Ironbark *E siderophloia*, Spotted Gum *C maculata*, Broad-leaved Ironbark *E fibrosa* and Bastard Mahogany *E umbra*.

An extensive area of substantially cleared grazing land also occurs in the central portion of the study area, west of the Karuah River. This area supports introduced pasture species, with scattered and isolated or small stands of upper canopy trees. Several larger islands of disturbed woodland are also located in this area, isolated from proximate vegetation by cleared lands.

This community type also includes areas of highly modified woodland/open forest on private land between the northeastern corner of Wallaroo SF/NR and Horse Island, and along a creekline at the eastern end of the proposed alignment. In these areas, a combination of extensive clearing, logging and grazing activities have resulted in the considerable modification of the upper canopy and understorey.

Conservation Status of Vegetation Communities

The vegetation communities recorded during the field investigations in the study area were considered by reference to the *Review of the Conservation Status of Vegetation Communities in New South Wales* (Hager & Benson 1992). However, the recent Regional Forest Agreement (RFA) and Comprehensive Regional Assessment (CRA) processes have already generated substantial increases in the conservation reserve system (including the 5000+ hectares of Nature Reserves adjacent to the Karuah Bypass), rendering the 1992 assessment of Hager & Benson somewhat obsolete.

4.2 Flora Species of Conservation Concern

A substantial number of flora species are listed as Rare Or Threatened Australian Plants (ROTAP species) by the Federal Government (Briggs & Leigh 1996). However, not all ROTAP species are classified as threatened species in NSW. Only those threatened plant species listed under either Schedules 1 or 2 of the TSC Act are protected by legislation in NSW. In New South Wales, threatened flora species are defined as those listed on Schedules 1 (Endangered) and 2 (Vulnerable) of the TSC Act. Threatened species include those which are considered of conservation concern because of restricted distributions or habitat requirements, significant population or distributional range declines, and where threats to species' survival still prevail.

Table 1 Flora species listed under the TSC Act and those of regional conservation concern, recorded during field investigations conducted along the proposed Horse Island Route for the Pacific Highway upgrade at Karuah.

Key

Vulnerable species (Schedule 2 of the *NSW Threatened Species Conservation Act 1995* - TSC Act)

Regionally significant species (Benson 1986)

ROTAP _ Rare Or Threatened Australian Plants (Briggs & Leigh 1996)

A Species recorded along the proposed Horse Island Route option and in the surrounding area.

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.

Botanical Name	Common Name	Conservation Status	A	B
Myrtaceae				
Eucalyptus robusta	Swamp Mahogany	Regionally significant	X	
Eucalyptus fergusonii ssp *fergusonii*	-	ROTAP	X	
Proteaceae				
Hakea bakeriana	-	Regionally significant	X	
Tremandraceae				
Tetratheca juncea	Black-eyed Susan	Vulnerable (TSC Act)	X	X
Blandfordiaceae				
Blandfordia grandiflora	-	Regionally significant	X	

A range of flora species of national and state conservation concern are known from the North Coast region of NSW, and the general 'bioregion' of which two species have been recorded within 10km of the study area during previous investigations (NP&WS Wildlife Atlas; Ecotone 1995; Gunninah 1997c). Only one of these flora species (*Tetratheca juncea*) was recorded during investigations conducted in the general area of the proposed alignment (see below). Three species of regional conservation concern, *Eucalyptus robusta*, *Hakea bakeriana* and *Blandfordia grandiflora* (Benson 1986) were also recorded during field investigations in the study area (Table 2).

4.2.1 Species Recorded in the Study Area

Flora Species of State Conservation Concern

Only one threatened plant species (*Tetratheca juncea*) was recorded during the botanical surveys of the study area.

Tetratheca juncea is an almost leafless prostrate shrub with stems to 1m long, which "*grows in sandy, occasionally swampy heath and in dry sclerophyll forest*" (Harden 1992). It occurs chiefly in coastal districts from Bulahdelah to Lake Macquarie, but has also been recorded from Port Jackson and Botany Bay, from which it is possibly extinct (Harden 1992).

Tetratheca juncea is listed as a Vulnerable species on Schedule 2 of the TSC Act, and has a ROTAP code of 3VCa (Table 2). However, it is considered relatively common in areas of suitable habitat within its range (Ecotone 1995), and is represented in a number of conservation reserves within its distribution (Briggs & Leigh 1996).

Targeted surveys for *T juncea* were conducted during November and December 1998, to coincide with the known flowering period of the species, and when specimens were observed to be flowering in the surrounding area. Several scattered and isolated patches of *T juncea* were recorded in woodland/open forest communities (Community 3) within Wallaroo State

Forest in the eastern portion of the study area, and other populations were identified during 1999 (Figure 8). This species is likely to occur widely in other areas of similar habitat in the study area; specimens have been recorded relatively recently within woodland communities immediately south of the study area (Gunninah 1997a) and at a number of other locations within 10km (NP&WS Wildlife Atlas; Ecotone 1995; Gunninah 1997c).

The potential impacts of the proposed Horse Island bypass of Karuah upon *Tetratheca juncea* are discussed in detail in Chapter 6 of this report.

Table 2 National conservation status codes for Rare Or Threatened Australian Plants (ROTAP) species (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).

Flora Species of National or Regional Conservation Concern

One plant listed as a ROTAP species (*Eucalyptus fergusonii* ssp *fergusonii*) was recorded along the alignment. Additionally, three plant species considered of regional conservation concern (Benson 1986) were recorded in woodland/open forest communities along the proposed Horse Island Route during the flora surveys (*Hakea bakeriana*, the Christmas Bell *Blandfordia grandiflora* and the Swamp Mahogany *Eucalyptus robusta*). Estimates of how much habitat will be removed for each of these species will be addressed in the SIS (Gunninah 1999c).

Eucalyptus fergusonii ssp *fergusonii*

Eucalyptus fergusonii ssp *fergusonii* grows to 25m high, and is "*scattered and sporadic, in wet sclerophyll forest or woodland on sandy soils*" (Harden 1991). This species occurs from Bulahdelah to Morisset, and was recorded at scattered locations along the Karuah Bypass alignment, particularly to the west of the Karuah River. It was present in Spotted Gum open forest (Community 1), and could occur widely (although somewhat sparsely) through the forested lands of the study area.

Eucalyptus fergusonii ssp *fergusonii* is listed as 3KC-, which indicates that, although it has a geographic range of greater than 100km and is present in a conservation reserve (population size unknown), it is poorly known.

Hakea bakeriana

Hakea bakeriana is a multi-stemmed shrub to 2m high, which bears large clusters of crimson flowers in late autumn and winter. This species grows in dry sclerophyll forest on the coast and adjacent ranges from the mid-north coast south to the Glenorie district (Harden 1991). *H bakeriana* was recorded in open forest/woodland dominated by Smooth-barked Apple and Sydney Peppermint (Community 2) and woodland/open forest dominated by Smooth-barked Apple, Brown Stringybark and Bastard Mahogany (Community 3) in Wallaroo SF (Figure 7a & 7b).

The vegetation communities containing *H bakeriana* are relatively widely distributed within the study area and along the Horse Island Route alignment. Similarly, specimens of *H bakeriana* were recorded widely, though generally sparsely, through the study area, and the proposed Horse Island Route will involve the removal of only relatively small numbers of this species.

Christmas Bell *Blandfordia grandiflora*

The Christmas Bell *Blandfordia grandiflora* is a tufted perennial herb with grass-like leaves to 70cm. Flower spikes bear up to ten large bell-like flowers, which vary from pure yellow to deep red with yellow tips. Flowers usually occur in late spring and early summer. This species grows in damp sandy and/or peaty soils in coastal and tableland areas north from the Hawkesbury River and inland to the Glen Innes district (Harden 1994). It was recorded in woodland/open forest dominated by Smooth-barked Apple, Brown Stringybark and Bastard Mahogany (Community 3) during flora investigations in the general study area (Figure 7a & 7b).

Suitable habitat for the Christmas Bell is not abundant through the study area or along the Horse Island Route alignment, and the proposed Horse Island Route will involve the removal of only small areas of habitat for this species. The proposed roadworks will involve the loss of some individuals of the Christmas Bell, but the limited area of suitable habitat along the proposed alignment compared to the available habitat in the locality indicates that only small numbers of this species relative to the overall population will be removed.

Swamp Mahogany *Eucalyptus robusta*

Swamp Mahogany *Eucalyptus robusta* is a tree to 25m, which occurs in heath or low swampy sites on sandy soils north from Moruya (Harden 1991). It is considered regionally significant by Benson (1986), but is often locally abundant in areas of suitable habitat (Harden 1991). It is considered of local significance in the study area as a preferred Koala food tree.

Swamp Mahogany was recorded in open forest dominated by Cabbage Gum, Forest Red Gum and White Mahogany (Community 4) around Wallaroo Swamp and along minor drainage lines to the east of the Karuah River (Figure 7a & 7b).

Swamp Mahogany is restricted in distribution to moist sites within the study area, and the most extensive stands (around Wallaroo Swamp) will not be affected by the proposed Horse Island Route. Individuals of this species will be removed, however, from creeklines throughout the study area.

4.2.2 Species Recorded in the Surrounding Area

One additional plant species of conservation concern (*Gonocarpus salsoloides*) has been recorded at various locations within 10km of the study area (NP&WS Wildlife Atlas), and could potentially occur in suitable habitat in the general vicinity.

Gonocarpus salsoloides is a perennial herb, which "*grows in swampy heath on sandy soils near the sea*" (Robinson 1991). It is an uncommon species which occurs in coastal districts from Royal National Park to Port Macquarie (Harden 1992). This species is not listed as a

threatened species under the TSC Act, but has a ROTAP code of 3RCa (Table 2). It is represented in six conservation reserves within NSW.

Gonocarpus salsoloides was not detected during the botanical investigations of the study area, despite particular attention being paid to its possible presence in areas of potential habitat.

5 FAUNA

5.1 Fauna Habitats

Three main fauna habitat types have been identified along the Horse Island Route and in the surrounding area, based on the vegetation communities and natural features present. These are woodland/open forest habitats, riverine and wetland habitats, and highly modified woodland/cleared agricultural lands.

5.1.1 Woodland/Open Forest Habitats

This habitat type comprises the four open forest/woodland communities recorded along the proposed Horse Island Route and in the surrounding area (Figure 7a & 7b). The communities present are of varied value for different native fauna due to differences in floristics, community structure and frequency of tree-hollows, hollow logs, rock outcrops and other features.

All of the woodland/open forest communities present along the proposed alignment and in the general vicinity have been disturbed to varying degrees through clearing, logging, grazing, weed infestation, and in some instances through fire and refuse dumping. Mature trees comprise a relatively small proportion of the upper canopy in most areas, which consists mainly of semi-mature and juvenile forms. Mature trees are particularly poorly represented in much of Wallaroo SF within the study area and on private vegetated land to the west of the Karuah River. Furthermore, woodland and forest communities in the study area do not provide many hollows given the general scarcity of large mature trees.

However, Horse Island and vegetation communities on private lands to the east of the River appear to support a higher number of mature upper canopy species, with hollows of varied size and some hollow stags scattered throughout other vegetated portions of the study area. Tree-hollows of various sizes provide shelter and nesting habitat for the Squirrel Glider, Glossy Black Cockatoo, Eastern Freetail Bat and Greater Broad-nosed Bat, which were recorded during the fauna investigations, and potential resources for other hollow-dependent fauna known from the wider area, such as the Brush-tailed Phascogale.

The woodland and forest habitats in the general area provide a wide range of habitat resources for passerine birds, including nest sites (on dead branches and in small tree-hollows, open cavities, amid dense shrubs or groundcover), nest materials (*eg* lichen and spider web), foraging substrates (*eg* bark surfaces, epiphytes and litter layers) and a diverse range of food resources (Recher 1991). Non-passerine species utilise similar resources, as well as large tree-hollows and hollow stags for nesting; high branch perches; and stable branch or trunk nest platforms (Recher 1991). Several large unidentified raptor nests were recorded in the crowns of tall eucalypts along the Karuah River during the fauna investigations. Whilst a number of raptors were recorded in the general area (including the Osprey), no bird activity was recorded during observations of the nests.

Woodland and forest communities in the study area also provide foraging resources for arboreal mammals, including browsing herbivores (such as the Koala and Common Brushtail and Ringtail Possums), insect and sap feeders (such as the Squirrel Glider), and nectar feeders (such as the Feathertail Glider), as well as for microchiropteran bat species, which forage for insects above and within the canopy. Preferred Koala food trees, including Tallow-wood *Eucalyptus microcorys*, Grey Gums *E punctata* and *E propinqua*, and Swamp Mahogany *E robusta*, occur within the woodland and forest communities of the study area, and are of varied age and density in different communities (Chapter 4.1).

Many areas of the woodland and open forest communities support a well-developed mid-storey, which includes a variety of *Melaleuca* and *Allocasuarina* species. Dense stands of flowering *Melaleuca* provide a rich nectar source for nectarivorous native fauna, including a variety of birds and arboreal mammals. Forest Oak *Allocasuarina littoralis* and Black She-Oak *A torulosa* stands in the study area (associated with Communities 1, 3 & 4 - Figure 6) provide potential foraging habitat for the Glossy Black Cockatoo, which is known to occur in the general area, but which was not recorded during fauna investigations for this report.

The shrub understorey and groundcover (where present) provides shelter and foraging habitat for terrestrial and arboreal mammals, reptiles and bird species. Groundcover vegetation, hollow logs, leaf-litter, and other vegetative debris, provide shelter and foraging substrates for medium and small mammals (such as the Brown Antechinus and bandicoots), and a range of reptiles, birds and amphibians.

5.1.2 Riverine & Wetland Habitats

The Karuah River flows through the central portion of the study area from north to south. A substantial number of wetlands occur in the general locality associated with the Karuah River and creeklines and their tributaries. Many of these wetlands are protected under SEPP 14 - Coastal Wetlands (Figure 4).

The wetlands along the proposed alignment include a variety of freshwater and estuarine wetland communities. The estuarine wetland communities comprise mangrove open scrub and saltmarsh communities which occur on intertidal mudflats along the Karuah River. Freshwater wetland communities include temporarily inundated sedgeland and fringing swamp forest associated with Wallaroo Swamp to the west of the proposed alignment, and sedgeland and swamp forest communities bordering estuarine wetland communities along the Karuah River. The general study area does not support any permanent free-standing freshwater bodies, although a large freshwater wetland is located near the Karuah township to the south (Gunninah 1997a) and the temporarily inundated Karuah Swamp is located to the west of the alignment. The wetland communities, in particular the estuarine communities, are of reasonable extent and display minimal levels of disturbance, given their distance from the main urban centre and the limited access available.

The fauna of riverine and wetland habitats is diverse, including species of both aquatic and terrestrial origin, which are present on either a permanent or temporary basis. These habitats provide food resources for a wide variety of native fauna (such as waterbirds, amphibians, reptiles, microchiropteran bats), generally supporting a large variety of food plants and foraging substrates, large populations of insects and other invertebrates, and aquatic plants and algae. Estuarine communities, including mangroves, saltmarshes and the river itself, also provide a rich source of fish, molluscs, and crustacea.

The wetland and riverine communities in the general study area provide a diverse array of foraging habitats for a variety of waterbirds, including filterers and dabblers (such as the ducks and shovelers), vegetarians (such as the moorhens and swamphens), omnivorous searchers (such as the spoonbills), hunters in shallow water or tidal flats (such as the herons, egrets, stilts and snipes), deeper water fishers (such as the cormorants and darter) and terrestrial feeders (such as the Straw-necked Ibis). The wetland communities also provide habitat for a number of migratory waders listed under International Agreements for the protection of migratory birds between Australia and Japan (JAMBA 1974) and Australia and China (CAMBA 1989), some of which were recorded during the current field investigations (Appendix 5).

The wetlands and surrounding vegetation also constitute valuable refuge and breeding and nursery grounds for many of the waterbirds observed. Many waterbirds utilise saltmarsh communities and dense sedge and reed beds for nesting and shelter, with the larger species nesting in trees within the fringing or nearby woodland communities.

Many bird species which utilise wetland habitats are not wetland specialists. Grassbirds, finches and warblers inhabit sedgeland and reed beds, and saltmarsh communities provide habitat for other small passerine species, such as the Golden-headed Cisticola and the

White-fronted Chat. Mangroves also provide shelter and foraging habitat for a range of essentially terrestrial bird species, such as honeyeaters, kingfishers and flycatchers.

Freshwater wetlands and associated communities provide shelter, breeding and foraging habitat for amphibian species. The sedgeland community of Wallaroo Swamp and fringing communities are likely to provide habitat for a variety of amphibians, when conditions are suitable. Amphibians cannot tolerate intertidal wetland communities, given the saline conditions and the high permeability of their skin. A range of aquatic and semi-aquatic reptile species, such as water dragons, the Red-bellied Black Snake and Tiger Snake, also inhabit freshwater wetland communities. Reptiles are generally rare in estuarine wetlands, except for arboreal species such as tree snakes and pythons, which often occur in mangrove communities.

Several terrestrial mammal species inhabit wetland habitats, including the Swamp Rat which occurs in freshwater sedgeland and the Water Rat which inhabits estuarine mangrove communities. Microchiropteran bats often forage over wetland communities and the Grey-headed Flying-fox occasionally roosts and forages in mangrove stands. Arboreal mammals, such as Koalas, may inhabit associated swamp woodland communities which support food trees, such as Swamp Mahogany. However, for these species the wetland community itself does not constitute critical habitat.

5.1.3 Highly Modified Woodland/Cleared Pasture Habitats

This habitat type is characteristic of the majority of the proposed alignment east of the Karuah River, and areas to the northwest and southeast of the western portion of the alignment. It comprises areas of cleared pasture where trees are present as scattered individuals or in small isolated groups, or areas of highly modified woodland where selected canopy species have been retained and the shrub understorey removed creating a 'park-like' environment. These areas are highly disturbed and modified and typically have a lack of structural and floristic diversity, primarily pasture grasses and weeds. Both communities are subject to ongoing disturbance from grazing and selective logging.

Small isolated stands of highly modified vegetation or scattered trees in pasture areas may contribute to the foraging and shelter resources of some bird and arboreal mammal species, such as Koalas and Bush-stone Curlews. These stands are potentially important as good quality Koala habitat has been identified near the pasture/modified woodland on the eastern side of the Karuah River, and potentially provide important linkages across these lands. Furthermore, core Koala habitat has been recorded on the property containing the Karuah Hard Rock quarry which is situated in close proximity to the proposed Bypass alignment (Gunninah 1997c).

In general, cleared areas provide only limited foraging resources for the more mobile fauna species in the study area, in particular some macropods, birds and some microchiropteran bats. Birds of prey often utilise these open areas to hunt for small introduced rodents and insects, whilst other fauna species (*eg* kangaroos and wallabies and a variety of bird species) utilise the grassy paddocks for grazing and foraging. The Eastern Grey Kangaroo and several birds (such as the Wedge-tailed Eagle, Masked Lapwing and Australian Raven) were recorded foraging in pasture areas in the study area, and are commonly associated with such habitats throughout northeastern NSW. The microchiropteran bat species recorded in the study area may also utilise the ecotone between cleared lands and woodland and forest communities to forage for insects. However, the isolated nature and disturbed condition of such forested stands renders them of little value for such hollow-dependent fauna species.

Whilst some reptiles (such as snakes and goannas) are also expected to occur in these habitats on occasion, the absence of substantial cover and foraging substrates (such as leaf-litter, logs and rocks) reduces their habitat value for most reptile species. Similarly, small terrestrial native mammal species are generally absent from such areas, given the lack of suitable foraging substrates and protective shelter.

Farm dams in the study area provide habitat and resources of relevance for a variety of amphibian and waterbird species. The dams of most value in this respect include those with some emergent wetland vegetation (such as *Typha orientalis*) and other aquatic plant species, which provide both foraging and breeding habitat for these fauna species.

Amphibian species, also utilise moist soaks, which are created in low-lying grassy areas within pasture lands following rain. These areas provide potential breeding habitat for amphibian species and a number of species were identified in association with these habitat features during the fauna survey (Chapter 5.2).

5.2 Native Fauna Recorded

A list of fauna species recorded in the study area was compiled during the field surveys (Appendix 4), and has been supplemented by records from previous investigations in the surrounding area (Ecotone 1995; Gunninah 1997a, b, c) and from the NP&WS Wildlife Atlas and the Birds Australia database. With regard to the NP&WS Atlas records, only those species recorded within approximately 10km of the study area were considered relevant for discussion.

The vegetation communities and natural features present within the study area provide suitable habitats for a wide variety of fauna species, including a number of threatened species listed on Schedules 1 and 2 of the TSC Act. A total of 107 native vertebrate fauna species was recorded during the fauna surveys conducted in the study area, including seventy-four birds, seventeen mammals (including six microchiropteran bats), ten reptiles and six amphibians (Appendix 4). A number of introduced species were also recorded.

Five threatened fauna species (the Osprey, Koala, Squirrel Glider, Eastern Freetail Bat and Little Bent-wing Bat) were positively recorded in the study area. The calls of one additional threatened microchiropteran bat species, the (Greater Broad-nosed Bat), were also recorded, although call identification was not definite (Chapter 5.3). Several additional threatened species could also potentially occur in the study area on occasion, based on records from the surrounding area and habitat preferences (Appendix 4). The threatened species recorded in the study area and other threatened species which could possibly occur are discussed in Chapter 5.3.

5.2.1 Birds

The range of habitats within the study area provide roosting, nesting and foraging resources for a variety of birds. Seventy-four native bird species (comprising thirty-two passerine and forty-two non-passerine species) and three introduced bird species were recorded during the fauna investigations, the majority of which are common to abundant and widespread in distribution.

Passerine birds include all species of the diverse order Passeriformes, which are known as 'song birds' or 'perching birds'. These species were representative of a variety of guilds, including insectivores (*eg* thornbills, scrubwrens, and fairy-wrens), forest pollinators (*eg* honeyeaters), ground feeders (*eg* the White-winged Chough), and predators and scavengers (*eg* the Pied Currawong, Pied and Grey Butcherbirds and Australian Raven).

Non-passerine bird species, include mostly large terrestrial and aquatic birds, which lack singing voices. Non-passerine species recorded during the field investigations in the study area and in adjacent habitats, include a range of waterbirds, waders, parrots and cockatoos, the Crested Pigeon and Kookaburra.

The majority of the bird species recorded in the study area are typically associated with forest and woodland habitats. All of the species recorded are common and widespread in suitable habitat throughout NSW, including the Yellow-tailed Black Cockatoo, Rufous Whistler, Spangled Drongo, White-winged Chough, Spotted Pardalote and Grey Fantail. The Glossy Black Cockatoo (a Vulnerable species under the TSC Act) has been recorded in the surrounding area (Appendix 4). Whilst the study area supports suitable foraging habitat, and to a lesser extent nesting habitat, for the Glossy Black Cockatoo, no evidence of its presence was detected during the field investigations. This species is discussed further in Chapter 5.3.

Two nocturnal birds (the Tawny Frogmouth and Australian Owlet-Nightjar) were recorded during spotlighting surveys conducted within the study area. Three additional nocturnal

species, the Bush Stone-curlew, and the Masked and Powerful Owl, have been recorded in the surrounding area and could possibly occur in the study area on occasion, given the habitats present. These three species are listed as Vulnerable in NSW (TSC Act 1995) and are discussed further in Chapter 5.3.

Waterbird species, typically associated with wetland, riverine and riparian habitats, were also common in the study area. Characteristic species include the Crested Tern, Eastern Curlew, Australasian Grebe, Black Swan, Royal Spoonbill and a variety of ducks, herons, ibis, egrets and cormorants (Appendix 4). The White-bellied Sea-eagle and Osprey were recorded soaring over the Karuah River, and are likely to forage in this and other coastal estuaries in the general area. The Osprey is regarded as Vulnerable in NSW (TSC Act 1995), and is discussed further in Chapter 5.3.

A large raptor nest recorded in the crowns of tall eucalypts along the Karuah River could potentially be that of a pair of Ospreys, given this species known presence at this locality. However, no bird activity was recorded at the nest during periods of observation. A number of other large raptors were recorded in the general area during the field investigation (Appendix 4).

Other bird species recorded in the study area are typically associated with the open agricultural lands which are characteristic of the surrounding landscape. Whilst generally relying on woodland and forest habitats for nesting and shelter, these species also utilise semi-natural pasture environments, in particular for foraging. Species recorded in these habitats along the proposed alignment include the Masked Lapwing, Eastern Rosella, Willie Wagtail, Kookaburra, Cattle Egret, Australian Magpie and Welcome Swallow. The Whistling Kite and Wedge-tailed Eagle were also recorded patrolling over agricultural land and woodland communities in the general study area.

Twenty-two bird species (Appendix 5) listed on international bilateral agreements for the protection of migratory birds between Australia and Japan (JAMBA 1974) and/or Australia and China (CAMBA 1989) have been recorded within 10km of the study area (NP&WS Wildlife Atlas), or within the general region (Birds Australia database). Of these species, five were recorded during current investigations in the study area: the Cattle Egret, White-bellied Sea Eagle, Eastern Curlew, White-throated Needletail and Rainbow Bee-eater (Appendix 4). The Cattle Egret and Rainbow Bee-eater are common and widespread in natural and agricultural landscapes in NSW, and the White-bellied Sea-eagle is a breeding resident in coastal areas. The White-throated Needletail is a totally migratory aerial species which breeds in Asia and migrates to Australia in summer (Blakers *et al* 1984). The Eastern Curlew breeds in eastern Russia and northern China migrating to Australia in summer (Lane 1987). During this time it is often abundant in marine embayments, foraging on tidal mudflats and sheltering in fringing saltmarsh communities.

An additional 129 bird species, including a number of threatened species, have been recorded in the general area during previous investigations (Appendix 4). Whilst some of these species could potentially occur in the study area (at least on occasion), others will not be present due to an absence of specific resources. Additional threatened bird species known from the surrounding area are discussed further in Chapter 5.3.

5.2.2 Mammals

Twenty native mammal species (including nine microchiropteran bat species) were recorded in the study area during the current fauna investigations (Appendix 4 & 6). A further three microchiropteran bat species were identified using an Anabat call detector, although a confident call identification could not be made in all instances. A number of additional native mammals have been recorded in the surrounding area (Appendix 4), some of which are also likely to occur in the general vicinity.

Three native small terrestrial mammals were captured in Elliott traps during the field investigation. The most frequently captured species was the Brown Antechinus *Antechinus stuartii*, which was recorded at all five trapping transects (Appendix 6; Figure 6). The native Bush Rat *Rattus fuscipes* and Swamp Rat *Rattus lutreolus* were also common and were both recorded at three trapping locations. The Common Dunnart *Sminthopsis murina* and the New Holland Mouse *Pseudomys australis* are also known from forest and woodland

communities in the general area (Appendix 4), and may also occur in suitable habitat within the study area.

A number of additional small to medium terrestrial mammal species have been recorded during previous investigations in the general area (Appendix 4). Species such as the Long-nosed Bandicoot *Perameles nasuta*, Northern Brown Bandicoot *Isoodon macrourus* and Wombat *Vombatus ursinus* could also occur in the study area. Cage traps and hair tubes at each trapping transect (Appendix 6; Figure 6) failed to reveal the presence of any of these small or medium-sized mammals in the study area. Whilst heavy rainfall occurred during the survey period, the lack of hair tube success cannot be attributed to this circumstance given the periods of dry weather and the protection of some hair tubes. One terrestrial mammal of conservation significance, the Tiger Quoll *Dasyurus maculatus*, has been recorded within 10km of the study area (Appendix 4) and could also possibly occur along the alignment given the habitats present (Chapter 5.3).

The Eastern Grey Kangaroo *Macropus giganteus* and Red-necked Wallaby *Macropus rufogriseus* were recorded during spotlighting surveys in the study area, and the Swamp Wallaby *Wallabia bicolor* was recorded during diurnal surveys. The Common Wallaroo *Macropus robustus* has been recorded from the vicinity (Appendix 4), and may also occur in the study area from time to time.

Five arboreal mammal species were recorded during the fauna surveys. The Common Brushtail Possum *Trichosurus vulpecula*, Common Ringtail Possum *Pseudocheirus peregrinus* and the Feathertail Glider *Acrobates pygmaeus* were all recorded during evening spotlighting activities in forest/woodland communities. Of these, the Common Brushtail Possum was the most frequently observed species (Appendix 6).

Two arboreal mammals of conservation significance were also recorded in the study area during spotlighting surveys. Two Squirrel Glider *Petaurus norfolcensis* sightings were recorded on consecutive nights in Spotted Gum woodland/open forest communities in Karuah NR north of Mines Hill Trail and southwest of Horse Island (Figure 8). One adult Koala *Phascolarctos cinereus* was recorded in a similar community on private property to the east of the Karuah River (Figure 8). Numerous Koala scats of varied size and age were also detected during dedicated scat searches and general habitat surveys conducted through the woodland/open forest communities on the eastern side of the Karuah River (Appendix 6). Both the Koala and Squirrel Glider are discussed in further detail in Chapter 5.3.

One additional threatened arboreal mammal (the Brush-tailed Phascogale *Phascogale tapoatafa*) is known from the surrounding area (Gunninah 1997a, b; NP&WS Wildlife Atlas). Whilst this species may theoretically occur in the study area based on the habitats present, no evidence for its presence was recorded during the field surveys conducted for this investigation or those conducted recently in the immediate vicinity (Chapter 5.3).

A total of twelve microchiropteran bat species were recorded during field investigations in the study area (Appendix 4 & 6). Of these, five species (the Little Forest Bat, Chocolate Wattled Bat, Gould's Wattled Bat, Lesser Long-eared Bat and the Little Bent-wing Bat) were captured in harp traps. The remaining species were identified using Anabat II ultrasonic call detectors. However, the reliability of call identification varied, with three additional confident species' identifications (the Little Freetail Bat, Eastern Freetail Bat and the White-striped Mastiff-bat), two probable identifications (the Greater Broad-nosed Bat and Eastern Broad-nosed Bat) and one possible identification (the Eastern Forest Bat).

Of the microchiropteran bat species recorded, the Little Bent-wing Bat, Eastern Freetail Bat and the Greater Broad-nosed Bat are listed as Vulnerable species on Schedule 2 of the TSC Act. A number of other microchiropteran bat species, including several other species of conservation concern, could also potentially occur in the general vicinity based on known distributions and habitat preferences. Microchiropteran bats of conservation concern recorded and those which may potentially occur are discussed further in Section 5.3.

Six introduced mammal species were recorded in the study area (Appendix 4). Of these, the Brown Hare and the European Rabbit were the most frequently encountered. Domestic stock, such as Cattle and Horses were also recorded in various habitats throughout the study area.

5.2.3 Reptiles

Ten reptile species were recorded in the study area, including one tortoise, two agamids, three skinks and three elapids (Appendix 4 & 6), all of which have widespread distributions in eastern NSW, and are generally common to abundant (Cogger 1992).

The Eastern Long-necked Tortoise was observed in a farm dam on private property east of the River during spotlighting activities, and an Eastern Water Skink was trapped in a ground Elliott trap in open forest at the eastern end of the proposed route option. The Eastern Brown Snake, Red-bellied Black Snake and the Black-bellied Swamp Snake were recorded during diurnal habitat searches in woodland/open forest communities near the Karuah River. Relatively large numbers of Garden Skinks *Lampropholis delicata* and Grass Skinks *Lampropholis guichenoti* were recorded during active searches in leaf-litter in woodland communities. The Jacky Lizard *Amphibolurus muricatus* and Bearded Dragon *Pogona barbata* were observed opportunistically during general field surveys activities.

A number of additional common and widespread reptile species have been recorded previously in the surrounding area, including a variety of skinks and elapids, as well as the Diamond Python and several gecko species (Appendix 4). Any of these species could also potentially occur in areas of suitable habitat within the study area.

No threatened reptile species were recorded in the study area during this investigation, and none have been recorded during previous investigations in the general area (NP&WS Wildlife Atlas; Ecotone 1995; Gunninah 1997a, b, c). Given the absence of any specific or unique resources or features relevant to threatened reptiles known from the broader region, it is considered unlikely that any such species or those restricted to specific habitats would occur in the study area or immediate vicinity.

5.2.4 Amphibians

A combination of warm temperatures and periods of rain during the fauna investigation provided ideal conditions for amphibian surveys, with individuals of a variety of species being both highly active and vocal. Five amphibian species were recorded in the study area, either through direct observation and/or using call identification (Appendix 4 & 6). All of the species recorded are considered widespread and generally common in areas of suitable habitat in northeastern NSW.

Amphibians were recorded during both dedicated diurnal and nocturnal habitat searches in non-saline creeklines, sedgeland and rushlands associated with Wallaroo Swamp, farm dams and in moist grassy depressions and puddles after rain. Of the species recorded, the Brown Toadlet *Pseudophryne bibroni*, appeared to be the most prevalent, being widespread and abundant in a variety of freshwater habitats throughout the study area.

A number of additional amphibian species have been recorded in the general area, many of which are also likely to be present in the study area (Appendix 4). These species are all considered common and widespread in northeastern NSW.

No evidence for the presence of any threatened amphibian species was recorded within the study area and none have been recorded in recent investigations in the surrounding area (Gunninah 1997a, b; Ecotone 1995; NP&WS Wildlife Atlas). However, three threatened species, the Green & Golden Bell Frog, Green-thighed Frog and Wallum Froglet, have been recorded in the wider region and could potentially occur in the study area based on the habitats present. These species are considered further in Chapter 5.3.

5.3 Fauna Species of Conservation Concern

In New South Wales, threatened fauna species are defined as those listed on Schedules 1 (Endangered) and 2 (Vulnerable) of the TSC Act. Threatened species include those which are considered of conservation concern because of restricted distributions or habitat requirements, significant population or distributional range declines, and where threats to species' survival still prevail.

Six species of threatened fauna were recorded during investigations in the study area, including one probable identification (Table 3; Figure 7). An array of additional threatened fauna species are known from the surrounding area (Appendix 4), some of which may also occur in the study area on occasion.

5.3.1 Threatened Fauna Recorded in the Study Area

All of the threatened fauna species recorded during the field investigations in the study area are dependent in one way or another on forest and woodland communities, with the exception of the Osprey. The species recorded and their habitat requirements are discussed briefly below, with record locations provided in Table 3 and Figure 8.

Table 3 Locations of threatened fauna species recorded during field surveys along the proposed Horse Island Route option and in the surrounding area (Figure 8).

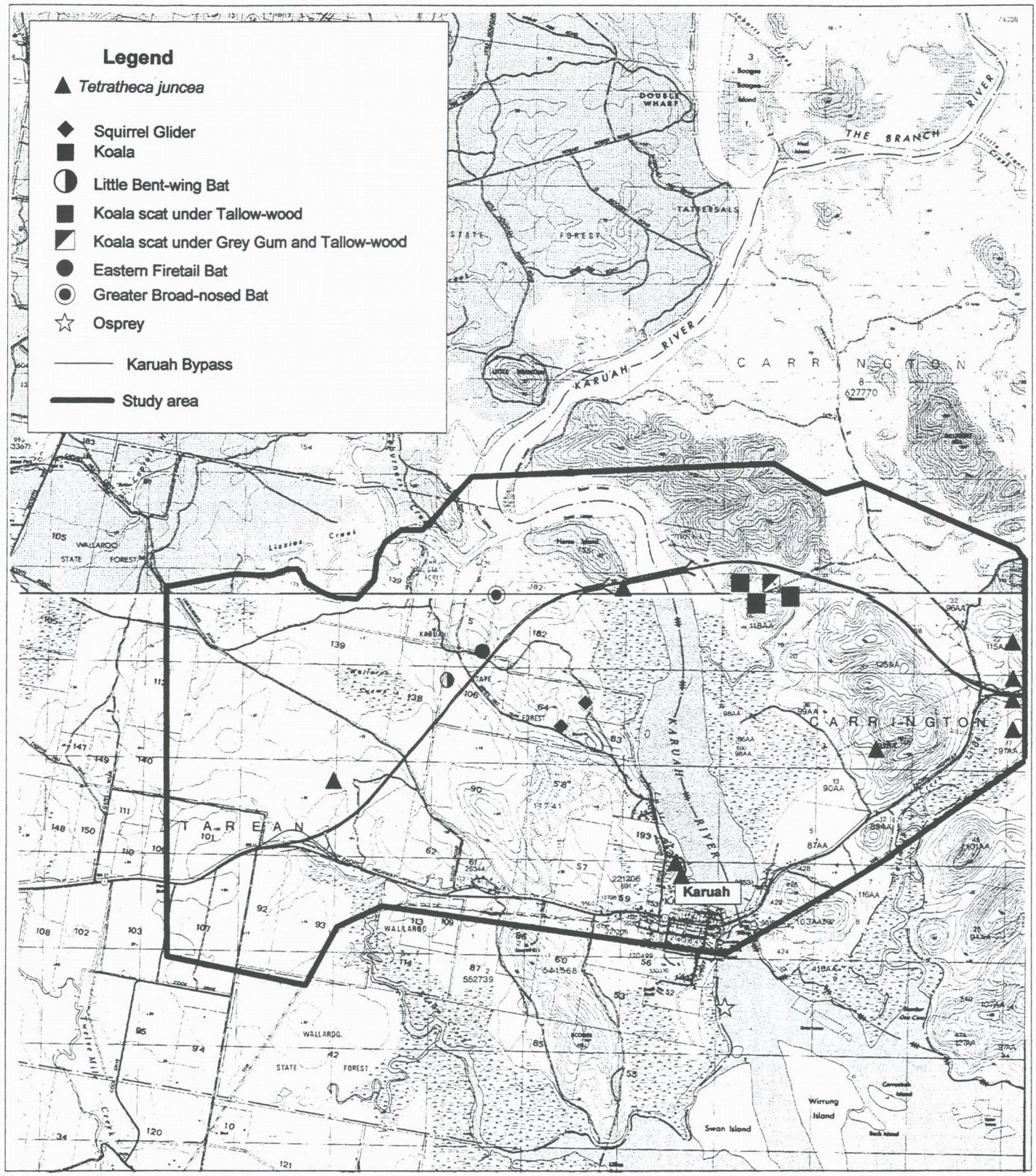
Species	Status	Location	Grid Reference	Method of Detection
Osprey	V	Karuah River	403100/6385500	Observation
Koala	V	Open forest east of the Karuah River	400110/6390450	Observed (spotlighting)
			403180/6389900	Scats (under *Eucalyptus microcorys*)
			403500/6389900	Scats (under *E microcorys)*
			403500/6389900	Scats (under *E punctata)*
			401800/6389900	Scats (under *E microcorys*)
Squirrel Glider	V	Karuah SF	399700/6398750	Observed (spotlighting)
			401600/6388650	Observed (spotlighting)
Little Bent-wing Bat	V	Harp trap no. 2	400150/6388850	Harp trap capture
Eastern Freetail Bat	V	Anabat survey site 3	400650/6389500	Anabat call analysis
Greater Broad-nosed Bat	V	Anabat survey site 3	400650/6389500	Anabat call analysis

a) Osprey *Pandion haliaetus*

The Osprey *Pandion haliaetus* has a disjunct distribution around the Australian coastline, and is much more numerous in the north than the south (Lindsey 1992). It is listed as a Vulnerable species in NSW under Schedule 2 of the TSC Act.

The Osprey occurs on off-shore islands and in littoral habitats, terrestrial wetlands and coastal lands of tropical and temperate Australia, often ranging inland along large rivers (Marchant & Higgins 1993). It requires extensive areas of clear open water (fresh, brackish or saline) for fishing, and nests in prominent positions (such as on rocky headlands or cliffs, or in tall trees with dead crowns or stags), usually in the vicinity of the ocean or large waterbodies.

The Osprey was recorded soaring over the Karuah River in the general vicinity of the study area during the fauna investigations conducted for this report (Figure 8). The species has not been recorded during previous fauna surveys in the immediate vicinity nor surrounding area (Gunninah 1997a, b, c), but is known to occur at coastal locations to the north and south of Karuah. In 1995, nesting pairs were reported as far south as the northern shores of Port Stephens (Morris & Burton 1997), and Ospreys have more recently been recorded in the Hawkesbury River (DF *pers obs*).



Karuah FFA
Project No. 98071

Gumninah Environmental Consultants
Phone: (02) 9906 5436 Fax: (02) 9906 770

0 1
Kilometre

Figure 8 **Topographic map of Proposed Karuah Bypass (Horse Island Route) and the location of threatened flora and fauna species identified from field surveys.**

Version: 3 11th October 1999

Portions of the woodland/forest communities in the study area near water could theoretically provide potential nesting resources for Ospreys. Although, a number of large raptor nests were recorded during the fauna investigations, no Osprey activity was detected at the nests during periods of observation, and no nests typical of the Osprey were recorded. The nests observed are considered more likely to belong to other large raptor species (such as the Wedge-tailed Eagle) recorded during the fauna investigations (Appendix 4).

The Osprey is wide-ranging and highly mobile, and is likely to forage extensively over the Karuah River and nearby coastal waters.

b) Koala *Phascolarctos cinereus*

The Koala *Phascolarctos cinereus* is listed as a Vulnerable species under Schedule 2 of TSC Act, and has a patchy and poorly understood distribution amongst favoured forest types and associated tree species throughout northeastern NSW (NP&WS 1994). Whilst Koala movements and habitat usage in the general area are largely unknown, the vegetation communities within the study area are considered likely to constitute part of the home-range and food requirements of a number of individuals, or an apparently scattered population.

The most significant Koala habitat in the study area appears to constitute open forest communities on private land on the eastern side of the Karuah River. One adult female was recorded in Spotted Gum open forest during spotlighting surveys (Figure 8), and this area is broadly continuous with the 'core Koala habitat' on the Karuah Quarry site, at the eastern end of the proposed Horse Island Route. Dedicated Koala scat searches and general habitat searches conducted throughout forest/woodland communities in the general vicinity detected widely distributed scats of varied size and age (Appendix 6). The presence of numerous scats of all sizes throughout areas of potential habitats indicates the likely presence of a breeding population of Koalas in the general area.

Whilst construction of the proposed Horse Island Route option would not involve substantial clearing of Koala habitat east of the Karuah River, it would sever extensive tracts of currently connected or partly connected Koala habitat to the north and south, potentially isolating individuals or a population between the River, the new Highway and the old Pacific Highway to the south.

No evidence of Koalas was located in areas of suitable habitat west of the Karuah River, despite spotlighting surveys and dedicated scat and scratch searches (Appendix 6). Notwithstanding the presence of preferred food trees in some areas, Koala use of the vegetation communities west of the River appears to be somewhat limited, based on the absence of sightings and the scarcity of Koala scats and scratches detected during the dedicated Koala surveys. However, Koalas have been recorded in contiguous communities to the south during previous investigations (Gunninah 1997a), and are known to occur throughout the general vicinity (NP&WS Wildlife Atlas). Heavy rainfall experienced for several days during the fauna investigations may have reduced the availability of scats at some locations, and may have biased the results of the Koala scat searches in some instances.

The proposed alignment would traverse good potential Koala habitat on the southern end of Horse Island, comprising Spotted Gum open forest with mature Grey Gum. This community is regarded of high potential value for the Koala given the general scarcity of mature Koala food trees throughout much of the vegetated land on the western side of the River. Private lands to the southwest of Horse Island are also considered good potential Koala habitat, with both mature and younger examples of Grey Gum and Tallow-wood (both preferred Koala food tree species). However, mature Grey Gums are generally scarce as a result of logging in most areas.

Whilst Wallaroo SF provides potential habitat for Koalas, much of the forest and woodland communities present are considered of only marginal value for this species. Koala food trees are generally under 20 years of age and have a Diameter at Breast Height (DBH) of less than 20cm. Mature preferred food tree species are limited, being generally restricted in distribution and only occurring in small isolated stands. Grey Gum, Tallow-wood and Forest Red Gum are not dominant in the young regenerating upper canopy throughout the majority of the portion of Wallaroo SF within the study area.

Lunney *et al* (1998) identify Wallaroo Swamp and vegetation fringing the estuarine communities along the Karuah River (south of Horse Island) as being preferred Koala habitat. Wallaroo Swamp supports a fringing vegetation containing Swamp Mahogany, a preferred Koala tree species in this locality, although the central portion of Wallaroo Swamp consists of low paperbark scrub which is of little value for Koalas. Investigations conducted for this report indicate that Koalas are widely though relatively sparsely distributed through the study area, with apparent higher densities and more substantial populations occurring to the east of the Karuah River than to the west. The Horse Island Route west of the Karuah River is primarily located in marginal Koala habitat (as mapped by Lunney *et al* 1998), essentially avoiding the Swamp Mahogany vegetation around Wallaroo Swamp and involving only limited impacts upon the preferred Koala habitat mapped by Lunney *et al* (1998) along the western bank of the Karuah River.

Nevertheless, the proposed alignment on the western side of the river would result in the loss of some areas of potential Koala habitat on private land and in State Forests and the Karuah NR. The vegetation communities present are contiguous with extensive tracts of potential Koala habitat located in Wallaroo SF to the west and Karuah SF to the north. The proposed route would sever currently contiguous potential Koala habitat through the area and potentially could isolate individual animals or a population between the River, the new alignment and the existing Pacific Highway to the south.

c) Squirrel Glider *Petaurus norfolcensis*

The Squirrel Glider inhabits dry sclerophyll forest and woodland in eastern Australia (Suckling 1995). Its diet consists of *Acacia* gum, *Eucalyptus* sap, invertebrates and insect exudates (such as lerps). Family groups require medium-sized tree-hollows for diurnal shelter and nesting and occupy home ranges of approximately 20-30ha.

Two sightings of a Squirrel Glider were recorded during spotlighting surveys in the study area, both sightings were recorded in Spotted Gum open forest (Community 1) in Karuah NR to the north of the Mines Hill Trail (Table 3; Figure 8). The sightings were recorded on consecutive nights within 1km of each other, and may represent the same individual. The Squirrel Glider is known to occur in forest and woodland throughout the surrounding area (Gunninah 1997b), and has been recorded previously at several localities within 10km of the study area (NP&WS Wildlife Atlas).

The construction of the proposed Horse Island Route option on the western side of the River would result in the loss of woodland and forest communities on private lands and within both Karuah NR and Karuah SF which provide potential foraging and denning habitat for the Squirrel Glider. This species is likely to occur widely through Wallaroo SF, notwithstanding the relatively low densities of mature trees with hollows, and the levels of disturbance (particularly fire and logging) which have affected the areas west of the River. The proposed alignment would impose a barrier to movement across large areas of potential habitat for this species and, as for the Koala, potentially could isolate individuals or a population between the River, the new alignment and the existing Pacific Highway.

No evidence for the Squirrel Glider was recorded in the study area east of the Karuah River, nor has it been recorded on the Karuah Quarry site (Gunninah 1997c). However, this species may occur, given the presence of suitable forest and woodland habitat and its known presence in the locality. Construction of the Horse Island Route on the eastern side of the River would not involve a substantial loss of potential habitat for the Squirrel Glider, but would effectively sever currently contiguous tracts of potential habitat to the north and south.

d) Little Bent-wing Bat *Miniopterus australis*

The Little Bent-wing Bat occurs along the coast and ranges in northeastern NSW, becoming increasingly coastal towards the southern end of its distributional range in the mid-north coast. It roosts during the day in caves and tunnels and depends upon specific nursery sites to rear its young and for winter hibernation (Dwyer 1995). All caves utilised by this species are located near relatively large areas of dense vegetation, including rainforest, wet sclerophyll forest or coastal Banksia scrub (Gilmore & Parnaby 1994). Foraging activities

appear to be concentrated between the understorey and canopy of vegetation communities, including most forest and woodland communities within the species' range.

Four Little Bent-wing Bats (amongst several other common species) were captured during harp trapping activities in open forest in the study area (Table 3; Figure 8), and the forest and woodland communities within the study area are likely to contribute to the foraging resources for Little Bent-wing Bats in the general vicinity. However, no potential roosting or nursery sites for this species are present in the immediate vicinity (*ie* within several hundred metres) of the proposed alignment. Animals are reported to roost in the Balickera Tunnel near Raymond Terrace, to the southwest of the study area, and may also roost in other artificial structures in the general vicinity. The only known nursery colony for the Little Bent-wing Bat in NSW is located at Willi Willi caves, inland from Kempsey (NP&WS 1994).

The Horse Island Route would involve the removal of some forest and woodland which is presumably utilised by the Little Bent-wing Bat for foraging. Conversely, forest and woodland communities suitable for foraging by this species are widespread in the study area and locality. There are no suitable roosting or maternity resources along the Horse Island Route alignment, and the project will not affect this species with respect to shelter or breeding.

e) Eastern Freetail Bat *Mormopterus norfolkensis*

Calls of the Eastern Freetail Bat were recorded in the study area using an Anabat II detector (Table 3; Figure 8). Very little is known of the biology of this species. Gilmore & Parnaby (1994) note that nearly all literature references to the Eastern Freetail Bat are not valid, resulting from confusion with the more common undescribed *Mormopterus* Sp 1 or the *M planiceps* species complex.

Most existing records of this species are from dry eucalypt forest and woodland east of the Great Dividing range, extending from southeast Queensland to southern NSW (Allison & Hoye 1995). The species is known to roost in tree-hollows or under bark (Gilmore & Parnaby 1994), but has also been recorded roosting in the roof of a hut (Allison & Hoye 1995).

The "*removal or modification of habitat*", particularly hollow-bearing trees and foraging habitat, may potentially reduce the availability of necessary resources for individuals in the locality, and thus adversely affect individuals of the Eastern Freetail Bat. 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.

f) Greater Broad-nosed Bat *Scoteanax rueppellii*

The probable calls of the Greater Broad-nosed Bat were recorded using an Anabat II ultrasonic call detector during field investigations in the Spotted Gum open forest in the study area (Table 3; Figure 8).

The Greater Broad-nosed Bat occurs in eastern Australia, from southeast Queensland to northeastern Victoria. Its stronghold is in the gullies and river systems of the Great Dividing range, but its distribution extends to the coast over much of its range (Hoye & Richards 1995). It is sparse but widely distributed along the north coast of NSW (Gilmore & Parnaby 1994).

The Greater Broad-nosed Bat occurs in a variety of habitats from woodland through moist and dry eucalypt forest to rainforest, although it prefers "moist gullies in mature coastal forest, or rainforest" (Churchill 1998). This species forages at a height of up to 20m in natural and artificial clearings in the vegetation, along ecotones between pastures and woodland, and along creeks and small rivers. This species preys on slow-flying insects, and

has been reported to kill and consume other bats in captivity (Gilmore & Parnaby 1994). Tree-hollows are generally utilised for maternity sites and for roosting, although it has also been found roosting in the roof spaces of old buildings (Hoye & Richards 1995).

Adverse impacts which are likely to affect the Greater Broad-nosed Bat are similar to those described for the Eastern Freetail Bat (above). The Horse Island Route would require the removal of forest and woodland utilised for foraging by the Greater Broad-nosed Bat, and the loss of some tree-hollows which may be used as roosting sites by this species.

The construction of the proposed Horse Island Route option would involve the removal of some woodland and forest habitat which may contribute to the foraging resources for this and several other threatened microchiropteran bat species in the general area. The communities present also provide roosting and/or maternity resources for hollow-dependent species and those which roost under bark. However, substantial areas of similar habitat occur in the State Forests in the immediate vicinity and surrounding area, and the proposed road would not constitute a barrier to the movements of these highly mobile and wide-ranging species.

5.3.2 Threatened Fauna Known from the Surrounding Area

A number of additional threatened fauna species, included on Schedule 1 and 2 of the TSC Act have been recorded within 10km of the study area (NP&WS Wildlife Atlas), or are listed on the Birds Australia database for the area. A number of other threatened fauna species, not recorded within 10km of the study area, but which have been recorded in the wider surrounding area are also discussed, given the presence of relevant potential resources and habitats in the study area.

Birds

Glossy Black Cockatoo
The Glossy Black Cockatoo *Calyptorhynchus lathami* has been recorded within 10km of the study area (NP&WS Wildlife Atlas) and is known to occur throughout the general locality (Gunninah 1997b; Birds Australia). It inhabits forest and woodland, feeding on the cones of Black Oak *Allocasuarina torulosa* and Forest Oak *A littoralis*, and requires large tree-hollows for nesting (Forshaw & Cooper 1981).

The study area supports resources of relevance for this species, including Forest She-Oak and Black Oak in the mid-canopy of woodland/open forest communities and some large tree-hollows suitable for nest sites. No evidence for the Glossy Black Cockatoo in the form of observations or chewed *Allocasuarina* cones was recorded in the immediate vicinity of the alignment during this or previous investigations (Gunninah 1997a).

Masked and Powerful Owls
The Masked Owl *Tyto novaehollandiae* and Powerful Owl *Ninox strenua* have both been recorded within 10km of the study area (NP&WS Wildlife Atlas). The Masked Owl has also been recently recorded in the vicinity of Grahamstown Dam near Raymond Terrace to the southwest of the study area (Gunninah 1997b). Powerful and Masked Owls occupy large home ranges (1000ha and 500-100ha respectively) in eucalypt forest and woodland (Debus & Rose 1994; Debus & Chafer 1994). They require large tree-hollows for nesting, and relatively high densities of arboreal and terrestrial mammals for prey (Debus & Rose 1994).

No evidence of Powerful or Masked Owl roosting sites was detected in the study area, although several large hollow-bearing stags of potential value for these species occur in the general study area. Woodland communities within the study area could potentially contribute to the foraging resources for pairs in the general area.

Bush Stone-curlew
The Bush Stone-curlew *Burhinus grallarius* has been recorded near Karuah and Tanilba Bay (NP&WS Wildlife Atlas; Birds Australia database). This species is a nocturnal ground-dwelling bird, which inhabits "*lightly timbered open forest and woodland, or partly cleared farmland with remnants of woodland, with a groundcover of short sparse grass and few or no shrubs*" (Marchant & Higgins 1993). It forages on dry open ground amongst grass, pasture

or crops, for insects, spiders, frogs, lizards and snakes, and nests on the ground in open areas under trees, often near dead fallen timber (Marchant & Higgins 1993).

The Bush Stone-curlew was not recorded during spotlighting surveys conducted for this investigation, but may occur in the study area, given the habitats present. It has not been recorded by observation in the general vicinity or surrounding area during a number of recent investigations (Gunninah 1997a, b, c; Ecotone 1995), however, calls were heard south of the Proposed alignment near the Karuah township (ERM Mitchell McCotter 1999.

Wompoo Fruit-dove
One rainforest-dependent species, the Wompoo Fruit-dove *Ptilinopus magnificus* has been recorded within 10km of the study area (NP&WS Wildlife Atlas). This species is frugivorous, feeding on a variety of rainforest fruits, and undertakes seasonal movements in response to food availability (Date & Recher 1989; Gilmore & Parnaby 1994). Rainforest or a well-developed rainforest midstorey are not present within the study area, and consequently the Wompoo Fruit-dove is not likely to be present.

A number of additional bird species of conservation concern, which are known to occur in the wider area, but which have not been recorded within 10km of the study area (Birds Australia; NP&WS Wildlife Atlas), could also occur in the general vicinity on the basis of the habitats present (as discussed below). However, no evidence for any of these species was detected during fauna investigations in the study area, nor have they been recorded in recent surveys in the immediate vicinity (Gunninah 1997a, b, c, d, 1998; Ecotone 1995).

The Black-necked Stork *Ephippiorhynchus asiaticus* is common in the tropical north, but its occurrence south of the Clarence River in NSW is erratic (Lindsey 1992) and rare, mainly comprising immature individuals or vagrants. The Black-necked Stork inhabits terrestrial wetlands, estuarine and littoral habitats, and occasionally grassland and wooded lands (Marchant & Higgins 1990). It forages in fresh or saline shallow waters for fish, crustaceans and insects. The study area is located south of the Black-necked Stork's core distributional range, and there is no suitable or relevant habitat for this species.

The Lesser Sand Plover *Charadrius mongolus* is a migratory species listed on the Japan-Australia Migratory Birds Agreement (JAMBA 1974), which spends the spring and summer months in northeastern Australia. It is most numerous in the Gulf of Carpentaria, although animals also migrate along the eastern coast into northern NSW. The Lesser Sand Plover is an exclusively coastal species, feeding at low tide on intertidal mudflats and roosting on sandy beaches and promontories at high tide. The estuarine wetland communities within the study area provide suitable foraging habitat for the Lesser Sand Plover, but do not support suitable nesting habitat.

The Little Tern *Sterna albifrons* is a migratory species listed on both JAMBA (1974) and CAMBA (1989). Little Terns are present in NSW from September to May, with some breeding populations (Smith 1990). Birds forage over coastal waters, diving for fish and crustaceans, and breeding birds nesting on sand or shingle beaches where there is very little, if any, vegetation (Smith 1990). Little Terns would be extremely unlikely to occur in the study area, although individuals could potentially forage along estuarine mudflats in the general vicinity on occasion.

Both the Pied Oystercatcher *Haematopus longirostris* and Sooty Oystercatcher *Haematopus fuliginosus* have been recorded in the general area (Birds Australia). Both species forage on intertidal mudflats and sometimes shelter in adjacent saltmarsh areas. The estuarine wetland communities associated with the Karuah River in the study area and to the north and south provide potential foraging and refuge habitat for these species, although no evidence of their presence has been detected during this study nor during recent surveys in the immediate vicinity (Gunninah 1997a).

The Australasian Bittern *Botaurus poiciloptilus* and Black Bittern *Ixobrychus flavicollis* inhabit dense vegetation along the edge of watercourses or wetlands (terrestrial or estuarine). Either species could theoretically occur in estuarine wetland communities along the Karuah River or in freshwater wetlands immediately south of the study area (Gunninah 1997a).

Mammals

One additional threatened arboreal mammal (the Brush-tailed Phascogale *Phascogale tapoatafa*) has been recorded at scattered locations within the general area (NP&WS Wildlife Atlas; Gunninah 1997b), and is known to occur near Grahamstown Dam near Raymond Terrace to the southwest (Gunninah 1997b). The Brush-tailed Phascogale occurs primarily in dry sclerophyll forest and woodland (Suckling 1995), but also in swamp forests and heathlands, wet sclerophyll forest and cool temperate rainforest (Dickman & McKechnie 1985). This species shelters in nests in tree-hollows (25-40mm wide), and feeds on spiders, insects, centipedes and small vertebrates (Gilmore & Parnaby 1994).

No evidence for the presence of the Brush-tailed Phascogale was detected within the study area, despite targeted trapping surveys and intensive spotlighting through potentially suitable habitats. This species has not been detected during previous field investigations in areas of suitable habitat immediately south of the study area (Gunninah 1997a), but could potentially occur in the general vicinity, given its presence in the region and the presence of potential habitat.

The Tiger Quoll *Dasyurus maculatus* has also been recorded within 10km of the study area (NP&WS Wildlife Atlas). This species utilises a range of forest and woodland habitats, particularly those with a dense to moderate understorey and with hollow logs which provide both shelter and den sites. The Tiger Quoll was not recorded in the study area despite targeted trapping surveys, and has not been recorded in recent investigations in the immediate vicinity or surrounding area (Gunninah 1997a, b, c; Ecotone 1995). Nevertheless, it may occur in forest and woodland communities throughout the general vicinity. Additionally, anecdotal evidence of this species has been obtained from land to the south of the alignment (Clarke *pers comm*).

Several additional microchiropteran bats of conservation concern, in addition to those recorded during the field investigations (including the Common Bent-wing Bat *Miniopterus schreibersii*, Large-footed Myotis *Myotis adversus* and Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*) have also been recorded in the wider area (Gunninah 1997b; NP&WS 1994, NP&WS Wildlife Atlas).

The Common Bent-wing Bat roosts in caves, old mines, tunnels or other similar structures and requires specific nursery caves for rearing its young. It forages above the canopy in wet sclerophyll, rainforest and dry forest, favouring valley areas (Gilmore & Parnaby 1994). The Large-footed Myotis also roosts in caves, and tunnels, and under brides and in culverts, generally located close to bodies of water (such as rivers and reservoirs), where it forages for aquatic insects and small fish (Parnaby & Gilmore 1994).

The study area does not support roosting resources for cave-dwelling microchiropteran bat species. However, forest and woodland communities within the study area could potentially contribute to foraging habitat for the Common Bent-wing Bat, and the Large-footed Myotis could potentially forage over the Karuah River and farm dams in the general vicinity.

The Yellow-bellied Sheathtail Bat roosts in tree-hollows and forages over and/or within woodland and open forest communities. Suitable habitat and resources for this species are present in the immediate vicinity and to a greater extent in the surrounding forest habitats.

Amphibians

No threatened amphibian species are listed on the NP&WS Wildlife Atlas within 10km of the study area. However, three threatened amphibian species, the Green-thighed Frog *Litoria brevipalmata*, Green & Golden Bell Frog *Litoria aurea* and Wallum Froglet *Crinia tinnula* have been recorded in the broader area.

The Green & Golden Bell Frog is confined to coastal lowlands in NSW, where it is now encountered most frequently in highly disturbed sites in urban areas (White & Pyke 1996). It requires a range of specific habitat attributes, including "*waterbodies which are still, shallow, ephemeral, unpolluted, unshaded and free of Gambusia* " for breeding, the presence of aquatic plants (preferably *Typha* sp) and nearby grassy areas for feeding, and vegetation and rocks which provide diurnal shelter and over-wintering sites (Pyke & White 1996).

The Green & Golden Bell Frog was not recorded during the field surveys conducted in the study area, despite specific searches in areas of potentially suitable habitat. None of the natural watercourses and few of the farm dams along the Horse Island Route option are regarded as suitable habitat for the Green & Golden Bell Frog, and it is not likely that this species is present in the study area or along the proposed alignment. Several populations of Green & Golden Bell Frogs which had historically occurred in the locality have not been recorded in recent times (White 1996).

In particular, Green & Golden Bell Frogs are noted as being absent from previously known sites at Bulahdelah, Ourimbah and Smith's Lake.

The Wallum Froglet inhabits shallow acidic swamps (usually temporary or semi-permanent) and associated watercourses on coastal lowlands from Maryborough (Qld) in the north to Kurnell in the south (Ehmann 1997). Known sites are typically characterised by the presence of wet heath and woodland on coastal sandplains and dunes, and sedgelands and swamps, usually with tea-tree and Broad-leaved Paperbark (Ehmann 1997).

The Wallum Froglet was not recorded during field investigations along the Horse Island Route option, or in the study area, and there is no suitable habitat present along the alignment for this species. Substantial populations of the Wallum Froglet are known to occur in sedge swamps at Tomago (to the southwest of Karuah) and on the southern side of Port Stephens, in low-lying sedge swamp communities on sand. Whilst sedgeland communities occur in parts of Wallaroo Swamp, these areas are not characteristic of the habitats utilised by the Wallum Froglet in this part of its range.

The Green-thighed Frog *Littoria brevipalmata* occurs in a range of vegetation types, including riparian rainforest, wet and dry sclerophyll forest, and woodland vegetation. This species breeds in areas of temporary inundation, including waterholes, ponds, artificial dams and ditches, which are mostly filled as a result of local heavy rain. The Green-thighed Frog appears to prefer shallow exposed ponds, with moderate leaf litter and/or submerged vegetation (Ehmann 1998).

Field investigations for the Horse Island Route option were conducted in late 1997 and early 1998 under ideal conditions for locating the Green-thighed Frog. Periods of heavy rainfall (probably exceeding 25mm in 24 hours) were encountered, which is regarded as the most appropriate circumstance for locating this species. To the west of the Karuah River, the proposed Horse Island Route option traverses little suitable habitat for the Green-thighed Frog, with few areas likely to be subjected to inundation to provide breeding habitat for this species. To the east of the Karuah River, more extensive areas of flood-prone land are present, although in most instances the alignment is located at some considerable distance from areas of adjoining forest and woodland. Consequently, the Horse Island Route option appears likely to affect only a very limited area of potential habitat for the Green-thighed Frog, and the lack of records of this species from the alignment is not considered unusual.

6 POTENTIAL IMPACTS of the PROPOSAL

In general terms, the principal effects and potential impacts on native fauna and flora and their habitats which will or could arise (unless addressed by appropriate design and/or environmental management and impact amelioration measures) as a result of the proposed road construction and operation activities include:

- habitat removal, involving the clearing of native vegetation, and the removal of habitat features and resources (such as hollow-bearing trees, swamps, ponds, rocks, logs *etc*);
- the loss of areas of 'significant vegetation communities', if any are present;
- the loss of individuals of threatened flora and fauna species, and also of protected species;
- the possibility of 'edge effects' being imposed upon adjacent habitat and vegetation communities, involving altered microclimates, changes in vegetation, and the potential displacement of more sensitive flora and fauna species with more opportunistic species;
- impacts on areas regarded as of conservation value and which are protected by state legislation (including the Karuah NR and SEPP 14 wetlands);
- contribution to the cumulative impacts on the natural environment arising from the upgrade of the Pacific Highway between Hexham and the Queensland border;
- the formation of barriers to animal movements, particularly for terrestrial and non-aerial mammals, reptiles and amphibians;
- habitat fragmentation, which may divide populations or communities into smaller, and less viable, units, and reduce genetic flow;
- wildlife mortality as a result of collision with motor vehicles; and
- the disturbance and degradation of adjacent habitat through clearing and construction activities, the discharge of sediment or contaminants both during and after construction, 'edge effects', hydrological changes and/or increases in weed-infestation.

The potential impacts and adverse effects on native fauna and flora which may or will be imposed upon the natural environment as the result of a road construction can be managed or mitigated to varying extents by incorporating environmental management and impact amelioration measures into the project design. Whilst the lost of natural vegetation and habitats cannot be avoided altogether, the severity and intensity of habitat loss can be reduced by appropriate design and planning, and by the implementation of sensitive construction methods.

Similarly, the formation of barriers to animal movements through the landscape generally cannot be avoided altogether, but can be reduced by the use of appropriate measures to facilitate fauna crossing the road. A range of measures are incorporated in the design of the roadworks to limit or mitigate adverse impacts with respect to habitat fragmentation, wildlife mortality and habitat degradation adjacent to the road.

In the case of the Karuah Bypass (Horse Island Route) of the Pacific Highway, as along the whole of the Pacific Highway upgrade project, road design and construction activities involve the implementation of 'best practice' environmental construction methods. Careful control and management of sediment and contaminant discharges, hydrologic and stormwater management measures, minimal vegetation clearing controls and an array of specific design elements to facilitate fauna crossings are included as integral elements of the project. The incorporation of these measures as parts of the proposed activity reduces the impacts of the Pacific Highway Bypass at Karuah. The environmental impact

assessment of the project is thus based upon the proposed roadworks including these impact amelioration measures.

6.1 Habitat Removal

The loss of vegetation and habitat for the construction of roads in general may constitute a significant adverse impact upon the natural environment and native biota, depending on the nature of the landscape through which the road is to pass and the extent of resources for native species in the locality. The general approach to habitat loss along the Pacific Highway upgrade is to locate the Highway wherever possible in areas of already cleared or disturbed landscape and, where native vegetation must be removed, to minimise the footprint of the road and limit the clearing of native vegetation and habitats to the smallest area possible.

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 34.16ha of forested and naturally vegetated land along the alignment, of which 3.6ha is located in Karuah NR. These forested areas predominantly involve 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) will also be affected, with 1.9ha of saline wetlands (both mangroves and salt-marsh) also being 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.

The extent of those vegetation communities which are to be removed for the Karuah Bypass of the Pacific Highway constitute only a relatively small proportion of those communities in the vicinity and in the locality (Figure 7a & 7b). Much of the vegetation to be removed is in relatively poor to moderate condition, as a consequence of the previous timber harvesting and burning regime.

Some of the open forest and woodland communities which are to be removed are relatively intact (floristically at least), although none appear to represent vegetation or habitats of restricted distribution in the vicinity or of exceptionally high conservation value (*eg* 'old growth' forest). It is recognised that an area of High Conservation Old Growth Forest has been identified in Wallaroo SF, in close proximity to the proposed alignment. Hollow-bearing trees and large stags are present at relatively low densities within the study area, and appear to be relatively evenly distributed throughout the landscape. In particular, very large hollow-bearing trees and stags are rare, a hollow-bearing tree report will be prepared as an Appendix for the SIS (Gunninah 1999c).

Whilst the Horse Island Route for the Karuah Bypass will involve the removal of a relatively small area of native vegetation in relation to the extent of forest and woodland, and wetland, habitats in the locality and region, the bypass will involve an increase in fragmentation of habitat and the imposition of a barrier to the movements of some fauna species (see below).

6.2 Flora

The clearing of natural habitats and vegetation communities for the Karuah Bypass (Horse Island Route) will result in the loss of individuals of a range of protected native flora species. However, as noted above, the areas of the vegetation communities which are to be removed for the Bypass are small in comparison to their local and regional distributions, and the loss of individual plants, whilst relevant in an immediate or local sense, is not likely to be regarded as significant in terms of the overall distribution and conservation status of protected flora species. The imposition of minimal clearing protocols as part of the construction activity is regarded as an appropriate measure to minimise the loss of native plants.

Similar considerations apply with respect to the vegetation communities present along the alignment. None of the vegetation to be removed constitutes a vegetation community of restricted or limited distribution in the locality, and the proposed Bypass will not remove significant areas of any vegetation communities. The conservation status of those communities present along the Bypass is currently uncertain, because of the CRA and RFA processes, which are substantially increasing the extent of conservation reserves in the locality and region. The proposed Karuah Bypass is not likely to involve the loss of significant areas of any vegetation communities, irrespective of their conservation status.

One threatened plant species (Black-eyed Susan *Tetratheca juncea*) has been located along the Karuah Bypass (Horse Island Route) alignment, with scattered and generally isolated patches of the species located in the woodland and open forest communities within private forest in the western portion of the study area and on Horse Island (Figure 8), as well as in the Karuah Quarry site at the eastern end of the alignment (Gunninah 1997c). Individuals of this species were also recorded scattered sparsely throughout the forest and woodland communities in Karuah SF at the western end of the Bypass alignment, and some individuals will be removed as part of the Karuah bypass project. The loss of individuals of *T juncea* as a consequence of the proposed roadworks is considered in detail in Chapter 7 of this report, which provides an assessment pursuant to s.5A of the EP&A Act[3].

6.3 Fauna

The Karuah Bypass (Horse Island Route) will involve the removal of vegetation communities and habitats for a range of native fauna species. The impacts of the proposed road will principally be of relevance in an immediate and local sense, affecting individuals of those species present along the alignment by the loss of resources and home ranges, and by disrupting local distributions and territories. However, the Bypass is not likely to significantly affect the regional conservation status of protected or threatened fauna species in the vicinity.

Whilst individuals of some species are likely to recolonise areas adjoining the alignment following landscaping and habitat rehabilitation, the road will permanently affect the fauna assemblage in the immediate vicinity, by the replacement of some less tolerant species with those less sensitive to disturbance, and by modifications to home ranges and territorial patterns. Additionally, for some species the road will provide a barrier to movements (as discussed below), potentially interrupting the regionally significant wildlife corridor identified by the NP&WS (see below).

Amphibians

All of the amphibian species recorded during the field investigations for the Karuah Bypass are common to abundant and widespread, and the loss of habitats and resources for these species as a result of the proposal is not regarded as significant. No threatened amphibian species have been recorded during the field investigations along the alignment or in the vicinity, although the Green-thighed Frog could possibly occur around Wallaroo Swamp or elsewhere along the alignment, given its apparent broad habitat tolerance (F Lemkert *pers comm*). Conversely, this species was not recorded during the field investigations for the Bypass (despite ideal survey conditions), and habitats and resources along the alignment are neither unique nor restricted in distribution.

The Karuah Bypass (Horse Island Route) will involve the clearing and disturbance of some drainage lines and creeklines, including small areas along Mosquito Creek and its tributary in the east, the Karuah River in the center of the project, and small ephemeral drainage lines in the west (in Karuah SF and NR). The road will also affect a few small pools and farm dams, none of which are regarded as of particular value for amphibians.

The proposed Karuah Bypass (Horse Island Route) will involve adverse impacts only to limited areas of likely significant or 'core' habitat for amphibians. Most of the alignment is characterised by cleared pasture or by dry sclerophyll forest and woodland, and there are

[3] Additional detail regarding *T juncea* is contained in the Species Impact Statement prepared for the Karuah Bypass.

few resources or habitats of particular value for this group of fauna along the Karuah Bypass alignment. Notwithstanding the inability of many amphibian species to survive away from water, few amphibians are regarded as likely to occur along most of the proposed alignment, because of the nature and extent of the resources present.

Reptiles

The ten reptile species recorded during the field investigations for the Karuah Bypass (Horse Island Route) are common to abundant and widespread. The loss of habitat and resources for these species (or of individuals) is not regarded as likely to constitute a significant impact upon their conservation status.

As for the amphibians recorded along the alignment, many of the reptile species are regarded as likely to recolonise areas of rehabilitated land adjoining the alignment, including artificial embankments, storm water control ponds and areas of revegetation. Whilst the proposed roadworks will undoubtedly displace individuals and disrupt populations of the reptile species recorded during the construction activities, the adverse impacts upon this group of native fauna is not regarded as likely to be significant.

No threatened reptiles were recorded along the Karuah Bypass (Horse Island Route) alignment, and none are regarded as likely to occur, given the nature and condition of habitats to be affected and the distribution of threatened reptile species in the region.

Birds

The majority of the seventy-four native bird species which were recorded along the Karuah Bypass (Horse Island Route) alignment are common to abundant and widespread in distribution. Most of the bird species recorded are inhabitants of forest and woodland communities, although a number of additional species which typically utilise cleared and open habitats or wetlands were also recorded.

The proposed Karuah Bypass will involve the removal of habitats and resources for most of the native bird species recorded in the vicinity, although the extent of habitat removal is relatively small compared to the broad distribution of forest and woodland communities and other habitats in the locality.

Loss of habitats and resources will require individual birds to vacate areas currently occupied, and is likely to involve some territorial disputes and some bird mortalities. However, as noted above, the extent of relevant habitats and resources, and of the bird communities, is such that the adverse impacts which will be imposed upon the native avifauna along the Karuah Bypass alignment are not considered likely to be significant.

A number of threatened bird species have been recorded along the Karuah Bypass (Horse Island Route) alignment or in the general vicinity. However, none is considered dependent upon resources or habitat features which will be removed for the proposed roadworks. Those threatened avifauna species known from the locality are generally sufficiently mobile to avoid the construction activities, and there is a substantial area of suitable habitat in the general locality for each of these species. Whilst the proposal clearly will remove habitat and resources which is or may be utilised by these avifauna species (the Powerful and Masked Owls, Bush Stone-curlew, Osprey, Glossy Black Cockatoo and others), habitat features and resources for all of these species are relatively widespread in the locality (Chapter 5). These species have moderate to very large home ranges, and none are limited to small habitat patches.

The Karuah Bypass (Horse Island Route) is likely to disrupt or modify the home ranges or territories of a number of individual native birds, possibly including several threatened species. These impacts are likely to be relatively local, however, and are not regarded as likely to adversely affect the conservation status of those avifauna species known to occur in the locality.

Mammals

Twenty native mammal species have been recorded in the study area, involving an array of terrestrial, arboreal and aerial species. As for the avifauna in the area, the proposed Karuah Bypass (Horse Island Route) project will involve the loss of habitats and resources which are or may be used by most or all of the native mammal species present. However, the extent of suitable habitats and resources in the locality (particularly in the Karuah, Medowie and Wallaroo State Forests, and in the Karuah Nature Reserve) limits the potential impacts of the loss of vegetation and habitats.

As is the case for several of the native bird species, a number of native mammal species are reliant on tree-hollows and large ('over-mature') trees for shelter or breeding sites. The Karuah SF and other forest vegetation along the alignment appear to have been intensively harvested for timber over a long period, and hollow-bearing trees are present only at relatively low densities. Large trees are uncommon along the alignment. Because of the low densities of hollow-bearing trees, the proposal will involve the removal of relatively few such trees[4], and measures are proposed to redress the loss which will occur.

Several of the mammalian species recorded along the alignment or in the vicinity are listed as 'threatened' (pursuant to the TSC Act), including the Squirrel Glider and Koala, the Tiger Quoll and three threatened microchiropteran bats (see Chapter 5). Notwithstanding the considerable extent of potential habitat in the locality for these species, there is the possibility *of "a significant effect"* being imposed upon the Squirrel Glider, Tiger Quoll and Koala. Consequently, a Species Impact Statement has been prepared for the project, pursuant to the conclusions of the s.5A Assessment of Significance (see Chapter 7).

6.4 Barrier Formation

Roads (particularly 4-lane dual-carriageway structures) can act as significant barriers to the movement of terrestrial and arboreal fauna, as a result of the break in vegetation and protective cover, the imposition of large structures, the levels of disturbance to roadside habitats, general disturbance generated by traffic, and direct wildlife mortalities (see below).

The barrier effect of roadways is of particular concern for terrestrial species, including small to moderate-sized terrestrial mammals, reptiles and amphibians. Roads can also constitute a significant barrier to gliding mammals (such as the Sugar Glider and Squirrel Glider), depending on the road width and the availability of tall trees adjacent to the road.

Amphibians

Amphibians generally do not rely on movement corridors, but do move throughout parts of the landscape depending upon climatic conditions and seasonal requirements (*eg* for breeding). Some amphibian species are mobile and wide-ranging (*eg* the Green & Golden Bell Frog and the Green-thighed Frog), whereas many other species are relatively sedentary and remain closely associated with wetlands and aquatic habitats.

Amphibians generally are likely to be able to use both fauna underpasses (to be installed along the Karuah Bypass alignment) and drainage culverts for continued movement through the landscape. Most of these structures are to be located at low points in the landscape (along drainage lines and creeklines), which are more conducive to amphibian movements than the drier ridges.

No threatened amphibian species were recorded along the Karuah Bypass (Horse Island Route) alignment. However, there is potential for the Green-thighed Frog to occur in the Wallaroo Swamp area and, if present, this species could in theory use low-lying areas in the cleared land to the southwest for breeding purposes. If it is present in the vicinity, and does use such a movement 'corridor', this species would be likely to use the array of culverts and fauna underpasses proposed for this portion of the alignment.

[4] The numbers and locations of hollow-bearing trees to be removed along the alignment are documented in the SIS.

Reptiles

Reptiles generally do not make large-scale migrations or extensive movements through the landscape, and are not likely to be adversely affected by the Karuah Bypass in this regard. Additionally, as for the amphibian fauna, reptiles are likely to utilise both drainage culverts and fauna underpasses to pass beneath the roadway. The proposed Karuah Bypass (Horse Island Route) will incorporate a variety of fauna underpass structures intended to avoid the imposition of a significant barrier to movements of reptiles in this locality.

Birds

Birds are generally highly mobile, and most species will be able to cross the road simply by flying across it. Bird mortalities along roads mostly involve species such as corvids and magpies (attracted to the road by other dead wildlife), or granivorous birds (such as parrots) in areas where grain harvesting is occurring (DF *pers obs*; Cooper 1998). Notwithstanding the use of fauna-proof fencing along the proposed Karuah Bypass, avian road mortalities are inevitable, although the numbers involved are not likely to be significant (given observations on other major roads in NSW and elsewhere).

The proposed Karuah Bypass crosses protected wetlands on the western side of the Karuah River near Horse Island. However, the road will be on a tall (approximately 10m high) bridge at this location, permitting wetland and aquatic birds to fly either over or under it. Consequently, the proposed Karuah Bypass (Horse Island Route) does not appear likely to impose a significant adverse impact upon bird movements through the locality.

Terrestrial mammals are the most likely to be adversely affected by the proposed Karuah Bypass with respect to movements through the landscape. Many species will either be repelled by the roadway and traffic, and will thus be unable to cross in the absence of dedicated fauna passages, or are likely to be struck by motor vehicles in attempting to cross the road. As a consequence, the proposed Bypass has the potential to adversely impact upon the movement of terrestrial mammals through the landscape, and could isolate populations of species on each side of the road. Similarly, in the absence of dedicated crossing points for arboreal fauna (particularly the Squirrel Glider and Sugar Glider), the proposed Bypass could impose a substantial barrier to movements of these species.

However, for both the terrestrial and the arboreal mammal fauna, a range of underpass, overpass and glider crossing points are to be provided along the Karuah Bypass (Horse Island Route) alignment[5] (Chapter 8). Nevertheless, the Bypass will restrict wildlife movements through the landscape in both the short-term and long-term.

For those species which may use underpasses or overpasses, relevant considerations include:

- the relative locations of the structures and the home ranges of individual animals (particularly for territorial species);
- restrictions on access where a structure is located in the home range of a dominant or territorial animal; and
- the suitability of habitat and features around the structure.

It is not possible to provide sufficient structures for all individuals of all species along the Karuah Bypass (Horse Island Route) alignment (or along any other road). Consequently, some restriction on fauna movements, as discussed above, is inevitable, although measures are proposed to reduce that impact (as far as is reasonably achievable). The potential impacts on regional 'wildlife corridors' and the contribution of the Karuah Bypass (Horse Island Route) to cumulative impacts are considered below.

---

[5] Chapter 8 of this report provides generic information regarding fauna underpasses, overpasses and crossing points. The SIS for the project provides greater detail and precise locations the Flora & Fauna Assessment report was prepared, although not finalised, prior to the SIS and completion of the engineering design for the Karuah Bypass (Horse Island Route).

6.5 Wildlife Corridors

In addition to the general movement of animals through the landscape (as discussed above), there are some known large-scale animal movements (*eg* rainforest pigeons between the coast and highlands - Date & Recher 1989) in places, and larger tracts of vegetation are generally regarded as 'wildlife corridors'. The NP&WS has identified the general area traversed by the Karuah Bypass as "*a regionally significant wildlife corridor*" (L Baker NP&WS *pers comm*), presumably on the basis of the presence of a relatively contiguous vegetative cover.

The western end of the Karuah Bypass is located in the eastern part of the 'wildlife corridor' identified by the NP&WS, and will involve the imposition of an additional barrier to fauna movements through part of, but not along the majority of, the 'corridor'. Furthermore, many of the species which may utilise the 'corridor' on an individual basis are likely to be highly mobile (*eg* rainforest pigeons and other migratory bird species), and are not likely to be significantly restricted by the Bypass. Species undertaking more local movements may be affected (as discussed above), and there may also be some reduction in long-term movements of native fauna in local or regional terms, and possibly in long-term flows of genetic material. Conversely, the Karuah Bypass will not sever that 'wildlife corridor' completely, as forested land to the west of the alignment will remain unaffected.

On a local scale, drainage lines and creeklines through the landscape may constitute 'wildlife corridors' for particular species because of the presence of appropriate or necessary habitat features and/or resources. In this regard, vegetation along the Karuah River, Mosquito Creek and a tributary creek in the eastern part of the alignment are likely to constitute 'corridors' for some species. Some native fauna species (particularly wetland birds associated with mangroves and saltmarsh communities) are likely to travel along the banks (particularly the western shore) of the Karuah River, and those wildlife species which are intolerant of disturbance and clearing would probably utilise the riparian corridors along Mosquito Creek and its tributary.

In the case of the Karuah River, the proposed road is to be constructed in a manner which retains the potential for wildlife to move along the River banks and riparian habitants. Substantial structures are also to be provided at Mosquito Creek and its tributary for wildlife movements (see Chapter 8).

The proposed Karuah Bypass (Horse Island Route) will impose a barrier to some fauna movements through the landscape (as discussed above), and may impose some restrictions on the functioning of the 'wildlife corridor' identified by the NP&WS on the western side of the Karuah River. The NP&WS also state that "*a corridor of vegetation connecting the coast to the hinterland*" occurs "*on the eastern side of the Karuah River, albeit through private property, and partially fragmented in some locations*" (L Baker NP&WS *pers comm*). The latter 'corridor' is potentially of less significance, and the Bypass includes crossing points which are intended to reduce the constraints to its functioning in this manner.

6.6 Habitat Fragmentation

The construction of major roads and other infrastructure can involve the fragmentation of habitats through the landscape and the creation of small and isolated (and sometimes non-viable) patches of habitat for native flora and fauna. The potential for habitat fragmentation is always a concern in assessing the environmental impacts of a proposed infrastructure project, particularly in the case of major roads which can substantially isolate populations of flora and fauna species on each side of the structure.

Habitat fragmentation is of particular concern where the location and construction of the road creates small fragments of native vegetation, which either become degraded and weed-infested or which are too small to support viable populations of native flora and fauna species.

The Karuah Bypass (Horse Island Route) is located either through extensive areas of native vegetation (to the west of the Karuah River) or predominantly through disturbed and modified pasture (to the east of the Karuah River). The Bypass will increase the level of

habitat fragmentation in the vicinity, and divide of vegetation communities and wildlife populations on either side of the roadway. Conversely, it is unlikely to create small areas of isolated habitat and vegetation which are incapable of maintaining viable populations of most native flora and fauna species.

East of the Karuah River, the Bypass will separate the wooded ridges to the north and south of the alignment (notwithstanding the dedicated crossings), creating a habitat fragment between the Karuah River, the existing Pacific Highway and the Bypass. This area is already substantially isolated, however, as a result of previous land clearing and agriculture.

West of the Karuah River, the Bypass will create two tenuously linked fragments:

- an area of approximately 175ha between the Karuah River, the proposed sewerage treatment works and the Bypass; and
- an area of approximately 125ha between the existing Pacific Highway, the proposed sewerage treatment works and the Bypass.

Many species using this portion of the study area (particularly birds, bats, some reptiles and larger terrestrial mammals) are likely to move between these two areas, but some species will avoid the open land, effectively isolating the areas. The Karuah Bypass project incorporates crossings for species such as terrestrial mammals and reptiles, and the Koala and Squirrel Glider, intended to avoid populations of these species in the fragments of habitat south of the Bypass becoming isolated from populations to the north.

6.7 Wildlife Mortality

Roadworks in general have the potential to involve increases in individual animal mortality, particularly where a new road is being located through previously relatively undisturbed landscapes. Wildlife mortality as a result of collisions with motor vehicles is of particular concern for terrestrial species, including macropods, Koalas, bandicoots, small terrestrial mammals, reptiles and amphibians (Andrews 1990; Fanning 1987, 1989, 1992).

An array of measures and design elements has been incorporated into the Karuah Bypass (Horse Island Route) project to reduce the likelihood of wildlife mortalities along the alignment. For terrestrial species, a combination of fauna-proof fencing, constructed elements (*eg* steep embankments, bridge structures, vertical retaining walls) are to be installed at appropriate locations, limiting the accessibility of the road surface to these species. Additionally, drainage culverts, fauna underpasses, bridge abutment setbacks, a fauna overpass and habitat rehabilitation measures are designed to minimise the level of wildlife mortalities along the road (see Chapter 8 and the SIS).

For arboreal gliding mammals (particularly the Sugar Glider, Squirrel Glider and Yellow-bellied Glider), the road footprint will be broadened at appropriate sites and trees retained or replanted in the central road reserve to reduce the distance across which animals are required to glide. Large trees are to be retained on both sides of the alignment (close to the road edge), to provide a suitable glider path and height for these mammals.

The reduced traffic volumes along the existing Pacific Highway (which will be retained as a local access road) may reduce the frequency of animal mortalities along this portion of road (which does not contain specific measures for safe wildlife crossings). Combined with the measures to be implemented along the Karuah Bypass, there is the possibility of a net reduction in wildlife mortalities in this location as a result of the proposal.

6.8 Disturbance and Degradation of Adjacent Habitat

The construction and subsequent operation of roads inevitably imposes some indirect adverse impacts upon adjacent habitats and vegetation, although these can readily be limited by the implementation of appropriate environmental management and impact amelioration measures.

During the construction phase, the potential for erosion and sediment discharges is generally addressed by an array of impact amelioration measures (such as silt fences, sediment ponds, mulching or matting). The appropriate management of these measures will avoid the imposition of significant adverse effects on adjacent vegetation communities, habitats or resources, and the application of 'best practice' approaches to the management of sediment and stormwater discharges along road construction projects in NSW is RTA policy.

Other indirect effects on the local environment are also possible, both during the construction and subsequent operational phases of the project. Potential impacts include the discharge of contaminants, alterations to the nutrient status of adjacent vegetation and soils (arising from road materials and discharges from vehicles), and alterations to water flows following rainfall events.

The disturbance to vegetation and habitats adjacent to roadworks can include an increase in or the initiation of weed-infestation. Alterations to hydrologic and nutrient regimes, the disturbance and exposure of soils, and the use of machinery and equipment which carry weed propagules can result in new weed species being introduced into an area of disturbance and/or an increase in the extent and intensity of weed infestations. The exposure of new vegetation edges can also result in significant weed infestations, unless appropriately managed.

The clearing of portions of native vegetation frequently involves the creation of new interfaces between cleared or disturbed lands and native vegetation communities. Interface zones are generally subjected to 'edge-effects', which involve the exposure of portions of vegetation communities and of individual plants to altered microclimates and climatic factors (*eg* strong winds, higher rates of desiccation). Other features of 'edge-effects' may include weed infestation, mortality of trees and other native plants, changes in plant species' composition and changes in fauna assemblages.

An array of impact amelioration and environmental management measures has been incorporated into the Karuah Bypass project, to reduce (as far as is reasonable) the imposition of direct and indirect impacts upon adjacent habitats along the alignment. However, it is not possible to eliminate all disturbances or modifications to the natural environment as a result of the adjoining roadworks

However, as is noted above, the RTA has adopted a policy of applying 'best practice' construction and management techniques along roadworks in NSW, which include protocols associated with minimal vegetation clearance, the installation of water quality control ponds, management of water discharges, control of contaminants, control and removal of weeds, and intensive site and habitat rehabilitation programs. Whilst the imposition of some adverse impacts on habitats immediately adjacent to the road cannot be avoided, the approach which has been adopted by the RTA involves the amelioration of any such impacts.

Details of the measures to be applied along the Karuah Bypass (Horse Island Route) are contained in other supporting documentation for the Bypass EIS, and in the EIS itself.

6.9 Alteration of Hydrologic Regimes

The proposed roadworks have the potential to modify hydrologic regimes in the landscape, by modifying (to a limited extent at least) the patterns of water discharge across the land, by re-directing water flows to stormwater quality control ponds, and by capturing and relocating incident rainfall and thus possibly modifying (slightly at least) groundwater levels. These issues are addressed in other documentation associated with the Karuah Bypass (Horse Island Route) EIS.

Existing drainage across the landscape will, however, generally be maintained, by the use of culverts beneath the roadway to provide passage for water. Similarly, water captured from the road surface will be directed to water quality treatment ponds and subsequently discharged into the natural environment. Given the topography and the nature of the landscape, and the maintenance of most flow paths across the alignment, it does not appear

likely that the Bypass will adversely affect the hydrologic regime of wetlands in the vicinity, including Wallaroo Swamp.

It is also likely that a variety of native fauna (including reptiles, amphibians, and some wetland birds) will utilise water quality treatment ponds following the completion of construction activities. The use of pond structures incorporating macrophyte beds for the treatment of water quality, and the rehabilitation program to be implemented along the alignment, are intended to ensure that hydrologic regimes are not significantly modified by the proposal, and that habitats and resources for native flora and fauna are provided in suitable locations.

6.10 SEPP 14 - Coastal Wetlands

State Environmental Planning Policy No 14 - Coastal Wetlands (SEPP 14) aims "*to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the state*". SEPP 14 applies to land which is mapped as Coastal Wetland on a series of maps maintained by the Department of Urban Affairs & Planning (DUAP). It requires that any activity which involves the clearing, construction of a levy, draining or filling of coastal wetlands may only proceed with the consent of the relevant Council and the concurrence of the Director-General of DUAP.

Whilst a number of SEPP 14 Wetlands are located along the Karuah River (Figure 4), the proposed Karuah Bypass traverses one wetland (Coastal Wetland No 743) on the western side of the Karuah River around Horse Island. This wetland is in extremely good condition as a result of its distance and isolation from intensive human activities, and will be affected by the proposed Karuah Bypass (Ecology Lab 1999). Although the proposed roadworks will involve some "*clearing*" and the temporary "*construction of a levee*", the activity will not include the permanent construction of embankments or levies across the wetland. Detailed engineering and construction controls on the construction of bridge piers and measures to reduce impacts upon the wetland will be implemented.

SEPP 14 has been addressed in detail by the Ecology Lab (1999), including provision of the details required to satisfy the requirements of SEPP 14 and achieving development consent from Port Stephens Shire. Of particular relevance in this regard are the stringent and environmentally sensitive engineering and construction activities to be applied across the wetland, including:

- minimal disturbance areas;
- the use of geo-textile fabrics to protect wetland soils;
- the stockpiling and re-use of topsoil and salt marsh vegetation in rehabilitation programs;
- replanting regimes where necessary;
- development of a compensating habitat program; and
- a detailed monitoring and rehabilitation program to ensure the ongoing survival of wetland vegetation in these areas. Following rehabilitation, the proposed bridge structure over SEPP Coastal Wetland No 743 on the Karuah River will involve only the footprints of the road support structures, with minimal impacts beyond those zones.

A Development Application will need to be lodged with Port Stephens Shire Council with respect to SEPP 14 and the Coastal Wetland No 743, for which the EIS and its accompanying documentation will provide the necessary information to enable Council to provide development consent and DUAP to provide concurrence.

6.11 SEPP 44 - Koala Habitat Protection

State Environmental Planning Policy No 44 - Koala Habitat Protection (SEPP 44) has, as its aims and objectives, the encouragement of "*the proper conservation and management of*

areas of natural vegetation that provide habitat for koalas to ensure a permanent free-living population over their present range and reverse the current trend of koala population decline:

(a) by requiring the preparation of plans of management before development consent can be granted in relation to areas of core koala habitat; and

(b) by encouraging the identification of areas of core koala habitat; and

(c) by encouraging the inclusion of areas of core koala habitat in environment protection zones".

SEPP 44 requires an assessment of whether land to which the SEPP applies is "*potential koala habitat*" or "*core koala habitat*". However, Clause 6 of SEPP 44 states that Part 2 - Development Control of Koala Habitats of the SEPP applies only to land "*in relation to which a development application has been made*", and under certain circumstances. The proposal does not involve the making of a Development Application, except with respect to the clearing of vegetation in SEPP 14 - Coastal Wetlands. With these exceptions, Part 2 of SEPP 44 does not therefore apply to the activity.

Those areas of the alignment which are of relevance (the SEPP 14 Wetland areas) do not support tree species of relevance to SEPP 44, and no portions of the proposal constitute "*potential koala habitat*". Furthermore, Part 3 - Plans of Management and Part 4 - Other Environment Planning Measures also do not apply to the proposed activity.

Whilst SEPP 44 does not apply to most of the proposal, and there is no "*potential koala habitat*" in that portion of the alignment to which SEPP 44 does apply, the presence of Koalas in the vicinity has been acknowledged. Appropriate measures to ensure the conservation of this species in the vicinity, both through the construction phase and in the subsequent operation of the proposal, have been incorporated into the project (see EIS and SIS).

6.12 Karuah Nature Reserve

The recently gazetted Karuah Nature Reserve (NR) is located to the northwest of the township of Karuah, with one portion of the Reserve extending as a roughly rectangular block of land to the west from the Karuah River. The proposed Karuah Bypass alignment traverses the northwestern corner of this portion of the Karuah NR, although it should be noted that the route selection process was completed before the Karuah NR was approved and gazetted.

Because the proposed bypass would include part of the Karuah Nature Reserve, an Act of Parliament to revoke the relevant portion of the Nature Reserve for the purposes of road construction. In this regard, impact amelioration and environmental management measures are to be applied particularly within the Nature Reserve area in recognition of the desire to maintain connectivity between habitats to the northwest and southeast of the Karuah Bypass alignment. Relevant measures in this regard (as detailed below) include fauna underpasses and glider crossing facilities, as well as a particular focus on environmentally responsible and sensitive engineering and construction activities.

6.13 Cumulative Impacts

The Karuah Bypass (Horse Island Route) will contribute to cumulative impacts on the natural environment and on native biota (both protected and threatened) in the locality and the region. As discussed above, the alignment will involve impacts on habitat connectivity, animal movements, and the direct and indirect effects of vegetation loss and the road construction and operation in the immediate locality. Additionally, the Karuah Bypass contributes to the "*substantial cumulative impact of the Highway on the natural environment*" which arises because of the "*current contiguous development of the Pacific Highway to a four lane carriageway from Raymond Terrace to Coolongolook*", and beyond (L Baker NP&WS *pers comm*).

Given the desirability (and inevitably) of the Pacific Highway upgrade, the most reasonable approach has been adopted by the RTA, the application of 'best practice' measures in the project, and the design of the road to reduce adverse impacts on the natural environment, wherever possible.

Whilst the Karuah Bypass (Horse Island Route) will contribute to the cumulative impacts of development generally, and to those arising from the Pacific Highway upgrade in particular, measures are to be implemented to limit that contribution. As noted above, measures are to be included to allow fauna movements across the alignment, for less mobile species, and the more nomadic or migratory species (particularly birds and bats) are not likely to be restricted by the road.

7 SIGNIFICANCE of POTENTIAL IMPACTS

The *NSW Threatened Species Conservation Act 1995* (TSC Act) has modified the *NSW Environmental Planning & Assessment Act 1979* (EP&A Act) by, *inter alia*, Section 5A (s.5A) which requires a determination as to "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*". The eight factors in s.5A "*must be taken into account*" by a consent or determining authority when considering a Development Application or development proposal, in administering sections 78, 79 and 112 of the EP&A Act.

A number of threatened flora and fauna species known to occur in the locality or general region were targeted during the field investigations for the Flora & Fauna Assessment report on the Karuah Bypass (Horse Island Route) of the Pacific Highway. The detailed investigations along the alignment provided evidence for the presence of a number of those threatened flora and fauna species, although it is considered likely that several other species are also present along the alignment or in the immediate vicinity.

One threatened plant species and six threatened fauna species have been recorded along the Karuah Bypass alignment (Table 4), and a detailed s.5A Assessment of Significance, addressing the eight factors has been prepared for these species (Appendix 7).

Table 4 Threatened fauna and flora species recorded during the field investigations in the Karuah Upgrade study area.

Common Name	Scientific Name
FAUNA	
Koala	*Phascolarctos cinereus*
Squirrel Glider	*Petaurus norfolcensis*
Little Bent-wing Bat	*Miniopterus australis*
Eastern Freetail Bat	*Mormopterus norfolkensis*
Greater Broad-nosed Bat	*Scoteanax rueppellii*
Osprey	*Pandion haliaetus*
FLORA	
Black-eyed Susan	*Tetratheca juncea*

Detailed consideration is provided in Appendix 7 with respect to the definition of and application of "*viable local population*" and other elements of s.5A of the EP&A Act, including "*endangered populations*", "*endangered ecological communities*", "*critical habitat*", "*threatening processes*" and "*region*", as defined in the TSC Act.

A detailed Assessment of Significance (Appendix 7) has been prepared for those threatened flora and fauna species which have been recorded along the proposed Karuah Bypass (Horse

Island Route) alignment (Table 4), but not for those threatened flora and fauna species known from the locality or region which were not recorded along the proposed Karuah Bypass (Table 2 of Appendix 7). As there are no data regarding these species, determining the likelihood or otherwise of " *a significant effect*" on the species is problematic, particularly with respect to Factor (a) of s.5A[6]. These species will, however, be considered further in the Species Impact Statement prepared for the Karuah Bypass (Horse Island Route).

The detailed assessment of significance pursuant to s.5A of the EP&A Act, which considers the likelihood or otherwise of *"a significant effect"* being imposed upon the relevant threatened fauna and flora species (Appendix 7), indicates that there is the potential for such an affect to be imposed upon several of the threatened fauna species which have been recorded from the alignment or the immediate vicinity.

Given the location of the proposed roadworks, there is the potential for *"a significant affect"* on the Squirrel Glider *Petaurus australis* , the Koala *Phascolarctos cinereus*, and the Black-eyed Susan *Tetratheca juncea*. Notwithstanding the impact amelioration and environmental management measures which are to be implemented along the proposed Karuah Bypass (Horse Island Route) project, and despite the lack of certainty that *"a significant effect"* is *"likely"* to be imposed upon these threatened biota or their habitats, a 'precautionary' approach has been adopted. Consequently, a Species Impact Statement (SIS) has been prepared for the proposed Karuah Bypass of the Pacific Highway.

8 ENVIRONMENTAL MANAGEMENT and IMPACT AMELIORATION

An array of impact amelioration and environmental management measures has been incorporated into the design of the Karuah Bypass as integral parts of the proposal. Some of these measures constitute actions designed to avoid or reduce the potential for adverse impacts to be imposed on the natural environment (*eg* by preventing the discharge of contaminants into the environment), rather than as responses to reduce or manage actual impacts which will unavoidably be imposed (*eg* the removal of vegetation within the road footprint).

8.1 General Measures

A range of general environmental management measures is included as part of the proposal, and contributes to the avoidance of or amelioration of potential adverse impacts on native fauna and flora. The general measures to be implemented along the proposal include:

- the minimisation of vegetation clearing at all locations, limiting that removal to the minimum necessary for the road's construction;
- 'best practice' management of erosion and sediment discharge 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 is 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;
- minimising or avoiding disturbance to acid sulphate soils, to prevent the potential for adverse impacts to be imposed on habitats, communities or species downslope or downstream. This consideration is of particular relevance in the vicinity of the Karuah River;

---

[6] Factor (a) of s.5A requires a determination, "*in the case of a threatened species*", as to "*whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction*".

- the construction and use of water quality control ponds, incorporating macrophyte vegetation, to ensure that the water quality of adjacent watercourses and water bodies does not deteriorate as a consequence of discharges from the construction and operational phases of the proposed road;
- the implementation of an intensive and extensive rehabilitation and replanting program along the road, involving the use of indigenous native species;
- the collection and propagation of cuttings, seed and fruit from native plant species cleared along the length of the proposal, for their utilisation in replanting and rehabilitation projects in the vicinity, and on landscaping along the alignment;
- the collection and chipping of suitable native plant material, to be used as a mulch and groundcover in landscaping and rehabilitation areas, to promote the regrowth of native and endemic plant species;
- 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 in the soil, 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 and vehicle parking and maintenance areas on already disturbed land, avoiding any necessity for the additional clearing of vegetation for these activities;
- the avoidance of any 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 ensure the appropriate disposal of rubbish and general waste materials, to prevent the loss or discharge of waste into remnant vegetation. Other relevant measures include the collection and removal of excess contaminants, the bunding of potential liquid contaminants, and the provision of appropriate ablution and work-shed facilities to prevent the discharge of contaminants into native vegetation.

Several of the measures which have been incorporated into the road design are specifically intended to minimise or avoid the imposition of adverse impacts upon the natural environment. For example, all stormwater collected on the bridge surface over the Karuah River is to be directed along the bridge rather than discharged directly into the River or a SEPP 14 wetland , so that contaminants from the road surface or contaminant spills can be collected and treated, minimising the risk of pollutants entering the natural environment. The management and treatment of stormwater discharges is a significant element of the project design.

As is current 'best practice' for infrastructure and other major developments in NSW, a Construction Environmental Management Plan (CEMP) is to be prepared for the Karuah Bypass project. The CEMP will incorporate all of the detailed measures for flora and fauna conservation and for the protection of the natural environment which are included within this report (and in the SIS), as well as an array of engineering and construction measures designed to protect the natural environment.

8.2 Specific Measures

In addition to the general measures to be implemented for the protection of the natural environment along the proposal, a range of specific environmental management and impact amelioration measures has been designed into the project to reduce or avoid the potential for adverse impacts to be imposed upon the natural environment in general, and on native fauna and flora (particularly threatened species).

8.2.1 Flora

Several specific environment management measures are to be implemented with respect to native vegetation, including (in all locations) the limiting of vegetation removal to the absolute minimum required for the project. Specific measures to be applied along the project with respect to plants of conservation significance will include:

- the avoidance of individual plants wherever possible, by the use of appropriate structures and design to enable individual plants to be retained;
- the appropriate design of constructed wetlands and stormwater discharge points along the roadway, to avoid affecting individual plants of conservation significance by alterations in 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;
- the collection and subsequent relocation of individual plants of conservation significance where appropriate (depending on the individual species and in consultation with the NP&WS), where it is not possible to avoid individuals in the clearing and construction phases of the project;
- 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 individual threatened plant species present;
- the collection of cuttings, seeds or plant material from individual 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 the Karuah NR, in consultation with 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 along the alignment during construction. Protective fencing, maintenance and monitoring, signage, and education of construction workers should be implemented at appropriate locations; and
- contribution by the RTA to the establishment of areas of compensatory habitat as a means of offsetting environmental impacts imposed by the proposal.

8.2.2 Fauna

A range of special measures are also proposed to address specific issues of relevance for native fauna. 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, particularly with respect to threatened fauna species, including:

- the conduct of pre-clearing surveys of native vegetation, wherever required, to identify individuals, fauna species or populations which require collection and relocation;
- specific searches for fauna of particular concern immediately prior to clearing activities, with particular attention paid to Koalas, 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*) wherever possible, particularly in areas of native vegetation of conservation value which are to be retained;

- the provision of stags (derived from trees felled for the project) and supplementary planting of trees or the retention of existing trees at appropriate locations in the central road reserve ('median strip') to enable gliding species (such as the Squirrel Glider) to traverse the roadway;
- re-use of elements of potential value for native fauna (such as hollow-bearing trees, hollow logs, rocks *etc*) in suitable areas;
- installation of fauna-proof fencing (particularly designed for terrestrial fauna and Koalas) to limit the opportunities for animals to gain access to the new roadway. Fauna-proof fencing should be installed at sites where fauna underpasses or bridges designed for fauna movements are located:
- use of large culverts (*ie* maximum size at each location) and fauna underpasses, which are to be designed and treated to facilitate fauna movements. Relevant measures will include the placement of rocks and logs in the culvert/underpass, landscaping and revegetation up to the underpass entrance, refuge poles or trees for Koalas and other treatments;
- the establishment and maintenance of communication 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; and
- contribution by the RTA to the establishment of areas of compensatory habitat for threatened fauna, as a means of offsetting the unavoidable environmental impacts imposed by the proposal.

8.2.3 SEPP 14 - Coastal Wetlands

The Karuah Bypass (Horse Island Route) project has included in the design and construction features of the bridge across the Karuah River a range of measures specifically intended to reduce impacts upon the SEPP 14 Wetlands, and particularly the mangrove and saltmarsh communities present (Figure 4). A number of specific measures are to be incorporated into the project design, including:

- construction protocols to reduce the footprint of disturbance over the SEPP 14 Wetlands area;
- the use of geo-textile materials to protect underlying salt marsh and mangrove soils during construction activities;
- stringent engineering and construction protocols to prevent disturbance outside areas which are required for construction activities; and
- removal of access roads and the geo-textile material, and rehabilitation of the wetland environments after completion of construction.

These measures are detailed in the specialist report on the SEPP 14 Wetland communities (Ecology Lab 1999).

BIBLIOGRAPHY

Allison FR and Hoye GA. 1995. Eastern Freetail-bat *Mormopterus norfolkensis* Pp484-485 In Strahan R (ed). *The Mammals of Australia.* Australian Museum/Reed Books.

ANCA. 1995. *Interim Biogeographic Regionalisation for Australia.* Australia Nature Conservation Agency, Canberra.

ANCA. undated. *A Directory of Important Wetlands in Australia.* Australian Nature Conservation Agency, Canberra.

Andrews A. 1990. Fragmentation of Habitat by Roads and Utility Corridors: A Review. *Australian Zoologist* 26(3 - 4):130 - 141.

Benson D. 1986. The vegetation of the Gosford and Lake Macquarie 1:100 000 vegetation Map Sheet. *Cunninghamia* 1(4).

Benson J. 1989. *Establishing Priorities for the Conservation of Rare of Threatened Plants and Plant Associations of New South Wales.* National Parks and Wildlife Service, New South Wales.

Birds Australia. Species listed on database in the general area (between latitude 32°30'S and 32°50'S and longitudes 151°50'E and 152°00'E). Birds Australia.

Blakers M, Davies SJJF and Reilly PN. 1984. *The Atlas of Australian Birds.* Royal Australasian Ornithologists Union. Melbourne University Press, Victoria.

Briggs J and Leigh J. 1996. *Rare or Threatened Australian Plants.* CSIRO, Canberra.

Brooker MIH and Kleinig D A. 1990. *Field Guide to Eucalypts Volume 1 - South-eastern Australia.* Inkata Press, Melbourne.

Callaghan J, Leathley S and Lunney D. 1994. *Draft Port Stephens Koala Management Plan.* NP&WS in association with Port Stephens Council and the Hunter Koala Preservation Society.

CAMBA. 1989. Agreement between the Government of Australia and the Government of the People's Republic of China for the protection of Migratory Birds and their environment.

Churchhill S. 1998. *Australian Bats.* Reed New Holland, Australia Pty Ltd.

Cogger HG. 1992. *Reptiles and Amphibians of Australia.* AH & AW Reed, Sydney.

Cooper DW. 1998. *Roadkills of animals on some New South Wales roads.* Macquaries University and Wildilfe Information and Rescue Service.

Cropper SC. 1993. *Managment of Endangered Plants.* CSIRO Publications, Melbourne.

Date EM and Recher HF. 1989. *Ecology and Management of Rainforest pigeons in New South Wales.* Report and Recommendations to the NSW NP&WS.

Davey SM. 1984. Habitat Preferences of Arboreal Marsupials within a Coastal Forest in Southern NSW. In Smith AP and Hume ID (eds) *Possums and Gliders.* Surrey Beatty & Sons, Sydney.

Debus SJS and Chafer CJ. 1994. The Powerful Owl *Ninox strenua* in New South Wales. *Aust Birds* 28: 21-38.

Debus S and Rose. 1994. The Masked Owl *Tyto novaehollandiae. Journal of the NSW Field Ornithologist Club Inc.* Volume 28 Supplement: 40-59.

Department of Urban Affairs and Planning. 1995. *State Environmental Planning Policy No. 44 Koala Habitat Protection.*

Dickman CR and McKechnie CA. 1985. A Survey of the Mammals of Mount Royal and Barrington Tops, New South Wales. *Australian Zoologist* 21(6): 531-43.

Dwyer PD. 1995. Little Bent-wing Bat *Miniopterus australis*.. In Strahan R (*ed*). The Mammals of Australia. Australian Museum/Reed Books.

Ecotone. 1995. *Flora and Fauna Assessment, Proposed Extension to Karuah Red Quarry at Karuah.* Ecotone Ecological Consultants.

Edgar R and Belcher C. 1995. Spotted-tailed Quoll *Dasyurus maculatus*. In R Strahan (*ed*). 1995. *The Mammals of Australia*. Australian Museum/Reed Books, Chatswood.

Ehmann H. 1996. 2. The Wallum Froglet, *Crinia tinnula*: Pages 48-54 *in* Harald Ehmann (*ed*) *Threatened Frogs of New South Wales: Habitats, Status and Conservation*. Frog and Tadpole Study Group of NSW Inc, NSW.

ERM Mitchell McCotter. 1999. Kaurah to Bulahdelah Pacific Highway Upgrading EIS Main Report & Appendicies.

Fanning FD 1992. *Koala Road Deaths: Causes and Measures*. Gunninah Environmental Consultants, Crows Nest, NSW.

Forshaw JM and Cooper. 1981. *Australian Parrots*. 2nd Edition. Lansdowne editions, Melbourne.

Garnett S (*ed*). 1992. *Threatened and Extinct Birds of Australia*. RAOU Report 82. York Press, Melbourne.

Gilmore AM and Parnaby H. 1994. *Vertebrate Fauna of Conservation Concern in North-east NSW Forests*. North East Forests Biodiversity Study Report No.3e, NSW National Parks & Wildlife Service.

Gunninah. 1995. Heavy Minerals Mining Operation Plant 6 Operation, Tomago: Fauna Impact Statement. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1997a. *Flora and Fauna Constraints for the proposed Pacific Highway Upgrade at Karuah*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1997b. *Flora and Fauna Assessment for the Proposed Upgrade of the Pacific Highway between Raymond Terrace and Karuah*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1997c. *Flora and Fauna Assessment for a Proposed Hardrock Quarry, north of Karuah*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1997d. *Flora and Fauna Issues for the Pacific Highway Upgrade at Karuah, Proposed Far-northern Route Option*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1998a. Preliminary Flora & Fauna Assessment for the Proposed Pacific Highway Upgrade at Karuah, NSW – Horse Island Route Option. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1998b. *Flora and Fauna Assessment for the Proposed Newstan Colliery Life Extension Project - Surface Facilities Upgrade*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1998c. *Queensland Interconnection: Assessments under Section 5A of the NSW Environmental Planning & Assessment Act 1979*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1998d. *Flora and Fauna Issues for the Pacific Highway Upgrade at Karuah, Proposed Far-northern Route Option*. Gunninah Environmental Consultants, Crows Nest, NSW.

Gunninah. 1998e *Flora and Fauna Issues for the Pacific Highway Upgrade: Prposed Duplication of the Brunswick Heads Bypass and Brunswick to Yelgun Upgrade*. Gunninah Environmental Consultants, Crowns Nest, NSW.

Gunninah. 1999c *Pacific Highway Upgrade at Karuah: Species Impact Statement*. Gunninah Environmental Consultants, Crown Nest, NSW.

Hager TC and Benson JS. 1992. *Review of the Conservation Status of Vegetation Communities in NSW - Part 3 Assessment of the Conservation Statius of Forest Plant Communities in NE NSW*. NP&WS and Royal Botanic Garden.

Hall LS and Richards GC. 1979. *Bats of Eastern Australia*. Queensland Museum Booklet No 12. Queensland Museum, Brisbane.

Harden G (*ed*). 1990. *Flora of New South Wales*. Volume 1. University Press, Kensington.

Harden G (*ed*). 1991. *Flora of New South* Wales. Volume 2. University Press, Kensington.

Harden G (*ed*). 1992. *Flora of New South* Wales. Volume 3. University Press, Kensington.

Harden G (*ed*). 1993. *Flora of New South* Wales. Volume 4. University Press, Kensington.

Higgins PJ and Davis SJJF (*eds*). 1996. *Handbook of Australian, New Zealand and Antarctic Birds. Volume 3 - Snipe to Pigeons.* Oxford University Press, Melbourne.

Hollands D. 1991. *Birds of the Night.* Redd Books, Balgowlah.

Hoye GA and Richards GC. 1995. Greater Broad-nosed Bat *Scoteanax rueppellii* Pp527-528. In Strahan R (ed). *The Mammals of Australia.* Australian Museum/Reed Books.

JAMBA. 1974. Agreement between the Government of Australia and the Government of Japan for the protection of Migratory Birds and birds in danger of extinction and their environment.

Lane B. 1987. *Shorebirds in Australia.* Nelson Publishers, Victoria.

Lee AK and Martin RW. 1988. *The Koala: a natural history.* New South Wales University Press, Sydney.

Lemckert F. 1996. Surveys for the Green & Golden Bell Frog Litoria aurea by the State Forests of NSW. In The Green & Golden Bell Frog *Litoria aurea* Biology and Conservation. *Australian Zoologist* 30(2): 208-213.

Leonard G. 1993. *Eucalypts: A Bushwalkers Guide.* NSW University Press, Kensington.

Lindsey TR. 1992. *Encyclopedia of Australian Animals: Birds.* The Australian Museum, Sydney.

Lunney D, Urquhart CA and Reed P (eds). 1990. *Koala Summit: Managing Koalas in New South Wales.* Proc of the Koala Summit held at the Uni Syd 7-8 Nov 1988. NSW National Parks and Wildlife Service, Sydney.

Lunney D, Phillips S, Callaghan J and Coburn D. 1998. Determining the distribution of Koala habitat across a shire basis for conservation: a case study from Port Stephens, New South Wales. *Pacific Conservation Biology.* 4(3):186 - 196.

Macdonald JD. 1987. *The Illustrated Dictionary of Australian Birds by Common Name.* Reed, Frenchs Forest Sydney.

Marchant S and Higgins PJ (*eds*). 1990. *Handbook of Australian, New Zealand and Antarctic Birds. Volume 1 - Pelicans to Petrels.* Oxford University Press, Melbourne.

Marchant S and Higgins PJ (*eds*). 1993. *Handbook of Australian, New Zealand and Antarctic Birds. Volume 2 - Raptors to Lapwings.* Oxford University Press, Melbourne.

Menkhorst P (eds). 1995. *Mammals of Victoria: Distribution, Ecology and Conservation.* Oxford University Press, Melbourne.

Mitchell McCotter. 1994. *Proposed Toll Road, Collonolook to Possum Brush, Environmental Impact Statement, Volumes 1 and 2.* Mitchell McCotter & Assocs Pty Ltd.

Morris AK and Burton A. 1997. New South Wales Annual Bird Report 1995. *Australian Birds* 30(4): 81-142.

NP&WS. 1994. *Fauna of North-East NSW Forests.* North East Forests Biodiversity Report No.3, NSW National Parks and Wildlife Service.

NP&WS *Wildlife Atlas Port Stephens (9332) and Newcastle (9732) 1:100 000 map-sheets.* NSW National Parks and Wildlife Service.

Outline 1997. *Proposed Hard Rock Quarry Adjacent to Karuah Red Quarry, Environmental Impact Statement.* Outline Planning Consultants Pty Ltd.

Parnaby H. 1992. *An Interim Guide to Identification of Insectivorous Bats of South-eastern Australia.* Australian Museum, Sydney.

Phillips B. 1990. *Koalas: The Little Australians we'd all hate to lose.* Australian Government Publishing Service, Canberra.

Pyke GH and White AW. 1996. Habitat Requirements for the Green & Golden Bell Frog *Litoria aurea* (Anura: Hylidae). In The Green & Golden Bell Frog *Litoria aurea* Biology and Conservation. *Australian Zoologist* 30(2): 224-232.

Quin DG. 1995. Population Ecology of the Squirrel Glider (*Petaurus norfolcensis*) and the Sugar Glider (*P breviceps*) (Marsupialia : Petauridae) at Limeburners Creek, on the Central North Coast of New South Coast. *Wildlife Research* 22(4):471 - 505.

Ramsar. 1971. *The Convention on Wetlands of International Importance*, signed at Ramsar, in Iran, 1971.

Recher HF. 1991. The Conservation and Management of Eucalypt Forest Birds: Resource Requirements for nesting and foraging. Pp 25-34. In Lunney D (ed). *Conservation of Australia's Forest Fauna.* Royal Zoological Society of NSW, Mosman.

Reed PC and Lunney D. 1990. Habitat loss: the key problem for the long term survival of koalas in NSW. Pp 9-31. In Lunney D, Urguhart CA and Reed PC (eds) *Koala Summit: Managing the Koala in NSW.* NSW National Parks and Wildlife Service, Hurstville.

Reed PC, Lunney D and Walker P. 1990. A 1986-87 Survey of the Koala Phascolarctos cinereus (Goldfuss) in New South Wales and an Ecological Interpretation of its Distribution. Pp 54-73. In Lee AK, Handasyde KA and Sanson GD (eds) *Biology of the Koala.* Surrey Beatty and Sons Pty Ltd. New South Wales.

Robinson L. 1991. *Field Guide to the Native Plants of Sydney.* Kangaroo Press, Sydney.

Robinson M. 1993. *A Field Guide to Frogs of Australia From Port Augusta to Fraser Island including Tasmania.* Australian Museum/Reed Books, Sydney.

Soderquist T. 1995. Brush-tailed Phascogale *Phascogale tapoatafa.* Pp 104-106. In R Strahan (*ed*). 1995. *The Mammals of Australia.* Australian Museum/Reed Books, Chatswood.

Slater P, Slater P and Slater R. 1989. *The Slater Field Guide to Australian Birds.* Weldon Publishing, Sydney.

Smith P. 1990. *The Biology and Management of the Little Tern* (Sterna albifrons) *in NSW.* Species Management Report N0.1. NSW National Parks & Wildlife Service, Hurstville, NSW.

Specht RL. 1970. Vegetation. In GW Leeper (*ed*). *The Australian Environment.* CSIRO Australia.

Specht RL, Specht A, Whelan MB and Hegarty EE. 1995. *Conservation Atlas of Plant Communities in Australia.* Southern Cross University Press, Lismore.

Strahan R (*ed*). 1995. *The Mammals of Australia.* Australian Museum/Reed Books, Chatswood

Suckling GC. 1995. Squirrel Glider *Petaurus norfolcensis.* Pp 234-235. In R Strahan (*ed*). 1995. *The Mammals of Australia.* Australian Museum/Reed Books, Chatswood.

Swan G. 1990. *A Field Guide to the Snakes and Lizards of New South Wales.* Three Sisters Productions, Katoomba.

SWC. 1988. *Wetlands in New South Wales.* Prepared for the Department of Water resources and the Sydney Water Board. Shortlands Wetlands Centre, Newcastle.

Tame T. 1992. *Acacias of South East Australia.* Kangaroo Press, Sydney.

Triggs B. 1996. *Tracks, Scats and Other Traces: A Field Guide to Australian Mammals.* Oxford University Press, Melbourne.

Tyler MJ. 1992. *Encyclopedia of Australian Animals: Frogs.* The Australian Museum, Sydney.

White A. 1995. Frogfacts No. 5. *Green & Golden Bell Frogs.* Frog and Tadpole Study (FATS) Group of NSW Inc, Sydney.

White A. 1996. 16. The Green & Golden Bell Frog, *Litoria aurea*: Pages 150-156 *in* Harald Ehmann (*ed*) *Threatened Frogs of New South Wales: Habitats, Status and Conservation.* Frog and Tadpole Study Group of NSW Inc, NSW.

White AW and Pyke GH. 1996. Distribution and Conservation Status of the Green & Golden Bell Frog *Litoria aurea* in NSW. In The Green & Golden Bell Frog *Litoria aurea* Biology and Conservation. *Australian Zoologist* 30(2): 224-232.

Winning G. 1992. *Conservation Status of Rare Plants in the Lake Macquarie Area.* NSW National Parks and Wildlife Service.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 1
Vegetation Communities

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

APPENDIX 1 Details of vegetation community structure and composition along the proposed Horse Island route for the proposed Pacific Highway upgrade at Karuah.

Seven broad vegetation communities were identified along the proposed Horse Island route for the Pacific Highway Upgrade at Karuah, as outlined below and indicated in Figure 7a and 7b. An inventory of all plant species recorded is provided in Appendix 2.

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).

Distribution
This community occurs widely in the study area, generally within the northeastern parts of Wallaroo State Forest, 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, 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-story
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.*

Occasional epiphytic species (*Cymbidium suave* and *Dendrobium aemulum*) and parasitic species (*Amyema pendulum, Muellerina eucalyptoides* and *Muellerina celastroides*) occur in places.

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.

Comments
This community occurs on moderate slopes and has been disturbed previously through grazing and logging activities. The community generally occurs as regeneration or regrowth open forest throughout the easement and in adjacent sites (eg in Wallaroo State Forest and on Horse Island). In these locations, regeneration appears common, with juvenile specimens common, often forming dense stands throughout, possibly as a function of altered fire regimes. Bushfires in November 1997 have burnt most of the sites with this community in Wallaroo State Forest. The shrub and groundcover layers were destroyed, with some scorching of the upper canopy in localised areas. On private property (eg land to the immediate north of the north eastern parts of Wallaroo State Forest) this community and its associated sub-community (Communities 1a and 1b) are difficult to distinguish from each other, probably due to repeated logging and grazing over a number of years (Mr. Powell, current landowner *pers comm*). The composition of vegetation in gullies on these sites is generally indistinguishable from surrounding drier communities on higher sites, with most sites having occasionally dense stands of commonly occurring pioneer species. The ROTAP species *Eucalyptus fergusonii* ssp *fergusonii* was detected in this community on private property to the north of the north eastern part of Wallaroo State Forest It may be more widespread in this community in the State Forest, but identification was hampered by the lack of fruit and flower due to recent bushfires.

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

Characteristics

- Open-Forest/Forest reaching 18-25m in height, Foliage Projective Cover (FPC) 20-55%;
- dominant species include Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Ironbark *E paniculata*, Northern Grey Ironbark, 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, though these remnants appear heavily modified. Better, more intact examples of this community occur on private land to the south of the 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*.

Occasional epiphytic species include *Cymbidium suave* and *Dendrobium aemulum*, and parasitic species *Amyema pendulum*, *Muellerina eucalyptoides* and *Muellerina celastroides*.

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.

Comments
This community occurs on lower slopes and sheltered sites, predominantly on the eastern side of Karuah River. The best examples surveyed occur on private land to the south of the proposed route at its eastern end, while those occurrences to the west appear to have been subject to higher and more prolonged disturbance from logging and grazing. More intact sites generally have more mature trees, with better-developed understorey strata, tree hollows and less weed species infestation; prior levels of logging have been reduced in recent years on some properties (Mr. Clarke, current landowner *pers comm*). Occurrences of this community to the west of Karuah River on private property appear less intact, probably as a result of previous logging and grazing pressures (Mr. Powell, current landowner *pers comm*); the understorey layers in gullies on these sites are generally indistinguishable from surrounding drier communities on higher sites, with most sites having sometimes dense stands of commonly occurring pioneer species.

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*.

Distribution
This community is located in Wallaroo SF primarily adjacent to Reedy Creek, and merges with Community 4 adjacent to Wallaroo Swamp, 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 *Echinopgon 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*.

Climbing and trailing species include *Geitonoplesium cymosum*, *Eustrephus latifolius*, *Glycine clandestina*, *Vigna vexillata* and *Parsonsia straminea*.

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.*

Comments
This community occurs on gently sloping terrain, with disturbance limited to the forest margins. The majority of sites within Wallaroo State Forest in the western parts of the easement were subject to major bushfire in November 1997; as a consequence, previous records of the TSC protected species *Tetratheca juncea* in this community were not able to be substantiated during the 1998 survey, as most of the existing shrub and herb layer was burnt. This community may also provide suitable habitat for *Grevillea guthrieana* but, due to recent bushfire, it was not possible to determine its presence in the area. Similarly, regionally significant species such as *Hakea bakeriana* may also be present, but was difficult to detect due to recent bushfire.

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* (TSC Act Schedule 2, 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 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.*

Comments
Disturbance has generally occurred along the margins of this community, including along roads, tracks and areas which have been subject to random clearing and rubbish dumping. Weed species appear limited to these disturbed areas and are generally restricted to hardy annual species. Evidence of recent bushfires is apparent in some sections of the community and some areas have been extensively modified through clearing activities. Some areas adjacent to this community in the north have been extensively modified by clearing. Bushfires in November 1997 have burnt most of the sites with this community in Wallaroo State Forest: the shrub and groundcover layers were destroyed, with some scorching of the upper canopy in localised areas. This community may also provide suitable habitat for *Grevillea guthrieana* but, due to recent bushfire, it was not possible to determine its presence in the area. Similarly, regionally significant species such as *Hakea bakeriana* may also be present, but was difficult to detect due to recent bushfire.

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. *Eucalyptus 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*.

Comments
The community occurs on flat to gently sloping terrain, with disturbance mostly limited to forest margins. Cattle grazing and trampling appear to be the most likely cause of the significant erosion

and weed-infestation in the vicinity. Recent bushfires throughout Wallaroo State Forest and adjacent Crown Land appear to have spread throughout the woodland and open forest communities surrounding Wallaroo Swamp. Regeneration of the lower strata appears healthy, but weed species in adjacent unburnt sites may colonise open ground along the borders of disturbed woodland. Occurrences of this community in other areas to the west are sporadic and generally limited to low-lying sites on private land. Most of these sites have been partly cleared for grazing, road construction *etc*, with consequent weed species infestation.

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*.

Occasional climbers and trailers include *Parsonsia straminea*, *Eustrephus latifolius* and *Geitonoplesium cymosum*. Some trees, notably *Eucalyptus punctata* and *Corymbia maculata*, are host to the mistletoe species *Dendrophthoe vittelina* and *Muellerina eucalyptoides*.

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*.

Comments
Most sites in or near Wallaroo Swamp appear relatively intact, exhibiting minimal disturbance and a diverse range of sedge and rush species. Where artificial dams have been created in agricultural sites, some elements of this community have colonised the banks of the dams, though most of those surveyed appear to be subject to disturbance from cattle grazing.

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 throughout the 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 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, though 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*.

Comments
Some patches of this community occur in disturbed pasture on the eastern side of Karuah River; these remnants generally have high levels of exotic species infestation, especially in the herb layer. They generally exhibit low levels of regeneration and most are subject to disturbance from cattle grazing.

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.

Comments
This community occurs on generally flat terrain.

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.*

Comments
The community occurs on generally flat terrain, with some steep banks occurring along some sections of the river banks.

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

Characteristics

- Highly disturbed 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*.

Comments
Vegetation clearing along the proposed alignment has occurred mainly for grazing. Some erosion along gullies and weed-infestation appears to be the result of current cattle grazing. Some minor clearing has occurred in the vicinity of Wallaroo Swamp for the installation of transmission lines and abandoned grazing areas.

CONSERVATION SIGNIFICANCE OF VEGETATION

Species of Conservation Significance

A National Parks and Wildlife Service database search was undertaken in order to ascertain the potential presence or absence of nationally rare species. Two species, both of national conservation significance had previously been recorded within a radius of 10km from the survey area. One of these, *Tetratheca juncea*, was recorded as scattered, sporadic clumps in Mapping Unit 3a, within Wallaroo State Forest, to the north-west and west of the proposed alignment (Table 1 & 2).

Table 1 Species of national conservation significance and previously recorded within a 10km range of Karuah.

Species	Rotap Code	Comments
Gonocarpus salsoides	3RCa	".... Grows in swampy areas on sand, uncommon; coastal districts from Port Macquarie to Royal National Park ...." (Wilson 1991). Botanical sub-divisions NC and CC. This species is not protected under the Threatened Species Conservation Act 1995, but is regarded as a Rare or Threatened Australian Plant species (ROTAP).
Tetratheca juncea	3VCa	".... Grows in sandy, occasionally swampy heathy and in dry sclerophyll forest; chiefly in coastal districts from Buladelah to Lake Macquarie, also recorded from Port Jackson to Botany Bay from which it is possibly extinct ...."(Gardener & Murray 1992). Botanical sub-divisions NC and CC. This species is protected under Schedule 2 of the Threatened Species Conservation Act 1995.

Table 2 Rare or Threatened Australian Plants (ROTAP) coding system; by distribution, conservation status and reservation adequacy.

Distribution Category			
1	Taxa known from type collection only	+	Species with a natural distribution outside Australia. These species are listed and coded according to their distribution and conservation status within Australia
2	Taxa known to have a geographic range of less than 100km	X	Presumed extinct
3	Taxa known to have a geographic range greater than 100km	x	Presumed extinct in Region
Conservation Status			
E	Endangered		Endangered species in serious risk of disappearing from the wild state within 1 or 2 decades if present land use and other causal factors persist
V	Vulnerable		Vulnerable species not presently endangered but at a risk of disappearing from the wild over a longer period of time through continued depletion, or which largely occur on sites that are prone to land use changes that would threaten the continued survival of the species

Table 2 contd Rare or Threatened Australian Plants (ROTAP) coding system; by distribution, conservation status and reservation adequacy.

Conservation Status contd		
R	Rare	Rare species that may be represented by a relatively large population in a very restricted area or by small populations spread over a wider range
K	Poorly Known	Species for which the conservation status cannot be reliably determined

Reservation Adequacy			
C	indicates taxon has at least one population within a National park, or other proclaimed/dedicated conservation reserve. The taxon may, or may not be adequately conserved within the reserve(s)	-	Reserved population size unknown
a	less than 1000 plants are known to occur within conservation reserve(s)	t	Total known population reserved
i	1000 plants are known to occur within conservation reserve(s)	?	Taxonomic status unknown

Vegetation Communities of Conservation Significance

The vegetation communities described during the survey appear to exhibit similarities to communities described by Benson (1989) and Hager and Benson (1992). Consequently, assessment of the conservation status of the vegetation recorded draws on comments and recommendations from this report (Table 3 & 4).

Table 3 Conservation significance of vegetation communities; Estuarine (Saline and Brackish) Communities, Closed-forest Communities, Sclerophyllous Communities and Wetland Communities as described by Benson (1989).

Community Number	Characteristic Species	Benson (1989)
Estuarine (Saline and brackish) Communities		
6a	*Avicennia marina* var *australasica*, *Aegiceras corniculatum*	Poorly conserved (below high water mark).
6b	*Sarcocornia quinqueflora*	Vulnerable to dredging, vehicles *etc*
6b	*Juncus kraussii*	This community *(Allocasuarina glauca* (sic.) and *Juncus kraussii)* are not threatened in the foreseeable future, however this could change with land use. He also notes that the community is inadequately conserved, either because only relatively small areas are located in reserves or major parts of its geographical range remain unprotected.
6b	*Casuarina glauca*, *Baumea juncea*	As for Rushland.

Table 3 contd Conservation significance of vegetation communities; Estuarine (Saline and Brackish) Communities, Closed-forest Communities, Sclerophyllous Communities and Wetland Communities as described by Benson (1989).

Community Number	Characteristic Species	Benson (1989)
Closed-forest Community		
4	*Melaleuca linariifolia, M styphelioides* Emergent species: *Eucalyptus robusta, E longifolia*	This community generally occurs on clayey soils which have been subjected to clearing for grazing purposes.
2	*Melaleuca ericifolia, M sieberi, M decora, M nodosa, M linariifolia, M thymifolia*	Benson (1989) does not comment on this community.
Sclerophyllous Communities		
3a	*Angophora costata, Corymbia gummifera, Eucalyptus capitellata, E pilularis*	*Angophora costata* and *Corymbia gummifera (+/-E haemastoma)* communities are not threatened in the foreseeable future, however this could change with land use. He also notes that the community is adequately conserved, either because large areas and/or a large proportion of its distribution are in reserves.
1a	*Corymbia maculata, Eucalyptus umbra, E siderophloia. E punctata*	Notes that control burning has effected the understorey in some areas. While not threatened in the foreseeable future, it is considered inadequately conserved, either because small areas are located within reserves or because major parts of its geographic range remain unprotected.
4a	*Angophora floribunda, Eucalyptus punctata, E tereticornis, E eugenioides, Allocasuarina torulosa*	Notes that *E tereticornis* and *E amplifolia/ Angophora subvelutina/ E tereticornis* communities have been reduced by agriculture.
2a	*Eucalyptus piperita, Angophora costata*	Notes that this community is not threatened in the foreseeable future, however this could change with land use. He also notes that the community is adequately conserved, either because large areas and/or a large proportion of its distribution are in reserves.
Wetland Communities		
5a	*Eleocharis spp, Baumea spp, Juncus spp, Alisma plantago - aquatica, Philydrum lanuginosum, Typha orientalis, Phragmites australis*	Benson (1989) does not comment on this community. However, he notes with reference to *Typha* and *Phragmites* communities that both are subject to minor clearing and disturbance due to draining and irrigation. While not threatened in the foreseeable future, they are considered inadequately conserved, either because small areas are located within reserves or because major parts of their geographic range remain unprotected.

Table 4 Description and conservation significance of vegetation communities as described by Hager and Benson (1992).

Community (this report)	Community (Hager & Benson 1992)	Conservation Status * (Hager & Benson 1992)
1a Open forest dominated by Spotted Gum *Corymbia maculata*	EF121	2
1b Open Forest/Forest Dominated by Spotted Gum *Corymbia maculata*	EF121	2
2 Open Forest dominated by Smooth-barked Apple *Angophora costata* and Sydney Peppermint *Eucalyptus piperita*	EF228	No code stated
3 Woodland/Open-forest dominated by Smooth-barked Apple *Angophora costata*, Brown Stringybark *Eucalyptus capitellata* and Bastard Mahogany *Eucalyptus umbra*	EF210	3
4 Open Forest dominated by Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea*, and Rough-baked Apple *Angophora floribunda*	EF120a	2
5a Freshwater Wetlands: Sedgeland	No corresponding community	-
5b Low Forest/Closed Forest	WT102	3
6a Estuarine communities - Mangrove Open Scrub	WT303	3
6b Estuarine Wetlands: Saltmarsh (merging with fringing freshwater communities)	WT400	No code stated
7 Cleared/Pasture/Highly Modified Land with remnant and/or regenerating native species	No corresponding community	-

* The conservation codes are defined as:

2. Inadequately conserved, because none or only minuscule areas located in reserves and major parts of its geographical range remain unprotected

3 Inadequately conserved, because major parts of its geographical range remain poorly protected despite moderate areas being located in reserves

Table 5 Comments on Vegetation Quadrats

Quadrat Number	Community Number	Comments
1	2	Woodland to 16m. Site and surrounds burnt 11/97; u/s and g/c regenerating. *Blandfordia grandiflora* c 60m to east
2	3	Woodland to 15m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Some g/c weed species.
3	2	Woodland/ Open Forest to 17m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species.
4	2	Woodland/ Open Forest to 16m. Site and surrounds burnt 11/97; u/s and g/c regenerating.
5	3	Woodland/ Open Forest to 16m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species. *Eucalyptus robusta* c 300m to north at edge of Wallaroo Swamp.
6	4	Open Forest to 18m, *Melaleuca* spp understorey to 6m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species.
7	4	Partly disturbed land near edge of Wallaroo Swamp. *Melaleuca* spp Low Forest with *Eucalyptus* spp emergents. Site unburnt but surrounds burnt 11/97. Moderate levels g/c weed species. *Eucalyptus robusta* to north.
8	1a	Open Forest to 17m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species. Possible habitat for *Eucalyptus fergusonii*, ID not confirmed due to lack of material.
9	3	Open Forest to 17m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species. Possible habitat for *Eucalyptus fergusonii*, *Blandfordia grandiflora*, *Grevillea guthrieana*, *Tetratheca juncea* but ID not confirmed due to lack of material.
10	1a	Open Forest to 16m. Site and surrounds burnt 11/97; u/s and g/c regenerating. Minor g/c weed species. Possible habitat for *Eucalyptus fergusonii*, ID not confirmed due to lack of material.
11	1a	Woodland/ Open Forest to 16m on private property. Site and surrounds disturbed due to logging, grazing; u/s and g/c regenerating. Moderate levels weed species in g/c. *Eucalyptus fergusonii* detected nearby.
12	6a	Mangrove woodland and emergent trees on banks of private property adjacent to SEPP 14 wetland. Reasonably continuous band of varying width on southern shore, narrower along edge of Horse Island. Some disturbance due to cattle grazing on southern side.
13	6b	Extensive saltmarsh extends to east and south to Karuah River.
14	1a	Open Forest on Horse Island. Population of *Tetratheca juncea* found along east and south-east facing banks, extending north for c 60m from centre-line of easement and similar distance to west along southern bank. No weed species detected in quad. High levels of regeneration of U/c species.
15	1a	Open Forest along northern easement on Horse Island. *Eucalyptus fergusonii* detected within and to north of easement. No weed species detected in quad.

Table 5 contd Comments on Vegetation Quadrats

Quadrat Number	Community Number	Comments
16	1a	Open Forest to 18m high on private property on eastern side of Karuah River. Quad and surrounding sites all grazed or disturbed by cattle, some clearing. Moderate levels of shrub and g/c weed species. Possible habitat for *Syzygium paniculatum* but not detected in quad or suitable nearby habitat.
17	1b	Tall Open Forest with mesic u/s on private property. Disturbance from cattle grazing, similar sites nearby also grazed. Potential habitat for *Syzygium paniculatum* but not detected in quad or suitable nearby habitat. Minor levels g/c weed species.
18	1a	Open Forest to 18m high on private property. Grazed, poor regeneration of all strata, shrub layer virtually absent, similar in adjacent areas.
19	1a	Open Forest to 16m high on private land. Steep slopes, rocky. Poor g/c and u/s and regeneration probably due to grazing. Moderate levels of weed species in g/c.
20	3	Woodland/Open Forest on steep slope, generally rocky. Poor herb layer and regeneration probably due to cattle grazing, moderate levels weed species in g/c.
21	5(7)	Vegetation surrounding artificial dam in grazed paddocks. Occasional remnant *Angophora costata* and *Eucalyptus umbra* nearby.
22	5b	Dense *Melaleuca* spp Low Forest with occasional *Eucalyptus* spp emergents. Grazed, site and adjacent creekline trampled by cattle, moderate levels shrub and g/c weed species.
23	7(3)	Disturbed, mostly cleared land on private property. Some limited tree species regeneration along fencelines, high levels weed species in g/c and shrub layers near quad.
24	5b	Dense regrowth of *Melaleuca* spp, with occasional *Eucalyptus* and *Angophora* spp emergents to 15m high. *E robusta* in quad and adjacent sites. Vegetation slashed below powerlines. Minor weed species in g/c.
25	4	Open Forest to 16m, with dense mid-canopy in low-lying depression alongside existing Pacific Highway. Moderate to high levels weed species in g/c where disturbed.
26	3	Woodland to 16m high on southern side of existing highway. Sporadic clumps of *Tetratheca juncea* in quad and in adjacent areas. Possible habitat for *Blandfordia grandiflora*. No weed species present in quad, though present along roadsides in vicinity.
27	4	Woodland/ Open Forest to 15m high, some prior disturbance probably due to road construction, dumping of fill *etc.* Dense regeneration of *Melaleuca* spp, some moderate levels weed species in swampy and disturbed sites along powerline easement.
28	3	Open Forest grading into Community 1a, with dense *Melaleuca* spp understorey, some dense *Lanatana camara* stands to east, moderate levels g/c weed species.
29	1b	Open Forest to 20m high in saddle between steep hills. Quad and all surrounding open forest sites grazed, generally poor regeneration, some areas of *Lantana camara* infestation. Moderate levels of weed species in g/c.
30	4	*Melaleuca* spp Low Open Forest to 8m +/- emergents to 15m high near edge of Wallaroo Swamp. Site and surrounds burnt 11/97, *M* understorey and g/c layer regenerating. Minor levels weed species in g/c, though higher levels present along tracks to east.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 2

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 2 Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

KEY

* Introduced species

H Vulnerable species (Schedule 2 of the *NSW Threatened Species Conservation Act 1995* - TSC Act)

\# Regionally significant species (Benson 1986)

A Species recorded along the proposed Horse Island route option and in the surrounding area

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.

BOTANICAL NAME	COMMON NAME	A	B
FILOCOPSIDA			
Adiantaceae			
Adiantum aethiopicum	Maiden-hair Fern	X	X
Cheilanthes sieberi	Mulga Fern	X	X
Azollaceae			
Azolla pinnata	-	X	X
Blechnaceae			
Blechnum cartilagineum	Gristle Fern		X
Blechnum indicum	Swamp Water Fern	X	X
Dennstaedtiaceae			
Pteridium esculentum	Bracken	X	X
Gleicheniaceae			
Gleichenia dicarpa	Pouched Coral Fern	X	X
Lindsaeaceae			
Lindsaea linearis	Screw Fern		X
Lindsaea microphylla	Lacy Wedge Fern	X	X
Selaginellaceae			
Selaginella uliginosa	-	X	X
CONIFEROPSIDA			
Pinaceae			
**Pinus radiata*	Radiata Pine	X	X
MAGNOLIOPSIDA: DICOTYLEDONS			
Acanthaceae			
Brunoniella australis	Blue Trumpet	X	X
Amaranthaceae			
Alternanthera denticulata	Lesser Joyweed	X	X
Apiaceae			
Actinotus helianthus	Flannel Flower		X
Centella asiatica	Pennywort	X	X
Trachymene incisa	-	X	X
Xanthosia pilosa	-	X	X
Xanthosia tridendata	-	X	X
Apocynaceae			
Parsonsia straminea	Common Silkpod	X	X
Araliaceae			
Astrotricha longifolia	Star-hair	X	X
Polyscias sambucifolia ssp A	Elderberry Panax	X	X
Asclepiadaceae			
**Araujia sericifolia*	Moth Vine	X	X
**Gomphocarpus fruticosus*	Narrow-leaved Cotton Bush	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Asteraceae			
**Ageratina adenophora*	Crofton Weed	X	X
**Ageratum houstonianum*	-	X	
**Bidens pilosa*	Cobbler's Pegs	X	X
Brachycome angustifolia var *angustifolia*	-	X	X
Calotis hispidula	Bogan Flea	X	X
**Carduus nutans* ssp *nutans*	Nodding Thistle	X	X
Cassinia uncata	Sticky Cassinia	X	X
Chrysocephalum apiculatum	Common Everlasting	X	X
**Cirsium vulgare*	Spear Thistle	X	X
**Conyza albida*	Tall Fleabane	X	X
**Conyza bonariensis*	Flaxleaf Fleabane	X	X
**Conyza canadensis*	Canadian Fleabane	X	X
Cotula coronopifolia	Water Buttons	X	
Epaltes australis	Spreading Nut-heads	X	X
Glossogyne tannensis	Cobbler's Tack	X	X
Gnaphalium involucratum	Star Cudweed	X	X
Gnaphalium sphaerocarpum	-	X	X
Helichrysm rutidolepis	Pale Everlasting	X	X
**Hypochaeris radicata*	Flatweed	X	X
Lagenifera stipitata	Blue Bottle-daisy	X	X
Ozothamnus diosmifolius	White Dogwood	X	X
Pseudognaphalium luteo-album	Jersey Cudweed	X	X
Senecio diaschides	-	X	X
**Senecio madagascariensis*	Fireweed	X	X
Senecio hispidulus var *hispidulus*	Hill Fireweed	X	X
**Silybum marianum*	Variegated Thistle	X	X
**Sonchus asper* ssp *glaucescens*	Prickly Sowthistle	X	
**Sonchus oleraceus*	Common Sowthistle	X	X
**Tagetes minuta*	Stinking Roger	X	X
Vernonia cinerea	-	X	X
Avicenniaceae			
Avicennia marina ssp *australiasica*	Grey Mangrove	X	X
Brassicaceae			
**Capsella bursa-pastoris*	Shepherd's Purse	X	X
**Coronopus didymus*	Lesser Swinecress	X	
**Raphanus raphanistrum*	Wild Radish	X	X
Campanulaceae			
Wahlenbergia communis	Tufted Bluebell	X	X
Wahlenbergia gracilis	Australian Bluebell	X	X
Wahlenbergia stricta var *stricta*	Tall Bluebell	X	X
Caprifoliaceae			
**Lonicera japonica*	Japanese Honeysuckle	X	X
Cassythaceae			
Cassytha glabella	Devil's Twine	X	X
Cassytha pubescens	Devil's Twine	X	X
Casuarinaceae			
Allocasuarina littoralis	Black Sheoak	X	X
Allocasuarina torulosa	Forest Oak	X	X
Casuarina glauca	Swamp Oak	X	X
Chenopodiaceae			
Atriplex semibaccata	Creeping Saltbush	X	X
**Chenopodium album*	Fat Hen	X	X
Einadia hastata	Berry Saltbush	X	X
Sarcocornia quinqueflora	-	X	X
Suaeda australis	-	X	X
Convolvulaceae			
Dichondra repens	Kidney Weed	X	X
Polymeria calycina	-	X	X
Cunoniaceae			
Callicoma serratifolia	Black Wattle		X
Ceratopetalum gummiferum	Coachwood		X
Dilleniaceae			
Hibbertia aspera	Guinea-flower	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Dilleniaceae contd			
Hibbertia diffusa	Guinea-flower	X	X
Hibbertia empetrifolia	Guinea-flower	X	
Hibbertia linearis	Guinea-flower	X	
Hibbertia obtusifolia	Guinea-flower	X	X
Hibbertia scandens	Climbing Guinea-flower	X	X
Epacridaceae			
Epacris pulchella	-	X	X
Leucopogon appressus	Beard-heath	X	X
Leucopogon juniperinus	Beard-heath	X	X
Leucopogon virgatus	Beard-heath	X	X
Euphorbiaceae			
Breynia oblongifolia	Coffee Bush	X	X
Euphorbia peplus	Petty Spurge		X
Glochidion ferdinandi ssp *ferdinandi*	Cheese Tree	X	X
Phyllanthus gasstroemii	-	X	X
Phyllanthus hirtellus	-	X	X
Phyllanthus virgatus	-	X	X
Poranthera microphylla	-	X	X
Fabaceae: Caesalpinoideae			
**Senna pendula* var *glabrata*	Cassia	X	X
Fabaceae: Faboideae			
Chorizema parviflorum	Eastern Flame Pea	X	X
Daviesia genistifolia	Broom Bitter Pea	X	X
Daviesia ulicifolia	Gorse Bitter Pea	X	X
Desmodium varians	Slender Tick-trefoil	X	X
Dillwynia retorta sp *complex*	Egg and Bacon Pea	X	X
Dillwynia phylicoides sp complex	Egg and Bacon Pea	X	X
Glycine clandestina	Glycine	X	X
Glycine microphylla	Glycine	X	X
Glycine tabacina	Glycine	X	X
Gompholobium glabratum	Dainty Wedge Pea		X
Gompholobium latifolium	Golden Glory Pea	X	X
Gompholobium pinnatum	Pinnate Wedge Pea	X	X
Gompholobium virgatum	Leafy Wedge Pea	X	X
Hardenbergia violacea	False Sarsaparilla	X	X
Kenedia rubicunda	Red Kennedy Pea	X	X
Mirbelia rubiifolia	-	X	X
Pultenaea elliptica	Egg and Bacon Pea	X	X
Pultenaea palacea var *palacea*	Egg and Bacon Pea	X	X
Pultenaea retusa	Egg and Bacon Pea	X	X
Pultenaea villosa	Egg and Bacon Pea	X	X
**Robinia pseudoacacia*	Black Locust	X	
**Vicia sativa*	-	X	X
**Vicia tetrasperma*	Slender Vetch	X	X
Vigna vexilata var *angustifolia*	Wild Cow Pea	X	X
**Wisteria floribunda*	Wisteria	X	
Fabaceae: Mimosoideae			
**Acacia baileyana*	Cootamundra Wattle	X	
Acacia brownii	-	X	X
Acacia falcata	-	X	X
Acacia floribunda	White Sally	X	X
Acacia implexa	Hickory Wattle	X	X
Acacia irrorata ssp *irrorata*	Green Wattle	X	X
Acacia longifolia	Sydney Golden Wattle	X	X
Acacia longissima	-	X	X
Acacia maidenii	Maiden's Wattle	X	X
Acacia myrtifolia	Red-stemmed Wattle	X	X
**Acacia podalyriifolia*	Queensland Silver Wattle	X	
Acacia terminalis	Sunshine Wattle	X	X
Acacia ulicifolia	Prickly Moses	X	X
Goodeniaceae			
Dampiera stricta	-	X	X
Goodenia bellidifolia ssp *bellidifolia*	-	X	X
Goodenia dimorpha var *dimorpha*	-	X	X
Goodenia hederacea var *hederacea*	-	X	X
Goodenia paniculata	-	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Goodeniaceae contd			
Selliera radicans	-		X
Haloraginaceae			
Gonocarpus tetragynus	-		X
Gonocarpus teucrioides	-	X	X
Myriophyllum variifolium	Water-milfoil		X
Hypericaceae			
Hypericum gramineum	Small St John's Wort	X	X
Lauraceae			
**Cinnamomun camphora*	Camphor Laurel	X	X
Lentibulariaceae			
Utricularia laterifolia	Small Bladderwort	X	X
Lobeliaceae			
Pratia purpurascens	Whiteroot	X	X
Loranthaceae			
Ameyema pendulum	Mistletoe	X	X
Dendrophthoe vittelina	Mistletoe		X
Muellerina celastroides	Mistletoe		X
Muellerina eucalyptoides	Mistletoe		X
Malvaceae			
**Pavonia hastata*	-	X	X
**Sida rhombifolia.*	Paddy's Lucerne	X	X
Myoporaceae			
Eremophila debilis	Winter Apple	X	X
Myrsinaceae			
Aegicerus corniculatum	River Mangrove	X	X
Myrtaceae			
Angophora costata	Smooth-barked Apple	X	X
Angophora floribunda	Rough-barked Apple	X	X
Callistemon linearis	Narrow-leaved Bottlebrush	X	X
Callistemon rigidus	Stiff Bottlebrush	X	X
Corymbia gummifera	Red Bloodwood	X	X
Corymbia maculata	Spotted Gum	X	X
Eucalyptus acmenoides	White Mahogany	X	X
Eucalyptus amplifolia ssp *amplifolia*	Cabbage Gum	X	X
Eucalyptus capitellata	Brown Stringybark	x	
Eucalyptus eugenioides	Thin-leaved Stringybark	X	X
#*Eucalyptus fergusonii* ssp *fergusonii*	-	X	
Eucalyptus fibrosa	Broad-leaved Ironbark	X	X
Eucalyptus globoidea	White Stringybark	X	X
Eucalyptus microcorys	Tallow-wood	X	X
Eucalyptus piperita	Sydney Peppermint	X	X
Eucalyptus propinqua	Grey Gum	X	X
Eucalyptus punctata	Grey Gum	x	
Eucalyptus resinifera ssp *resinifera*	Red Mahogany	X	X
# *Eucalyptus robusta*	Swamp Mahogany	X	
Eucalyptus siderophloia	Grey Ironbark	X	X
Eucalyptus tereticornis	Forest Red Gum	X	X
Eucalyptus umbra	Bastard White Mahogany	X	X
Kunzea ambigua	Tick Bush	X	X
Leptspermum arachnoides	Tea-tree		X
Leptospermum juniperinum	Tea-tree	X	X
Leptospermum laevigatum	Coast Tea-tree	X	X
Leptospermum liversidgei	-	X	X
Leptospermum polygalifolium ssp *cismontanum*	-	X	X
Leptospermum polygalifolium ssp *polygalifolium*	-	X	X
Leptospermum trinervium	-	X	X
Melaleuca decora	Paperbark	X	X
Melaleuca linariifolia	Paperbark	X	X
Melaleuca nodosa	Paperbark	X	X
Melaleuca styphelioides	Prickly-leaved Tea-tree	X	X
Melaleuca squarrosa	Paperbark	X	X
Melaleuca quinquenervia	Paperbark	X	X
Syncarpia glomulifera	Turpentine	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Nymphaeceae			
**Nymphaea capensis*	Cape Waterlily	X	X
Oleaceae			
**Ligustrum lucidum*	Large-leaved Privet	X	X
**Ligustrum sinense*	Small-leaved Privet	X	X
Olea europaea ssp africana	African Olive	X	X
Notolaea longifolia forma longifolia	Large Mock-olive	X	X
Notolaea ovata	-	X	X
Notolaea venosa	Veined Mock-olive	X	X
Onagraceae			
Ludwigia peploides ssp *montevidensis*	Water Primrose	X	X
Oxalidaceae			
**Oxalis corniculata*	Creeping Oxalis	X	X
**Oxalis pes-caprae*	Soursob	X	X
Passifloraceae			
**Passiflora edulis*	Passionfruit	X	X
Pittosporaceae			
Billardiera scandens	Appleberry	X	X
Bursaria spinosa var *spinosa*	Blackthorn	X	X
Pittosporum undulatum	Sweet Pittosporum	X	X
Plantaginaceae			
**Plantago lanceolata*	Lamb's Tongues	X	X
**Plantago varia*	Plantain	X	X
Polygalaceae			
Comesperma ericinum	-	X	X
Polygonaceae			
Persicaria decipiens	Slender Knotweed	X	X
Persicaria lapathifolia	Pale Knotweed	X	X
**Polygonum aviculare*	Wireweed	X	X
**Rumex crispus*	Curled Dock	X	X
Proteaceae			
Banksia serrata	Old Man Banksia	X	X
Banksia spinulosa var collina	Hairpin Banksia	X	X
Banksia spinulosa var *spinosa*	Hairpin Banksia	X	X
Grevillea buxifolia	Grey Spider Flower		X
Grevillea linearifolia	-		X
Grevillea speciosa	Red Spider Flower	X	X
# Hakea bakeriana	-	X	
Hakea dactyloides	-	X	X
Hakea gibbosa	-	X	X
Hakea sericea	-	X	X
Lambertia formosa	Mountain Devil	X	X
Lomatia silaifolia	Crinkle Bush	X	X
Persoonia levis	Broad-leaved Geebung	X	X
Persoonia linearis	Narrow-leaved Geebung	X	X
Xylomelum pyriforme	-		X
Ranunculaceae			
Ranunculus inundatus	Buttercup	X	X
**Ranunculus repens*	Creeping Buttercup	X	X
Rosaceae			
**Rubus fruticosus* species aggregate	Blackberry	X	X
Rubus hillii	Molucca Bramble		X
Rubiaceae			
Opercularia diphylla	Stinkweed	X	X
Opercularia varia	Variable Stinkweed	X	X
Pomax umbellata	-	X	X
Rutaceae			
Boronia pinnata	Pinnate Boronia		X
Phebalium squamulosum	Scaly Phebalium		X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Salicaceae			
**Salix fragilis*	Crack Wattle	X	
Santalaceae			
Exocarpus cuppressiformis	Blueberry Ash	X	X
Sapindaceae			
Dodonaea triquetra	Common Hop Bush	X	X
Solanaceae			
**Solanum mauritianum*	Wild Tobacco	X	X
**Solanum nigrum*	Blackberry Nightshade	X	X
**Solanum pseudocapsicum*	Madeira Winter Cherry	X	X
**Solanum seaforthianum*	Brazilian Nightshade	X	X
Thymeleaceae			
Pimelea linifolia ssp *linifolia*	Rice-flower	X	X
Tremandraceae			
H *Tetratheca juncea*	Black-eyed Susan	X	X
Tetratheca thymifolia	Black-eyed Susan		X
Verbenaceae			
**Lantana camara*	Lantana	X	X
**Verbena bonariensis*	Purpletop	X	X
**Verbena rigida*	Veined Verbena	X	X
Violaceae			
Viola hederacea forma B	Ivy-leaved Violet	X	X
MAGNOLOPSIDA: MONOCOTYLEDONS			
Anthericaceae			
Caesia parviflora var *parviflora*	Pale Grass Lily	X	X
Tricoryne elatior	Yellow Autumn Lily	X	X
Arthropodiaceae			
Arthropodium minus	Small Vanilla Lily	X	X
Asparagaceae			
**Protosparagus densiflorus*	Asparagus fern	X	X
Blandfordiaceae			
# Blandfordia grandiflora	-	X	
Commelinaceae			
Commelina cyanea	Scurvey Weed	X	X
**Tradescantia albiflora*	Wandering Jew	X	X
Cyperaceae			
Baumea articulata	Jointed Twig-rush	X	X
Baumea juncea	-	X	
Baumea nuda	-	X	X
Baumea rubiginosa	-	X	X
Bolboschoenus caldwellii	-	X	X
Caustis pentandra	-	X	X
Cyathocheta diandra	-	X	X
Cyperus difformis	Dirty Dora	X	X
**Cyperus eragrostis*	Umbrella Sedge	X	X
Cyperus polystachyos	-	X	X
**Cyperus rotundus*	Nutgrass	X	X
Eleocharis acuta	-	X	X
Eleocharis cylindrostachys	-	X	X
Eleocharis sphacelata	Tall Spikerush	X	X
Fimbristylis dichotoma	-	X	X
Gahnia clarkei	Saw-sedge	X	X
Gahnia melanocarpa	Saw-sedge	X	X
Gahnia sieberana	Saw-sedge	X	X
Isolepis nodosa	Knobby Club-rush	X	
Lepidosperma flexuosum	-	X	X
Lepidosperma laterale	-	X	X
Lepidosperma lineare	-	X	X
Lepidosperma longitudinale	-	X	X
Lepidosperma lumicola	-	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Cyperaceae contd			
Schoenoplectus mucronatus	-	X	X
Schoenoplectus validus	-	X	X
Schoenus brevifolius	-	X	X
Doryanthaceae			
Doryanthes excelsa	Gymea Lily		X
Hydrocharitaceae			
**Elodea canadensis*	Canadian Pondweed	X	
Hypoxidaceae			
Hypoxis hygrometrica var *hygrometrica*	Golden Weather-grass	X	X
Iridaceae			
**Crocosmia crocosmiiflora*	Montbretia	X	X
Patersonia glabrata	Native Iris	X	X
Patersonia sericea	Native Iris	X	X
**Romulea rosea* var *australis*	Onion Grass	X	X
Juncaceae			
Juncus krausii ssp *australiensis*	Sea Rush	X	X
Juncus mollis	-	X	X
Juncus planifolius	-	X	X
Juncus polyanthemus	-	X	
Juncus prismatocarpus	-	X	X
Juncus usitatus	-	X	X
Luzula flaccida	Woodrush	X	X
Liliaceae			
Thysanotus microtuberosum	Fringe-lily		X
Thysanotus tuberosus	Common Fringe-lily	X	X
Lomandraceae			
Lomandra filiformis ssp *filiformis*	Wattle Mat-rush	X	X
Lomandra glauca	Pale mat-rush	X	X
Lomandra longifolia	Spiny-headed Mat-rush	X	X
Lomandra obliqua	Mat-rush	X	X
Orchidaceae			
Caladenia catenata	White Caladenia		X
Caladenia major	-		X
Cymbidium suave	Snake Orchid		X
Dendrobium aemulum	White Feather Orchid		X
Dipodium punctatum	Hyacinth Orchid		X
Philydraceae			
Philydrum lanuginosum	Frogsmouth	X	X
Phormiaceae			
Dianella caerula var *producta*	Blue Flax Lily	X	X
Dianella crinoides	Blue Flax Lily	X	X
Dianella pruinosa	Blue Flax Lily	X	X
Poaceae			
Agrostis avenacea	Blowngrass	X	X
**Andropogon virginicus*	Whiskey Grass	X	X
Aristida ramosa	Threeawn Grass	X	X
Aristida vagans	Threeawn Speargrass	X	X
**Arundo donax*	Giant Reed	X	X
**Avena fatua*	Wild Oats	X	X
**Axonopus affinis*	Narrow-leaved Carpet Grass	X	X
Bothriochloa biloba	-	X	X
Bothriochloa decipiens	Pitted Bluegrass	X	X
Bothriochloa macra	Red Grass	X	X
**Briza minor*	Shivery Grass	X	X
Capillipedium parviflorum	Scented-top Grass	X	X
Chionochloa pallida	Silvertop Wallaby Grass		X
**Chloris gayana*	Rhodes Grass	X	X
Cymbopogon refractus	Barbed Wire Grass	X	X
**Cynodon dactylon*	Couch Grass	X	X
Danthonia linkii var *fulva*	Wallaby Grass	X	X
Danthonia pilosa	Smooth-flowered Wallaby Grass	X	X
Danthonia racemosa var *racemosa*	Wallaby Grass	X	X

APPENDIX 2 contd Flora species recorded during field investigations conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

BOTANICAL NAME	COMMON NAME	A	B
Poaceae contd			
Danthonia tenuior	Wallaby Grass	X	X
Dichantheum sericeum ssp *sericeum*	Queensland Bluegrass	X	X
Digitaria parviflora	Small-flowered Finger Grass		X
**Digitaria sanguinalis*	Crab Grass	X	X
**Echinochloa crus-galli*	Barnyard Grass	X	X
Echinopogon caespitosus var *caespitosus*	Hedgehog Grass	X	X
Entolasia marginata	Bordered Panic	X	X
Entolasia stricta	Wiry Panic	X	X
Eragrostis brownii	Brown's Lovegrass	X	X
Imperata cylindrica var *major*	Blady Grass	X	X
Microlaena stipoides var *stipoides*	-	X	X
Oplismenus aemulus	Basket Grass	X	X
**Ottochloa gracillima*	-	X	
**Paspalum dilatatum*	Paspalum	X	X
Phragmites australis	Common Reed	X	X
**Poa annua*	Winter Grass	X	X
**Setaria pumila*	Pale Pigeon Grass	X	X
**Sporobolus capensis*	-	X	X
**Sporobolus indicus* var *africanus*	Parramatta Grass	X	X
**Sporobolus virginicus* var *capensis*	-	X	X
Stipa pubescens	Speargrass	X	X
Themeda australis	Kangaroo Grass	X	X
**Urochloa panicoides*	Liverseed Grass	X	X
**Vulpia bromoides*	Squirrel Tail Fescue	X	X
Zoysia macrantha	Prickly Couch	X	X
Potamogetonaceae			
Potamogeton tricarinatus	Floating Pondweed	X	X
Restionaceae			
Lepyrodia interrupta	-	X	X
Lepyrodia muelleri	-	X	X
Leptocarpus tenax	-	X	X
Restio pallens	-	X	X
Ripogonaceae			
Geitonoplesium cymosum	Scrambling Lily	X	X
Eustrephus latifolius	Wombat Berry	X	X
Typhaceae			
Typha orientalis	Cumbungi	X	X
Xanthorrhoeaceae			
Xanthorrhoea fulva	Grass Tree	X	X
Xanthorrhoea latifolia ssp *latifolia*	Grass Tree	X	X

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 3

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 3 Details of flora and fauna investigations conducted along the proposed Horse Island route for the upgrade of the Pacific Highway at Karuah.

Details of the flora and fauna survey methods and survey effort are detailed below, with survey locations indicated on Figures 5 and 6 respectively. Results of the fauna surveys are provided in Appendix 6. Details of weather conditions throughout the survey are provided below. Details of the total flora and fauna effort (transects and trap nights/hours) invested into each survey method and the months over which they were conducted are outlined in Table 6.

PART A 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 1). The vegetation quadrats were standard 20m x 20m (*ie* 400m^2), and were intensively surveyed, with all plant species present recorded (Appendix 2).

All vegetation communities present were described, mapped (Appendix 1; Figure 7a & 7b), 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 2). 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.

Table 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

PART B FAUNA

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 the 3rd of March 1998. Investigations for the Flora & Fauna Assessment report were part of the route selection process, and based on the premise that additional investigations would be conducted for the SIS (Gunninah 1999c). A combination of standard fauna trapping techniques were utilised at five survey transects at selected representative survey locations, identified from a preliminary route inspection and the use of aerial photographs (Table 2; Figure 6). Each trapping transect was sampled on each of four survey nights (Table 3).

Areas of habitat regarded as potentially suitable for the Tiger Quoll and Long-nosed Potoroo along the alignment are relatively few, as the groundcover was generally relatively sparse following the bushfire west of the Karuah River. In additionally to cage trapping, the extensive spotlighting and

spotlighting and hair tube surveys provide appropriate supplementary survey techniques for these species throughout the study area.

Table 2 Details of 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	20	5	1	-
2	19	5	1	6
3	20	5	1	5
4	15	-	1	-
5	19	5	1	5

Table 3 Details of mammal trapping survey effort. Each trapping transect was sampled on each of 4 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
Hair tubes	650	peanut butter/honey/rolled oats chicken

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.

2.1 Anabat II microchiropteran bat call detectors

- seven survey sites located in woodland/open forest communities (Table 4; Figure 6);
- conducted over four nights (2nd-5th of March inclusive); and
- tapes sent to Mr Glenn Hoye for analysis.

Table 4 Location of Anabat recording sites along the route and in the immediate vicinity (Figure 6).

Date	Anabat Survey Site No	Location (AMGs)	
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 Harp traps

- five trap locations; two - four nights trapping at each location (Table 5; Figure 3);
- 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 5 Location of harp trap sites along the alignment and in the immediate vicinity, with details of survey effort (Figure 6).

Trap No	Harp Trap Locations		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

3 SPOTLIGHTING

Extensive spotlighting surveys, including both walked and driven surveys, were conducted along the route alignment and in the immediate vicinity (Figure 6):

- spotlighting over four nights (2nd - 5th of March inclusive);
- total of approximately seventeen person hours;
- total of approximately 48km; and
- records maintained of all species observed or identified by calls.

4 HERPETOLOGICAL SURVEYS

Surveys involved random periods of concentrated investigations during all diurnal and nocturnal surveys, supplementing the opportunistic records obtained throughout all field investigations in the study area:

- a total of approximately twenty-six person hours;
- 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;
- 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.

5 BIRD SURVEYS

Surveys involved random periods of concentrated investigations during all diurnal and nocturnal surveys, supplementing the opportunistic records obtained throughout all field investigations in the study area:

- total of twenty-one person hours
- 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 6); and
- records maintained of all species observed or identified by call.

6 KOALA SURVEYS

A two-method approach was used to determine the presence and useage of preferred food trees by Koalas,:

- a point sampling method (1) was undertaken at sixteen survey transects staggered along the proposed route alignment to determine useage patterns in areas dominated largely by non-browse species. At each transect, a sample of mature trees were checked for scats, and in the case of smooth-barked species scratches indicative of Koala (Figure 6);

- a browse sampling method (2) was undertaken in areas identified in the field as having a canopy composition of 15% or greater of known preferred Koala browse species. The survey areas were identified by walking the entire proposed road corridor, and through examination of aerial photographs that indicated areas with a high likelihood of preferred Koala browse sites outside the road corridor. Due to the small extent of such patches, all trees were generally sampled;

- species targeted were Forest Red Gum *Eucalyptus tereticornis*, Tallow-wood *E microcorys*, and the Grey Gums *E punctata* and *E propinqua*. Swamp Mahogany *E robusta* and Broad-leaved Paperbark *Melaleuca quinquenervia* were located south of the existing Highway at the eastern end of the proposed route alignment;

- a total of 193 trees were examined for signs of Koala scratches and for the presence of Koala scats located around their bases (Appendix 7); and

- spotlighting surveys involved dedicated Koala searches (3-Spotlighting).

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;

- scats, bones or hair collected sent to Mr AB Rose for analysis.

8 OPPORTUNISTIC OBSERVATIONS

- records maintained of all species observed or identified from calls whilst conducting all survey work and travelling between survey sites.

9 WEATHER CONDITIONS

Table 6 Weather conditions for the period over which fauna field investigations were conducted.

Date	Time	Conditions
17/02/98	morning	19.6; light cloud; light rain; light wind
*	afternoon	22.3; light cloud; light rain; moderate wind
18/02/98	morning	18.2; light cloud; no rain; light wind
*	afternoon	25.0; clear skies; no rain; moderate wind
19/02/98	morning	21.4; light cloud; no rain; light wind
*	afternoon	33.6; light cloud; no rain; moderate wind
20/02/98	morning	26.6; moderate cloud; no rain; light wind
*	afternoon	32.8; overcast; no rain; moderate wind
21/02/98	morning	23.3; overcast; no rain; light wind
*	afternoon	26.3; light cloud; no rain; moderate wind

Table 6 Weather conditions for the period over which fauna field investigations were conducted.

Date	Time	Conditions
22/02/98 *	morning afternoon	21.8; clear skies; no rain; light to moderate wind 32.7; clear skies; no rain; light to moderate wind
23/02/98 *	morning afternoon	23.0; light cloud; no rain; light wind 23.4; overcast; no rain; moderate to strong wind
24/02/98 *	morning afternoon	20.6; clear skies; no rain; light wind 25.0; clear skies; no rain; moderate wind
25/02/98 *	morning afternoon	20.9; clear skies; no rain; light wind 33.1; light cloud; no rain; light wind
26/02/98	morning afternoon evening	19-32°C; clear skies; no rain; light wind 32-36°C; clear skies; no rain; calm 20-25°C; clears skies; no rain; calm
27/02/98	morning afternoon evening	20-33°C; clear skies; no rain; calm 35-39°C; clear skies; no rain; calm; storm approaching 20-25°C; full cloud cover; steady rain; moderate to strong winds
28/02/98	morning afternoon evening	18-23°C; full cloud cover; light drizzle; light winds 18-23°C; full cloud cover; light drizzle to intermittent rain; calm 18-23°C; full cloud cover; light drizzle to intermittent rain; calm
01/03/98	morning afternoon evening	18-23°C; full cloud cover; light drizzle to intermittent rain; calm 18-23°C; starting to clear; light drizzle to intermittent rain; calm 18-23°C; clearing; no rain; light wind
02/03/98	morning afternoon evening	19-24°C; light cloud cover; no rain; calm 24-29°C; clear skies; no rain; calm 18-23°C; clear skies; no rain; calm
03/03/98	morning afternoon evening	19-25°C; minimal cloud cover; no rain; light wind 24-29°C; clear skies; no rain; light wind 20-25°C; minimal cloud cover; no rain; calm
04/03/98	morning afternoon evening	19-26°C; clear skies; no rain; light wind 23-29°C; some clouds; no rain; light wind 18-23°C; minimal cloud cover; no rain; light wind
05/03/98	morning afternoon evening	19-24°C; some clouds; no rain; light wind 21-26°C; increasing cloud cover; no rain; moderate wind 20-25°C; full cloud cover; some light rain after 11pm; moderate wind
06/03/98	morning afternoon	17-22°C; some clouds; no rain; light to moderate wind 19-24°C; minimal cloud cover; no rain; light wind

* The weather details for these days were generated from meteorological observations at Williamtown RAAF Weather Station; information supplied by the Bureau of Meteorology.

Table 7 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 the Proposed Horse Island Route-Flora & Fauna Assessment report (Gunninah 1999b).

REPORT	SURVEY METHOD	EFFORT		MONTHS
		TRANSECTS	NIGHTS/HOURS	
1999b	**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	48 km	17.5 hours	March 1998
	Herpetological Searches	Continuous & opportunistic	26 hours	Jan - March 1998
	Bird Surveys	Continuous & opportunistic	21 hours	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.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 4

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 4 Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

KEY

* Introduced species.

H Threatened species, as listed on the NSW *Threatened Species Conservation Act* 1995 (TSC Act).

- **E** Schedule 1 - Endangered
- **V** Schedule 2 - Vulnerable

Microchiropteran bat call identification reliabilirt estimates:

C Confident **P** Probable **Po** Possible

Sources of Information

A Species recorded in the study area during investigations conducted for this report.

B Species recorded in the general vicinity of the subject site during surveys conducted for previous reports (Ecotone 1995; Gunninah 1997a, 1997b, 1997c).

C NSW NP&WS Wildlife Atlas Port Stephens (9332) and Newcastle (9732) 1:100000 map-sheets. Species recorded within 10km of the general study area.

D 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).

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
BIRDS					
Casuariidae					
Emu	*Dromaius novaehollandiae*			×	
Phasianidae					
Brown Quail	*Coturnix ypsilophora*				×
Anatidae					
Musk Duck	*Biziura lobata*		×		×
Black Swan	*Cygnus atratus*	×	×		×
Australian Wood Duck	*Chenonetta jubata*	×	×	×	×
Pacific Black Duck	*Anas superciliosa*	×	×		×
Australasian Shoveler	*Anas rhynchotis*		×		
Grey Teal	*Anas gracilis*				×
Chestnut Teal	*Anas castanea*				×
Hardhead	*Aythya australis*		×		×
Podicipedidae					
Australasian Grebe	*Tachybaptus novaehollandiae*	×	×		×
Hoary-headed Grebe	*Poliocephalus poliocephalus*				×
Great Crested Grebe	*Podiceps cristatus*				×
Anhingidae					
Darter	*Anhinga melanogaster*		×		×
Phalacrocoracidae					
Little Pied Cormorant	*Phalacrocorax melanoleucos*	×	×		×
Pied Cormorant	*Phalacrocorax varius*				×
Little Black Cormorant	*Phalacrocorax sulcirostris*	×	×		×
Great Cormorant	*Phalacrocorax carbo*	×	×		×
Pelecanidae					
Australian Pelican	*Pelecanus conspicillatus*		×		×
Ardeidae					
White-faced Heron	*Egretta novaehollandiae*	×	×		×
White-necked Heron	*Ardea pacifica*	×			×
Great Egret	*Ardea alba*				×
Intermediate Egret	*Ardea intermedia*	×	×		
Cattle Egret	*Ardea ibis*	×	×		×
Striated Heron	*Butorides striatus*		×		×
Nankeen Night Heron	*Nycticorax caledonicus*				×
Threskiornithidae					
Glossy Ibis	*Plegadis falcinellus*				×
Australian White Ibis	*Threskiornis molucca*	×	×		×
Straw-necked Ibis	*Threskiornis spinicollis*	×	×		×

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Threskiornithidae contd					
Royal Spoonbill	*Platalea regia*	×	×		×
Yellow-billed Spoonbill	*Platalea flavipes*				×
Ciconiidae					
H(V) Black-necked Stork	*Ephippiorhynchus asiaticus*				×
Accipitridae					
H(V) Osprey	*Pandion haliaetus*	×			
Pacific Baza	*Aviceda subcristata*			×	
Black-shouldered Kite	*Elanus axillaris*	×	×		×
Whistling Kite	*Haliastur sphenurus*	×	×	×	×
Brahminy Kite	*Haliastur indus*			×	
White-bellied Sea-Eagle	*Haliaetus leucogaster*	×	×	×	×
Brown Goshawk	*Accipiter fasciatus*		×		×
Grey Goshawk	*Accipiter novaehollandiae*		×		
Wedge-tailed Eagle	*Aquila audax*	×		×	
Little Eagle	*Hieraaetus morphnoides*		×		
Falconidae					
Brown Falcon	*Falco berigora*	×			×
Australian Hobby	*Falco longipennis*				×
Peregrine Falcon	*Falco peregrinus*			×	
Nankeen Kestrel	*Falco cenchroides*			×	×
Rallidae					
Lewin's Rail	*Gallirallus pectoralis*				×
Purple Swamphen	*Porphyrio porphyrio*		×		×
Dusky Moorhen	*Gallinula tenebrosa*		×		
Eurasian Coot	*Fulica atra*		×		×
Scolopacidae					
Latham's Snipe	*Gallinago hardwickii*				×
Bar-tailed Godwit	*Limosa lapponica*				×
Whimbrel	*Numenius phaeopus*			×	×
Eastern Curlew	*Numenius madagascariensis*	×			×
Marsh Sandpiper	*Tringa stagnatilis*				×
Common Greenshank	*Tringa nebularia*				×
Common Sandpiper	*Actitis hypoleucos*				×
Grey-tailed Tattler	*Heteroscelus brevipes*				×
Red-necked Stint	*Calidris ruficollis*				×
Sharp-tailed Sandpiper	*Calidris acuminata*				×
Curlew Sandpiper	*Calidris ferruginea*				×
Burhinidae					
H(E) Bush Stone-curlew	*Burhinus grallarius*			×	×
Recurvirostridae					
Black-winged Stilt	*Himantopus himantopus*				×
Charadriidae					
Pacific Golden Plover	*Pluvialis fulva*			×	
Red-capped Plover	*Charadrius ruficapillus*				×
Double-banded Plover	*Charadrius bicinctus*			×	
H(V) Lesser Sand Plover	*Charadrius mongolus*				×
Black-fronted Plover	*Elseyornis melanops*				×
Masked Lapwing	*Vanellus miles*	×	×	×	×
Laridae					
Silver Gull	*Larus novaehollandiae*	×			×
Gull-billed Tern	*Sterna nilotica*				×
Caspian Tern	*Sterna caspia*			×	
Common Tern	*Sterna hirundo*				×
H(E) Little Tern	*Sterna albifrons*				×
Crested Tern	*Sterna bergii*	×			×
Columbidae					
* Rock Dove	*Columba livia*				×
* Spotted Turtle-Dove	*Streptopelia chinensis*	×	×	×	×
Common Bronzewing	*Phaps chalcoptera*		×		
Brush Bronzewing	*Phaps elegans*			×	
Crested Pigeon	*Ocyphaps lophotes*	×	×	×	×
Peaceful Dove	*Geopelia placida*	×	×		×
Bar-shouldered Dove	*Geopelia humeralis*	×			×

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Columbidae contd					
Wonga Pigeon	*Leucosarcia melanoleuca*		×	×	
H(V) Wompoo Fruit-Dove	*Ptilinopus magnificus*			×	
Topknot Pigeon	*Lopholaimus antarcticus*				×
Cacatuidae					
H(V) Glossy Black-Cockatoo	*Calyptorhynchus lathami*		×	×	×
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*	×	×	×	×
Galah	*Cacatua roseicapilla*	×	×	×	×
Little Corella	*Cacatua sanguinea*		×		
Sulphur-crested Cockatoo	*Cacatua galerita*	×	×	×	
Psittacidae					
Rainbow Lorikeet	*Trichoglossus haematodus*	×		×	×
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*		×		×
Little Lorikeet	*Glossopsitta pusilla*			×	×
Australian King-Parrot	*Alisterus scapularis*		×	×	×
Eastern Rosella	*Platycercus eximius*	×	×	×	×
Red-rumped Parrot	*Psephotus haematonotus*	×			×
Cuculidae					
Pallid Cuckoo	*Cuculus pallidus*			×	×
Brush Cuckoo	*Cuculus variolosus*				×
Fan-tailed Cuckoo	*Cacomantis flabelliformis*		×	×	×
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*				×
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*			×	×
Common Koel	*Eudynamis scolopacea*			×	×
Channel-billed Cuckoo	*Scythrops novaehollandiae*			×	×
Centropodidae					
Pheasant Coucal	*Centropus phasianinus*			×	×
Strigidae					
H(V) Powerful Owl	*Ninox strenua*			×	
Southern Boobook	*Ninox novaeseelandiae*		×	×	
Tytonidae					
H(V) Masked Owl	*Tyto novaehollandiae*		×	×	
Podargidae					
Tawny Frogmouth	*Podargus strigoides*	×	×	×	
Caprimulgidae					
White-throated Nightjar	*Eurostopodus mystacalis*	×		×	
Aegothelidae					
Australian Owlet-nightjar	*Aegotheles cristatus*	×	×	×	
Apodidae					
White-throated Needletail	*Hirundapus caudacutus*	×	×		×
Alcedinidae					
Azure Kingfisher	*Alcedo azurea*		×	×	
Halcyonidae					
Laughing Kookaburra	*Dacelo novaeguineae*	×	×	×	×
Forest Kingfisher	*Todiramphus macleayii*		×		
Sacred Kingfisher	*Todiramphus sanctus*	×	×	×	×
Meropidae					
Rainbow Bee-eater	*Merops ornatus*	×		×	
Coraciidae					
Dollarbird	*Eurystomus orientalis*	×	×	×	×
Climacteridae					
White-throated Treecreeper	*Cormobates leucophaeus*	×	×	×	×
Brown Treecreeper	*Climacteris picumnus*				×
Maluridae					
Superb Fairy-wren	*Malurus cyaneus*	×	×	×	×
Variegated Fairy-wren	*Malurus lamberti*	×	×	×	×
Southern Emu-wren	*Stipiturus malachurus*		×	×	×

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Pardalotidae					
Spotted Pardalote	*Pardalotus punctatus*	×	×	×	×
Striated Pardalote	*Pardalotus striatus*		×		×
Yellow-throated Scrubwren	*Sericornis citreogularis*				×
White-browed Scrubwren	*Sericornis frontalis*	×	×	×	×
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*			×	
Weebill	*Smicrornis brevirostris*		×		
Brown Gerygone	*Gerygone mouki*			×	×
White-throated Gerygone	*Gerygone olivacea*	×	×	×	×
Brown Thornbill	*Acanthiza pusilla*	×	×	×	×
Buff-rumped Thornbill	*Acanthiza reguloides*	×		×	×
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*				×
Yellow Thornbill	*Acanthiza nana*		×	×	×
Striated Thornbill	*Acanthiza lineata*	×	×	×	×
Meliphagidae					
Red Wattlebird	*Anthochaera carunculata*		×	×	×
Little Wattlebird	*Anthochaera chrysoptera*			×	×
Noisy Friarbird	*Philemon corniculatus*		×	×	×
Blue-faced Honeyeater	*Entomyzon cyanotis*			×	
Noisy Miner	*Manorina melanocephala*	×	×	×	×
Lewin's Honeyeater	*Meliphaga lewinii*		×	×	×
Yellow-faced Honeyeater	*Lichenostomus chrysops*	×	×	×	×
Fuscous Honeyeater	*Lichenostomus fuscus*			×	×
Brown-headed Honeyeater	*Melithreptus brevirostris*	×		×	×
White-naped Honeyeater	*Melithreptus lunatus*		×	×	
Brown Honeyeater	*Lichmera indistincta*		×	×	×
White-cheeked Honeyeater	*Phylidonyris nigra*	×	×	×	×
Tawny-crowned Honeyeater	*Phylidonyris melanops*				×
Eastern Spinebill	*Acanthorhynchus tenuirostris*		×	×	×
Scarlet Honeyeater	*Myzomela sanguinolenta*			×	×
White-fronted Chat	*Epthianura albifrons*			×	×
Petroicidae					
Scarlet Robin	*Petroica multicolor*		×	×	
Hooded Robin	*Melanodryas cucullata*				×
Eastern Yellow Robin	*Eopsaltria australis*	×	×	×	×
Jacky Winter	*Microeca fascinans*	×			×
Pomatostomidae					
Grey-crowned Babbler	*Pomatostomus temporalis*				×
Cinclosomatidae					
Eastern Whipbird	*Psophodes olivaceus*		×	×	×
Neosittidae					
Varied Sittella	*Daphoenositta chrysoptera*				×
Pachycephalidae					
Crested Shrike-tit	*Falcunculus frontatus*				×
Golden Whistler	*Pachycephala pectoralis*		×	×	×
Rufous Whistler	*Pachycephala rufiventris*	×	×	×	×
Grey Shrike-thrush	*Colluricincla harmonica*	×	×	×	×
Dicruridae					
Black-faced Monarch	*Monarcha melanopsis*		×	×	×
Leaden Flycatcher	*Myiagra rubecula*		×	×	×
Restless Flycatcher	*Myiagra inquieta*				×
Magpie-lark	*Grallina cyanoleuca*	×	×	×	×
Rufous Fantail	*Rhipidura rufifrons*		×	×	×
Grey Fantail	*Rhipidura fuliginosa*	×	×	×	×
Willie Wagtail	*Rhipidura leucophrys*	×	×	×	×
Spangled Drongo	*Dicrurus bracteatus*	×	×		
Campephagidae					
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	×	×	×	×
White-bellied Cuckoo-shrike	*Coracina papuensis*			×	
Cicadabird	*Coracina tenuirostris*	×	×	×	×
White-winged Triller	*Lalage sueurii*				×
Oriolidae					
Olive-backed Oriole	*Oriolus sagittatus*		×	×	×
Figbird	*Sphecotheres viridis*		×	×	

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Artamidae					
White-breasted Woodswallow	*Artamus leucorhynchus*			×	×
Dusky Woodswallow	*Artamus cyanopterus*			×	×
Grey Butcherbird	*Cracticus torquatus*	×	×	×	×
Pied Butcherbird	*Cracticus nigrogularis*	×		×	×
Australian Magpie	*Gymnorhina tibicen*	×	×	×	×
Pied Currawong	*Strepera graculina*	×	×	×	×
Corvidae					
Australian Raven	*Corvus coronoides*	×	×	×	×
Forest Raven	*Corvus tasmanicus*			×	
Corcoracidae					
White-winged Chough	*Corcorax melanorhamphos*	×	×	×	×
Ptilonorhynchidae					
Satin Bowerbird	*Ptilonorhynchus violaceus*		×	×	×
Motacillidae					
Richard's Pipit	*Anthus novaeseelandiae*	×	×		×
Passeridae					
* House Sparrow	*Passer domesticus*				×
Zebra Finch	*Taeniopygia guttata*				×
Double-barred Finch	*Taeniopygia bichenovii*				×
Red-browed Finch	*Neochmia temporalis*	×	×	×	×
Diamond Firetail	*Stagonopleura guttata*				×
Chestnut-breasted Mannikin	*Lonchura castaneothorax*				×
Dicaeidae					
Mistletoebird	*Dicaeum hirundinaceum*	×	×	×	×
Hirundinidae					
Welcome Swallow	*Hirundo neoxena*	×	×	×	×
Tree Martin	*Hirundo nigricans*			×	×
Fairy Martin	*Hirundo ariel*				×
Sylviidae					
Clamorous Reed-Warbler	*Acrocephalus stentoreus*				×
Little Grassbird	*Megalurus gramineus*				×
Golden-headed Cisticola	*Cisticola exilis*		×		×
Rufous Songlark	*Cincloramphus mathewsi*				×
Brown Songlark	*Cincloramphus cruralis*				×
Zosteropidae					
Silvereye	*Zosterops lateralis*		×	×	×
Muscicapidae					
Bassian Thrush	*Zoothera lunulata*				×
Sturnidae					
* Common Starling	*Sturnus vulgaris*	×	×		×
* Common Mynah	*Acridotheres tristis*	×	×		×
AMPHIBIANS					
Myobatrachidae					
Tusked Frog	*Adelotus brevis*			×	
Common Eastern Froglet	*Crinia signifera*		×	×	
Eastern Banjo Frog	*Limnodynastes dumerilii*	×		×	
Ornate Burrowing Frog	*Limnodynastes ornatus*			×	
Brown-striped Frog	*Limnodynastes peronii*		×	×	
Spotted Grass Frog	*Limnodynastes tasmaniensis*		×	×	
Brown Toadlet	*Pseudophryne bibroni*	×		×	
Red-backed Toadlet	*Pseudophryne coriacea*		×	×	
Smooth Toadlet	*Uperoleia laevigata*		×	×	
Hylidae					
Bleating Tree Frog	*Litoria dentata*			×	
Eastern Dwarf Tree Frog	*Litoria fallax*	×	×	×	
Frecinet's Frog	*Litoria freycineti*			×	
Günther's Frog	*Litoria latopalmata*	×	×	×	
Peron's Tree Frog	*Litoria peronii*	×	×	×	
Leaf Green Tree Frog	*Litoria phyllochroa*			×	

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Hylidae contd					
Verreaux's Tree Frog	*Litoria verreauxii*		×		
REPTILES					
Chelidae					
Long-necked Tortoise	*Chelodina longicollis*	×			
Agamidae					
Jacky Lizard	*Amphibolurus muricatus*	×	×	×	
Bearded Dragon	*Pogona barbata*	×	×	×	
Eastern Water Dragon	*Physignathus lesueurii*		×		
Varanidae					
Lace Monitor	*Varanus varius*	×	×	×	
Gekkonidae					
Southern Leaf-tailed Gecko	*Phyllurus cornatus*		×		
Robust Velvet Gecko	*Oedura robusta*		×		
Scincidae					
Striped Skink	*Ctenotus robustus*		×	×	
Land Mullet	*Egernia major*			×	
Eastern Water Skink	*Eulamprus quoyii*	×	×	×	
Pink-tongued Lizard	*Hemisphaeriodon gerrardii*		×		
Friendly Sunskink	*Lampropholis amicula*			×	
Garden Skink	*Lampropholis delicata*	×	×	×	
Grass Skink	*Lampropholis guichenoti*	×	×		
Eastern Blue-tongued Lizard	*Tiliqua scincoides*		×	×	
Shingleback	*Trachydosaurus rugosus*			×	
Boidae					
Diamond Python	*Morelia spilota* ssp *spilota*		×		
Elapidae					
Golden-crowned Snake	*Cacophis squamulosus*			×	
Yellow-faced Whip Snake	*Demansia psammophis*		×		
Black-bellied Swamp Snake	*Hemiaspis signata*	×	×		
Red-bellied Black Snake	*Pseudechis porphyriacus*	×	×	×	
Eastern Brown Snake	*Pseudonaja textilis*	×		×	
MAMMALS					
Ornithorhynchidae					
Platypus	*Ornithorhynchus anatinus*			×	
Tachyglossidae					
Short-beaked Echidna	*Tachyglossus aculeatus*		×	×	
Dasyuridae					
Brown Antechinus	*Antechinus stuartii*	×	×	×	
H(V) Tiger Quoll	*Dasyurus maculatus*			×	
H(V) Brush-tailed Phascogale	*Phascogale tapoatafa*		×	×	
Common Dunnart	*Sminthopsis murina*		×		
Peramelidae					
Long-nosed Bandicoot	*Perameles nasuta*			×	
Northern Brown Bandicoot	*Isoodon macrourus*		×	×	
Phascolarctidae					
H(V) Koala	*Phascolarctos cinereus*	×	×	×	
Vombatidae					
Common Wombat	*Vombatus ursinus*			×	
Petaurdiae					
Sugar Glider	*Petaurus breviceps*		×	×	
H(V) Squirrel Glider	*Petaurus norfolcensis*	×	×	×	
Pseudocheiridae					
Common Ringtail Possum	*Pseudocheirus peregrinus*	×	×	×	

APPENDIX 4 contd Fauna species recorded along the proposed Horse Island route for the Pacific Highway upgrade at Karuah, NSW.

COMMON NAME	SCIENTIFIC NAME	A	B	C	D
Acrobatidae					
Feathertail Glider	*Acrobates pygmaeus*	×	×	×	
Phalangeridae					
Mountain Brushtail Possum	*Trichosurus caninus*		×		
Common Brushtail Possum	*Trichosurus vulpecula*	×	×	×	
Macropodidae					
Kangaroo	*Macropus* sp			×	
Red-necked Wallaby	*Macropus rufogriseus*	×	×	×	
Eastern Grey Kangaroo	*Macropus giganteus*	×	×	×	
Common Wallaroo	*Macropus robusta*		×	×	
Swamp Wallaby	*Wallabia bicolor*	×	×	×	
Pteropidae					
Grey-headed Flying-fox	*Pteropus poliocephalus*			×	
Rhinolophidae					
Eastern Horseshoe-bat	*Rhinolophus megaphyllus*		×		
Molossidae					
Little Freetail Bat	*Mormopterus* sp1	C	×		
H(V) Eastern Free-tail Bat	*Mormopterus norfolkensis*	C	×		
White-striped Mastiff Bat	*Nyctinomus australis*	×	×	×	
Vespertilionidae					
Gould's Wattled Bat	*Chalinolobus gouldii*	×	×	×	
Chocloate Wattled Bat	*Chalinolobus morio*	×	×	×	
Long-eared Bat	*Nyctophilus* sp	C	×		
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	×		×	
Gould's Long-eared Bat	*Nyctophilus gouldi*			×	
H(V) Large Bent-wing Bat	*Miniopterus schreibersii*		×		
H(V) Little Bent-wing Bat	*Miniopterus australis*	×	×		
Eastern Broad-nosed Bat	*Scotorepens orion*	P	×		
H(V) Greater Broad-nosed Bat	*Scoteanax rueppellii*	P			
Eastern Forest Bat	*Vespadelus pumilus*	Po			
Little Forest Bat	*Vespadelus vulturnus*	×	×	×	
Muridae					
Bush Rat	*Rattus fuscipes*	×	×	×	
Swamp Rat	*Rattus lutreolus*	×	×	×	
New Holland Mouse	*Pseudomys novaehollandiae*			×	
Introduced Mammals					
* Black Rat	*Rattus rattus*		×		
* Dingo/Dog	*Canis familiaris*	×		×	
* Goat	*Capra hircus*			×	
* Cattle	*Bos taurus*	×			
* Horse	*Equus caballus*	×	×	×	
* Cat	*Felis catus*	×		×	
* Rabbit	*Oryctolagus cuniculus*	×			
* Brown Hare	*Lepus capensis*	×	×	×	
* House Mouse	*Mus musculus*			×	
* Sheep	*Ovis aries*			×	
* Fox	*Vulpes vulpes*			×	

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 5

Migratory Bird 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 5 Migratory birds protected under bilateral agreements between the Australian Commonwealth and Japan (JAMBA) and/or China (CAMBA), recorded from within 10km of the proposed Horse Island route option (this study; previous investigations).

COMMON NAME	SCIENTIFIC NAME	JAMBA	CAMBA
Great Egret	Ardea alba	✔	✔
Cattle Egret #	*Ardea ibis*	✔	
Glossy Ibis	*Plegadis falcinellus*		✔
White-bellied Sea-Eagle #	*Haliaeetus leucogaster*		✔
Latham's Snipe	*Gallinago hardwickii*	✔	✔
Bar-tailed Godwit	*Limosa lapponica*	✔	✔
Whimbrel	*Numenius phaeopus*	✔	✔
Eastern Curlew #	*Numenius madagascariensis*	✔	✔
Marsh Sandpiper	*Tringa stagnatilis*	✔	✔
Common Greenshank	*Tringa nebularia*	✔	✔
Common Sandpiper	*Actitis hypoleucos*	✔	✔
Grey-tailed Tattler	*Heteroscelus brevipes*	✔	
Red-necked Stint	*Calidris ruficollis*	✔	✔
Sharp-tailed Sandpiper	*Calidris acuminata*	✔	✔
Curlew Sandpiper	*Calidris ferruginea*	✔	✔
Pacific Golden Plover	*Pluvialis fulva*	✔	
Lesser Sand Plover	*Charadrius mongolus*	✔	✔
Caspian Tern	*Sterna caspia*	✔	✔
Common Tern	*Sterna hirundo*	✔	✔
Little Tern	*Sterna albifrons*	✔	✔
White-throated Needletail #	*Hirundapus caudacutus*	✔	✔
Rainbow Bee-eater #	*Merops ornatus*	✔	

Species recorded in the study area during the field investigation for this report.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 6
Details of Fauna 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 6 Details of fauna recorded during surveys conducted along the proposed Horse Island route for the Pacific Highway upgrade at Karuah.

Results of the fauna surveys are provided below, with threatened fauna locations indicated on Figure 8. Specific fauna survey methods and survey effort are detailed in Appendix 3, with survey locations indicated on Figure 6.

1 TRAPPING TRANSECT RESULTS

1.1 Small Mammal Trapping

Cage traps and hair tubes at each trapping transect failed to reveal the presence of any small or medium-sized mammals in the study area (Figure 6). Whilst heavy rainfall occurred during the survey period, the lack of hair tube success cannot be attributed to this circumstance given the periods of dry weather and the protection of some hair tubes.

Table 1.1 Results of mammals captured in Elliott traps along the five trapping transects (Figure 6).

Transect #	Common Name	Species	Total Capture*
1	Brown Antechinus	*Antechinus stuartii*	11
2	Brown Antechinus	*Antechinus stuartii*	3
	Bush Rat	*Rattus fuscipes*	1
3	Brown Antechinus	*Antechinus stuartii*	11
	Swamp Rat	*Rattus lutreolus*	1
4	Brown Antechinus	*Antechinus stuartii*	1
	Swamp Rat	*Rattus lutreolus*	4
	Bush Rat	*Rattus fuscipes*	1
	Eastern Water Skink	*Eulamprus quoyii*	1
5	Brown Antechinus	*Antechinus stuartii*	5
	Swamp Rat	*Rattus lutreolus*	2
	Bush Rat	*Rattus fuscipes*	5

* Total number of animals captured, including re-captures.

2 MICROCHIROPTERAN BAT SURVEYS

2.1 Harp Traps

Table 2.1 Results of microchiropteran bat trapping surveys at Karuah (Figure 6 & 8).

Trap No	Common Name	Species	Total Capture*
1	Little Forest Bat	*Vespadelus vulturnus*	2
2	Little Forest Bat	*Vespadelus vulturnus*	7
	Chocolate wattled Bat	*Chalinolobus morio*	1
	Gould's Wattled Bat	*Chalinolobus gouldii*	1
	V Little Bent-wing Bat	*Miniopterus australis*	4
3	Little Forest Bat	*Vespadelus vulturnus*	16
	Chocolate wattled Bat	*Chalinolobus morio*	16
	Lesser Long-eared Bat	*Nyctophilus geoffroyi*	2
4	-	-	nil
5	-	-	nil

* Total number of animals captured, including re-captures.

V Vulnerable species (Schedule 2 of the TSC Act 1995)

2.2 Anabat Microchiropteran Bat Call Identification

Table 2.2 Microchiropteran bat species identified from calls recorded using Anabat II ultrasonic call detectors (Figure 6 & 8).

Location	Common Name	Scientific Name	Reliability
1	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P
2	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P
3	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Gould's Wattled Bat	*Chalinolobus gouldii*	P
	Little Forest Bat	*Vespadelus vulturnus*	P
	Eastern Forest Bat	*Vespadelus pumilus*	Po
	White-striped Mastiff Bat	*Nyctinomus australis*	C
	V Eastern Freetail Bat	*Mormopterus norfolkensis*	C
	Little Freetail-bat	*Mormopterus* sp 1	C
	V Greater Broad-nosed Bat	*Scoteanax rueppellii*	P
4	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P
5	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P
	Eastern Forest Bat	*Vespadelus pumilus*	Po
6	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Gould's Wattled Bat	*Chalinolobus gouldii*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P
	Eastern Broad-nosed Bat	*Scotorepens orion*	P
	Long-eared Bat	*Nyctophilus* sp	C
	Little Freetail-bat	*Mormopterus* Sp 1	P
7	Chocolate Wattled Bat	*Chalinolobus morio*	Po
	Little Forest Bat	*Vespadelus vulturnus*	P

V Vulnerable species (Schedule 2 of the TSC Act 1995)

Codes for reliability of call identification:

C Confident identification **P** Probable identification **Po** Possible identification

3 Spotlighting Surveys

Table 3.1 Bird and Mammal species recorded during spotlighting surveys (Figure 6 & 8).

Date	Common Name	Species	No.	Observation Type
2/3/98	**V** Squirrel Glider	*Petaurus norfolcensis*	1	Observed
	Common Brushtail Possum	*Trichosurus vulpecula*	1	Observed
	Common Ringtail Possum	*Pseudocheirus peregrinus*	1	Observed
	Feathertail Glider	*Acrobates pygmaeus*	1	Observed
	Tawny Frogmouth	*Podargus strigoides*	1	Observed
	* Feral Cat	*Felis catus*	1	Observed
3/3/98	**V** Squirrel Glider	*Petaurus norfolcensis*	1	Observed
	Common Brushtail Possum	*Trichosurus vulpecula*	2	Observed
	Feathertail Glider	*Acrobates pygmaeus*	1	Observed
	Tawny Frogmouth	*Podargus strigoides*	2	Observed
	Red-necked Wallaby	*Macropus rufogriseus*	1	Observed
	White-striped Mastiff-bat	*Nyctinomus australis*	1	Heard
4/3/98	Common Brushtail Possum	*Trichosurus vulpecula*	2	Observed
	Red-necked Wallaby	*Macropus rufogriseus*	many	Observed
	Eastern Grey Kangaroo	*Macropus giganteus*	many	Observed
	Australian Owlet Nightjar	*Aegotheles cristatus*	2	Observed
	Feral Cat	*Felis catus*	1	Observed
5/3/98	Common Brushtail Possum	*Trichosurus vulpecula*	6	Observed
	V Koala	*Phascolarctos cinereus*	1	Observed
	Australian Owlet Nightjar	*Aegotheles cristatus*	1	Observed
	Common Ringtail Possum	*Pseudocheirus peregrinus*	1	Observed

* Introduced species

V Vulnerable species (Schedule 2 of the TSC Act 1995)

4 HEPETOLOGICAL SURVEYS

The proposed Horse Island route and the surrounding area were divided into three broad areas for the purposes of recording: Sector 1 including the western section of the proposed alignment (from the existing Pacific Highway to approximately 1km past Wallaroo Swamp), Sector 2 including the central part of the route (from 1km past Wallaroo Swamp to the Karuah River crossing, including Horse Island), and Sector 3 covering the remaining eastern section of the route (from the Karuah River to the existing Highway).

4.1 General Diurnal Hepetofauna Records

Table 4.1 Results of diurnal herpetofauna searches.

Sector	Common Name	Scientific Name
1	Brown Toadlet	*Pseudophryne bibroni*
	Eastern Banjo Frog	*Limnodynastes dumerilii*
	Bearded Dragon	*Pogona barbata*
	Lace Monitor	*Varanus varius*
	Grass Skink	*Lampropholis guichenoti*
	Eastern Brown Snake	*Pseudonaja textilis*
	Black-bellied Swamp Snake	*Hemiaspis signata*
2	Brown Toadlet	*Pseudophryne bibroni*
	Bearded Dragon	*Pogona barbata*
	Jacky Lizard	*Amphibolurus muricatus*
	Lace Monitor	*Varanus varius*
	Grass Skink	*Lampropholis guichenoti*
3	Brown Toadlet	*Pseudophryne bibroni*
	Gunther's Frog	*Litoria latopalmata*
	Eastern Dwarf Tree Frog	*Litoria fallax*
	Peron's Tree Frog	*Litoria peronii*
	Eastern Water Skink	*Eulamprus quoyii*
	Grass Skink	*Lampropholis guichenoti*
	Garden Skink	*Lampropholis delicata*
	Red-bellied Black Snake	*Pseudechis porphyriacus*

4.2 Nocturnal Herpetofauna Surveys

Table 4.2 Results of nocturnal herpetofauna searches.

Sector	Species	Location/Habitat	Record Type
1,2,3	Brown Toadlet *Pseudophryne bibroni*	Most creeks and dam areas	Observed
1,2.3	Brown Toadlet *Pseudophryne bibroni*	Most non-saline wet areas	Heard
1	Eastern Banjo Frog *Limnodynastes dumerilii*	Near Wallaroo Swamp	Observed
3	Peron's Tree Frog *Litoria peronii*	East of Karuah River in a creek	Heard
3	Gunther's Frog *Litoria latopalmata*	East of Karuah River in a dam	Heard
2,3	Brown Toadlet *Pseudophryne bibroni*	Dams and non-saline creeks	Heard
3	Eastern Long-necked Tortoise *Chelodina longicollis*	East of Karuah River in a dam	Observed

5 DIURNAL BIRD SURVEYS

Bird species recorded during general bird surveys conducted throughout the study area and immediate vicinity are indicated in Appendix 4 - Column A.

The use of Owl call playback failed to elicit response calls from any owl species.

6 KOALA TRANSECT SURVEYS

Table 6.1 Koala scat survey results (Figure 6 & 8*).

Site	Location	Tree Species	No. Searched	No. with DBH >30cm	Scats
1	399250 6387200	*Eucalyptus gummifera*	1	4	
		Eucalyptus piperata	2	4	
2	399400 6387200	*Eucalyptus gummifera*	4	4	
		Angophora costata	4	4	
3	399700 6387800	*Angophora costata*	3	2	
		Eucalyptus gummifera	4	3	
		Eucalyptus piperata	5	1	
4	399720 6387850	*Eucalyptus sider/fibrosa*	6	5	
		Eucalyptus tereticornis	2	1	
5	399975 6388200	*Angophora costata*	2	2	
		Eucalyptus molucanna	1	1	
		Eucalyptus sid/fibrosa	2	2	
		Eucalyptus tereticornis	12	12	
6	400000 6388450	*Eucalyptus resinifera*	15	3	
		Eucalyptus tereticornis	14	14	
7	400350 6388800	*Angophora costata*	10	4	
		Eucalyptus globoidea	8	8	
		Eucalyptus umbra	9	2	
8	400500 6389220	*Eucalyptus punctata*	3		
		Eucalyptus siderophloia	3		
9	400650 6389400	*Eucalyptus piperata*	5	4	
		Eucalyptus punctata	4	4	
10	401100 6389700	*Eucalyptus gummifera*	2	2	
		Eucalyptus resinifera	6	5	
11	401500 6389800	*Eucalyptus piperata*	2	2	
		Eucalyptus punctata	2	2	
		Eucalyptus sid/fibrosa	7	4	
12	401800 6389900	*Eucalyptus punctata*	8	6	
		Eucalyptus umbra	3	3	
13	403180 6389900	*Eucalyptus crebra*	2	2	
		Eucalyptus microcorys	8	5	scats under 3
		Eucalyptus umbra	1	1	
14	403350 6389700	*Eucalyptus crebra/siderophloia*	6	2	
		Eucalyptus microcorys	3	2	scats under 2

Table 6.1 contd Koala scat survey results (Figure 6 & 8*)..

Site	Location	Tree Species	No. Searched	No. with DBH >30cm	Scats
15	403500 6389900	*Eucalyptus microcorys*	7	5	scats under 1
		Eucalyptus punctata	4	4	scats under 2
		Eucalyptus siderophloia	2	2	
16	404075 6390100	*Angophora costata*	2	2	
		Eucalyptus gummifera	4	3	
		Eucalyptus piperata	3	3	

* Searches for Koala scats were also conducted as part of the general habitat searches throughout the general study area (Figure 6). General habitat searches detected Koala scats of varied size and age associated with preferred food trees in woodland/open forest communities throughout private lands on the eastern side of the Karuah River.

Pacific Highway Upgrade at Karuah

Flora & Fauna Assessment

APPENDIX 7
Assessment of Significance pursuant to Section 5A of the EP&A Act

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

Assessment of Significance Pursuant to Section 5a of the EP&A Act

March 1999

1 INTRODUCTION

1.1 General

The *NSW Threatened Species Conservation Act 1995* (TSC Act) has modified the *NSW Environmental Planning & Assessment Act 1979* (EP&A Act) by including, *inter alia*, Section 5A (s.5A) which requires a determination as to "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*". The eight factors of s.5A "*must be taken into account*" by a consent or determining authority when considering a Development Application or development proposal, in administering sections 78, 79 and 112 of the EP&A Act.

This document provides an individual s.5A Assessment of Significance for each of the threatened fauna and flora species recorded in the study area for the proposed Karuah Bypass (Horse Island Route) of the Pacific Highway. Whilst a range of additional threatened fauna species are known from the locality and may occur along the alignment, field investigations to date have not provided sufficient information to exclude several of these species, or to prepare appropriate individual s.5A Assessments of Significance. However, several of these additional species could be significantly affected by the proposed Karuah Upgrade project (if present), and will be addressed in detail in the next stage of the assessment process (*ie* in the Species Impact Statement).

Consideration of s.5A of the EP&A Act for the Karuah Bypass (Horse Island Route) project and for each of the individual threatened species recorded along the proposed alignment includes the assessment of appropriate environmental management measures which have been incorporated into the project to reduce and manage the potential for adverse impacts on native (including threatened) flora and fauna. These in measures are an integral part of the activity, and are therefore to be considered when assessing the development.

There are difficulties in addressing several of the factors in s.5A of the EP&A Act. Of particular concern in this regard are the definition of "*a viable local population*" for many species, the relevance of "*endangered population*" (Factor b) and "*endangered ecological community*" (factor c), the relevance of "*critical habitat*" (Factor e), the adequacy of representation of threatened species in "*conservation reserves*" (Factor f), and the definition of "*a threatening process*" (Factor g), as discussed further below.

1.2 Viable Local Population

For many of the threatened species which do or may occur along or in the vicinity of the proposed Karuah Bypass (Horse Island Route), the definition of "*a viable local population*" is problematic. In the first instance, the data available for most of the relevant threatened species is inadequate. Furthermore, for wide-ranging fauna species, particularly those which are widely distributed but at low density, it is not certain that a valid or meaningful definition of "*viable local population*" can be determined. Similarly, it is not clear what would constitute "*a viable local population*" (emphasis added) of a migratory or nomadic species.

Determining the presence or otherwise of "*a viable local population*" of threatened plants can also be difficult, particularly in instances where the only representatives present at a location are individuals or juvenile specimens.

Whilst the TSC Act does not provide a definition for "*a viable local population*", it does provide a definition for "*population*". In s.4, the TSC Act defines "*population*" as "*a group of organisms, all of the same species, occupying a particular area*". On the basis of this definition, the presence of a single individual of a threatened species does not constitute a "*population*", and therefore cannot be

reasonably considered to constitute "*a viable local population*". Furthermore, Population Viability Analysis and other ecological theory and considerations suggest that for a population of any organisms to be considered "*viable*", numbers of individuals ranging from about a hundred to several thousand need to be present.

In this regard, difficulties arise with the definition of a "*viable local population*" for many of the threatened fauna and flora species known to occur along the proposed alignment, or which are likely to be present on occasions in this locality. Of relevance in this regard are considerations concerning:

- the Osprey - whether one individual or a pair of this species along the Karuah River would constitute "*a viable local population*";
- the microchiropteran bats - given their wide-ranging natures and habits, whether it is possible to define a discreet "*local population*", separate from the metapopulation or overlapping populations likely to be located throughout the region, and whether there is "*a viable local population*" of relevance to the proposal;
- the Black-necked Stork - given that this species is known to inhabit a large home-range, encompassing a number of suitable foraging wetlands, whether the presence of an individual or a pair foraging along the Karuah River (for example would constitute "*a viable local population*"; and
- the Lesser Sand Plover - whether the presence of individuals of this migratory species (which breeds in the northern hemisphere) constitutes "*a viable local population*".

As a consequence of the difficulties described above with respect to the definition of "*a viable local population*" of many of the threatened fauna and flora species known from the locality, or which could occur in the vicinity, a 'conservative' approach has been adopted for the Karuah Bypass (Horse Island Route) project, and for the s.5A Assessments of Significance for individual species. Where an individual of a threatened species has been recorded along the corridor, the assumption has been made that "*a viable local population*" of that species may be present in the vicinity, even if only a single individual was located. Conversely, it is not assumed that such a population would be dependent solely or particularly upon the habitats and resources present along the corridor.

1.3 Endangered Populations and Ecological Communities

"*Endangered populations*" are those listed in Part 2 of Schedule 1 of the TSC Act. With respect to the Karuah Upgrade project, there is no relevant "*endangered population*" of any species declared under the TSC Act. Consequently, Factor (b) of the s.5A Assessment of Significance cannot be relevantly addressed.

Similar considerations apply to "*endangered ecological communities*". The TSC Act defines an "*endangered ecological community*" as "*an ecological community specified in part 3 of schedule 1*" of the Act. No relevant "*ecological community*" has been so defined by the NSW Scientific Committee, and consideration of the proposal with respect to potential impacts upon "*endangered ecological communities*", pursuant to s.5A of the EP&A Act, cannot be relevantly addressed.

1.4 Critical Habitat

The TSC Act defines "*critical habitat*" as "*habitat declared to be critical habitat under Part 3*" of the Act. It is a requirement of the Act that the Director-General of the NSW National Parks & Wildlife Service (NP&WS) declare "*critical habitat*" for "*threatened species, populations or ecological communities*".

At the time of preparation of this report, no "*critical habitat*" for any such "*species, populations or ecological communities*" had been declared by the Director-General of the NP&WS. Consequently, the issue of "*critical habitat*" cannot be relevantly addressed with respect to the Karuah Bypass (Horse Island Route) project.

1.5 Threatening Processes

The TSC Act defines "*threatening process*" as "*a process that threatens, or may have the capability to threaten, the survival or evolutionary development of species populations or ecological communities*". Schedule 3 of the TSC Act is intended to provide a list of the "*key threatening processes*" which are regarded as of relevance to the Act.

Several "*key threatening processes*" have been listed or considered by The NSW Scientific Committee, including predation by the European Red Fox *Vulpes vulpes*, the removal of bush rock, invasion by the Bitou Bush *Monilifera* rotunda, and predation by the Plague Minnow *Gambusia holbrooki*. It is not intended, or likely, that the Karuah Bypass (Horse Island Route) project will exacerbate any of these "*threatening processes*".

The construction and maintenance of roads is not included on Schedule 3 of the TSC Act, and consequently is not "*recognised as a key threatening process*", pursuant to the Act. However, the construction of major roads through areas of native vegetation and natural habitats may constitute "*a threatening process*" for individual species in general terms, as a result of direct or indirect impacts. The removal of vegetation, habitats and resources, the imposition of barriers to fauna movement, the fragmentation of natural habitats, and the imposition of indirect impacts (such as altered hydrologic regimes or contaminant discharges) can pose threats to the conservation of native flora and fauna.

These issues have been recognised with respect to the proposal, and are discussed in detail in the main Flora & Fauna Assessment report (to which this s.5A Assessment is attached). Furthermore, measures to avoid or reduce the potential "*threatening processes*" which may result from the Karuah Bypass (Horse Island Route) project are being incorporated into the project design, and into impact amelioration and environmental management measures which are to be implemented as part of the project.

1.6 The Region

The TSC Act defines "*region*" as "*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*". The Director-General of the NSW NP&WS has given notice that the *Interim Biogeographic Regionalisation of Australia* (IBRA), published by the Australian Nature Conservation Agency (now Environment Australia), is the appropriate definition of "*region*" for the TSC Act (Government Gazette No 65 - 24 May 1996).

According to the IBRA (ANCA 1995), the Karuah Bypass (Horse Island Route) is located in the NSW North Coast (NNC) region, which comprises the coastal portion of northeastern NSW, north from Port Stephens to the Queensland border, with the western boundary being defined approximately by the Great Dividing Range. The NNC region occupies an area of approximately 58189km^2. The study area is located at the southern boundary of the NNC region, adjacent to the northern parts of the Sydney Basin (SB) region. The latter region occupies an area of approximately 40000^{km2}, and the biota of both regions is relevant to the project (given the distribution of threatened species located along the alignment or considered likely to occur.

1.7 Conservation Reserves

The NSW North Coast region (ANCA 1995) contains a relatively large number of dedicated National Parks (NPs) and Nature Reserves (NRs), of which Tomaree and Myall Lakes NPs are located in the vicinity of the Karuah Upgrade study area. Of particular relevance is the recent gazettal of additional Nature Reserves in the vicinity of the Karuah Bypass (Horse Island Route), including Wallaroo and Karuah NRs. These conservation reserves cover 2572ha and 2521ha, respectively, and contain habitats and vegetation communities representative of those recorded along the Karuah Bypass (Horse Island Route). The proposed route traverses a small portion of the northwestern corner of the eastern part of Karuah NR.

Other NPs and Nature Reserves in the southern portion of the North Coast region include coastal reserves, such as Crowdy Bay and Booti Booti NPs and Lake Innes and Limeburners Creek NRs, and inland reserves, such as Barrington Tops and Woko NPs. These National Parks cover approximately 113665ha, with Myall Lakes (31571ha) and Barrington Tops (65000ha) NPs covering the largest areas.

The Sydney Basin region also supports substantial conservation reserves, with significant areas of forest and woodland contained within the extensive National Parks and Nature Reserves of the region. The National Parks and Nature Reserves in the sub-region (including the southern portion of the North Coast region and the northern part of the Sydney Basin region) support a variety of vegetation communities and habitats for native flora and fauna, including littoral rainforest, coastal heath, dry and wet sclerophyll forest and swamps, rivers and estuarine habitats.

In addition to the National Parks and Nature Reserves in the regions and sub-region, the general locality also supports State Forests which, although not managed exclusively for the conservation of flora and fauna, do provide a substantial resource for native species, including theatened biota. State Forests in the vicinity of the Karuah Bypass (Horse Island Route) include Wallaroo and Karuah SFs, portions of which are included within the study area, as well as Medowie SF to the south, and Nerong, Renwick, Myall River and Bulahdelah SFs to the north.

1.8 Species Considered Pursuant to s.5A

A determination as to "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*" as a result of the proposal is documented below, individually for each of the threatened fauna and flora species which were recorded during field investigations for this project.

The threatened fauna and flora species discussed in this s.5A Assessment (Table 1) are a subset of a more comprehensive list of such species (Tables 1 and 2) which are known from the region in which the Karuah Upgrade proposal is located, or species which have distributional ranges which include these areas. The full list of threatened species was derived from several sources, including:

- threatened species listed on the NSW National Parks & Wildlife Service (NP&WS) Wildlife Atlas for the relevant 1:100 000 map sheets;
- previous biological investigations conducted in the surrounding area;
- searches of relevant scientific literature; and
- the Birds Australia (Royal Australasian Ornithologists Union) database.

Table 1 Threatened fauna and flora species recorded during the field investigations in the Karuah Bypass (Horse Island Route) study area.

Common Name	Scientific Name
FAUNA	
Koala	*Phascolarctos cinereus*
Squirrel Glider	*Petaurus norfolcensis*
Little Bent-wing Bat	*Miniopterus australis*
Eastern Freetail Bat	*Mormopterus norfolkensis*
Greater Broad-nosed Bat	*Scoteanax rueppellii*
Osprey	*Pandion haliaetus*
FLORA	
Black-eyed Susan	*Tetratheca juncea*

1.9 Other Threatened Species

In addition to those threatened species actually recorded during field surveys in the vicinity of the Karuah Bypass (Horse Island Route), a number of threatened species are known from the locality (Table 2). Several of these species are expected to occur in the study area, either as residents or on a transitory or occasional basis. The field investigations conducted along the Karuah Bypass (Horse Island Route) for this report have not determined with certainty the presence or absence of these additional species, or the extent to which they will be affected by the proposed upgrade of the Pacific Highway at Karuah.

However, on the basis of existing information, it is likely that many of these species are present along the alignment or in the study area, even if only on an occasional basis. For several of these additional threatened species, (in particular the Bush Stone-curlew, Tiger Quoll and Brush-tailed Phascogale), it is possible that "*a significant effect*" could result from the Karuah Bypass (Horse Island Route) project. These and other potentially relevant threatened species will be addressed in detail in the Species Impact Statement stage of the project.

2 GENERAL APPROACH

The intention is for the Karuah Bypass (Horse Island Route) project in general to be designed, constructed and maintained in an environmentally sensitive manner, to reduce and manage environmental disturbance or degradation, and to reduce and manage the imposition of significant impacts upon native biota in general and on threatened fauna and flora in particular. To this end, a range of environmental management and impact amelioration measures have been proposed (consistent with those currently accepted by the NP&WS and others along other portions of the Pacific Highway Upgrade project), aimed at reducing the potential for adverse impacts on the natural environment generally, and on native biota in particular.

Table 2 Threatened fauna species known from the vicinity of the study area, their habitat requirements and the likelihood for the imposition of a significant effect.

Species	Habitat Requirements	Potential Habitat Present	Significant Effect
Black-necked Stork *Ephippiorhynchus asiaticus*	Occurs in tropical and warm-temperate terrestrial wetlands, estuarine and littoral habitats, and occasionally grass and woodlands. Forages in fresh or saline waters up to 0.5m deep (Marchant & Higgins 1990).	Yes	Possible, but not likely
Bush Stone-curlew *Burhinus grallarius*	Inhabits open woodland, including remnants within agricultural landscapes. Forages nocturnally for invertebrates, reptiles and amphibians amongst native grass and scattered shrubs, or in pasture. Nests on the ground, often near fallen timber (Marchant & Higgins 1993).	Yes	Possible
Lesser Sand Plover *Charadrius mongolus*	Migratory shorebird which breeds in the northern hemisphere and migrates in the winter. Forages on mudflats at low tide and roosts on sandy beaches. Sparse in northeastern NSW (Marchant & Higgins 1993).	Yes	No
Little Tern *Sterna albifrons*	Migratory shorebird which forages over coastal waters for fish and crustaceans. Nests on sandy beaches.	Extremely Marginal	No
Wompoo Fruit Dove *Ptilinopus magnificus*	Inhabits rainforest and forages in the dense canopy on rainforest fruit (Higgins & Davies 1996).	No	No
Glossy Black Cockatoo *Calyptorhynchus lathami*	Inhabits forest and woodland, feeding on the cones of *Allocasuarina torulosa* and *A littoralis* (Garnett 1992). Roosts and nests in large eucalypts with hollows. Also uses partly cleared agricultural land (Garnett 1992).	Yes	Possible
Powerful Owl *Ninox strenua*	Requires closed or open forest and woodland communities which support large tree-hollows for nesting and a supply of arboreal mammals for feeding (Debus & Chafer 1994).	Yes	Possible

Table 2 Threatened fauna species known from the vicinity of the study area, their habitat requirements and the likelihood for the imposition of a significant effect.

Species	Habitat Requirements	Potential Habitat Present	Significant Effect
Masked Owl *Tyto novaehollandiae*	Occurs in a wide range of habitats including tall open forest, wooded farmland and urban areas with scattered trees (Debus & Rose 1994). Nests in large hollows in living or dead trees, usually in the trunk (Hollands 1991).	Yes	Possible
Green-thighed Frog *Litoria brevipalmata*	Occurs in a variety of woodland and forest habitats, and utilises shallow, ephemeral waterbodies (such as flooded grassland and artificial ditches) for breeding (Ehmann 1997). Specific habitat requirements are poorly understood (F Lemckert *pers comm*).	Yes	Possible
Green & Golden Bell Frog *Litoria aurea*	Occurs in shallow, ephemeral waterbodies (such as dams and ponds). Breeding sites must be free of the Plague Minnow. Forages in grassy areas and shelters in rock piles and aquatic vegetation (Pyke & White 1996).	Marginal	Extremely Unlikely
Wallum Froglet *Crinia tinnula*	Inhabits shallow acid swamps (usually semi-permanent) on coastal lowlands and dunes, generally supporting coastal heath and woodland, often with tea-tree and paperbark.	Marginal	Extremely Unlikely
Tiger Quoll *Dasyurus maculatus*	Inhabits a range of habitats from dense sclerophyll forests and rainforest to coastal heathland, where it nests in rock caves and hollow logs (Edgar & Belcher 1995).	Yes	Possible
Brush-tailed Phascogale *Phascogale tapoatafa*	Inhabits dry sclerophyll forest and woodland, swamp forests, heathland and rainforest. Shelters in tree-hollows and forages on invertebrates and small vertebrates (Soderquist 1995).	Yes	Possible
Large Bent-wing Bat *Miniopterus schreibersii*	Occurs in wooded valleys along the east coast of Australia, where it forages above the canopy and roosts in caves and man-made structures (Dwyer 1995b).	Yes	Unlikely

3 FACTORS for CONSIDERATION

An individual s.5A Assessment of Significance has been prepared for each of the threatened species recorded in the Karuah Bypass (Horse Island Route) study area.

As discussed above, some of the additional threatened species listed in Table 2 may occur in the study area, either as residents or on a transitory or occasional basis. However, the field surveys conducted for the Flora & Fauna Assessment report do not provide sufficient information to prepare assessments pursuant to s.5A of the EP&A Act, or to assess the likely level of impacts on these additional species.

Consequently, these species have not been addressed below, but will be considered in detail during the next stage of the Karuah Bypass (Horse Island Route) project (*ie* in the Species Impact Statement).

3.1 Koala *Phascolarctos cinereus*	Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The Koala favours open eucalypt forest and woodland communities, although it occurs in a range of disturbed and modified habitats, including agricultural and pastoral land throughout northeastern NSW and southeastern Queensland.

The Koala has been recorded feeding in or resting in a total of 120 species of eucalypt and forty other tree species (Lee & Martin 1988; Phillips 1990; Reed & Lunney 1990). However, at any one locality Koalas predominantly feed in a small range of preferred food tree species which vary substantially on a regional basis (Maxwell *et al* 1995). Of the eucalypts present within the Karuah Bypass (Horse Island Route) study area, the species generally preferred by, and considered of greatest relevance for, the Koala include the Grey Gums *E propinqua* and *E punctata*, Tallow-wood *E microcorys*, Forest Red Gum *E tereticornis*, Swamp Mahogany *E robusta* and Spotted Gum *E maculata* (Lee & Martin 1988; Reed & Lunney 1990; Pahl *et al* 1990). Lunney *et al* (1998) also include the Parramatta Red Gum *E parramattensis* and White Mahogany *E acmenoides* as preferred Koala food trees in the Port Stephens area.

The Koala has been recorded at numerous locations throughout the locality, and may be assumed to occur in essentially any suitable habitat along the proposed Karuah Bypass (Horse Island Route) alignment. Areas where Koalas are unlikely to be present, or are likely to be present only in extremely low numbers, include extensive agricultural landscapes (where intensive farming practices are being conducted), and in steep low productivity terrain (where preferred eucalypts are not present and where nutrient levels in eucalypt leaves are likely to be extremely low).

Preferred habitat for Koalas along the Karuah Bypass (Horse Island Route) alignment includes open forest and woodland along watercourses and on gently undulating land, where soil fertility is somewhat higher and nutrient levels in eucalypts are likely to be acceptable. Conversely, the State Forests in the locality do not appear to provide habitat of particular value, given the general absence of mature trees (*ie* Diameter at Breast Height DBH in most areas is less than 20cm), particularly those species preferred by Koalas. Despite the general lack of suitably mature trees in much of the forest on the western side of the Karuah River, the majority of this area had been identified as prime or moderate/potential Koala habitat in the Draft Port Stephens Koala Management Plan (Callaghan *et al* 1994; Lunney *et al* 1998). The general area has been identified as of value for Koalas (Lunney *et al* 1998), with vegetation along the edge of the Karuah River near Horse Island and the Wallaroo Swamp being identified as 'preferred Koala habitat'.

The Koala was recorded both directly (*ie* observed) and indirectly (*ie* scats and scratches on trees) during the dedicated field surveys conducted along the Karuah Bypass (Horse Island Route) alignment. One individual was observed in privately owned Spotted Gum forest on the eastern side of the Karuah River, and numerous scats of varying size and age were located throughout this area. No evidence for Koala activity was observed on the western side of the Karuah River, despite dedicated searches. However, this area is likely to constitute part of the wider home range for this mobile and wide-ranging species, given the presence of suitable habitat, and the known presence of Koalas in contiguous vegetation to the southwest (Gunninah 1997a) and within the study area as defined for the Proposal (NP&WS Wildlife Atlas).

Koalas and evidence of their presence have been recorded along the eastern portion of the alignment and on immediately adjacent lands, and the species appears to occur widely in areas of suitable habitat. Based on the observation of an adult female, and scats of various sizes and ages, the presence of "*a viable local population*" of the Koala along the alignment is regarded likely, and it is assumed that such a population (or populations) is present.

On the basis of the potential for habitat fragmentation, isolation of individuals or populations, and the creation of barriers to movement, as well as the potential for the removal of areas of suitable foraging resources and mortality as a result of vehicle collisions, the proposed Karuah Upgrade project is considered likely to cause disruption to the "*viable local population*[s]" which occur in the locality. Although it is not regarded as "*likely*" that any such population would be "*placed at risk of extinction*", because of the extent of other suitable habitat in the locality, such an outcome is possible.

b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Koala has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Koala in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

"*Known habitat*" for the Koala occurs on both the eastern and western side of the Karuah River and potential habitat occurs in the majority of the woodland and forest along the proposed Karuah Upgrade alignment (NP&WS Wildlife Atlas). In addition, "*known habitat*" occurs in adjacent areas on both sides of the Karuah River, including within the township of Karuah itself, as well as in the vicinity of the golf course (Gunninah 1997b). "*Known habitat*" for the Koala is also widely distributed in the locality, including throughout Port Stephens Shire (Callaghan *et al* 1994; Lunney *et al* 1998) to the south and southwest, as well as throughout the North Coast Region.

On the basis of the extent of "*known*" and potential habitat for Koalas in the region, the clearing of native vegetation required for the proposed Karuah Bypass (Horse Island Route) project (involving only approximately 40ha) is not considered likely to constitute the modification or removal of "*a significant area of known habitat ... in relation to the regional distribution of habitat*".

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

In general terms, any development which requires the clearing of native vegetation and fauna habitats has the potential to fragment habitats and resources for threatened fauna and flora, and possibly to provide barriers to movement for threatened species.

As noted above, the population of Koalas in this locality appears widely distributed and sparse, and suitable habitat is patchily distributed throughout the locality. Areas regarded as of potential or known value for the Koala include forested lands to the east of the Karuah River and to a lesser extent the forested lands to the west of the River. The tracts of forest comprising known or potential Koala habitat are generally contiguous, and Koalas are currently able to move throughout the locality.

On a 'regional' basis, a 'wildlife corridor' has been identified between Port Stephens and the forested lands to the north, which includes the recently gazetted Karuah Nature Reserve and areas of state forest (L Baker NP&WS *pers comm*). Currently, the only existing barrier to the movements of Koalas through this 'corridor' is the existing Pacific Highway to the south, and the Karuah River.

The proposed Karuah Bypass (Horse Island Route) will involve the construction of a major road through currently forested land, the majority of which is known or likely to support Koalas. The Bypass will pose a substantial barrier to the movement of Koalas, and would, in the absence of measures to enable Koalas to safely cross it, isolate of areas of habitat "*from currently interconnection or proximate areas of habitat*". In particular, the road would create an isolated pocket of habitat bounded by the existing Pacific Highway, the Karuah River and the proposed Bypass. Despite some existing fragmentation in the locality by the existing Pacific Highway, urban areas and cleared agricultural land, the proposed new Bypass will increase the levels of habitat fragmentation, and may isolate individuals or a population of the Koala.

Given the above considerations, it appears that "*an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat*" for the Koala as a consequence of the Karuah Bypass (Horse Island Route).

(e) whether critical habitat will be affected

Not applicable (section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

It is generally recognised that few native fauna or flora species, particularly threatened species, are "*adequately represented in conservation reserves*". The majority of Koala records, for example, are obtained from private and agricultural lands rather than from the State reserve system (Lunney *et al* 1990; Phillips 1990; Reed *et al* 1990). This may be attributed, in part at least, to relatively low numbers of Koalas occurring on low nutrient soils or steep slopes, which often characterise National Parks and Nature Reserves.

Whilst it is likely that the Koala occurs within National Parks (such as Myall Lakes and Tomaree NPs to the northeast and east of the alignment, respectively), or other conservation reserves in the NSW region (such as Nature Reserves, Flora and Forest Reserves), it is generally considered unlikely that it would be "*adequately represented*" in such reserves. A combination of its moderate to large home-range and wide-ranging habits and its generally sparse abundance, even where relatively widely distributed, indicates that conservation reserves are unlikely to support 'adequate' populations of this species. Even including State Forests, which constitute a significant and substantial conservation resource in the NSW North Coast region, and which are of particular relevance to the Karuah Bypass (Horse Island Route) project (given their proximity), it is considered unlikely that the Koala would be "*adequately represented in conservation reserves*".

The Koala is not considered to be "*adequately represented*" in "*conservation reserves (or other similar protected areas) in the region*".

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the survival of the Koala include the fragmentation and clearing of habitat, bushfires and disease, as well as death from predation and vehicle collisions (Maxwell *et al* 1996). The proposed Karuah Bypass (Horse Island Route) will increase the intensity of threats to Koalas in the locality, particularly through the loss and fragmentation of habitats and increased mortality as a result of vehicle collisions.

The Karuah Bypass (Horse Island Route) project will not exacerbate any "*key threatening process*", as listed under the TSC Act, and none of those listed are relevant to the survival of the Koala.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The Koala is distributed from western Victoria through coastal and eastern NSW to the base of Cape York, in several large but disjunct distributional ranges. The southern populations in Victoria and southern NSW are isolated from populations in northern NSW and southern Queensland by substantial gaps in the distribution of the species. Northeastern NSW and southeastern Queensland constitute one of the major concentrations of Koalas in Australia (Phillips 1990), with most of the focus of Koala populations in the state being located within the NSW North Coast region, particularly at Port Stephens, Port Macquarie, Coffs Harbour and Tweed Shire (Phillips 1990). The species is known from the Tweed, Brunswick, Richmond, Clarence, Bellinger, Macleay, Hastings, Camden Haven, Manning and Hunter Valleys in the NSW North Coast region (Gilmore & Parnaby 1994).

In the general locality, Koalas are known from south of the Karuah Upgrade study area, in particular in the Port Stephens Shire (Callaghan *et al* 1994; Lunney *et al* 1998), as well as north of the study area, including in Myall Lakes National Park, Coolongolook State Forest and in the vicinity of Wang Wauk River (Gunninah 1997c).

On this basis of its range throughout eastern Australia, the Koala is not "*at the limit of its known distribution*" in the Karuah Bypass (Horse Island Route) study area.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular reference to the Koala, are discussed in detail above.

The proposed Karuah Bypass (Horse Island Route) will fragment habitat for the Koala, will create a barrier to the movement of Koalas through the landscape and has the potential to directly impact on Koalas through road kills. Consequently, the proposed Karuah Bypass is considered likely to disrupt "*a viable local population*", and it is likely that the Karuah Bypass (Horse Island Route) project will impose "a *significant effect*" on this species.

A Species Impact Statement is required for the proposed Karuah Bypass (Horse Island Route) project with respect to the Koala.

3.2 Eastern Freetail Bat *Mormopterus norfolkensis* Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The habitat requirements of the Eastern Freetail Bat are not well understood, primarily as a result of confusion with the more common and as yet un-named *Mormopterus* sp 1 and the *Mormopterus planiceps* species complex (Gilmore & Parnaby 1994). Most records of the Eastern Freetail Bat are from dry sclerophyll forest and woodland communities, and less commonly in moister communities and rainforest (Allison & Hoye 1995).

Although this species apparently forages in open vegetation (such as woodland communities) or above the canopy of closed woodland and forest communities, there is little information available regarding its diet and foraging habits (NP&WS 1994). The Eastern Freetail Bat roosts in mature hollow-bearing trees or under decorticating bark, although little is known of its reproduction and social biology (Allison & Hoye 1995).

Calls of the Eastern Freetail Bat were identified during the field investigations from Anabat II echolocation recordings near Wallaroo Swamp in the vicinity of the proposed Karuah Bypass (Horse Island Route) alignment. This species has also been recorded in the vicinity of the study area during previous investigations (ERM Mitchell McCotter 1994; Gunninah 1997a). The study area does not support unique features or resources, however, and any resources of relevance for the Eastern Freetail Bat are widely represented throughout the surrounding forest and woodland. This species is likely to forage and roost in forest and woodland communities throughout the surrounding landscape, and its activities would not be restricted to the study area.

Given the limited information available regarding this species, it is not clear that a valid definition of "*a viable local population*" is possible. The apparent low densities of this species suggest that "*a viable local population*" may constitute a sparse and widely distributed assemblage of animals over a considerable area, rather than a more discrete 'population' or local grouping. Furthermore, given the highly mobile and wide-ranging habits of microchiropteran bats generally, it is unlikely that individuals comprising "*a viable local population*" of the Eastern Freetail Bat are confined to the study area. Conversely, the study area is likely to constitute only part of a wider home-range for one or more "*viable local population*[s]", particularly given the relatively sparse distribution of mature hollow-bearing trees in the study area to provide roosting and nesting resources.

Whilst some resources for this species are likely to be removed as a result of the proposed Karuah Upgrade project (in particular tree-hollows and foraging resources), the proposal is unlikely to disrupt "*a viable local population*" of the Eastern Freetail Bat so as to place it "*at risk of extinction*".

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Eastern Freetail Bat has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Eastern Freetail Bat in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

"*Known habitat*" for the Eastern Freetail Bat is provided in the Karuah Bypass (Horse Island Route) study area, and the proposed Bypass will involve the modification or removal of some habitats and resources for the Eastern Freetail Bat, by virtue of the removal of forest and woodland vegetation (including hollow-bearing trees) along the alignment. However, many of the areas to be affected do not support significant roosting resources for this or other hollow-dependent fauna, as a result of previous disturbance and the scarcity of hollow-bearing trees (particularly within the State Forests and cleared agricultural land). Conversely, the Karuah Bypass (Horse Island Route) will involve the disturbance to less disturbed remnant and regeneration vegetation along the alignment, in particular Horse Island, which provide potential habitat of value for this species.

"*Known habitat*" for this species also occurs in the vicinity of the proposed Bypass (including a tentative identification near Karuah to the south of the study area - Gunninah 1997a), as well as throughout the NSW North Coast region (Allison & Hoye 1995; NP&WS Wildlife Atlas). In particular, the State Forests, National Parks and forested private land throughout the locality all provide habitats and resources for the Eastern Freetail Bat. Whilst some "*known habitat*" for this species will require removal, it cannot be considered likely that the proposed Karuah Bypass (Horse Island Route) will involve "*a significant area of known habitat*" for the Eastern Freetail Bat being "*modified or removed*", particularly in respect of "*the regional distribution of the habitat*".

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

Microchiropteran bats are highly mobile and wide-ranging, and are not reliant on continuous tracts of forest and woodland for movement. Whilst the proposed Karuah Bypass (Horse Island Route) will impose a barrier to movement for less mobile species, is not considered likely to impose a movement barrier for the Eastern Freetail Bat.

Given the habits and habitat characteristics of the Eastern Freetail Bat, there is no likelihood that "*an area of known habitat*" for this species will "*become isolated from currently interconnecting or proximate areas of habitat*".

(e) whether critical habitat will be affected

Not applicable (section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

Considering its known distribution in the NSW North Coast region, it is likely that populations of the Eastern Freetail Bat occur in many of the National Parks and Nature Reserves within the region, including Tomaree, Myall Lakes and Booti Booti National Parks and the Karuah and Wallaroo Nature Reserves.

However, given this species' apparently relatively sparse densities, its highly mobile and wide-ranging habitats and its threatened status, the Eastern Freetail Bat is not likely to be "*adequately represented in conservation reserves (or other similar protected areas) in the region*".

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the Eastern Freetail Bat are likely to include loss of habitat, in particular areas supporting mature hollow-bearing trees suitable for nesting and roosting, and foraging resources. The invasion of the European Honey Bee may also pose a threat to this species by competing for

tree-hollows. The Karuah Bypass (Horse Island Route) project will involve the loss of foraging and roosting resources for this species, by virtue of the removal of native vegetation, and will therefore contribute to the processes threatening the Eastern Freetail Bat.

The Karuah Bypass project will not exacerbate any "*key threatening process*" as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The Eastern Freetail Bat has a relatively constrained distribution in eastern Australia, occurring along the eastern coast from southern NSW into southeastern Queensland (Allison & Hoye 1995). It is generally restricted to coastal areas in NSW, east of the Great Dividing Range (Allison & Hoye 1995; NP&WS 1994b), although recent records in northwestern NSW appear to constitute a range extension for this species (Gunninah 1998b). Throughout its range, the Eastern Freetail Bat appears to be

relatively sparse and localised in distribution, with few recorded localities and small numbers of individuals.

The Karuah Bypass (Horse Island Route) study area is located within the known distribution of this species (Allison & Hoye 1995), rather than at its periphery, and the Eastern Freetail Bat is not "*at the limit of its known distribution*" in the Karuah Bypass study area.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular relevance to the Eastern Freetail Bat, are discussed in detail above.

The Karuah Bypass (Horse Island Route) project involves the loss of potential habitats and resources for the Eastern Freetail Bat, including forest and some hollow-bearing trees. However, the habitats in the study area are not unique, and a range of identical resources will be retained in the immediate vicinity. Given this species' highly mobile and wide-ranging habits, the proposed Bypass will not impose a barrier to movement for this species. Whilst some habitats and resources of potential value for this species are likely to be removed, the project is not likely to involve the imposition of "*a significant effect*" on this species.

A Species Impact Statement is not required for the proposed Karuah Upgrade project with respect to the Eastern Freetail Bat.

3.3 Little Bent-wing Bat *Miniopterus australis* Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The Little Bent-wing Bat is a cave-roosting species, congregating in large colonies in caves, mine shafts and rock shelters (Dwyer 1995). It relies on specific nursery caves to which it returns annually, and which it often shares with the Common Bent-wing Bat (Hall & Richards 1979). All caves utilised by this species are located near relatively large areas of dense vegetation, including rainforest, wet sclerophyll forest or coastal Banksia scrub (Gilmore & Parnaby 1994). Foraging activities appear to be concentrated between the understorey and canopy of vegetation communities.

Four Little Bent-wing Bats were captured during harp trapping surveys in woodland in the vicinity of Wallaroo Swamp. This species has also been recorded at a number of other locations within 10km of the alignment including in the vicinity of Karuah, to the south of the study area (Gunninah 1997a), and is likely to forage widely through forest and woodland communities in the area.

No roosting or nursery caves for the Little Bent-wing Bat are located along the proposed alignment. The closest known maternity cave for this species is located at Willi Willi, inland from Kempsey (Gilmore & Parnaby 1994), and a possible nursery cave has been located recently in a mine shaft near Lake Macquarie (Gunninah 1998a). The proposed Karuah Upgrade of the Pacific Highway will have no impact on these features.

The presence of a number of individuals along the proposed Karuah Upgrade alignment indicates the likely presence of "*a viable local population*" of the Little Bent-wing Bat in the general locality. A Little Bent-wing Bat roost site is located near Raymond Terrace (to the west of the study area) in the Balickera Tunnel. However, the Karuah Bypass study area does not support unique features or resources and is likely to form only part of the range of "*a viable local population*" of the Little Bent-wing Bat. It is not considered likely that any such population would be dependent upon or reliant exclusively upon the resources which are to be affected by the proposed Karuah Bypass (Horse Island Route) project. The resources present constitute only an extremely small proportion of potentially suitable foraging habitat for this species in the immediate vicinity and wider region.

Foraging habitats and resources for this species are widespread in the locality and region, and the proposed development will not adversely affect any nursery and/or hibernation caves in the region.

Given the highly mobile and wide-ranging habits of the Little Bent-wing Bat and the absence of its specific habitat requirements in the study area (*ie* caves and other suitable roosting and nesting features), it is not likely that the project could involve "*a viable local population of the species*" being "*placed at risk of extinction*".

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Little Bent-wing Bat has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Little Bent-wing Bat in the Karuah Bypass (Horse Island Route) project study area.

c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

"*Known habitat*" for the Little Bent-wing Bat occurs along the proposed Karuah Bypass (Horse Island Route) alignment and in the general vicinity. The proposed Bypass project could involve some foraging habitat for the Little Bent-wing Bat being "*modified or removed*", by virtue of the removal of some disturbed forest and woodland vegetation along the alignment. However, no "*known habitat*" in the form of roosting resources or nursery/hibernation caves will be "*modified or removed*" as a result of the upgrade.

Given the widespread distribution of the Little Bent-wing Bat in the "*region*" (the NSW North Coast region), the area of potential or known foraging habitat for this species which could be affected by the proposed project is extremely limited. Furthermore, given the extent of known and potential habitat for this species in the region, the absence of any requirement for the loss of roosting or nesting resources, and the highly mobile and wide-ranging habits of microchiropteran bats generally, "*a significant area of known habitat*" for the Little Bent-wing Bat is extremely unlikely to be "*modified or removed*", in respect of the "*regional distribution of the habitat*" for this species.

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

Microchiropteran bats are highly mobile and wide-ranging, and are not reliant on continuous tracts of forest and woodland for movement. Whilst the proposed Bypass will pose a barrier to movement for less mobile species, is not considered likely to impose a movement barrier for the Little Bent-wing Bat.

Given the habits and habitat characteristics of the Little Bent-wing Bat, there is no likelihood that "*an area of known habitat*" for this species will "*become isolated from currently interconnecting or proximate areas of habitat*".

(e) whether critical habitat will be affected

Not applicable (section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

Considering its known distribution in northeastern NSW, it is extremely likely that the Little Bent-wing Bat occurs in conservation reserves within the region. However, given this species threatened status, its highly specific breeding and maternity site requirements and its wide-ranging habits, it is not considered likely that the Little Bent-wing Bat is "*adequately represented in conservation reserves (or other similar protected areas) in the region*".

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the Little Bent-wing Bat primarily include the destruction of nursery sites and the removal of foraging resources. Given this species' dependence on specific nursery caves, to which it returns annually, the loss of such a feature is a significant threat to this species' survival. The Karuah Bypass (Horse Island Route) project will involve the loss of some foraging resources for the Little Bent-wing Bat. However, no nursery sites will be adversely affected, and the project is not likely to significantly contribute to the threats to the Little Bent-wing Bat in the locality.

The Karuah Upgrade project will not exacerbate any "*key threatening process*" as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The distributional range of the Little Bent-wing Bat includes the east coast of Australia from Cape York in Queensland to the mid-north coast of NSW. In northern NSW, the Little Bent-wing Bat occurs on the coast and ranges, becoming increasingly coastal towards the southern limit of its range.

Known nursery caves are largely restricted to the subtropical coastal areas of northeastern NSW as far south as about Kempsey (Gilmore & Parnaby 1994), although a possible breeding colony has recently been located near Lake Macquarie (Gunninah 1998a). Little Bent-wing Bats have also been recorded roosting in artificial structures throughout their range (*eg* at the Balickera Canal east of Raymond Terrace).

Recent records of the Little Bent-wing Bat at Lake Macquarie (Gunninah 1998a) extend this species southern distributional limit, formerly thought to lie in the vicinity of Kempsey (Hall & Richards 1979; Gilmore & Parnaby 1994).

The study area is located within the known distributional range of the Little Bent-wing Bat in northern NSW and this species is not "*at the limit of its known distribution*" in the study area.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular relevance to the Little Bent-wing Bat, are discussed in detail above.
Although some potential foraging resources for the Little Bent-wing Bat will require removal, the project will not affect breeding or roosting features for this species. The proposed Karuah Bypass (Horse Island Route) will not affect habitat or resources for the Little Bent-wing Bat to any significant

extent. As a consequence, it is not likely that the proposed highway upgrade will involve the imposition of "*a significant effect*" on this species.

A Species Impact Statement is not required for the proposed Karuah Bypass (Horse Island Route) project with respect to the Little Bent-wing Bat.

3.4 Greater Broad-nosed Bat *Scoteanax rueppellii* Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The Greater Broad-nosed Bat inhabits eucalypt forests and woodlands, particularly more open communities where there are less obstacles to flight (Hoye & Richards 1995). Most records for this species have been obtained from sclerophyll forest and in woodland habitats rather than rainforest (Gilmore & Parnaby 1994). It generally feeds by flying slowly at low heights, along tree-lined creeks (including through rainforest) and along the ecotone between cleared land and woodland (Hoye & Richards 1995). This species roosts in tree-hollows. Forested areas adjacent to cleared agricultural land, or along rivers and creeklines provide the most suitable habitat for this species in the study area, given the more open nature of the vegetation in these areas.

The Greater Broad-nosed Bat was tentatively identified in open forest in the western portion of the study area, near Wallaroo Swamp, based on Anabat II echolocation recordings and habitat characteristics. Despite a substantial survey effort for microchiropteran bats and records of this species in the general locality, the Greater Broad-nosed Bat could not be positively identified, and it is not possible to determine whether a "*viable local population*" of this species occurs in the study area.

Nevertheless, the Greater Broad-nosed Bat is known from the locality (Gunninah 1997c) and this species is likely to utilise the resources in the study area. However, the features present are widely represented throughout the locality, and given the highly mobile nature of microchiropteran bats, this species is unlikely to rely exclusively on the study area. Given the extent of suitable foraging and roosting habitat for this species to remain in the general locality, the life cycle of the Greater Broad-nosed Bat will not be "*disrupted*" by the proposed Karuah Bypass (Horse Island Route) project to the extent that a "*viable local population*" will be "*placed at risk of extinction*".

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Greater Broad-nosed Bat has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Greater Broad-nosed Bat in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

The proposed Karuah Bypass (Horse Island Route) project will involve the removal of potential habitat, but not "*known habitat*", for the Greater Broad-nosed Bat, given that this species was only tentatively identified.

The Greater Broad-nosed Bat is known from throughout the North Coast region (Hoye & Richards 1995), and is not restricted to the vicinity of the subject site. Particularly considering the highly mobile nature of this species, and the extent of suitable habitat which will remain intact in the general locality (including State Forests), a "*significant area of known habitat*" will not be "*modified or removed*" for this species, in terms of the "*regional distribution of habitat*".

Consequently, it appears highly unlikely that "*in relation to the regional distribution*" of potential or suitable habitat, "*a significant area of known habitat is to be modified or removed*" for the Greater Broad-nosed Bat.

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

In general terms, any development which requires the clearing of native vegetation and fauna habitats has the potential to fragment habitats and resources for threatened fauna and flora, and possibly to provide barriers to movement for threatened species.

As is the case with the other microchiropteran bats, however, the Greater Broad-nosed Bat is a highly mobile and relatively wide-ranging species. The Karuah Bypass (Horse Island Route) will not provide an impediment to movement of Greater Broad-nosed Bats throughout the landscape, and will not involve any potential or "*known habitat*" becoming "*isolated from currently interconnecting or proximate areas of habitat*" for this species. There is no likelihood that the Karuah Bypass proposal will prevent the Greater Broad-nosed Bat from moving between habitats or resources in this locality.

(e) whether critical habitat will be affected

Not applicable (see section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

Whilst the Greater Broad-nosed Bat doubtless occurs within National Parks or other conservation reserves in the region (the NSW North Coast region, as defined in Section 1.6), or is likely to do so, it is generally considered unlikely that this species would be "*adequately represented*" in such reserves. Moderate to large home-ranges and wide-ranging habits for this species indicates that conservation reserves are generally unlikely to support significant populations of this species.

Even including State Forests, which constitute a significant and substantial conservation resource in most parts of coastal NSW, and which are of particular relevance to the proposed activities at Karuah (given their proximity), it is considered unlikely that the Greater Broad-nosed Bat is "*adequately represented in conservation reserves*".

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the Greater Broad-nosed Bat are likely to include loss of habitat, in particular areas supporting mature hollow-bearing trees suitable for nesting and roosting, and foraging resources. The invasion of the European Bee may also pose a threat to this species by competing for tree-hollows. The Karuah Bypass (Horse Island Route) project will involve the loss of foraging and roosting resources for this species, by virtue of the removal of native vegetation, and will therefore contribute to the processes threatening the Greater Broad-nosed Bat.

The Karuah Bypass project will not exacerbate any "*key threatening process*" as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The Greater Broad-nosed Bat occurs throughout coastal eastern Australia from southern NSW to Ingham, Queensland (Hall & Richards 1979). Hoye & Richards (1995) comment that the range of this species is from northeastern Victoria to the Atherton Tableland in Queensland, where it occurs in the gully and river systems which drain the Great Dividing Range. In NSW it is restricted to the Great Dividing Range and to the east (Strahan 1995).

This species is sparsely but widely distributed throughout the NSW North Coast region (Gilmore & Parnaby 1994). Consequently, this species is not "*at the limit of its known distribution*" in the Karuah Bypass (Horse Island Route) study area.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular relevance to the Greater Broad-nosed Bat, are discussed in detail above.

The Greater Broad-nosed Bat was tentatively identified in the Karuah Bypass (Horse Island Route) study area, and has been recorded in the vicinity (Gunninah 1997c). Whilst the proposal will involve the removal of some potential habitat and resources for this species, given its wide-ranging habits and the extent of suitable habitat to remain in the locality and in the general region, it is not considered likely that "*a significant effect*" will be imposed upon "*a viable local population*" of the Greater Broad-nosed Bat.

A Species Impact Statement is not required for the proposal with respect to the Greater Broad-nosed Bat.

3.5 Osprey *Pandion haliaetus* **Vulnerable**

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The Osprey occurs on offshore islands and in littoral habitats, terrestrial wetlands and coastal lands of tropical and temperate Australia, often ranging inland along large rivers (Marchant & Higgins 1993). It requires extensive areas of clear open water (fresh, brackish or saline) for fishing, and nests in prominent positions (such as on rocky headlands or cliffs, or in tall trees with dead crowns or stags). Nest sites are usually located within 1km of the coastline, estuaries or rivers, although birds will nest up to 40km from the sea (Marchant & Higgins 1993). This species exhibits high nest site fidelity, returning to the same nest site over successive years.

The Osprey was recorded during the field investigations, soaring over the Karuah River south of the township of Karuah. Ospreys have also been recorded at other locations within 10km of the study area (NP&WS Wildlife Atlas). This species could potentially occur anywhere in the Karuah Bypass (Horse Island Route) study area, given its high mobility and wide-ranging habits, and is likely to forage over the Karuah River as well as other major rivers and river estuaries along this portion of the coast.

Large raptor nests were observed in mature trees along the banks of the Karuah River, including in the vicinity of the proposed bridge. However, no Osprey activity was observed at these nests, and they may belong to other species of raptor known from the locality, including the Wedge-tailed Eagle or Brahminy Kite.

It is difficult, if not impossible, to define what "*a viable local population*" of the Osprey might be. Whilst individuals are likely to utilise the portion of the Karuah River within the study area for foraging, they would not rely exclusively on this portion of the River and would range widely throughout the locality. Given the habits of and habitats utilised by the Osprey, and the implementation of a range of appropriate environmental management measures it is not likely that the proposed Karuah Bypass, either in the construction phase or in its subsequent maintenance, would disrupt any "*viable local population of the species*" (if one exists) to the extent that any such population "*is likely to be placed at risk of extinction*".

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Osprey has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Osprey in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

"*Known habitat*" for the Osprey occurs along the Karuah River in the Karuah Bypass (Horse Island Route) project study area. "*Known*" and potential habitat for this species also occurs throughout the general locality, including coastal areas and large rivers.

Given the widespread distribution of the Osprey in the "*region*" (the NSW North Coast region), the area of potential or known foraging habitat for this species which could be affected by the proposed project is extremely limited. Furthermore, given the extent of known and potential habitat for this species in the region, the implementation of measures to avoid disturbance to nesting sites, and the highly mobile and wide-ranging habits of this species, "*a significant area of known habitat*" for the Osprey is extremely unlikely to be "*modified or removed*", in respect of the "*regional distribution of the habitat*" for this species.

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

The Osprey is an extremely mobile and wide-ranging species and there is no likelihood that "*an area of known habitat*" for the Osprey "*is likely to become isolated from currently interconnecting or proximate areas of habitat*" as a result of the proposed Karuah Bypass (Horse Island Route).

(e) whether critical habitat will be affected

Not applicable (section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

There are no known records of the Osprey from any "*conservation reserves (or other similarly protected areas) in the region*". However, it is considered extremely likely that this species occurs in regional reserves in coastal areas, such as Crowdy Bay, Tomaree and Myall Lakes National Parks, all of which occur in the vicinity of the study area.

Because of a lack of information regarding representation in any "*conservation reserves (or other similar protected areas) in the region*", the Osprey is not known or considered likely to be "*adequately represented*" in such reserves, particularly given its specialised habitat requirements, its wide-ranging nature and its threatened status.

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the Osprey primarily include the destruction of nests, widespread clearing for urban or agricultural development and the removal or degradation of foraging resources, in particular the siltation and/or pollution of waterbodies (Marchant & Higgins 1993). On the basis of the incorporation of appropriate environmental management measures aimed at reducing the potential for the imposition of the above threats, the project is not likely to significantly contribute to the threats to the Osprey in the locality.

The Karuah Upgrade project will not exacerbate any "*key threatening process*" of relevance to the Osprey, as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The Osprey has an apparently disjunct distribution around the Australian coastline, and is much more numerous in the north than the south. It occurs in the north and east from Broome in WA to the south coast of NSW, in the south from Kangaroo Island to the Great Australian Bight, and from Esperance to Cape Keraudren in the west (Marchant & Higgins 1993). In NSW, the Osprey has a primarily coastal distribution south to Womboyne Lake, but has been occasionally recorded over inland lakes.

The Osprey does not occur "*at the limit of its known distribution*" in the study area. Irrespective of whether this species "*is at the limit of its known distribution*", the Karuah Upgrade project will not reduce or affect this species' range.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular relevance to the Osprey, are discussed above.

The Karuah Bypass (Horse Island Route) project, whilst involving a bridge over the Karuah River and some disturbance to vegetation on either side, will not reduce the availability of resources for the Osprey. The implementation of appropriate environmental management measures will further reduce the potential for adverse impacts on this species. As a consequence, it is not likely that the proposed Karuah Bypass will involve the imposition of "*a significant effect*" on the Osprey.

A Species Impact Statement is not required for the activity with respect to this species.

3.6 Squirrel Glider *Petaurus norfolcensis* Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

The Squirrel Glider inhabits dry sclerophyll forest and woodland and is dependent upon the presence of medium size tree-hollows for shelter and nesting. This species can glide through the canopy for over 50m in a single movement (Suckling 1995), depending upon the availability of suitably large trees. Maximum nightly movements between foraging and den sites are reported as 500m (Quin 1995) and 1km (Menkhorst 1995), and the Squirrel Glider has a relatively limited home range of between 20 and 30 hectares (Gilmore & Parnaby 1994). The study area provides a range of resources for the Squirrel Glider, including hollow-bearing trees for nesting and shelter and a range of tree and shrub species to provide foraging resources.

On this basis, it is likely that a "*viable local population*" of this species occurs in the study area. Conversely, it is unlikely that such a population would rely exclusively or solely on the resources in the study area.

Resources for the Squirrel Glider are scattered throughout the study area, with hollow-bearing trees for nesting and shelter scattered throughout the study area, and a range of tree and shrub species present (at varying densities) to provide foraging resources. Despite the relatively low densities of mature hollow-bearing trees and a generally low to moderate floristic diversity along much of the Karuah Bypass (Horse Island Route) study area, the Squirrel Glider could potentially be present in all areas of open forest and woodland.

The proposed Karuah Bypass (Horse Island Route) will require the removal of habitat features and resources, such as hollow-bearing trees and vegetation suitable for foraging. However, the study area does not support unique resources, and any habitat features which occur are also well represented in adjacent areas. Therefore, habitat for any "*viable local population*" of the Squirrel Glider will be retained both in the immediate locality and in the vicinity (including the nearby State Forests and Nature Reserves, and private forested lands).

On the basis of the requirement for the removal of habitats and resources of relevance for the Squirrel Glider, and given the potential for fragmentation and barriers to movement, the proposed Karuah Bypass (Horse Island Route) project is considered likely to disrupt "*the life cycle*" of the "*viable local population*[s]" in the locality, which may consequently be "*placed at risk of extinction*".

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of the Squirrel Glider has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for the Squirrel Glider in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

"*Known habitat*" for the Squirrel Glider occurs in the Karuah State Forest and the Karuah Nature Reserve, with a record during these investigations approximately 1.5km to the south of the proposed Bypass. In addition, other portions of the study area provide potential habitat for this species, particularly Horse Island, Karuah and Wallaroo State Forests and Nature Reserves, and other forested lands in the locality. "*Known habitat*" for the Squirrel Glider also occurs in other areas in the NSW North Coast region, including in the vicinity of Wang Wauk (Mitchell McCotter 1994) and at Brunswick Heads (Gunninah 1998e), and is widespread in the locality.

The study area clearly involves only an extremely small proportion of the "*regional distribution of the habitat*" of the Squirrel Glider, and only 40ha (approximately) of forest and woodland vegetation is to be removed for the project. Consequently, it appears highly unlikely that "*in relation to the regional distribution*" of potential or suitable habitat, "*a significant area of known habitat is to be modified or removed*" for the Squirrel Glider by the proposed activities.

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

In general terms, any development which requires the clearing of native vegetation and fauna habitats has the potential to fragment habitats and resources for threatened fauna and flora, and possibly to provide barriers to movement for threatened species.

The population of Squirrel Gliders in this locality is likely to be widely distributed and relatively sparse, and suitable habitat is patchily distributed throughout the locality. Areas regarded as of potential or known value for the Squirrel Glider include forested lands to the west of the Karuah River and to a lesser extent the forested lands to the east of the River, which provide fewer resources of relevance, such as tree-hollows and foraging resources.

Conversely, the tracts of forest comprising known or potential Squirrel Glider habitat are generally contiguous, and Squirrel Gliders are currently able to move throughout the locality. On a 'regional' basis, a corridor has been identified from Port Stephens north, including the State Forests and newly gazetted Nature Reserves (L Baker NP&WS *pers comm*). Currently, the only existing barrier to the movements of Squirrel Gliders is the existing Pacific Highway to the south and the Karuah River.

The proposed Karuah Bypass (Horse Island Route) will involve the construction of a wide roadway through currently forested land, the majority of which is likely to support Squirrel Gliders. The Bypass will pose a substantial barrier to the movement of Squirrel Gliders, and in the absence of environmental management measures providing for the safe movement of Squirrel Gliders across it, would cause the isolation of areas of habitat "*from currently interconnection or proximate areas of habitat*".

In particular, the Bypass would potentially create an isolated pocket bounded by the existing Pacific Highway to the south, the Karuah River and the proposed Bypass. Despite some existing fragmentation in the locality by the existing Pacific Highway, urban areas and cleared agricultural

land, the proposed new Bypass could significantly increase the levels of fragmentation, and may isolate individuals or a population of this species.

Given the considerations above, "*an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat*" for the Squirrel Glider as a result of the Karuah Bypass (Horse Island Route).

(e) whether critical habitat will be affected

Not applicable (see section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

Whilst the Squirrel Glider doubtless occurs within National Parks or other conservation reserves in the NSW North Coast region, or is likely to do so, it is generally considered unlikely that this species would be "*adequately represented*" in such reserves. The relatively sparse abundance of the Squirrel Glider even where widely distributed, indicates that conservation reserves are generally unlikely to support significant populations of this species.

Even including State Forests, which constitute a significant and substantial conservation resource in most parts of coastal NSW (despite not being managed exclusively for conservation), and which are of particular relevance to the proposed activities (given their proximity), it is considered unlikely that the Squirrel Glider would be "*adequately represented in conservation reserves*".

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the survival of the Squirrel Glider include the fragmentation and clearing of habitat, lack of suitable tree-hollows as a result of selective logging and clearing, and a lack of regeneration due to grazing (Maxwell *et al* 1996). The proposed Karuah Bypass (Horse Island Route) will increase the threats to Squirrel Gliders in the locality, in particular through the fragmentation of habitat, and the loss of foraging resources and suitable tree-hollows.

The Karuah Bypass (Horse Island Route) project will not exacerbate any "*key threatening process*" as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

The Squirrel Glider occurs from central Victoria to northeastern Queensland. Consequently, this species is not "*at the limit of its known distribution*" in the study area.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular reference to the Squirrel Glider, are discussed in detail above.

The proposed Karuah Bypass (Horse Island Route) project will fragment habitat for the Squirrel Glider and could create a barrier to the movement of Squirrel Gliders through the landscape. The proposed Bypass is considered likely to cause the fragmentation of and disruption to "*a viable local population*", and it is likely that the project will impose "a *significant effect*" on this species.

A Species Impact Statement is likely to be required for the proposed Karuah Upgrade project with respect to the Squirrel Glider.

3.7 Black-eyed Susan *Tetratheca juncea* Vulnerable

(a) in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction

Tetratheca juncea inhabits dry sclerophyll woodland and open forest, often on ridgetops and southerly-facing upper slopes (Gunninah 1998b). This species occurs as stands or individual plant clumps, generally in vegetation communities which are relatively intact, supporting a diverse and often dense suite of native fauna species. Commonly occurring overstorey species are Smooth-barked Apple *Angophora costata*, Scribbly Gum *Eucalyptus haemastoma* and Red Bloodwood *Corymbia gummifera* (Gunninah 1998b).

T juncea was recorded during the field investigations in the western portion of the study area, approximately 1km from where the proposed Karuah Bypass (Horse Island Route) leaves the existing Pacific Highway. Several scattered and isolated stands of this species were recorded in woodland/open forest within Wallaroo State Forest. Other populations are known to occur on Horse Island and in forested lands around the Karuah Quarry, east of the Karuah River.

T juncea generally occurs in discrete clumps, either individually or forming larger stands. There is little available information regarding the number of individual plants occurring in a single plant clump, but it is generally agreed that a clump comprises more than one individual plant. Consequently, it is not possible to estimate the number of individual plants which occur in the study area.

Furthermore, there are no precise guidelines as to what constitutes a 'population' of *Tetratheca juncea* (R Payne *pers comm*). Payne (1993) defines a small population as including "*between twenty and fifty plant clumps*", with a large population containing "*more than fifty clumps*". However, this definition is arbitrary and may not reflect the true situation in all circumstances (R Payne *pers comm*). Therefore, whilst several plant clumps occur in the study area, with others likely to also be present, it is not possible to determine the number of "*viable local population*[s]" which occur.

On this basis, it is likely that at least one "*viable local population*" of *T juncea* occurs in the study area and, given the requirement to clear native vegetation supporting (or potentially supporting) this species, the proposed activities may place "*at risk of extinction*" at least one "*viable local population*" of *Tetratheca juncea*.

(b) in the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised

No population of *T juncea* has been identified as "*an endangered population*" under the TSC Act.

This factor cannot be relevantly addressed for *T juncea* in the Karuah Bypass (Horse Island Route) project study area.

(c) in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed

Whilst *T juncea* is widespread and abundant in the locality, the distribution of habitat for this species in the NSW North Coast region is restricted to the area from Bulahdelah to the southern boundary of the region. On this basis, any "*area of known habitat*" for *T juncea* which is to be "*modified or removed*" could be regarded as significant in terms of the "*regional distribution of habitat*". Conversely, this species is primarily distributed to the south of the study area, and the requirement for removal or modification of "*known habitat*" for the species as a result of the Karuah Bypass (Horse Island Route) is limited in terms of its distribution.

Given the nature of the proposed disturbance (*ie* the removal of native vegetation) and the limited "*regional distribution of the habitat*" of *T juncea*, the Karuah Bypass (Horse Island Route) may be likely to involve the removal of "*a significant area of known habitat ... in relation to the regional distribution of the habitat*" of this species.

(d) whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community

The proposed Karuah Bypass (Horse Island Route) project may involve the isolation of "*currently interconnecting or proximate areas of habitat*" for *Tetratheca juncea*. Populations of this species currently connected by pollinators (depending on the method of pollination) may become isolated by the removal of native vegetation and populations.

However, the limited information currently available on the ecology of *T juncea*, particularly in terms of pollination mechanisms, makes it difficult to determine whether "*an area of known habitat is likely to become isolated from currently interconnecting or proximate areas*".

(e) whether critical habitat will be affected

Not applicable (see section 1.4).

(f) whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region

Tetratheca juncea is not considered to be "*adequately represented in conservation reserves*" in the NSW North Coast region. *T juncea* is conserved in Awabakal Nature Reserve and also occurs in

Glenrock and Munmorah State Recreation Areas (Briggs & Leigh 1996), and in Heaton and Awaba State Forests, all of which are in the Sydney Basin region. Furthermore *T juncea* is substantially represented on private and crown-owned land (Winning 1992), leaving it vulnerable to altering land uses, agriculture and clearing.

Even including State Forests, which constitute a significant and substantial conservation resource in most parts of coastal NSW, and which are of particular relevance to the proposed activities at Karuah (given their proximity), it is considered unlikely that *Tetratheca juncea* is "*adequately represented in conservation reserves*" in the North Coast region.

(g) whether the development or activity is of a class of development or activity that is recognised as a threatening process

Threats to the survival of the *Tetratheca juncea* include the clearing of individuals and stands, loss of habitat, inappropriate fire regimes, and a lack of regeneration due to grazing. The proposed Karuah Bypass (Horse Island Route) will increase the threats to *T juncea* in the locality, in particular through the loss of habitat.

The Karuah Bypass (Horse Island Route) project will not exacerbate any "*key threatening process*" as listed under the TSC Act.

(h) whether any threatened species, population or ecological community is at the limit of its known distribution

Tetratheca juncea occurs primarily in coastal districts from Bulahdelah to Morisset (Harden 1992), with a large concentration of this species around Lake Macquarie. Consequently, the study area appears to be near the northern "*limit of its known distribution*" of this species.

Conclusion

The eight factors which are required to be considered pursuant to the EP&A Act in the determination of "*whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats*", with particular reference to *Tetratheca juncea*, are discussed in detail above.

On the basis of field investigations to date, part of "*a viable local population*" of *T juncea* in the area appears likely to be disturbed by the proposed activity. Furthermore, the proposed Karuah Bypass

(Horse Island Route) will remove suitable habitat for *T juncea*, and may isolate remnant stands, depending on the method of pollination. Given the potential for loss of habitat, loss of individuals and disruption to the life cycle of *T juncea* in the locality resulting from the proposal, it is possible that the Karuah Bypass (Horse Island Route) project will impose "*a significant effect*" on this species.

A Species Impact Statement may be required for the proposed Karuah Bypass (Horse Island Route) project with respect to *T juncea*.

9

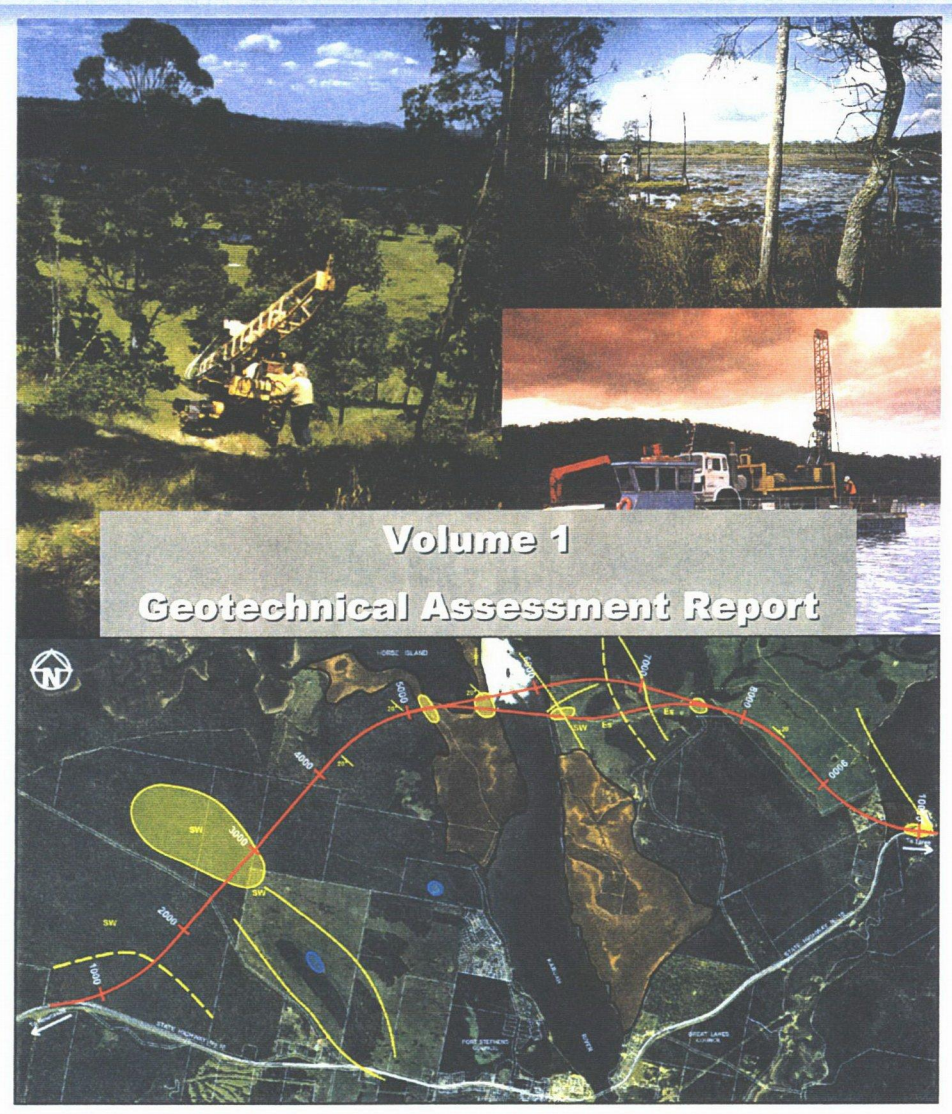
Geotechnical assessment



ARUP

Pacific Highway Upgrade, Karuah

Concept Design and EIS



Prepared for

NSW Roads and Traffic Authority

by

OVE ARUP & PARTNERS

October 1999

9809/510

LIMITATION ON USE AND LIABILITY

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical and environmental engineering involve gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground and groundwater on a particular site under certain conditions. Arup may report such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so they are directly relevant only to the ground and groundwater at the place where and the time when the investigation was carried out and are believed to be reported accurately. Any interpretation or recommendation given by Arup shall be understood to be based on judgement and experience and not on greater knowledge of the facts than the reported investigations would imply. The interpretation and recommendations are therefore opinions provided for our Client's sole use in accordance with a specific brief. As such they do not necessarily address all aspects of ground behaviour on the subject site.

REPORT ISSUE AUTHORISATION

PROJECT: Pacific Highway Upgrade at Karuah - Geotechnical Assessment Report
Project No: 9809/510

Rev	Date	Purpose of Issue/Nature of Revision	Prepared By	Issue Authorised By
a	2/7/99	Draft issued to RTA	CPM	HGB
0	17/7/99	Draft issued to Coffey Partners for external review	CPM	HGB/ABP
1	9/9/99	Final Report issued to RTA (client)	CPM	ABP 13/9/99

This report takes into account the particular instructions and requirements of our Client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Ove Arup & Partners
477 Kent Street
Sydney NSW 2000
PO Box Q116
QVB Post Office
Sydney NSW 1230
Australia
Telephone (02) 9320 9320
Facsimile (02) 9320 9321

Arup Partner Pty Ltd
ACN 002 536 647

Ove Arup Consult Pty Ltd
ACN 002 536 503

Ove Arup Pty Ltd
ACN 000 966 165

CONTENTS

SUMMARY 1

1. INTRODUCTION 1
- **1.1 General** 1
- **1.2 Terms of Reference** 1
- **1.3 Report Format** 2

2. COMMENTARY 3
- **2.1 Structural Geology of Karuah** 3
- **2.2 Topsoil** 4
- **2.3 Unsuitable Material** 5
- **2.4 Subgrade Materials** 5
- **2.5 Bulking Factors** 6
- **2.6 Erodibility** 6
- **2.7 Fill Batters** 7
  - 2.7.1 Wallaroo Swamp 8
- **2.8 Cut Batters** 8
- **2.9 Bridge Crossings** 9
- **2.10 Alternative Alignments** 10
- **2.11 Sources of Materials** 11
  - 2.11.1 East of the Karuah River 11
  - 2.11.2 West of the Karuah River 11
- **2.12 Groundwater** 12
- **2.13 Excavations in Rock** 12
- **2.14 Pedogenic Materials** 13
- **2.15 Acid Sulphate Soils and Sulphate Attack** 13
  - 2.15.1 Management of acid sulphate soils 14
  - 2.15.2 Groundwater monitoring 16
- **2.16 Contamination Survey** 16
- **2.17 Construction Issues** 16
- **2.18 Further Investigations** 17

3. THE PROJECT 19

4. DESK STUDY 20
- **4.1 General** 20
- **4.2 Review of Geological Literature** 20
  - 4.2.1 Geological Maps 20
- **4.3 Aerial Photography Analysis** 20
  - 4.3.1 Ch 0000 - 1000 21
  - 4.3.2 Ch 1000 - 2500 21
  - 4.3.3 Ch 2500 - 3500 21
  - 4.3.4 Ch 3500 - 5100 22
  - 4.3.5 Ch 5050 - 5300 22
  - 4.3.6 Ch 5300 - 5600 22
  - 4.3.7 Ch 5600 - 6200 23
  - 4.3.8 Ch 6200 - 6600 23
  - 4.3.9 Ch 6800 - 7700 24
  - 4.3.10 Ch 8000 - 9600 24
  - 4.3.11 Ch 9600 - 10500 25
- **4.4 Topography** 25
- **4.5 Soils** 26
  - 4.5.1 *tm* 'Ten Mile Road' (Erosional Landscape) 26
  - 4.5.2 *me* 'Medowie' (Residual Landscape) 26

4.5.3 *ts* 'Tacoma Swamp' (Swamp Landscapes) 27
4.5.4 *fc* 'Fullerton Cove' (Estuarine Landscape) 28
4.5.5 *gi* 'Gilmore Hill' (Colluvial Landscape) 28
4.5.6 *tb* 'The Branch' (Residual Landscape) 29
4.5.7 *nc* 'North Arm Cove' (Associated Landscape) 29
4.5.8 *gg* 'Gan Gan' (Associated Landscape) 30
4.5.9 *ng* 'Nungra' (Tranferral Landscape) 31
4.5.10 Summary of Limitations 31

5. SURFACE MAPPING 32
5.1 General 32
5.2 West of Karuah River - Tomago Coal Measures/Mulbring Formation 32
5.3 East of Karuah River - Nerong Volcanics 33

6. NATURE OF THE FIELD INVESTIGATIONS 35
6.1 General 35
6.2 Detailed Methodology 35
6.2.1 Investigation Techniques 35
6.2.2 Chainage 0000-0950, Pacific Highway Embankment 37
6.2.3 Chainage 0950-2350, State Forest Cut I 38
6.2.4 Chainage 2350-3400, Wallaroo Embankment 38
6.2.5 Chainage 3400-3900, State Forest Cut II 38
6.2.6 Chainage 3900-4350, Powells Creek Embankment 38
6.2.7 Chainage 4350-5050, Powells Cut 38
6.2.8 Chainage 5050-5300, West Horse Island Bridge 39
6.2.9 Chainage 5300-5600, Horse Island 39
6.2.10 Chainage 5600-6150, Karuah River Bridge 39
6.2.11 Chainage 6150-6200, Bridge Abutment 40
6.2.12 Chainage 6200- 6650, AMP Embankment I 40
6.2.13 Chainage 6650-6900, Saddle Cut 40
6.2.14 Chainage 6900-8050, AMP Embankment II 41
6.2.15 Chainage 8050-8500, AMP Cut I 41
6.2.16 Chainage 8500-8900, AMP Embankment III 41
6.2.17 Chainage 8900-9500, AMP Cut II 41
6.2.18 Chainage 9500-9950, Branch Lane Embankment 41
6.2.19 Chainage 9950-10500, Pacific Highway Re-entrance 42

7. GEOTECHNICAL CONDITIONS 43
7.1 Chainage 0000-0950, Pacific Highway Embankment 43
7.2 Chainage 0950-2350, State Forest Cut I 44
7.3 Chainage 2350-3400, Wallaroo Embankment 46
7.4 Chainage 3400-3900, State Forest Cut II 47
7.5 Chainage 3900-4350, Powells Creek Embankment 49
7.6 Chainage 4350-5050, Powells Cut 50
7.7 Chainage 5050-5300, West Horse Island Bridge 50
7.8 Chainage 5300-5600, Horse Island 51
7.9 Chainage 5600-6150, Karuah River Bridge 52
7.10 Chainage 6150-6200, Karuah River - Eastern Bridge Abutment 54
7.11 Chainage 6200-6650, AMP Embankment I 54
7.12 Chainage 6650-6900, Saddle Cut 56
7.13 Chainage 6900-8050, AMP Embankment II 58
7.14 Chainage 8050-8500, AMP Cut I 59
7.15 Chainage 8500-8900, AMP Embankment III 60
7.16 Chainage 8900-9500, AMP Cut II 61
7.17 Chainage 9500-9950, Branch Lane Embankment 62
7.18 Chainage 9950-10500, Pacific Highway Re-entrance 62

8. REFERENCES 64

FIGURES

Figure 1 Original Study Area
Figure 2 Current Horse Island Alignment
Figure 3 Site Investigation Location Map (a-g)
Figure 4 Field Mapping (a-h)
Figure 5 Soil Landscapes of Karuah
Figure 6 Plasticity Chart – West of River
Figure 7 Plasticity Chart – East of River (Ch. 6200-6800)
Figure 8 Plasticity Chart – East of River (Ch. 6800-8050)
Figure 9 Plasticity Chart – East of River (Ch. 8050-10500)
Figure 10 Plasticity Chart – Karuah River Crossing
Figure 11 Atterberg Limits and Moisture Contents – West of River
Figure 12 Atterberg Limits and Moisture Contents – East of River (Ch. 6800-8050)
Figure 13 Atterberg Limits and Moisture Contents – East of River (Ch. 8050-10500)
Figure 14 Atterberg Limits and Moisture Contents – East of River (Ch. 6200-6800)
Figure 15 Atterberg Limits and Moisture Contents –Karuah River Crossing
Figure 16 Standard Penetration Test Results – BH-101
Figure 17 Standard Penetration Test Results – West of River
Figure 18 Standard Penetration Test Results – Eastern Abutment
Figure 19 Standard Penetration Test results – Karuah River Crossing

APPENDICES

Volume 2 Boreholes, Test Pits, Laboratory Testing
Volume 3 Seismic Survey, Downhole Geophysics
Volume 4 Contamination and Pedological Survey
Volume 5 Comparison of Karuah and Bulahdelah Cut Conditions

LIST OF ABBREVIATIONS

API	Aerial photograph interpretation
ASS	Actual sulphate soils
BH	Borehole
BHTV	Borehole televiewer (downhole geophysical tool)
CBR	California bearing ratio (as per RTA specification)
LL	Liquid limit
MDD	Maximum dry density
MC	Moisture content
NMC	Natural moisture content
NP	Non plastic
OMC	Optimum moisture content
PASS	Potential acid sulphate soils
POCAS	Peroxide oxidation – combined acidity and sulphate (ASS method 21)
SPT	Standard penetration test
RQD	Rock quality designation (Deere 1968)
TP	Test pit

1. INTRODUCTION

1.1 General

The New South Wales Roads & Traffic Authority (RTA) is undertaking the upgrade of the Pacific Highway around the town of Karuah. Ove Arup & Partners was appointed by the RTA to carry out the Environmental Impact Study (EIS) and design of the alignment adopted from the EIS and community consultation process. Arup Geotechnics Pty Ltd was appointed by Ove Arup & Partners to carry out the geotechnical investigations for the project.

The original study area (Area 1) is shown in Figure 1a. The study area extended from approximately 5 km west of the Karuah river to 4 km east. To the south the study area was bounded by the Pacific Highway and extended some 3 km to the north. Depending on the route adopted, the new alignment would be some 5 km in length.

Preliminary geotechnical investigations were carried out for this study area. These investigations are documented in Arup Geotechnics Report, May 1997 (Reference 1). These investigations essentially comprised a desk study, site reconnaissance and seismic survey in the river. During the course of this preliminary investigation, a route to the north of the study area, crossing Horse Island was mooted and was included in the study.

Following a range of studies, value management assessments and community consultation, the Horse Island Route (Area 2) was adopted, as shown in Figure 1a. This alignment is approximately 10 km in length and extends from the existing Pacific Highway in a wide arc that clips the southern side of Horse Island.

1.2 Terms of Reference

Following Ove Arup & Partners' appointment by the RTA to carry out the EIS for the Pacific Highway upgrade at Karuah, Arup Geotechnics was appointed by Ove Arup & Partners to carry out the geotechnical investigations in terms of letter ref: AK:KJS:9809 dated 10 March 1997. The appointment was in response to Arup Geotechnics' proposal dated 17 December 1996 which was based on the RTA's invitation to tender and brief titled Tender Documents PSC 96/14, Project Management Services for Karuah Upgrade 50.5 km to 55.9 km North of Newcastle. The scope of works in the brief comprised the geotechnical investigations within the original study area. Following the adoption of the Horse Island route, the length of the alignment was increased to approximately 10 km. Terrain and access were considerably different from the original alignment and in addition legislative changes affecting the way the geotechnical investigations could be carried out meant that the investigation program had to be revised. The revised program was submitted to the RTA as a detailed method statement dated 23 September 1998 and has been adopted for the investigations. Essentially access, bridge design and legislative considerations dictated that the investigations be carried out in a phased manner to provide the necessary design information in a cost-effective manner. The Phase 2 investigations were modified after the submission of the draft Phase 1 report, at the request of the RTA. Arup Geotechnics provided two proposals (20 January 1999) and the RTA, on the basis of a risk assessment, chose the lower budget option (RTA e-mail dated 2 March 1999). The investigations were to be separated into the two phases outlined below.

- Phase 1 (September 1998):
  - desk study of the whole alignment,
  - detailed investigations of accessible overland areas,
  - seismic survey of the river crossing and wetland areas, and
- Phase 2 (March 1999):
  - drilling investigations of over water areas,
  - investigations in areas previously inaccessible due to constraints placed on access and ground disturbance.

This report covers both the Phase 1 and Phase 2 investigations. These investigations required:

- desk study;
- surface inspection and geological mapping;
- seismic survey;
- boreholes on land and over water;
- test pits;
- down hole geophysical survey;
- soil survey (acid sulphate soils);
- laboratory testing; and
- submission of a geotechnical site investigation report.

1.3 Report Format

Section 2 provides commentary on selected engineering aspects of the site highlighted as a result of the investigations. It is intended as an extended executive summary of the report. Subsequent sections provide backup detail on the commentary.

Section 3 gives general details of the project.

Sections 4 and 5 contain detailed discussion on the desk study, including geological field mapping and air photo interpretation, topography and soils and investigations undertaken. These sections stand separate from the direct investigations at the site.

Section 6 provides information on the nature of the investigations carried out at the site, and the rationale involved.

Section 7 gives detailed information about the major cuts, embankments and bridge sites.

2. COMMENTARY

2.1 Structural Geology of Karuah

The desk study, seismic surveys, surface mapping, air photo interpretation and drilling have been integrated to provide a model for the geological setting of the alignment. The model is summarised in Figures 2a-g.

Geologically this area lies to the north of the Hunter Thrust. The main structural features of the area consist of sub-parallel synclines and anticlines trending from north to northwest (Engel 1962). These folds are disrupted by faulting of normal, strike slip and thrust types. The Karuah area lies on the western limb of the Girvan anticline.

West of the river, there is a fault bounded block in the Hunter Water Corporation area. It is likely to be a strike slip fault which bounds the microgranite intrusion here, but has also allowed some upward movement. Such intrusions are common within the Carboniferous sedimentary sequence in this area.

The Karuah River is the major feature in the area. This is part of the Port Stephens inlet, which is a drowned river valley. The river system is likely to have followed weakness in the underlying geology. BH-217 has encountered faulted material at the edge of the wetland area. The steep jointing within the faulted section indicates the fault to be of strike slip.

There is evidence of the fault in BH-112S, with gouge material at depths of greater than 23 m. This is inferred as a fault running northwest. BH-203 contains a vertical joint set which is also indicative of strike slip faulting.

The topographical highs of the saddles may be fault controlled. These faults would trend in the region northwest, as is often found in areas with strike slip faults (also known as wrench faults).

BH-113S is highly fractured. The most likely explanation for these joints is the presence of a fault, as these joints are not found in BH-114N, which is within the same ridge system and at the same topographical level. Any fault would be expected to follow the same direction as the joints, that is, in a northwest direction as determined from the down hole geophysical investigations.

BH-114N had a high angled fault (high angled joints and gouge) at approximately 10 m depth. This may be bounding the high ground and the system, which controls the creek direction.

Horse Island appears to be terminated as noted in the section on air photograph interpretation. This may be due to the underlying structural geology, which controls the direction of the river, with a dominant north-west fault system, being cross cut by an east-west fault to the north of Horse Island.

The Karuah Red quarry at the eastern end of the alignment contains classic fault planes, one strike slip and one thrust fault, both of which are trending to the northwest. These fault systems may well control the high ground along the alignment and the curvature may be due to an east-west set (similar to the truncation of Horse Island).

2.2 Topsoil

The topsoils along the alignment are generally loose clayey to silty sands or sandy silts. They are susceptible to becoming waterlogged and the investigations, especially for the drilling rig were controlled by accessibility of tracks after rainfall. The depth of topsoil is generally in the range 0.1 m to 0.5 m. It is at the thicker end of the range in level or low lying areas such as at the beginning of the alignment or the flood plain east of the Karuah River. In the vicinity of Wallaroo Swamp it is up to 0.6 m thick. It is thinner on the hillsides and from Ch 6650 to Ch 6900 there is minimal topsoil cover. An estimate of the topsoil quantities is summarised in Table 1 below.

At cuts, the topsoils may be stripped, stockpiled and reused.

In fills, a number of options are available:

- Strip topsoil and stockpile for reuse on embankments. This removes potentially weak materials from the base of the fill and ensures that the same soil type is replaced in the same area. This may require working in waterlogged soils.
- Strip topsoil along edges of embankments. This reduces the risk of toe failure due to weak materials beneath the embankment without stripping all the topsoil. Stockpiled topsoil could be reused over embankments, although additional topsoil would probably need to be imported. The stockpiles should have a maximum height of 3 m.
- Leave topsoil in place. Place geotextile separation/reinforcing layer over topsoil and construct embankment directly on topsoil. This type of construction is best suited to embankments on soft soil foundations where geotextile reinforcement and other special construction techniques would be required to provide stability.

Testing of pH has been carried out as part of the pedological survey (refer to Volume 4). The soil is slightly acidic, with pH generally ranging from 5.5-7.0. Stockpiling of this material will not cause generation of acid materials. DUAP Guidelines, 1997 (Reference 4) indicate that PASS materials be remediated to pH of 5.5, which is at the lower bound of pH recorded on this project.

Table 1 Summary of Topsoil Quantities

Chainage		Depth (Max)		Nominal Rock Depth (m)	Topsoil Depth (m)
From	To	Cut (m)	Fill (m)		
0	950		7.0		0.55
950	2350	6.0		2.0	0.25
2350	3400		4.0		0.50
3400	3900	12.0		1.0	0.25
3900	4350		7.0		0.45
4350	4950	10.0		1.0	0.25
4950	5000	10.0		1.0	0.50
6100	6650		7.0		0.25
6650	6850	28.0		2.0	0.10
6850	7200		6.0		0.45
7200	7300	3.0			0.25
7300	7950		6.0		0.45
7950	8450	14.0		6.5	0.25
8450	8850		4.0		0.25
8850	9250	5.5		2.0	0.25
9250	9600		6.0		0.25
9600	9800		9.0		0.50
9800	End		8.0		0.25

2.3 Unsuitable Material

The investigations have identified some materials, which are of low CBR and high plasticity. In general these are soft clays which may require some form of treatment to enable its use as fill material. However when compared with the RTA QA specification for earthworks materials, a maximum particle size of 75 mm and a maximum plasticity index of 25% is suggested. On this basis it would be suggested that some of the excavated clay materials will be unsuitable for re-use. However we feel that if plasticity indices of less than 45% are achieved, the material can be reused, provided adequate moisture control and compaction procedures are adhered to.

In general the plasticities are variable, but generally medium-high. Medium plasticity clay materials underlie the majority of the site. It may be pertinent to allow for 10% of the clay material to be considered unsuitable in these areas.

2.4 Subgrade Materials

The soils won from cuts are generally suitable for reuse in fills. Some material from Ch 0000 to Ch 2350 generally has a CBR of 2% or less where it is silty or clayey. Subgrades in this area will need to be stabilised and material won from this area must be placed centrally at the base of fills.

Soil cover in cut areas is generally thin and the material won can be placed in the base of fills with the more competent material won from rock excavation at the base of the cuts used on the outside and upper portions of fills.

2.5 Bulking Factors

In-situ densities of rock materials indicate values in the 2.35-2.6 t/m³ range. This material would be compacted at densities in the range of 2.0-2.2 t/m³. Bulking factors would therefore range from 1.05 to 1.25, with a value of 1.2 being predominant.

Within soil materials in-situ densities have been estimated at 1.45 t/m³, and would be compacted at maximum dry density (MDD) which ranges from 1.5-1.8 t/m³, with 1.7 t/m³ being a typical MDD. Bulking factors in clay soils may therefore be estimated at 0.95 for bulk earthwork calculations.

2.6 Erodibility

Measurement of Emerson Class Number and Pinhole Dispersion tests for samples of clay (which comprise the dominant component of the soil profile) derived from the upper levels of proposed cuts indicated that the materials were generally non-dispersive. This is in contrast to the physical evidence along the alignment, especially east of the Karuah river where incised drainage lines, erosion gullies and generally cloudy natural run-off indicates that the soils are highly susceptible to erosion. Also, reference to Soils Landscapes of the Port Stephens 1:100,000 (Murphy, 1995) indicates moderate to high dispersion potential and high erodibility potential for both topsoil (A horizon) and subsoil (B horizon). It is therefore anticipated that these soils will present an erosion hazard in some areas, and that design and construction should be based on the assumption that the soils are generally erodible.

Isolated profiles of silt and sand rich, colluvial and alluvial soils are potentially more susceptible to erosion. Scour protection measures have been accounted for within the concept design due to the erodibility of the soils. These include lining of culverts and drains.

As a consequence of the assessed risk of soil erodibility, construction works would need to include lined catch drainage at cut crests and intermediate benches. These should be spaced to reflect the respective batter catchment and run-off potential, as well as stability concerns. Prompt surface protection should be provided (such as spray mulch or a temporary bituminous coating) during the excavation process rather than at the end of the works. Suitable vegetation cover of soil batters may be necessary due to the high intensity rainfall conditions of the Central Coast. Similar protection would be required for compacted (unarmoured) fill embankments.

Hydrological studies have been conducted on the Karuah River. There are signs of existing erosion on the east bank of the river and there is some potential for this bank to retreat further. Suitable erosion protection measures should be constructed at this abutment

Further laboratory testing should be undertaken in construction stage investigations to assess erosion potential.

2.7 Fill Batters

The fill batters have been assessed on the basis of both the geotechnical information and the working design. The batter details are summarised in Table 2 below.

Table 2 Summary of Fill batters

Approx Chainages		Approx Height (max)	Fill Slope		Berm Width (depth)	Topsoil & unsuitable (m)	Comments
From	To		H<3*m	H>3m			
Start	1600	7.0	1V:4H	1V:3H	NA	0.55	Subgrade could be unsuitable due to moisture content
2400	3400	4.0	1V:3H	1V:3H	NA	0.50	Subgrade could be unsuitable due to moisture content
3900	4350	7.0	1V:4H	1V:2H	NA	0.45	Subgrade could be unsuitable due to moisture content
4950	5000	10.0	1V:2H	1V:2H	NA	0.50	
Horse Island		13.0	1V:2H	1V:2H	NA	0.25	
6100	6600	7.0	1V:4H	1V:2H	NA	0.25	
6900	8000	6.0	1V:4H	1V:2H	NA	0.45	Subgrade could be unsuitable due to moisture content
8450	8850	4.0	1V:4H	NA	NA	0.25	
9300	9600	6.0	1V:4H	1V:2H	NA	0.25	
9600	9800	9.0	1V:4H	1V:2H	NA	0.50	
9800	end	8.0	1V:4H	1V:2H	NA	0.25	

Note: the fill slope angles relate to the local material and not necessarily the fill embankment at that location

From stability considerations, cut and fill batters of 1:2 (vertical:horizontal) would generally be suitable for the soils found along the alignment. Steeper batters of 1:1.75 (vertical:horizontal) could be used for crushed rock fills on competent foundation soils or rock.

However due to the potential erodibility of the soils on the alignment, it is recommended that cut and fill batters of 1:4 (vertical:horizontal) be used for the soils where erosion is expected to be worst (unless the slope surfaces are stabilised). The batter angles are indicated in Table 2, and relate to both the information gained during direct investigations and also observations during the site walkover, such as the locations of erosive soils.

Settlements have been assessed for embankments at Wallaroo Swamp, Horse Island and the AMP Embankment I. Settlements of 15-50 mm are anticipated beneath these embankments. These total settlements, and time-dependant consolidation settlements, are not considered significant for general embankment construction.

Special measures such as the use of basal reinforcement may be required in the Wallaroo Swamp area although current indications are that this is unlikely.

The base of fills on slopes must be benched before filling proceeds.

2.7.1 Wallaroo Swamp

It is considered unlikely that the project will have an adverse effect on groundwater quality generally, provided adequate erosion and stormwater management measures are taken. This is due to both the impermeable nature of the clayey soils and the lack of groundwater within test pits and boreholes during the Phase 1 investigations.

In the vicinity of Wallaroo Swamp two boreholes have been drilled to rock, and two test pits have been excavated to depths of approximately 4.5 m. Within these locations there was no evidence of groundwater seepage. The subsoil conditions in this area are composed of sandy clays overlying bedrock. The bedrock consists of a microgranite. The depth of sandy clay overlying the weathered bedrock is approximately 5 m. Within this material greater than 50% of the particles pass the 75 micron sieve size, and samples of this clay from other areas on the site have a considerably higher fines content. The permeability of such clays would be of the order of 10^{-7} m/s (3 m/yr) which is a low permeability.

This material generally acts as an aquitard and will prevent the flow of subsurface water. It is this material which prevents the infiltration of rainwater and caused the buildup of the surface water which is now Wallaroo Swamp. The natural drainage of the area is towards the Wallaroo basin (ie towards the northwest) as overland flow.

Due to the absence of significant observed groundwater flow in the area, the main issue in the vicinity of the swamp will be to preserve the pathway for surface drainage towards the swamp. To achieve this it is recommended that the basal layers of the embankment be constructed from granular fill materials with a fines content of less than 10% (ie less than 10% passing the 75 micron sieve). Actual thickness of the drainage layer will have to be calculated based on anticipated overland flow rates. This will allow the drainage of materials to continue in a slow fashion towards the swamp, in addition to allowing the embankment improved consolidation characteristics. Alternatively culverts may be required to accept flood flows.

2.8 Cut Batters

Downhole geophysical surveys have been carried out to assess the discontinuity orientation of rock material within cut areas. This data is included within Volume 3, and the joint orientation data is summarised in the stereoplots in Figure 4a-h. It is possible that some joints have been missed by the investigation, and further investigations can include oriented boreholes to intercept steep joints. The available stereoplots have been assessed in terms of planar, wedge and toppling failure. This information has allowed analysis of slope stability to be carried out. A summary of the batter angles and slope designs is included in Table 3 below.

From stability considerations, cut and fill batters of 1:2 (vertical:horizontal) would generally be suitable for the soils found along the alignment. However due to the potential erodibility of the soils on the alignment, it is recommended that cut batters of 1:3 (vertical:horizontal) be used for the some of the cuts in soils unless the slope surfaces are stabilised (see Table 3).

Table 3 Summary of Cut Batters

Approx. Chainages		App. Depth (max)	Nom. Rock Depth	Top			Middle			Lower			Dish Drain Width	Verge Width	Topsoil Removal
From	To			Depth Range	Slope	Bench Width	Depth Range	Slope	Bench Width	Depth Range	Slope	Bench Width			
1000	2350	6.0	2.0	0 - 2m	1V:3H	NA	>2m	1V:1H	NA			NA	1.0	1.0	0.25
3400	3900	12.0	1.0	0 - 1m	1V:3H	4m (@1m)	>1m	2V:1H	NA			NA	1.0	2.0	0.25
4350	4950	10.0	1.0	0 - 1m	1V:3H	NA	>1m	4V:1H	NA			NA	1.0	1.0	0.25
6650	6850	28.0	2.0	0 - 2m	1V:2H	4m (@1m)	2m - 5m	2V:1H	4m (@5m)	> 5m	4V:1H	4m (@7m)	1.0	2.0	0.10
7200	7300	3.0	NA	all	1V:3H	NA			NA			NA	1.0	1.0	0.25
7950	8450	14.0	0.5	0 - 2m	1V:2H	4m (@2m)	2m - 7m	2V:1H	4m (@7m)	> 7m	4V:1H	4m (@7m)	1.0	2.0	0.25
8850	9250	5.5	2.0	0 - 2m	1V:2H	NA	>2m	4V:1H	NA			NA	1.0	1.0	0.25

In general cut batters of 2:1 (vertical:horizontal) can be used in the weathered and fractured zones and 4:1 (vertical:horizontal) can be used in the medium to high strength rock. The cuts have been battered according to slope height and to the material type present. Benches are provided at 7m vertical intervals and the base of the slopes will have dish drains and verge widths related to the materials within the slope. It is anticipated that spot bolting will be required in rock cuttings to stabilise isolated wedges. The location of these wedges will need to be decided during excavation.

In the Saddle Cut, groundwater has been encountered at a depth of 18 m in BH-213. With this piezometric pressure it is possible to cause some heave at the base of the excavation. This would require further investigation prior to construction. The piezometric pressures can be reduced by the installation of relief wells, to the level of the core loss in BH-213 (ie 34 m BGL). It may also be possible to place subhorizontal drainage holes within the cut.

Within the Saddle Cut, there will be stress relief upon excavation of the overlying rock. The lateral stress within the rock will then become concentrated in the rock immediately beneath the road pavement. These stresses may lead to displacements in the subgrade, especially if high angled joints are present. Lateral stresses in the rock in the Saddle Cut need to be addressed within pre-construction investigations.

2.9 Bridge Crossings

The seismic surveys indicate that for the bridge crossing west of Horse Island rock occurs at approximately -10 m AHD, with a deeper channel around Ch 5220. Saturated soils occur above the rock head and it is therefore difficult to assess the consistency of this soil.

The bridge crossing of both the SEPP 14 wetlands and the Karuah River will involve piled foundations. The boreholes and the seismic profile over this area indicate a variable geology. On the east of the river section the piles will be founded in rock material (either sandstone, conglomerate or shale). On the west of the river section piled foundations will be founded in gravels, which appear to be dense and did not allow penetration by the drilling rig used in this investigation. The upper loose soil horizons should not be considered for support in the design of the piling operations.

The seismic survey indicates that the gravels at the western side of the river section are of similar velocity to the rock materials on the east of the river. The seismics have not differentiated the gravel and rock strata, and therefore it would be necessary to confirm the investigations in this area with deep boreholes, which would involve drilling the gravels with large diameter ODEX drilling.

The ground conditions over the river section are variable and the pile will be founded in either rock or gravels. It is therefore pertinent to use a piling method suitable for both conditions. Bored piers could be used within the rock material. However, this will involve the removal of PASS material, which would require treatment or disposal. Driven precast piers could be used and driven to refusal. The favoured option of concept design is the use of driven steel tubes, which will be suitable in both the rock material and gravels, and will not require removal of PASS.

Piers in the river section will need to account for river scour, due to the granular nature of the soils at the top of the piers.

The remainder of the bridges will be founded within rock material at depth by piled foundations. Either bored piles or precast driven piles may be used to drive through the clays, to the underlying bedrock.

Where driven piling is used it may be pertinent to limit noise by using a resilient pad (dolly) between pile and hammer head. It may also be possible to enclose the hammer head in a temporary acoustic shroud.

2.10 Alternative Alignments

Two alternative alignments through the saddles east of the river have been considered and from purely geotechnical considerations the northern alignment would generally appear to be the more favourable for the following reasons:

- The alluvium from the abutments to the saddles is both shallower and of higher strength on the northern alignment. This will mean smaller embankment settlements, smaller differential settlements at the abutment and less likelihood of embankment instability on the northern alignment.
- The height of embankment is lower on the northern alignment, once again leading to lower settlements, less risk of embankment instability and lower cost.
- The depth to rock for the river crossing is also reduced over a section of the northern alignment.
- The rock quality and joint orientation in the northern saddle is more favourable and allows for steeper batters with less risk of local instability. The disadvantage of this better quality rock will be more difficult excavation, however both saddles may require blasting.

2.11 Sources of Materials

Current commercial sources of materials were discussed in the preliminary geotechnical report. Essentially pavement materials could be sourced from the quarry at the eastern end of the alignment and from Raymond Terrace. An assessment of reserves for the road will need to be made once preliminary quantities of pavement materials are known.

2.11.1 East of the Karuah River

Pavement quality materials could probably be sourced from the saddles around Ch 6800. East of the river, the existing Karuah Red quarry is probably the most suitable source, though it would be necessary to utilise the new quarry at this location (as the existing quarry produces high-grade expensive stone). This material is of rhyodacite, dacite and microgranite. Similar material will be excavated from cuttings in the AMP land. This material does not appear to be high in deleterious materials or clay minerals.

According to the EIS for the quarry, total reserves of base material, gabion rocks, select fill and fine crushed rock are in excess of 2.2 million tonnes. Annual production is estimated at between 250,000 to 500,000 tonnes, giving sufficient material for five to ten years of operation. This would be sufficient for the requirements of the Karuah Upgrade.

Design stage investigations should include sampling and testing of existing quarries to assess their suitability as pavement materials.

2.11.2 West of the Karuah River

If pavement construction materials for construction on the western side of the Karuah River are obtained from the existing quarry at the eastern end of the alignment (Karuah Red) the requirement may exceed reserves. Also the pavement materials would need to be trucked through the town of Karuah to the east of the alignment.

The alternative of sourcing the materials from Newcastle (Boral Quarries or Metromix Steelstone), Seaham (Boral Country) or Salamander Bay (McAndrew Collins) will mean a longer haul route on the Pacific Highway.

A potential source of suitable construction materials can be found on or near Powell's property in the vicinity of Ch 4500. The source is close to the alignment and away from existing developments and the impact of a quarry in this area could be mitigated. The rock in this area comprises medium to high strength siltstone and sandstone and conglomerate. The conglomerate has rounded igneous clasts in a sandstone matrix and is clast controlled. The conglomerate will need to be crushed due to both the rounded nature of the clasts and the potential lack of fines in the matrix. The extent of reserves could be assessed for detailed design or earthworks volumes.

2.12 Groundwater

During Phase 1 investigations, the boreholes and test pits were largely dry during the field period. Seepage was noted in some test pits and these may have formed a static water table if the pits had been left open.

Hand dug pits within the Wallaroo Swamp area indicate seepage at depths of 0.2 to 0.3 m. The seepage is above the silty CLAY, which may represent an aquitard. Given the topography and the drainage patterns of the area (ie drainage towards the swamp), it is likely that any excavations in this area will experience inflow of water. This will apply to sedimentation basins in this area, which will be unlined and will be constructed above current ground level in the permanent condition.

In BH-213 at the northern saddle groundwater was encountered at a depth of 18.2 m within the hole. It therefore appears that groundwater may be of concern in the rock slope stability analyses. The berms at 7 m height increments will incorporate drains, which will remove water from the cut face and improve stability.

2.13 Excavations in Rock

Cuts beyond Ch 2300 will generally require excavations in rock. In general, the rock encountered on the alignment is medium to high strength horizontally or sub-horizontally bedded and relatively massive. Excavation in rock will therefore require heavy ripping, presplitting or blasting. The rock will be suitable for use as fill when sufficiently crushed. Batters in rock will vary from 2:1 to 4:1 (vertical:horizontal) depending more on the defect spacing and orientation than on the rock strength.

The EPA provides guidelines for the assessment of blasting vibration and overpressure noise with regard to human comfort based on the Australian and New Zealand Environment Conservation Council guideline entitled *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration*. Criteria are specified in terms of time of day, overpressure noise levels and blast vibration levels for operations involving the repeated use of explosives. The guidelines may be varied according to local site conditions. Conformance to limitations of peak particle velocity and minimisation of air blast may require procedures such as maximum instantaneous charge, reduced hole diameters, optimisation of blast design (drilling pattern, delay layout, hole inclination) and consideration of atmospheric conditions. Reference should be made to the acoustic report within the EIS for further information on this topic.

Large excavations in rock should also take account of in-situ horizontal stresses. In-situ stress fields can be different from the general regional pattern (eg Kangy Angy) with high but variable sub-horizontal stress fields with respect to depth and the maximum stress field oriented parallel to the axis of ridges. The horizontal stress may be twice the vertical stress in this area.

Bulking factors in rock material can be taken as 1.2 for estimation of earthworks volumes.

2.14 Pedogenic Materials

Pedogenic material in the form of silcrete was found on Horse Island and in the boreholes and test pits on the east bank of the Karuah River. On Horse Island the silcrete occurs as a ridge on the eastern side of the island. It forms a hardpan layer that has been undercut by erosion of the underlying sands. On the east bank of the river it occurs as a hardpan layer at a depth of up to 5 m below ground level. It is not known how persistent this material is.

This has the following impacts on the road and structures where it occurs:

- Installation of preformed driven piles could be difficult as the piles could refuse. Pile settlement due to settlement of underlying softer sediments could occur. However large diameter driven steel tubes should penetrate this material.
- The silcrete will affect the installation of bored piles. These piles will probably need to be cased in the water bearing soils above and below the silcrete. Installing casing through this material could be problematic.
- Depending on the extent and thickness of the silcrete it could affect the performance of embankments constructed on the surface. Total settlements will be reduced, but differential settlements may arise depending on the extent of the material.
- Hardpan silcrete can be difficult to excavate in cut, and hard ripping or even blasting may be required. The material will however be suitable for use in fill.
- Differential settlements of pavements could result where the material is discontinuous and settlements occur where the material is absent.
- The material generally forms an aquaclude and seepage can occur in cuts where perched watertables could occur immediately above the silcrete.

2.15 Acid Sulphate Soils and Sulphate Attack

Potential acid sulphate soils (PASS) have been identified in the wetlands and Karuah River approximately from Ch 5000 to Ch 6200 and Ch 9800 to Ch 9900. These are dealt with in detail in the pedological and contaminated soils survey report in Volume 4. In addition, the geotechnical investigations indicate the possible presence of PASS in the subsoils on the east bank of the river.

In these areas special precautions need to be taken to ensure that construction operations such as earthworks, piling and other forms of ground disturbance do not generate acid sulphates.

The geotechnical investigations also established the need to use sulphate resistant cement for the bridge structures at the Karuah River. Further testing will need to be carried out at other locations in the second phase of investigations once the position of underpasses and the like have been finalised.

As an integral part of the investigations, samples were analysed from pits to assess the regional distribution of PASS materials. This testing work should not be regarded as the conclusion of the ASS/PASS testing rather it should be the initial round intended only to provide a regional appreciation of the PASS risk.

These analyses indicate that the low-lying areas in the SEPP 14 wetlands and in the Karuah River channel should be considered as PASS. The extent of the PASS appears to be from Ch 5000 to Ch 6195.

2.15.1 Management of acid sulphate soils

Before construction a detailed acid sulfate management plan (ASMP) will be required to cover all projected excavations involving ASS/PASS materials. This will include both pre-construction testing protocols, monitoring of both ASS/PASS during excavation (for liming rate control) and water quality monitoring of flowing waters, leachates and groundwaters both prior to and during construction.

Further site specific ASS testing will need to be carried out during the final design geotechnical investigations once the route alignment is finalised within the EIS process. This testing will target those areas involving either large volumes to be excavated, particularly for the realignment and reconstruction of major and minor drainage lines, or those sites that have had no testing in close proximity to date.

From data currently available recommended liming rates are included within the report included in Volume 4. This was based on nearest available test pit data.

The results of testing during the geotechnical investigations of the finalised route will be incorporated into a final ASMP to provide detailed recommendations for site specific remedial or precautionary works. An ASMP template is included in Volume 4. The following provides an initial framework ASMP with recommended management options.

a) No excavation – Minimal earthworks

This is the principal recommended management option for those areas where PASS materials are:

- too voluminous to remove and rebury, or
- too difficult to remove and neutralise with lime, or
- where there would be too much risk of contaminating groundwater, or
- where the geotechnical properties of the soils demand deep driving of load bearing piles as the best combined solution.

This option is being implemented within this project. Driven steel tube piles are recommended within the bridged area (ie Ch 5000 to Ch 6195). This piling technique will involve displacement of the PASS materials and avoid their excavation.

b) Controlled Excavation and Treatment

This option has two parts. Firstly substantial voids left by excavation of PASS materials, if not promptly filled will cause surface water or groundwater to pond and an acid risk will ensue. If such voids are temporarily unavoidable, then the side and bottom should be treated with neutralising materials. Secondly, if excavated ASS/PASS materials are to be left above ground (such as in a temporary stockpile or

embankment), or disposed of by any means other than immediate burial below the water table, these should be treated with neutralising materials; thorough mixing is a necessary requirement for this option. A number of points follow:

For monitoring of excavations during construction, and for better spatial analysis for a fixed budget, the more cost effective TPA method is recommended, with 1 in 5 or 1 in 10 POCAS as a check.

The recommended neutralising material for mixing into soils is medium to fine aglime, which is fine ground (at least <1 mm) calcium carbonate or calcite (limestone or marble). This need not be pure, and whatever dosage is calculated for pure calcite, a factor of 100/NV is used as a multiplier to correct for less than 100% purity. (NV or neutralisation value, is a chemical measure of calcium carbonate content. For pure calcite rocks such as marble or limestone NV is 100.) Coarse grained calcite is not recommended, as one of the products of the neutralisation is gypsum ($CaSO_4.2H_2O$) which has a relatively low solubility and tends to coat the reacting calcite grain, forming a partial barrier against further reaction.

Dolomite is not recommended for neutralisation. It will certainly neutralise acidity, but half of the dolomite produces hydrated calcium sulfate ($CaSO_4.2H_2O$) and half produces hydrated magnesium sulfate ($MgSO_4.7H_20$). The solubility of the former is just 2.1 g/L of water, and hence cannot build up a high salinity in any leachate, but that of the latter is 364 g/L, and this can and will affect the overall water quality.

Mixing of aglime with ASS/PASS materials may pose a problem. Gently sloping liming pads of appropriate area should be planned for, near each site requiring liming of appreciable volumes of soil. In this study area it is suggested that this be constructed adjacent to the bridge abutment at approximately Ch 6200. A basal layer of lime should be placed first (the kg/m² liming rates being determined from the assessed acid generating potential) whereafter 150 mm to 200 mm layers of PASS materials should be spread, lime applied, then harrowed and the sequence repeated until all materials are limed.

Sandy, low clay or freely draining soils will dry readily, and a safety factor of 1.5 should be applied to the determined liming rate, multiplied by 100/NV. For moderately clay rich soils, which will not dry and mix well, a safety factor of 2 should be applied to the liming rate. For clays and clay rich soils, the safety factor should be at least 3, and the spread layers should be no thicker than 150 mm.

Liming pads of any size should be either bunded off, or a circumferential drain dug to collect and localise leachate. This should be monitored daily until time trends are established and a calcium hydroxide solution used for spot neutralisation if required.

Since acidity is transported by water, construction requiring large volume earthworks is best planned for the dry periods in the annual hydraulic cycle. This minimises the risk associated with sudden or heavy rain, allows better control of treated waters for discharge, and provides some safety for unattended weekend periods.

It is thought that only minor amounts of PASS material will be excavated on this project. This material could be incorporated in the embankment, provided that some treatment has been applied as outlined above.

2.15.2 Groundwater monitoring

It is recommended that a series of groundwater monitoring stations be placed either side of the bridge and in the SEPP 14 wetland area due to its sensitivity. Monitoring should commence as soon as practicable to allow baseline measurements to be taken.

It is envisaged that monitoring would be carried out frequently during construction (daily for stockpiles and permanent embankments of PASS materials), with a progressive reduction in monitoring frequency once time trends are established. Monitoring should continue in the long term after construction. Parameters tested should include pH, aluminium and iron, sulphate and TDS.

2.16 Contamination Survey

As part of the Phase 1 investigations ADI Ltd carried out a desk study and walkover survey. The report of this survey is contained within the Volume 4. In summary, the major potential contamination issue is the impact of the disturbance of PASS (as discussed in the previous section). Metal and organic contaminant concentrations in riverbed sediments are substantially lower than ANZECC and NHMRC (1992) environmental guidelines.

Surface water samples were analysed and some parameters gave values exceeding ANZECC (1992) water quality guidelines. Concentrations of aluminium (Al) exceeding guidelines were found in samples from creeks and dams around Ch 6400 and Ch 7400. The high Al concentrations are associated with leachate from the region's aluminium rich clay soils. The pH of the soil in the area was between 5.0 and 6.0 and the pH of the surface water ranged between 6.6-6.9, indicating leaching has occurred under slightly acidic conditions.

Concentrations of iron (Fe) exceeding ANZECC (1992) water quality guidelines for fresh water found in surface water samples taken from the majority of the locations. The source of high Fe concentrations is the pyritic soils of the area.

2.17 Construction Issues

The geotechnical investigation highlighted several issues, which will affect the construction progress. The investigations began after several days of rain. Transport around the site was quite difficult and it was decided to complete test pits with a tracked excavator. The soil is of medium plasticity in places and when this material became wet, access became very difficult.

The site tends to take some time to dry out after a wet period. However, dust control will be required during dry weather. This was noted near the end of Phase 1 investigations, when the site had experienced three weeks of uninterrupted good weather.

Access to Horse Island will present difficulties due to the wetlands, which surround it. The wetlands are protected under SEPP 14. Aside from this, the wetland material is very soft and will not support a vehicle unless it is extremely dry. The area is tidally influenced.

Unsuitable material has been assessed earlier within this section. Given the volumes of material to be excavated and the small relative volume of material, which has been investigated, it is likely that some unsuitable material will be encountered. Contractors should conduct further investigations pre-construction to make further assessment of this issue.

Wallaroo Swamp embankment will involve construction works on the edge of the wet area. Standing water has been observed during both the API and walkover phase. This area could provide particularly difficult work access if adverse weather conditions are encountered.

2.18 Further Investigations

The geotechnical site investigations have been planned as a phased operation due to constraints placed on some segments of the alignment and cost efficiencies that can be gained in others. Further investigations are outlined below.

- **Chainage 0-950:** Once the alignment issues have been decided for the over/underpass, boreholes will be drilled at specific pier locations in a further phase of investigation, in accordance with RTA requirements. Additional test pits will also be required for the exit ramp.
- **Chainage 950-2350:** Once centreline access can be obtained along the route additional boreholes and test pits will be required to provide the required frequency of investigation points along the alignment. Slake durability testing should be carried out to assess the potential for rock within the cut to break down upon exposure.
- **Chainage 2350-3400:** In this area it may be pertinent to place a borehole centrally within the swamp area to provide information on soil stiffness with depth.
- **Chainage 3400-4350:** Additional boreholes and test pits will be required to complete the investigations in this area once centre-line access has been obtained. Slake durability testing should be carried out to assess the potential for rock within the cut to break down upon exposure. Further testing of erodibility of soil should be carried out.
- **Chainage 4350-5050:** Additional boreholes will be required in this area to complete the investigations once centre-line access has been obtained. Slake durability testing should be carried out to assess the potential for rock within the cut to break down upon exposure. Further testing of erodibility of soil should be carried out.
- **Chainage 5050-5400:** On completion of the bridge concept design, boreholes will be drilled at the specific pier and abutment locations. Further investigations will require careful planning and close liaison with the various authorities due to the sensitivity of the area. Within the river gravel it may be necessary to use large diameter ODEX drilling techniques, as conventional drilling was difficult in this material.
- **Chainage 5400-5580:** Further boreholes and test pits will be required on Horse Island to assess parameters for embankment design. The additional investigations will need to assess the persistence of the pedogenic materials here.

- **Chainage 5550-6200:** On completion of the bridge concept design a second phase of the investigation will be carried out involving the drilling over water boreholes at the specific pier locations. Due to the presence of dense gravels, large diameter ODEX drilling will be required to assess the nature and thickness of the gravels and the depth to the underlying rock.

- **Chainage 6950-7200:** Inclined boreholes should be drilled to provide joint orientation data on steep angled discontinuities within this rock cut. Further drilling using downhole geophysical techniques would also be required to provide in-situ joint orientations. Lateral earth pressures should be assessed (as set out in Section 2.8). Slake durability testing should be carried out to assess the potential for the rock material in the cut to break down upon exposure. Further testing of erodibility of soil; should be carried out.

- **Chainage 7900-9500:** Inclined boreholes should be drilled to provide joint orientation data on steep angled discontinuities within rock cuts. Further drilling using downhole geophysical techniques would also be required to provide in-situ joint orientations. Slake durability testing should be carried out to assess the potential for the rock material in the cut to break down upon exposure.

- **Chainage 9500-10500:** Further test pits and boreholes will be required in this area if access can be obtained in drier conditions to provide information on the geological profile around the swamp, and at specific pier locations.

3. THE PROJECT

This report describes the results of geotechnical investigations carried out to provide EIS and concept design stage information for the realignment of the Pacific Highway at Karuah. The proposed route is shown in Figure 1a.

The alignment commences approximately 3000 m west of the Amoco Service Station on the Pacific Highway. Initially the route is sub-parallel to the existing highway, and turns northeast at Ch 0950. The alignment cuts east across Horse Island and arcs around the high ground adjacent to the Branch Lane, before rejoining the Pacific Highway. The route is 10.5 km long.

The alignment involves five areas of embankment, six areas of cut and two major bridges over the wetlands and river section adjacent to Horse Island.

These discrete areas based on the proposed alignment consist of the following:

Table 4 Proposed Alignment

Chainage (m)	Area
0000 – 0950	Pacific Highway Embankment
0950 – 2350	State Forest Cut I
2350 – 3400	Wallaroo Swamp Embankment
3400 – 3900	State Forest Cut II
3900 – 4350	Powell's Creek Embankment
4350 – 5050	Powell's Cut
5050 – 5300	West Horse Island Bridge
5300 – 5600	Horse Island Cut
5600 – 6150	Karuah River Bridge
6150 – 6200	Bridge Abutment
6200 – 6650	AMP Embankment I
6650 – 6900	Saddle Cut
6900 – 8050	AMP Embankment II
8050 – 8500	AMP Cut I
8500 – 8900	AMP Embankment III
8900 – 9500	AMP Cut II
9500 – 9950	Branch Lane Embankment
9950 - 10500	Pacific Highway Re-entrance

Alternative alignments were considered over the course of the route. Two separate options were assessed as part of the Phase 1 geotechnical investigation.

4. DESK STUDY

4.1 General

A desk study was carried out to provide a preliminary assessment of the ground conditions at the site. The findings of the desk study have enabled the investigation to focus on certain areas and issues, in addition to providing an overall assessment of the prevailing ground conditions. The desk study involved the following:

- review of geological literature;
- aerial photographic interpretation;
- review of existing reports

4.2 Review of Geological Literature

The following sources of geological information have been used:

- NSW Geological Map 1:250,000;
- Soil Landscapes of Newcastle;
- Engineering Geology of the Newcastle Gosford Region;
- Liaison with Geology Department of UNSW and University of Newcastle.

4.2.1 Geological Maps

The geology of the alignment is shown in the Geological Series Sheet S1 56-2 1966 (Newcastle). There appear to be two distinct geologies in the study area, with the Karuah River forming a natural division between the two. The map shows the alignment to be overlain by "Undifferentiated" Carboniferous Sediments - "mostly clastics with some volcanics". East of the river the map indicates the presence of Nerong Volcanics, described as Carboniferous in age and including rhyolite (toscanite), dacite, andesite, ignimbrite, agglomerate, conglomerate, sandstone and siltstone. The geological map is based on large-scale mapping and aerial photography. The area itself has not been mapped in detail and therefore the geology is best assessed from a field mapping exercise, as carried out during these investigations. The area has been divided into the field mapping units indicated on the geological map presented in Figure 2(a-f), and these maps also show the aerial photography analysis.

4.3 Aerial Photography Analysis

The alignment has been assessed by aerial photography interpretation (API). Aerial photographs taken at a scale of 1:8000 were analysed under stereoscope. The route was flown on 19 July 1998, and the visibility is good. This technique allows the ground conditions to be assessed from an aboveground three-dimensional perspective. The findings of the analyses are given below in order of chainage.

4.3.1 Ch 0000 - 1000

This area is parallel to the existing Pacific Highway. At the time the photographs were taken, this section was exposed by construction works enabling assessment of the sub-soils to be made. The area drains towards a creek at approximately Ch 800. The soil in the area around the creek appears to be soft in consistency, as there are vehicle marks in the soils adjacent to the creek, indicative of soft or wet soils. The upper soil strata are likely to be impermeable, which would indicate fine grained soils such as clays. The topography is smooth and undulating, with differences in levels of approximately 5-6 m over this section of alignment. This may indicate that rock is of variable depth at this location. Given the slope gradients it is possible that soil erosion could be an issue.

4.3.2 Ch 1000 - 2500

In this area the land is densely forested. The soils in this area are likely to be clayey in nature. The topography is composed of gently rolling hills and valleys. The drainage beside the existing forestry tracks seems to be quite incised. This would suggest that the soils are both soft and erodible. This would indicate the presence of a clay subsoil, which is soft when wet but erodible by both water and wind during dry periods.

There is a topographical ridge, which runs through the alignment at approximately Ch 2000. This ridge trends east -west and is likely to represent an area of shallow bedrock, which lies at the crest of a hill. The drainage patterns diverge either side of the ridge. This ridge is a local watershed. The ridge falls away steeper on the north, indicating that the rock will also fall away in this direction. This scarp may represent a fault line preserving a harder stratum, possibly with a change of rock type to the north.

4.3.3 Ch 2500 - 3500

To the west of the alignment in this area there is a wetland area (Wallaroo Swamp). There is standing water on the surface. The drainage of the general wetland area is related to the topography. The wet swamp area forms the low ground and this is fed by a system of drainage channels and overland flow from the higher ground to the north, south and east. The wetland area is west of the alignment and is likely to consist of impermeable upper strata, which do not allow the infiltration of the surface water. The swamp area is enclosed and therefore the water simply ponds and accumulates fine sediment in suspension. The alignment itself does not have standing water, but due to the proximity to the swamp it may contain impermeable soft sediments.

To the east of the alignment (in the Hunter Water Property) there is a prominent topographic high. This represents a block of competent rock with side slopes that are at a consistent angle (approximately 20°). This slope represents the colluvial degradation of the parent bedrock. This feature is a discrete element within the landscape and does not relate to the gently rolling hills and valleys, which surround it. It is likely that the bedrock is of different origin to the rest of the alignment west of the river. The block trends northwest and while the high ground appears to be of discrete rock material, the rock type may continue sub-surface under the alignment (and extend towards Wallaroo Swamp).

Through the forest tracks in this area there are many vehicle marks, including a chaotic set in the centre. This indicates the tracks to be occasionally saturated. This would indicate that the soil materials are impermeable and generally fine grained. The nature of the rutting would also suggest the soils to be erosive.

4.3.4 Ch 3500 - 5100

The alignment rises in this section from the topographic low of the wet area, to one of hills and valleys. The slope angles in this area are generally steeper than those in the section south of Ch 2500. The drainage system is also essentially different in that it is cut by incised channels. This would suggest that the soil cover is thin in this section, and that bedrock can be expected closer to surface. The drainage pattern is more likely to be related to the jointing pattern and planes of weakness within the rock material, than due to the topographical constraints.

4.3.5 Ch 5050 - 5300

The alignment is in an area of wetland, which contains standing water. The standing water is likely to be the ground water level. The vegetation on the surface is indicative of mangrove swamps and would suggest the area to be tidally influenced. The wetland is adjacent to the river. The groundwater regime is likely also to be saline. This would have an effect on the susceptibility to corrosion of the structures in this area.

The gradient of the slope from the landside (ie the Powell Property) is approximately 25°. This is in contrast to the slopes in the section from Ch 3500 to Ch 5100. The rock profile is likely to fall away, and it is probable that the depth to bedrock beneath the wetland area will be deeper than the previous section. From an estimate of the slope of the rock between the land and that on Horse Island it is possible that the rock-head may be at a depth of greater than 10 m below the wetland surface.

The wetland formation is likely to have been slow to allow the vegetation to develop. It is likely that the sediments within this area have been deposited by relatively slow moving water. Such deposition is likely to involve unconsolidated sands, silts and clays. These soils will be saturated over this section.

A causeway over the section to the northwest of the alignment indicates that the surface is of low strength and requires improvement to allow human transit.

4.3.6 Ch 5300 - 5600

Horse Island stands isolated in the river. It is a prominent feature on the landscape and as such must represent a competent material, as it has resisted the erosive abilities of the Karuah River over recent geological time. The structural trend of the island is northwest to southeast, however the geomorphology is unusual in that there is a dogleg feature. This is also related to the meander in the Karuah River to the north of the island. The meander may be related to a cross cutting fault system, which runs east-west.

There is a definite cliff face, approximately 5 to 8 m high at the eastern side of the island on the alignment. The cliff stands at a high angle (approximately 45°) and is likely to be composed of competent material. There is out crop of rock material in the wave cut platform at the base of the cliff. The western side of the island appears to rise at a shallower angle. The rock therefore appears to dip away from the platform at the east of the island at a shallow angle towards the southwest.

4.3.7 Ch 5600 - 6200

The alignment is again over wetland. The mangrove vegetation in this section is denser than Ch 5100 to Ch 5300. The rock is quite shallow at the eastern side of the island where a rock platform can be observed. The soil materials will be composed of unconsolidated sands, silts and clays. The rock is likely to fall of steeply at the start of the river section.

The river section appears to indicate that the rock material will be at considerable depth below the surface. It is beyond the scope of aerial photography analysis to estimate the depth to rock over this section. The river crossing will be directly after the river meander. It is likely that the river will erode more on the east of the channel and deposit material on the west. Therefore the depth to bedrock may be deeper to the east of the channel.

4.3.8 Ch 6200 - 6600

The Karuah River flood plain extends over this section. The topography consists of a steep cliff face of approximately 2 m height at the river shore. The flood plain is quite flat until Ch 6275. Beyond this point there is a slight gradient which remains constant.

The presence of mature trees at the shoreline, and the mangrove growth in the tidal zone, indicates that the shoreline is not receding quickly. This may be due to the presence of a competent layer within the cliff face. Such a competent layer would not be expected in a shallow flood plain. The flood plain sediments from the river and related drainage systems would normally consist of unconsolidated soft/loose sediments.

There is a drainage channel, which flows from the high ground to the east towards the southeast. From Ch 6800 on the northern saddle alignment this channel is a narrow creek, with soft saturated soils in its immediate vicinity. However after approximately Ch 6350, the creek slows down as it meets the flat topography and an alluvial fan type deposit has formed. This area has a high perched water table. The drainage channel is likely to have caused deeper soft sediments on the southern saddle alignment than on the northern alignment, as its trend is towards the southeast. This feature may be related to the structural geology of the region, and may represent a plane of weakness, which could be repeated in the bedrock at depth.

There is a possible rock outcrop on the track adjacent to the southern saddle alignment at approximately Ch 6600. The rock may dip away under the alignment, as there is a fall in topography of 4 to 5m from the track to the centre-line.

To the north of the proposed bridge abutment there is an erosional feature, which is dendritic in shape. This may indicate that there will be variability in depth to bedrock in this area, which may have an impact on depths of piling.

Rock outcrop is present in the hill to the north of Ch 6700 on the northern saddle alignment. This appears to be a large flat bed and may indicate that the slope angle is at a similar angle to the bedding.

The track in the area of the northern saddle is highly incised and contains evidence of severe erosion of the sediments. This is partly due to the steep topography and also indicates the presence of erodible soils.

4.3.9 Ch 6800 - 7700

The topography in this section involves valleys and hills, with steep slopes. The alignment passes though one of two saddles within the rocky ridge. Rock outcrop can be seen at the crest of the ridge on both saddle alignments. This would indicate competent rock material to be at shallow depth. The presence of the saddles would indicate that there is a plane of weakness within the rock mass at these two locations. This may be due to a faulted system trending northeast between the saddles. The ridge itself has a dominant northwest trend.

Rock is also present in outcrop to the east of the northern saddle adjacent to the creek. The creek is quite incised at this point, which would indicate that it is eroding through soft material, not the competent material of which the ridge is formed. Therefore the rock levels may fall off at the creek.

The southern saddle alignment is in high ground for a greater distance than the northern alignment and will consequently involve the excavation of more rock, which will be at shallow depth.

The soils to the east and west of the saddles are highly erodible as the tracks are sided by steep drainage channels, formed by the erosion of clay subsoils.

The northern saddle alignment will need to traverse some soft soils at approximately Ch 7100, which are saturated by the minor creek, which runs south from the high ground. This soft soil will be of limited lateral extent.

The two saddle alignments rejoin to cross the creek at Ch 7500. There appears to be evidence of rock outcrop within the stream to the south of the crossing. The stream is likely to have deposited soft sediments to the west of the crossing, as it meandered over recent geological time. Therefore rock may be deeper to the west of the creek, and consequently piles for a bridge structure would be deeper.

4.3.10 Ch 8000 - 9600

Over this section the topography is one of steep hills. This indicates the presence of shallow bedrock. The absence of scree in this area suggests the rock to be competent and covered by thin fine grained residual soils.

Rock outcrops are visible in the small creek at Ch 7800, and also at Ch 8200 and Ch 9000. The rock appears to be present in flat beds, which are at a similar angle to the slope.

The intricate pattern of drainage in the valley section to the north of the alignment indicates that slope instability in not an issue within these slopes. Any slope instability in the slope would have masked the intricate drainage pattern down-slope. In this area there are many remnants of meandering streams and ox-bow lakes.

From Ch 9200-9600 the rock is likely to get deeper, as the alignment now passes down onto lower ground and intercepts some of the ancient drainage patterns. The soils within this area are likely to be fine grained as the river patterns represent stream systems in old age (ie moving slowly with finer sediment in suspension).

4.3.11 Ch 9600 - 10500

In the section between the Branch Lane and the Pacific Highway, there is a wetland area with standing water. These wetlands will consist of fine grained sediments with low permeability materials near the ground surface. The depth to rock will be deeper here as this is the low point in the local topography. The dominant drainage pattern in this area is towards the southeast.

The topography from Ch 9900 eastwards is composed of steep sided hills and valleys. There is a quarry adjacent to the Pacific Highway, which contains steep sides. The quarry appears to be within competent rock material. The section of alignment parallel to the Pacific Highway is likely to have shallow bedrock.

4.4 Topography

Similar to the geology, the topography of the alignment is quite varied. The area is divided by the Karuah River, which runs generally north to south towards Port Stephens. There are distinct trends to the land shapes on either side of the river.

To the west of the river the topography is composed of rolling hills. In the centre of the State Forest, Wallaroo Swamp is an area of wetland, which lies adjacent to the alignment. There are rock outcrops at the crests of the hills and scree material indicating rock to be in close proximity.

Immediately to the west and east of Horse Island there is an area of wetland swamp. This area is designated as a special protection area and is covered by State Environmental Protection Policy (SEPP 14). The topography is flat and the area is tidally influenced.

Horse Island is a rocky island that stands within the wetland area to the west of the river. The island is approximately 300 m wide and 600 m long.

To the east of Karuah River, there is a broad floodplain. At the east of the flood plain, there is an area of high relief, which is traversed by two saddles (passes). The area east of the saddles is composed of hills and smooth u-shaped valleys.

4.5 Soils

The 1:100,000 Soil Landscapes of Newcastle map (DLWC 1995), included as Figure 5, contains general soil and bedrock information along the alignment. The report indicates the nature of the landscape, the soil type and highlights issues which could be limitations on the proposed project.

The sheet recommends values of K-factor for use in the revised universal soil loss equation (RUSLE) to determine the soil erosion potential. The values have been used in this report to estimate erosion potential of the soil types along the alignment in accordance with Managing Urban Stormwater, 3rd Edition, August 1998.

The map shows the site to comprise the following soil landscapes:

4.5.1 *tm* 'Ten Mile Road' (Erosional Landscape)

Approximate Chainage (m) Ch 1100 - Ch 2400, Ch 3300 - Ch 5100

a) Landscape

- undulating hills on carboniferous sediments and acid volcanics in the Medowie lowlands
- local relief 40-80 m
- elevation 70-150 m
- slopes 5-10% (occ. 10-20% tma)
- generally uncleared open forest

b) Soils

- moderately deep (0.55 m) to deep (>2 m)

c) Limitations

- high water erosion hazard
- localised shallow soils
- high run-on and seasonal waterlogging
- strongly to extremely acid soils of low fertility
- effect of constraints on earthworks for urban development: moderate (generally) to high (locally).

4.5.2 *me* 'Medowie' (Residual Landscape)

Approximate Chainage (m) Ch 0000 - Ch 1100, Ch 2400 - Ch 3300

a) Landscape

- gently undulating low hills on relief landscape, very broad flat crests and long gently inclined sideslopes

- local relief to 30 m
- elevation 30-70 m
- slopes 2-15%
- partially cleared open forest

b) Soils

- deep (>0.15 m) well drained red and yellow structured loams on deeply weathered clay deposits

c) Limitations

- seasonal waterlogging (localised lower slopes)
- water erosion hazard (localised)
- strongly acid soils
- low inherent fertility
- high potential aluminium toxicity
- effect of constraints on earthworks for urban development: low (generally) to moderate (locally).

4.5.3 *ts* 'Tacoma Swamp' (Swamp Landscapes)

Possible Chainage (m) Ch 2700 - Ch 3100

a) Landscape

- swampy flood plains and closed depressions on Quaternary sediments
- slope gradients <3%
- local relief <5 m
- uncleared swampland

b) Soils

- deep (>0.2 m) acid peats and humic gleys

c) Limitations

- flooding
- strongly saline
- permanent waterlogging
- potential acid sulphate soil (PASS)
- foundation hazard
- very low fertility

4.5.4 *fc* 'Fullerton Cove' (Estuarine Landscape)

Approximate Chainage (m) Ch 5100 - Ch 5200, Ch 5500 - Ch 5700
Possible Chainage (m) Ch 9800 - Ch 10000

a) Landscape

- tidal flats and creeks in tidal inlets (Medowie lowlands)
- slope gradients <3%
- elevation <3 m
- local relief <3 m
- mangrove scrub and salt marsh
- some open forest

b) Soils

- deep (>0.1 m) very poorly drained

c) Limitations

- flooding
- wave erosion hazard
- foundation hazard
- saturated
- saline, PASS
- effect of constraints on earthworks for urban development: severe (generally) to extreme (locally).

4.5.5 *gi* 'Gilmore Hill' (Colluvial Landscape)

Approximate Chainage (m) Ch 5200 - Ch 5500

a) Landscape

- steep conical hills on carboniferous lithic sandstones and ignimbrites
- slopes 20-50%
- relief 120-170 m
- elevation 150-230 m
- uncleared open forest

b) Soils

- shallow to moderately deep (0.45-0.85 m) rapidly drained bleached loams

c) Limitations

- steep slopes
- water erosion hazard and foundation hazard
- shallow stony, strongly acid soils
- low fertility
- effect of constraints on earthworks for urban development: high-very high (generally) to extreme (locally)

4.5.6 *tb* 'The Branch' (Residual Landscape)

Approximate Chainage (m) Ch 6100 - Ch 6300

a) Landscape

- broad plains on deep pleistocene clay deposits in the Medowie lowlands
- slope gradients <2%
- local relief <1 m
- elevation 15-30 m
- partially cleared tall open forest and woodland

b) Soils

- deep (>0.3 m) poorly drained

c) Limitations

- seasonal waterlogging
- foundation hazard
- highly erodible
- strongly acid soils with extremely low wet strength
- low fertility
- low permeability
- effect of constraints on earthworks for urban development: moderate-high (generally) to extreme (locally)

4.5.7 *nc* 'North Arm Cove' (Associated Landscape)

Approximate Chainage (m) Ch 6300 - Ch 6500

a) Landscape

- undulating hills on ignimbrites of the Nerong Volcanics

- local relief to 50 m
- slope gradients <15%
- broad crests, gently inclined slopes and narrow drainage lines
- minor rock peaked crests
- open forest to tall closed forest and woodland, partially to extensively cleared

b) Soils

- moderately deep (0.5-0.15 m)

c) Limitations

- high erosion hazard
- low to moderate foundation hazard
- highly erodible
- low permeability
- acid soils of low fertility
- localised shrink-swell
- effect of constraints on earthworks for urban development: moderate (generally) to high (locally).

4.5.8 *gg* 'Gan Gan' (Associated Landscape)

Approximate Chainage (m) Ch 6500 - Ch 6700

a) Landscape

- steep hills on ignimbrites of the Nerong Volcanics
- local relief to 100-200 m
- slope gradients >25%
- peaked crests, upper slopes occasionally precipitous, rocky and narrow

b) Soils

- shallow (<0.3 m) well drained soils on crests

c) Limitations

- steep slopes, water erosion hazard, localised mass movement hazard
- high run-on, shallow soils, rock "boulder " outcrop, foundation hazard
- effect of constraints on earthworks for urban development: severe (generally) to extreme (locally)

4.5.9 *ng* 'Nungra' (Tranferral Landscape)

Approximate Chainage (m) Ch 6700 - Ch 10000

a) Landscape

- gently inclined footslopes and drainage plains on Quaternary deposits
- local relief to 10 m
- slope gradients <3%
- predominantly cleared, tall, open forest

b) Soils

- deep (>0.3 m)

c) Limitations

- water erosion hazard, localised flood hazard, high run-on, seasonal waterlogging
- foundation hazard, low fertility, very low wet strength, localised salinity

4.5.10 Summary of Limitations

The desk study identified several issues, which were then incorporated into the site investigation program. These issues are displayed in Table 5 below.

Table 5 Summary of Limitations

Soil Landscape	tm	me	ts	fc	gi	tb	nc	gg	ng
Chainage	1100-2400 3300-5100	0000-1100 2400-3300	2700-3100	5100-5200 5500-5700 9800-10000	5200-5500	6100-6300	6300-6500	6500-6700	6700-10000
PASS			✓	✓					
Acid soils	✓	✓			✓	✓	✓		
Potential Al toxicity		✓							
Saline soils			✓	✓					✓
Shrink-swell							✓		
Foundation hazard			✓	✓	✓	✓	✓	✓	✓
High erodibility						✓	✓		
Water erosion hazard	✓	✓			✓		✓	✓	✓
High run-on	✓							✓	✓
Saturated soils/waterlogging	✓	✓	✓	✓		✓			✓
Flooding			✓	✓					✓
Wave erosion hazard				✓					
Steep slopes					✓			✓	

It should be noted that the above information was assessed as a desk study. More detailed site-specific information is contained within other sections of this report.

5. SURFACE MAPPING

5.1 General

The purpose of the mapping survey was to inspect the accessible rock outcrops, and to make assessment of the general geology along the alignment from topographical and vegetative relationships. Some rock outcrops had been identified from the aerial photograph analysis and the remainder were revealed during the walkover study.

The ground conditions vary considerably over the site, and are far more heterogeneous than implied by the published geological mapping. The geological sequence lies north of the Hunter Thrust, which demarcates the northern extremity of the Sydney Basin and Hunter Valley lithologies. The geological sequence on the site is composed of mid-late Carboniferous rocks.

The site geology has identified the presence of the distinctive Nerong Volcanics. These include rhyolite (toscanite), dacite, andesite, ignimbrite, agglomerate, conglomerate and lithic arenite. Regional geological studies (Engel 1962) show this strata to be conformably overlain by the Crawford Formation which has been identified in rock outcrop on high ground east of the river by the presence of plant fossils (Rhacopteris). The Nerong Volcanics are underlain by the Conger Formation, which is composed of arenites and conglomerates with volcanic clasts. This stratum has been encountered in the boreholes over the Karuah River.

To the west of the Karuah river the Carboniferous sequence is less well defined, and consists of sandstones, conglomerates and organic shales. There is also a microgranite intrusion, which trends northwest adjacent to the Wallaroo Swamp.

Petrographic analyses indicate similar mineralogical contents from clastic lithologies on either side of the river. This may be due to the deposition history of the area, with both volcanic flows and sediments derived from volcanic rocks being deposited at approximately the same time.

The area lies on the western limb of the Girvan Anticline. The regional scale folding of this anticline may have associated faulting. Both high angled strike slip and low angled thrust faults have been identified in rock outcrops at the site.

5.2 West of Karuah River - Tomago Coal Measures/Mulbring Formation

At the western end of the alignment it appears that rock is quite deep, as there is a cutting at the creek at the Pacific Highway which appears to be in sandy clay material. The rock type in the area appears to consist of sandstone and conglomerate. The conglomerate is quite distinctive in that it is a clast-supported conglomerate with large boulder sized clasts, as well as gravels. The sandstone cement is of medium strength, and generally the rock breaks down to a sandy coarse gravel, which is rounded in shape. There is a gravel pit on the Miners Hill trail from where this material is won. The sandstone is a fine grained medium strength. The clasts are rounded and of igneous origin.

The high ground within the Hunter Water Corporation property to the east of the alignment (approximately Ch 2500) is composed of coarse grained microgranites and dacites. This agrees with the API which identified this block as a competent rock

which may differ from the surrounding rock. These rocks are intrusive (ie they are formed at great depth within the earth's crust and rise through fault systems into the overlying rocks). The mineralogy of the rock includes plagioclase, biotite and potassium feldspar. Such intrusions are common within the Carboniferous sequence in the area. The rock is high strength but appears to break down to medium sized block size. Despite an abundance of scree at this location, there is little actual visible outcrop. This material is likely to be a fault-bounded package within the generally sedimentary rock, which surrounds it. No indication of the joint pattern within this material has been ascertained, however the shape of the block indicates that the dominant joint direction will be northwest to southeast. This rock type is likely therefore to plunge below the Wallaroo Swamp. The chosen alignment will encounter this material only at the cut-fill lines either side of the swamp area. This rock is likely to weather to a sandy clay residual soil, and depth to rock in the area of the embankment may be less than 10 m.

The material found in outcrops (Ch 3950) within the Powell property is purple coloured coarse sandstone. The rock dips 20° to the south and is quite thickly bedded. Some scree material contains blocks of matrix supported conglomerate, indicating that there are changes in grain size within this formation over short distances up and down-dip. Similar material is found in outcrops towards the edge of the wetlands close to Ch 4900. There is also an outcrop of coarse sandstone within the creek at Ch 4000.

The rock outcrops found at the eastern side of Horse Island are comprised of high strength siltstones, and coarse sandstones. The sandstones exhibit exfoliation (concentric, onion peeling). The cliff at the eastern side of the island also has a pedogenic silcrete layer, composed of a cemented silty sand. The silcrete is resistant to erosion, but is undercut by tidal effects on the uncemented sands, which underlie the silcrete layer. It is this material which was identified within the API to be the competent layer which supports this face. The persistence of this pedogenic layer is difficult to assess but may affect the interpretation of the seismic surveys in this area.

5.3 East of Karuah River - Nerong Volcanics

On the east of the Karuah River the first rock outcrops are on the high ground either side of the saddles. To the north of the of the northern saddle alignment, there are outcrops of coarse lithic arenites and dacite materials. These appear to have bedding orientations trending NNW and dipping at approximately 20° to the southwest (as indicated by the API study). The bedding appears to be generally 400-600 mm thick and the material is of very high strength in outcrop.

In the area at the crest of the northern saddle, there is no visible outcrop, however there is a persistent scree deposit of fine grained mudstone which contains abundant plant fossil remains. The plant fossil is bipedal in nature and several examples show a circular stem with leaves of approximately fingernail size. This is Rhacopteris Nova and is of late Carboniferous age. The rhacopteris flora is found within the Nerong Volcanics and also within the overlying Crawford Formation.

The southern saddle option has dacite and microgranite scree. The area is quite elevated and the topography suggests that rock is quite shallow (probably within 1 to 2 m). However the absence of rock outcrop at the saddle indicates that the uppermost rock type is fine grained and therefore weathers to a soil which covers the underlying rock types. Some fine grained rhyolite material is found within the incised drainage channels to the east of the saddle crest.

The rock material on the elevated ground in the AMP and Pickford properties is composed of coarse grained dacite and microgranite. The bedding in this area appears to dip towards the north, which may indicate that the elevated ground is an anticlinal fold with bedding dip changing either side of the fold axis. The coarse acid igneous material is also found within the Karuah Red Quarry at the east end of the alignment, on the Pacific Highway. Here the material is clearly faulted with high angled wrench faults and low angled thrusts observed. The faults are trending NNW and appear to have significant displacements. The structural geology is controlled by the wrench (strike slip) faults with the thrust being a secondary effect. The strike slip faults would have caused the high angled cleavage and jointing which also follows the NNW structural trend.

At approximately Ch 10200 along the Pacific Highway, there are cuttings, which are approximately 2 to 3 m high. The rocks in these cuttings are rhyolite and rhyodacite, of medium strength. The bedding is high angled and strikes towards the northwest. The slope appears to be stable.

6. NATURE OF THE FIELD INVESTIGATIONS

6.1 General

The alignment for the detailed geotechnical investigation is approximately 10 km long and traverses some diverse terrain in terms of access, topography, vegetative cover, drainage and materials. In view of the access and legislative constraints, the investigations were carried out in stages. Some of the factors affecting the investigations are outlined below and discussed in detail in the sections that follow.

- The alignment to the west of Karuah River (ie Wallaroo State Forest and the Powell property) is quite densely forested. A dedicated track would be necessary to enable access to the alignment for the required frequency of test pits and boreholes. However, this was not possible due to current legislative constraints. It was therefore necessary to restrict the investigation here to existing tracks. Further investigations will be required at a later stage, possibly after the EIS has been completed, to provide the necessary geotechnical information.
- To the east and west of Horse Island the alignment passes through SEPP 14 wetlands. It was therefore necessary to liaise closely with Port Stephens Local Council with respect to the investigations in the wetlands. The legislative requirements did not allow the clearing, removal, drainage or construction of levees within the wetland area and the investigations were therefore tailored to suit these requirements.
- The RTA brief required three bridge options to be assessed. In order to provide cost effective information at the bridge sites, the current investigations were of a preliminary nature and restricted to seismic survey and limited borehole drilling. Detailed investigations will be carried out once the alignment and bridge concept designs have been completed.
- East of the Karuah River the alignment crosses a ridge of high ground. This ridge can be traversed through one of two saddles, and alignments have been investigated through both saddles in the Phase 1. The high point of the northern saddle is not accessible from an existing track, and it was necessary to use a tracked drilling rig to gain access to the locations at the crest and behind the saddle.
- Sub-tidal wetlands and mangroves surround Horse Island. Access to the island was therefore limited. In order to undertake geotechnical investigation of this area, hand held equipment was used.

6.2 Detailed Methodology

6.2.1 Investigation Techniques

The fieldwork for this project has been conducted using a variety of investigative techniques. These are outlined below and included a total of 39 boreholes, 67 test pits, 7 seismic spreads along 6 longitudinal lines and 1 transverse line, down hole geophysical investigations in 8 boreholes and laboratory testing. In addition a contamination and pedological survey has been carried out. The detailed results of these investigations are presented in the appendices listed below.

- Volume 2 - Explanatory Notes,
  - Borehole and Test Pit Logs,
  - Core Photographs
  - Geotechnical Laboratory Testing
- Volume 3 - Seismic Survey
  - Down-hole Geophysical Survey
- Volume 4 - Contamination, Pedological Survey
- Volume 5 - Comparison of Bulahdelah and Karuah Cut Conditions

The site investigation locations are listed in a table in Volume 2, in terms of easting, northing and reduced level.

Test pits have been excavated in fill areas, at cut and fill interfaces and also in some cut areas to provide a rock profile. The pits were excavated using an Atlas excavator which was track mounted. A 450 mm bucket was used to minimise the disturbed area. The excavator had a maximum reach of approximately 5 m.

Boreholes were drilled in cut areas. Boreholes were drilled using either a truck mounted Edson 3000 rig or a Gemco HC10 on land, using rotary coring techniques. Auger drilling with tungsten carbide bits was used above the rockhead. Overwater holes were drilled using an APS 300 rig mounted on a barge. The boreholes were drilled vertically with water flush and occasionally with approved mud where the core was too fractured to be recovered otherwise. The boreholes were generally cased within the overburden material to prevent caving. NMLC core barrels were used and these produced a core of approximately 50 mm diameter.

Boreholes were also drilled near Wallaroo swamp and at the bridge abutments on the east of Karuah River, hollow auger drilling was used within the soil materials. Tungsten carbide bits were used to auger through the overburden materials. Standard penetration tests (SPTs) were taken at 1.5 m intervals to allow assessment of soil properties and also to take samples. In clayey materials undisturbed U50 samples were recovered where possible for laboratory testing.

The borehole investigations in the deep cuts in the vicinity of Ch 6800 indicated the presence of fractured rock at depth. Down hole geophysical investigations were therefore carried out to assess the quality of the rock material and the discontinuity orientations. Full waveform sonic and borehole televiewer tools were used in these boreholes. The detailed results of these investigations are presented in Volume 3.

Seismic refraction surveys were conducted over the more inaccessible areas of the project to provide preliminary information for bridge concept design. The seismic survey was necessary in the wetland areas adjacent to Horse Island and also over the river section. An electrically detonated seismic energy source was used and the impulses were received by geophones spaced at regular intervals. Over the wetland areas the geophones were in the form of marsh phones, which keep the recorders above the water. Over the river section a "seismic eel" was used which kept the geophones buoyant within the water. The seismic spreads were overlapping to give a continuous profile of the ground conditions over the study area. The spreads were

continued past borehole locations at either end of the survey, to allow correlation of the geophysical data with direct investigations. The results of the seismic survey are included in Volume 3 of this report.

A contamination and pedological survey was carried out to identify soil types (particularly Potential Acid Sulphate Soil, PASS) and potential sources of contamination. The investigation was carried out by ADI Limited, and involved excavation of test pits and hand augured holes, as well as laboratory testing. Their report is attached in Volume 4, and comments on the findings are included within Section 7.

The samples recovered from boreholes and test pits were sealed in plastic sample bags and dispatched to Australian Soil Testing, a NATA registered laboratory, in Sydney. Both soil and rock samples were tested. The testing included:

- moisture content;
- Atterberg limits;
- particle size distribution;
- Emerson crumb dispersion;
- Pinhole dispersion test;
- unconfined compressive strength (UCS);
- point load strength;
- undrained shear strength (cu);
- compaction test;
- California bearing ratio (CBR);
- consolidation test; and
- petrographic analysis.

The site investigation locations are shown in Figure 2 (a-g). The areas are discussed below by chainage.

6.2.2 Chainage 0000-0950, Pacific Highway Embankment

This section of the alignment is parallel to the existing Pacific Highway. Currently the alignment and exit ramp has not been finalised but it is anticipated that the new alignment will generally follow the existing ground levels with shallow cuts and fills. Access to the town of Karuah will be provided by some form of grade separated change. At this stage one borehole BH-101, was drilled in this area to give an initial assessment of the ground conditions. Four test pits, TP-101 to TP-104, were excavated along this section at the margins of the existing road. TP-101 to TP-104 were excavated from Chainage 000-600. This area has subsequently been excavated for road construction as part of the ongoing Karuah-Raymond Terrace Upgrade. These pits were excavated to depths of 1-1.5 m, and are now obsolete and do not appear in the figures. However they are discussed within Section 7 as they provide indicative ground conditions in this area.

Once the alignment issues have been decided boreholes will be drilled at specific pier locations in a further phase of investigation, in accordance with RTA requirements. Additional test pits will also be required for the exit ramp.

6.2.3 Chainage 0950-2350, State Forest Cut I

This section of the alignment is quite densely forested. The topography suggests that rock is close to the surface. The alignment is mostly in shallow cut in this section. Due to legislative limitations on ground disturbance permitted here, boreholes and test pits have been excavated only along the existing tracks where they meet the alignment. Phase 1 investigations within this area comprised two boreholes (BH-101, BH-102) and three test pits (TP-105 to TP-107) while phase II investigations within this area comprised five hand dug test pits and one borehole (BH-218).

6.2.4 Chainage 2350-3400, Wallaroo Embankment

Along this section of the alignment the terrain is forested and was quite wet during the investigation. The Wallaroo Swamp lies to the west of the centre line of the proposed alignment here. Three boreholes and three test pits have been excavated on or close to the existing forestry tracks to allow an initial assessment of the soils. Four hand dug test pits (TP-206 to TP-209) were excavated during the Phase 2 investigations.

A further phase of investigation involving Cone Penetration Testing (CPT) or additional test pitting and drilling will need to be conducted once centreline access can be obtained.

6.2.5 Chainage 3400-3900, State Forest Cut II

The alignment is mostly in cut (up to 11 m) within this section and passes through densely wooded forest. Borehole access was limited to the existing Miners Hill Trail and the other tracks in the area owned by the State Forest and a local landowner. Two boreholes (BH-106, BH-107) were drilled. A down-hole geophysical survey was carried out within BH-107. Excavation of the test pits was by a tracked excavator. It was possible to excavate two test pits (TP-111, TP-112), at a suitable spacing.

6.2.6 Chainage 3900-4350, Powells Creek Embankment

Within this section the alignment is in fill embankment. Access to this area was via the Miners Hill Trail, and also tracks within the property of the local landowner. The area is in dense forest, and investigations were kept to the areas where access was possible from existing tracks. Three test pits (TP-113 to TP-115) were excavated in the area using a tracked excavator.

6.2.7 Chainage 4350-5050, Powells Cut

Within this area the alignment slopes down to the edge of the wetlands area. Due to the lack of existing tracks in this area only BH-108, BH-109 and BH-110 could be drilled. Test pits TP-116, and TP-117 have been excavated also. The seismic survey in the next section of the alignment has been continued here to provide overlap with BH-110, to allow correlation between the borehole and geophysical investigations.

BH-217 was drilled in this area to 20 m depth to provide information on the bearing capacity of the rock at depth and also to assess the regional geology.

Additional boreholes will be required in this area to complete the investigations for detailed design phase.

6.2.8 Chainage 5050-5300, West Horse Island Bridge

This section of the alignment comprises tidal mudflats. This area is included within SEPP 14, as a protected wetland area. At low tide the flats will support only hand held equipment, or possibly a light tracked rig or hovercraft. At high tide the ground surface is covered in water and no effective access was possible. The section was investigated by means of seismic refraction survey. Both longitudinal and transverse surveys were conducted to profile the geology and especially the rock level. The seismic data can be correlated with the borehole information from Horse Island. As this section will be bridged, the seismic data will allow the bridge concept designs to be formulated.

On completion of the bridge concept design, boreholes will be drilled at the pier and abutment locations. Further investigations will require careful planning and close liaison with the various authorities due to the sensitivity of the area.

6.2.9 Chainage 5300-5600, Horse Island

This is the Horse Island section of the alignment and investigations here were constrained by access. Borehole investigation was limited to a hand-held proline hole (BH-111) at the western limit of the island. Three hand dug test pits (TP-210 to TP-212) were excavated during the Phase 2 investigations.

Along this section there are two alternative alignments depending on which saddle option the alignment passes through east of the river. Seismic surveys have been carried out along both alignments, although comments in Section 7 will refer only to the adopted northern saddle option.

The seismic survey was continued across the island, to allow direct correlation with the borehole information and give a continuous subsurface profile. The seismic survey has provided some information on the variability of the pedogenic sediments above the rock.

Further boreholes or test pits will be required in this area. The precise nature of these additional investigations is still to be determined and will be dependent on access and the final vertical alignment. The additional investigations will need to assess the persistence of the pedogenic materials here.

6.2.10 Chainage 5600-6150, Karuah River Bridge

Within the section over the Karuah River the alignment will be bridged. In order to provide sufficient information for concept design of the bridges, geophysical survey was conducted in the river supplemented by boreholes on the east abutment side in the following section. Again there are two alternative alignments here and seismic refraction surveys were carried out along both.

The seismic survey was conducted using a seismic "eel" which involved placing the geophones on the river bed, and the seismic pulse was provided by a water gun. The seismic data has been correlated with the borehole data at the bridge abutment locations either side of the river.

Ten boreholes were drilled in the river section (BH-201 to BH-210). The holes were drilled from a barge using a truck mounted rig. The boreholes included auger drilling and rotary coring in rock.

6.2.11 Chainage 6150-6200, Bridge Abutment

The access to this area was via the private tracks, leading from The Branch Lane. The bridge abutments at the rivers edge were investigated for the two saddle alignments. Three boreholes (BH-112N&S, BH-211) were drilled using a combination of auger drilling in soil and rotary coring in rock. In the soils, SPT testing at regular intervals and U-50 sampling where possible were carried out. Test pits (TP-118N&S, TP-213) have also been excavated at the abutment locations.

6.2.12 Chainage 6200- 6650, AMP Embankment I

The chainage details for this section are for the northern saddle. The southern alignment is essentially similar.

The alignment is in fill over this section. The fill has a maximum height of 8 m. Test pits have been excavated at approximately 150 m intervals. Test pits have been excavated at approximately the same chainage on both alignments, to allow comparison between the two routes. A borehole (BH-212) has also been drilled to provide information on the embankment design parameters.

6.2.13 Chainage 6650-6900, Saddle Cut

This section of the alignment crosses a ridgeline and two alternative routes are possible, passing through a saddle either to the north or the south. Both saddle options are in substantial rock cut. The cuts have been assessed by drilling two boreholes on each of the alignments. One borehole was drilled at the saddle crest (BH-113S and BH-113N) to a depth of 20 m, and the other hole drilled to approximately 10 m at the eastern side of the cutting (BH-114S and BH-114N). The holes were drilled using truck-mounted coring rigs, with the exception of BH-114N, which was drilled with a track-mounted rig due to the exceptionally steep topography in the area.

The borehole investigations indicated the presence of highly jointed or fractured rock and the borehole investigation was therefore supplemented with down-hole geophysical investigations to provide information on joint orientation and rock mass properties (BH-113S, BH-113N, BH-114S and BH-114N). As the alignment changed during the design process, BH-213N was drilled to a depth of 34m within the existing BH-113N, to extend the data below the formation level. Down-hole geophysics was not extended to this final depth.

6.2.14 Chainage 6900-8050, AMP Embankment II

Both alternatives in this section are in fill. The maximum fill height is nominally 9 m where the route crosses the creek at the AMP/Pickford property boundary (Ch 7600). More typically the fill is 4-5 m high. The area has been investigated by test pitting at 150 m intervals. Due to the different curvatures of the alternative alignments it has not been possible to match test pits for direct comparison.

Some form of bridge or culvert structure will be required over the creek at the AMP/Pickford property boundary (Ch 7600). BH-115 was drilled near the western bank of the creek and BH-214 was drilled on the eastern bank during Phase 2 investigations

6.2.15 Chainage 8050-8500, AMP Cut I

The two alternative saddle alignments meet at the start of this section. The alignment here is in cut. The area has been investigated by test pits TP-130, TP-131 and TP-132. The excavator generally reached refusal on rock. Rotary cored boreholes have also been drilled in two locations in this area of cut (BH-116 and BH-117) to allow the nature of the rock material to be assessed.

Down-hole geophysics have been used within BH-116 to allow further assessment of the rock materials and more importantly to assess the nature and orientation of the joint patterns. BH-215 was drilled during Phase 2 investigations to extend the depth of data to below the formation level.

6.2.16 Chainage 8500-8900, AMP Embankment III

The alignment here is in relatively shallow fill, generally 1-2 m. Test pits have been excavated at 150 m intervals along the centre line and samples were collected, of both soil and rock, for laboratory testing.

6.2.17 Chainage 8900-9500, AMP Cut II

The alignment here is in cut in this section. The maximum depth of cut is approximately 5 m. Test pits have been excavated at approximately 150 m intervals along the centre line. A rotary cored borehole has been drilled (BH-118) to allow the nature of the rock within the cutting to be assessed.

6.2.18 Chainage 9500-9950, Branch Lane Embankment

The alignment in this section is in fill. In this area the route will have to cross the wet waterlogged section between The Branch Lane and the Pacific Highway. Standing water was present here and it was not possible to move machinery in this soft material. A test pit was excavated at Ch 9620 and samples collected from it for laboratory testing. BH-216 was drilled along The Branch Lane to assess the depth to bedrock adjacent to the interchange.

Further test pits will be required in this area if access can be obtained in drier conditions.

6.2.19 Chainage 9950-10500, Pacific Highway Re-entrance

Over this section the alignment is at or near grade. The proposed route is likely to make use of the existing Pacific Highway on the northern side. Therefore the investigations in this area have been concentrated in the southern side of the current highway. Test pits have been excavated at approximately 150 m intervals, where it was possible to gain access for the excavator to safely dig pits. Four pits have been excavated in this area.

7. GEOTECHNICAL CONDITIONS

7.1 Chainage 0000-0950, Pacific Highway Embankment

At the time of investigation the design was at a preliminary stage, and the alignment was generally at grade. The alignment has subsequently changed and this section will now be in fill up to 3 m high. The fieldwork in this area comprised four test pits, which were excavated to depths of 1.5-2.5 m. Samples were recovered for laboratory testing. Subsequently the area has been excavated for road construction (Karuah-Raymond Terrace Upgrade), rendering the investigations obsolete. However the results are included below to provide an indication of the ground conditions in the area.

The subsoil profile encountered in these holes is summarised in Table 6 below. The results of laboratory testing carried out over this section are presented in Table 7.

Table 6 Soil Profile Ch 0000-0950

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.1 m - 0.55 m	Dark brown, sandy silty CLAY, firm to loose where granular
0.55 m (TP-102 only)	Alluvial	0.45 m	Light brown, silty SAND, loose
0.1-0.55 m	Residual	0.65 m to end of pit	Brown, silty sandy CLAY, firm to stiff, high-medium plasticity
0.95 - 1.20 m	Residual	To termination of pits	Brown, silty sandy CLAY, very stiff, low to high plasticity

Table 7 Laboratory Test Results Ch 0000-0950

TP/BH	Depth (m)	NMC (%)	LL (%)	PI (%)	CBR	OMC (%)	MDD (t/m³)
TP-101	1.0-1.5	22.5			1	21.0	1.67
TP-102	1.0-1.5	24.5			1	24.5	1.50
TP-104	1.0-1.5	13.0	21	3	10	13.0	1.84

The residual clays in this section are similar to those from Ch 950 to Ch 2350 and the laboratory tests indicate a wide range in plasticity index (PI), varying from 3 to 34 (TP-105 Ch 1000) for both these sections.

The CBRs in the clayey material are low; 1 at 100% maximum dry density ratio (standard). These materials will therefore need to be stabilised where they form the subgrade.

The CBR improves significantly where the sand fraction increases, with a CBR of 10 measured in TP-104.

The natural moisture contents of the materials are at or near their optimum moisture contents. The optimum moisture contents are lower for the more granular materials. Maximum dry densities range from 1.5 tonnes/m³ for the clayey materials to 1.84 tonnes/m³ for the more granular materials. These densities are not indicative of problematic clay minerals such as halloysites.

Two Emerson crumb tests were conducted on samples from pits, and both yielded Emerson class 6, indicating non-dispersive material. However, soil material has been observed in suspension in surface water in the area. Evidence of erodible soils has been identified from the walkover survey. It is therefore recommended that this material be regarded as erodible.

Fill embankments up to 5 m in height are not considered to have a stability problem as the undrained shear strength of the foundation soil is in excess of 100 kPa based on pocket penetrometer test results. The stability of embankments in excess of 5 m will need to be checked once the alignment has been finalised.

Maximum fill batters should be limited to 1:3 (vertical:horizontal) for stability considerations, but should be flattened to 1:4 (vertical:horizontal) for consideration of erosion and maintenance.

7.2 Chainage 0950-2350, State Forest Cut I

In this section the alignment is in cut, with a maximum batter height of 7m at approximately Ch 2100. Eight test pits and three boreholes have been drilled in this section. The test pits were excavated to a maximum depth of 2.5 m and the boreholes were drilled to depths of 10.0 m and 6.6 m for BH-101 and BH-102 respectively. BH-218 was drilled to 7.35 m.

The ground conditions observed in these holes are summarised in Table 8 and the laboratory test results are given in Table 9.

Table 8 Soil Profile Ch 0950-2350

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.2 m - 0.3 m	Brown, sandy CLAY, rootlets, soft to firm
0.2 - 0.3 m	Residual	0.25 m - 0.3 m	Brown, silty sandy CLAY, firm to stiff, medium plasticity
0.55 - 0.8 m	Residual	0.45 m (BH-102) to 8.4 m (BH-101)	Brown, silty sandy CLAY, medium plasticity, very stiff
0.7 m (BH-102) - 9.1 m (BH-101)	Bedrock		Interbedded SANDSTONE and shale, low to medium strength

Table 9 Laboratory Test Results Ch 0950-2350

TP/BH	Depth (m)	NMC (%)	LL (%)	PI (%)	CBR	OMC (%)	MDD (t/m^3)
TP-105	1.0-1.5		50	34	2.0	17.0	1.77
BH-101	1.25-1.70		28	16			
BH-101	5.75-6.20		62	32			
TP-201	0.9-1.4		79	53	5.0	28.0	1.50
TP-204	0.75-2.6	26.7	69	43			
TP-204	2.6-3.0		38	11	17.0	20.0	1.65
BH-218	2.0-2.45	23	65	39			
BH-218	5.0-5.95	23	58	34			

The ground conditions in this area are similar to those described in the previous section. The topsoil is underlain by sandy CLAY which is of medium plasticity. In the upper 2 m, the clay is firm in terms of consistency with SPT N values of 8 to 9, increasing in stiffness with depth in BH-101 (see Figure 16). The tested CBR values within this area ranged from 2 to 17. This would indicate that the sub-grade might need to be treated before road construction in some areas. In terms of assessment of unsuitable material, it should be noted that only three CBRs have been tested over this 1.4 km long section.

The maximum dry density of the clays ranges from 1.50 t/m^3 to 1.77 tonnes/m^3, while the optimum moisture content ranges from 17% to 28%. Plasticity results against depth are shown in Figure 6, and Atterberg limit results are compared with NMC against depth in Figure 11.

The desk study information indicated the soils to be susceptible to erosion. Pinhole dispersion test on a sample from BH-218 indicated the clay material to be non-dispersive (pinhole dispersion classification ND-2). However, evidence on the ground suggest that the soils are erodible and therefore erosion protection measures will be required along the battered slopes.

Maximum cut and fill batters from stability considerations would be 1:2 (vertical:horizontal) but these need to be flattened to 1:3 (vertical:horizontal) due to potential erosion.

Siltstone and shale rock was encountered in BH-101 at a depth of 9.1m. Foundations for the creek crossing structure will depend on the type of structure envisaged. Culverts may be designed using an allowable bearing pressure of 150 kPa if founded in the stiff clay at a depth of approximately 2 m.

Heavily loaded structures would need to be piled to rock (encountered at a depth of 9.1 m in BH-101, and consisting of siltstone and shale). Either preformed piles driven to rock or bored piles socketed into rock would be suitable. For bored piles an allowable end bearing capacity of 1 MPa may be used and allowable shaft friction of 100 kPa for concept design.

Rock was encountered at a depth of 0.75 m in BH-102. Low-medium plasticity clay overlies the rock. The rock is composed of sandstone and inter-bedded siltstones. The bedding dips at 20°, which is quite shallow. The cut will be of the order of 2 m at this point.

Maximum fill batters should be limited to 1:2 (vertical:horizontal) for stability considerations within the soil, but should be flattened to 1:3 (vertical:horizontal) for consideration of erosion and maintenance. This batter angle is the optimal angle, however there will be some ongoing erosion. The cut batter angle within the rock should be 1:1.

7.3 Chainage 2350-3400, Wallaroo Embankment

This section of the alignment is in fill. The embankment ranges in height from approximately 3 m to 4 m. The embankment in this area runs along the eastern extremities of Wallaroo Swamp. The topography of the section consists of a gently undulating valley with the Wallaroo Swamp in the centre of the area. It was anticipated that soft ground conditions would be encountered in this section of the alignment due to the proximity of Wallaroo Swamp. The fieldwork comprised seven test pits (four of which were hand excavated, due to the swampy conditions - TP-206, TP-207, TP-208 and TP-209) and three boreholes. The test pits were excavated to a maximum depth of 4.4 m and the boreholes were drilled to a maximum depth of 10.75 m.

The ground conditions observed in this section are summarised in Table 10 and the laboratory results are given in Table 11.

Table 10 Soil Profile Ch 2350-3400

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.5 m - 0.6 m	Brown sandy silty CLAY, rootlets, firm (to loose where granular)
0.6 m (TP-108 only)	Alluvial	0.75 m	Brown, clayey SAND, low plasticity clay, loose to medium dense
0.5 m - 0.9 m	Residual	1.25 m - 2.1 m	Brown silty CLAY, medium plasticity, firm to stiff
1.35 m - 1.75 m	Residual	5.8 m - 6.8 m	Brown silty CLAY, medium plasticity, stiff to very stiff
4.20 m - 8.8 m	Weathered Bedrock	-	Black-purple, MICROGRANITE, medium strength (Siltstone in BH-105)

Table 11 Laboratory Test Results Ch 2350-3400

TP/BH	Depth (m)	MC (%)	LL (%)	PI (%)	DD (t/m³)	Cu	Phi'
TP-108	1.2	11	21	5			
BH-104	1.6 - 0.95		43	28			
BH-104	0.75 - 1.1	16.7*			1.83	128	0
BH-104	3.15 - 3.5	41.9*			1.25	180	0
BH-105	0.6 - 0.95		61	40			
BH-105	3.05 - 3.4	37.8*	91	57	1.37	180	0

* Moisture content calculated from UU triaxial tests

The soil is composed of a topsoil layer, which is soft to firm in consistency. The topsoil ranges in thickness from 0.3 m to 0.5 m.

The topsoil is underlain by low to high plasticity, firm to stiff sandy clay and clayey sand. Plasticity indices show a large range, from 5% to 57%. The two natural moisture contents in the upper 2 m of the soil profile are below 20%. Below this depth the moisture contents rise significantly to in the order of 40%. This, together with the low dry densities of 1.25 t/m³ to 1.37 t/m³, indicates that there may be soft normally consolidated clays at depth with a thin over consolidated surficial crust. This

is not borne out by the SPT tests however, which indicate the presence of firm to stiff clays (see Figure 15).

The SPT N values in the clay range from 8 to 26 and are plotted on Figure 17). Undrained shear strengths of the clays lie in the range 128 kPa to 180 kPa (refer to laboratory test results Volume 2 for details). From a depth of approximately 4 m in boreholes BH-103 and BH-104 the material grades from a very stiff/dense silty clay/clayey silt to siltstone.

In view of the SPT and pocket penetrometer results it is considered that these materials will be able to adequately support the embankments to be constructed here. Settlement analyses indicate 25-50 mm total settlement due to the embankment.

In view of the low order of settlement predicted in this area, the following embankment construction methods can be considered. The method adopted will depend on ground conditions at the time and the preference of the construction team.

- **Construct embankment directly on existing surface**
  When using this method of construction, existing ground conditions will need to be considered. The area form part of an overland flow path from the higher ground at the Hunter Water property, and the surface materials can therefore be expected to be saturated for a period after rainfall. Vegetation cover would be stripped, the insitu material compacted, a drainage layer with geofabric base would be constructed and the embankment constructed over this. As stated above, the area forms an overland flow path and the drainage layer at the base of the embankment can be designed to cope with this flow or, alternatively, provision can be made to provide drainage culverts below the embankment. Using this method topsoil will need to be imported for the embankment slopes at the completion of construction.

- **Remove topsoil and construct embankment**
  Removal of the topsoil will allow this material to be reused for the embankment batters and will allow better working conditions in wet conditions, provided suitable drainage is installed prior to construction to divert surface and near surface flows during this time. After removal of the topsoil the embankment can be constructed using materials from cuts elsewhere on site. Provision also needs to be made for drainage of the overland flows.

7.4 Chainage 3400-3900, State Forest Cut II

The alignment will be in cut in this section. The depth of cut is irregular due to the irregular topography, but has a maximum depth of approximately 10 m at Ch 3800. The field investigations comprised two boreholes and two test pits.

The ground conditions observed at this section are summarised in Table 12.

Table 12 Soil Profile Ch 3400-3900

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.1 - 0.55 m	Brown clayey SILT/SAND, loose, organic, medium plasticity
0.1 m - 0.55 m	Residual	0.40 - 0.55 m	Brown sandy gravelly CLAY, medium plasticity
0.55 m - 0.70 m	Bedrock	-	Grey, interbedded SANDSTONE, SILTSTONE, MUDSTONE and CONGLOMERATE, medium to high strength

In this section the rock is blanketed by a thin layer of topsoil and residual clay, which is less than 1 m thick.

No laboratory tests were scheduled in this section of the alignment due to the thin soil cover.

Rock was encountered at depths of 0.55m and 0.7m in BH-106 and BH-107 respectively.

The rock consists of sandstone, siltstone and conglomerate. The rock mass quality varies between the two boreholes. At BH-106 the rock strengths vary from medium to high strength. The RQD values average 27% for the upper 5m, while the lower 5 m has an average RQD of 78%. The rock mass quality is "fair", in accordance with the rock mass rating system or RMR (Bieniawski 1983). In BH-107, the RQD values are all greater than 70% and the rock is generally high to very high strength. The rock mass quality can be categorised as "good".

The dominant joint set within the rock is the bedding, which dips at 20° or shallower. A stereoplot containing poles of planes is included as Figure 4a. The bedding orientations are centred around the origin, indicating shallow bedding, with scattered higher angled joints. Planar failure is unlikely in the rock cuttings at this angle due to the roughness and waviness of the joints and the shallow angle of the bedding planes. Some high angled truncated joints are also presented in Figure 4a, and these are unlikely to present significant slope stability problems. Wedge failure may occur due to intersection of bedding planes with high angled joints. Such wedges are likely to be small in nature and would be stabilised using localised rock bolting or removal. The rock cuttings can stand at a batter angle of 4:1 (vertical:horizontal) where the rock mass quality is good and 2:1 (vertical:horizontal) where fair or worse rock is encountered. The soil at the surface should be stepped back at a batter angle of 1:2 (vertical:horizontal). The rock cuttings should be benched at approximately 7 m intervals.

Down the hole geophysical surveys in BH-107 have provided information regarding joint orientations within the rock mass. Detailed results of these investigations are given in Volume 3. The joint orientation, spacing and strength indicate that this material will be very hard ripping to marginal blast. The excavated rock should be suitable for use as general rock fill.

7.5 Chainage 3900-4350, Powells Creek Embankment

The alignment in this area is in fill and crosses the creek, which runs through the Powell property. The embankment has a maximum height of 11 m where it crosses the creek, though more typically the fill height is 5 m to 6 m. The field investigations comprised three test pits excavated to refusal in bedrock.

The ground conditions observed at this section are summarised in Table 13. The results of the laboratory testing carried out on samples taken from this section are presented in Table 14.

Table 13 Soil Profile Ch 3900-4350

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.4 m - 0.45 m	Brown silty clayey SAND, rootlets, loose
0.1 m - 0.45 m	Alluvial	0.5 m	Red silty SAND, loose to medium dense to silty CLAY, stiff
1.10 m	Residual	1.0 m	Red silty SAND, dense, slightly cemented
0.6 - 2.10 m	Weathered Bedrock	-	Red SANDSTONE, medium to high strength

Table 14 Laboratory Test Results Ch 3900 - 4350

TP/BH	Depth (m)	NMC (%)	LL (%)	PI (%)	CBR	OMC (%)	MDD (t/m³)
TP-113	0.3 - 0.6 CH	20	67	42	4	20.5	1.60
TP-115	1.0 CL	20			9	22.0	1.59

Ground conditions observed generally consist of relatively shallow bedrock. At TP-113, TP-114 and TP-115 rock was encountered at depths of 0.6 m, 0.7 m and 2.1 m BGL respectively. Bedrock also outcrops at the stream/creek. The overburden in this area consists of silty sand and sandy silt. Topsoil cover is in the range 0.1 m to 0.5 m and is generally loose clayey silty sand with organic matter. The alluvium is predominantly silty sand with silty clay. The residual soil is mostly a silty sand, a product of the weathering of the underlying bedrock. It is generally medium dense to dense.

The CBR tests carried out close to the cut/fill interfaces have values of 4 and 9 at compaction of 100% of the standard, maximum dry density ratio.

The natural moisture contents at 20% are a little below the respective optimum moisture contents of 20.5% and 22%.

No stability or settlement problems are anticipated with the fills proposed for this section.

7.6 Chainage 4350-5050, Powells Cut

The area to the northeast of the Powell property is within cut. The maximum depth of cut is approximately 12 m at Ch 4925, though more typically the cut is 5 m (ie from Ch 4400-4700). Investigations have been carried out in this section and comprise three cored boreholes and the excavation of two test pits. No laboratory tests were scheduled in this section of the alignment due to the thin soil cover.

The subsurface profile is summarised in Table 15 below.

Table 15 Soil Profile Ch 4350-5050

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.3 m	Brown clayey SAND, rootlets, loose
0.3 m	Residual	0.1 - 0.5 m	Brown sandy silty CLAY, firm to stiff, medium to low plasticity
0.2 m - 0.8 m	Weathered Bedrock	-	Brown-red, fine to medium grained Sandstone, medium to high strength

Rock was encountered at depths of 0.2 m, 0.8 m and 0.6 m BGL in the boreholes in this section, BH-108, BH-109 and BH-110 respectively. The rock mass quality in each of the boreholes can be classified as "good". The rock in this area is composed of sandstones and siltstones. The bedding is closely to medium spaced. The discontinuities are generally rough, though dominantly planar. The cuttings in this material have been assessed using stereographic analysis. The stereoplot of the jointing from downhole geophysics in BH-108 is shown in Figure 4b and BH-110 in Figure 4c (specific joint orientation is described in Volume 3). The predominant discontinuity set is bedding which appears to dip at an angle of less than 10° to the southwest. This analysis indicates that it is not likely that the cuttings in this area will be susceptible to planar or toppling failure. Wedge failure may occur in isolated areas, and these would be stabilised using rock bolts or anchors.

The rock mass in this area is of high strength. The bedding dips dominantly at a shallow angle (0-10°) and is medium spaced. This rock will require extremely hard ripping or perhaps pre-blasting. The excavated material can be re-used as road fill.

7.7 Chainage 5050-5300, West Horse Island Bridge

The alignment over this section crosses the SEPP 14 wetlands area. Due to environmental considerations the investigation in this area was restricted to a seismic refraction survey and the drilling of BH-111 and BH-217 at the edges of the wetlands. The results of the seismic survey are contained in Volume 3. The seismic survey indicates that the rock head dips from 1 to 2 m depth at the Powell property boundary to 14 m BGL under the wetland area, a distance of 150 m. The seismic velocity of 4500 m/s indicates the rock material to be of "good" quality. The seismic velocity rises to 5100 m/s at Horse Island, indicating the presence of competent rock. The overlying soil has an average velocity of 800 m/s, which can be interpreted as soft to firm saturated silts and clays. There are some inconsistencies between the seismic survey and the direct investigations (see Figure 3c), which will necessitate further investigations in the construction phase.

The presence or absence of a thin pedogenic layer could not be confirmed by the seismic survey, due to the saturation of the soils and the thinness of the layer. Pedogenic material (silcrete) has been identified in holes on the AMP embankment (see Section 6.11) and also in test pits on Horse Island. These test pits refused on the silcrete. BH-111 on the western side of Horse Island also encountered silcrete between 1.5 m and 5.6 m. This material is a weakly cemented sand, which is dense in terms of compaction. It is formed by precipitation of materials during wetting and drying cycles over long periods. The pedogenic layer can form a hard pan, which may be underlain by softer materials. This issue will be important in deciding on the method of pile installation for the bridge piers across the swamp and the presence of pedogenic material at pier locations needs to be resolved in the next phase of the investigations.

BH-217 has been drilled at the edge of the wetland area. Rock (tuff) was encountered at a depth of 0.62m and was drilled to 20.25 m. The borehole encountered rock, which was generally composed of very closely spaced fractures, distinctly weathered and of high strength from 0.6 m to 11.55 m. Below this depth the rock material improved with closely spaced fractures and very high strength. For the purposes of the pile design for the abutment, rock material below a depth of 11.55 m will provide allowable end bearing pressure of 5 MPa and a socket adhesion of 500 kPa. The rock above 11.55 m will provide allowable end bearing pressure of 1 MPa and a socket adhesion of 150 kPa, due to the fracturing of the rock.

The Pedological and Contamination Survey (Volume 4) indicates the presence of potential acid sulphate soils (PASS) in this area of the alignment.

At this stage it is considered that driven steel tubular piles will be the most suitable piling system, due to the generally shallow depth to rock. Any excavated material would need to be treated in accordance with guidelines on acid sulphate management. The driven pile option has the advantage of not removing PASS, which would require treatment (this is further covered within Section 1). The concrete for the piles will also require sulphate resistant concrete.

The subsurface profile is summarised in Table 16 below.

Table 16 Soil Profile Ch 5050 - 5300

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.1	Silty sandy CLAY, organic, soft to firm
1.5 m (BH-111)	Pedogenic	4.1m	Cemented, sandy SILT, dense
0.6 m - 13.0 m	Weathered Bedrock	-	Weathered Sandstone and Conglomerate, Tuff, seismic velocity of 4000m/s

7.8 Chainage 5300-5600, Horse Island

This section covers Horse Island, and it is from Ch 5300 that two separate alignments through the saddles on the eastern side of Karuah River diverge. These are the Northern Saddle and Southern Saddle. Over the length of Horse Island the two alternative alignments are approximately 50 m apart. The investigation has involved two boreholes either side of the island, and a seismic refraction survey over both alignments. Test pitting was also carried out and three pits were excavated by hand.

The seismic survey over the island section indicates rock to be at depth of approximately 8 to 10 m below the surface, at the west of the island. BH-111 on the west of the island met rock at a depth of 5.60 m. The seismic survey shows that the rock becomes shallower towards the eastern side of the island. There is rock outcrop on the east shore at approximately Ch 5600. This sandstone and conglomerate rock is of very high strength. This appears to correspond with a seismic velocity of 4300 to 4100 m/s. For design purposes it may be assumed that the rock has an allowable end bearing pressure of 3.5 MPa, and an allowable shaft adhesion of 250 kPa.

Test pits were excavated by hand over the island during Phase 2 of the investigations to depths of 0.6m to 1.1m. These pits encountered low to medium plasticity clays (firm to stiff) above dense pedogenic materials. Total settlements of 15 mm to 40 mm are anticipated under embankment loading over Horse Island, where the maximum embankment height of 10m corresponds to the maximum settlement.

The geological walkover study identified a pedogenic layer within the soil materials in an exposed face at approximately Ch 6100. This material may provide suitable foundation for lightly loaded structures, but is underlain by unconsolidated weaker sediments. Therefore abutment foundations must taken down to rock.

The extent of the pedogenic layer is difficult to assess. BH-111 on the western side of the island indicates the presence of silcrete. The test pits excavated indicate the presence of pedogenic materials on Horse Island itself. The seismic survey indicates slightly higher velocities in the area where the pedogenic layer can be observed. However it is not clear whether this layer is continuous.

7.9 Chainage 5600-6150, Karuah River Bridge

This section of both alignments covers the wetland area east of Horse Island and the length of river crossing (Ch 5600-6150). Within this area, the Phase 1 investigations involved the use of seismic refraction techniques.

As part of the Phase 2 investigations, ten over-water boreholes were drilled in this section. Rock was found to be shallower at the eastern side of the river. However there are variations in the quality of rock material at depth. This is because the rock sequence is of interbedded sandstones, shales and conglomerates. The beds appear to dip towards the southeast at 20 degrees. In the river section east of Ch 5870, piles can be founded in rock materials. An allowable end bearing pressure of 1 MPa can be adopted for these piles. This may be increased where the piles are founded in sandstone.

The boreholes west of Ch 5870 did not encounter rock, despite drilling to depths of up to 34.3 m below bed level (BH-204). The bridge piers in this area will be founded in the dense gravels, where standard penetration tests reached refusal. Due to "cave-in" experienced during drilling, it is difficult to interpret the SPT test results within this coarse gravel. It may be pertinent to adopt a typical SPT of 35 for this material for design purposes. Figure 19 contains SPT plots against depth for the over-water boreholes. Figure 10 indicates the plasticity of materials within the river profile.

The seismic survey report shows two different profiles for the two saddle options over the river section. The topography of the southern saddle alignment dips gradually away from the mangrove swamp at the west of the river. The depth to rockhead over the main section of the river is approximately 29 m to 30 m. At the east of the river the rockhead appears to rise steeply at approximately Ch 6100. BH-112S at the abutment location indicates rock at a depth of 19 m. It is important to note that there is some difference between the rock levels from the boreholes and the seismic survey. This is due to the presence of dense gravels above the rock, at the west of the river. These materials are at similar seismic velocity to bedrock. It will be necessary to conduct further investigations of these areas

At the detailed design stage it may be necessary to drill deeper boreholes (possibly using a large ODEX rig) to assess the geology beneath the gravels.

The subsurface profile encountered at this location is summarised in Table 17 below.

Table 17 Soil Profile Ch 5600-6150

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Alluvial	1.5 – 12.25	Black silty SAND, loose, containing carbonate shells
6.6-12.25m	Alluvial	1.4 - 4.35	Black, organic, silty CLAY, firm
12.3 – 14.6m	Alluvial	Base not defined by drilling	Grey, coarse sandy GRAVEL, medium dense to dense
4.7 – 14.6m	Rock	-	SANDSTONE, MUDSTONE, SHALE, SILTSTONE, CONGLOMERATE

The seismic survey has not differentiated between rock and gravel at the western side of the Karuah River. This is most likely due to the density of the gravels, and the weathered nature of the rock in the central area of the river. However further investigations should be carried out at construction design stage, to establish the thickness of the gravels and their relationship with the rock material both vertically and laterally within the river section.

The piling technique most suitable for the over-water work would be large diameter driven steel tubes. These would achieve the required loads in compression in either the dense gravels or in rock socket. It is not anticipated that uplift will affect the piled foundations as the dead load of the superstructure is sufficiently large.

The Pedological Report indicates the presence of PASS in the mangrove swamp to the east of Horse Island and also in river bed samples taken at the east of Karuah River. It is therefore assumed that PASS is present all over this section. Geotechnical testing of pH and sulphates has indicated the need for sulphate resisting concrete in the structures founded within the soils in this area of the alignment.

7.10 Chainage 6150-6200, Karuah River - Eastern Bridge Abutment

Boreholes have been drilled at the approximate abutment locations. The ground conditions are summarised in Table 18. At shallow depth the same geology occurs on both alignments (ie north and south saddle options), with sandy clay to a depth of 1 m to 2 m overlying silcrete to a depth of approximately 5 m. However below this level the materials above the rock head vary substantially between the northern and southern alignments.

On the northern alignment, at BH-112N, rock was encountered at 7.9 m, whereas on the southern alignment, BH-112S, rock was encountered at a depth of 19.0 m. BH-211 was drilled as part of the Phase 2 investigations. This hole encountered well graded sands above extremely weathered sandstone. The weathered rock had a medium dense consistency. Competent rock material was encountered at a depth of 31.10 m. The boreholes were drilled to rock, which may be assumed, for design purposes to have an allowable end bearing capacity of 3.5 MPa and an allowable shaft adhesion of 350 kPa.

It is apparent that the depths of piles will vary at the location of the eastern abutment. Piles in this area should be extended to competent rock material.

Testing of pH and sulphates from soil samples indicates that sulphate resistant concrete will be required for structures within the soil. The pedological survey indicates the presence of acid sulphate soils at the river edge but not at the abutment.

7.11 Chainage 6200-6650, AMP Embankment I

Both alignment alternatives are in fill in this section. The bridge abutments on the east bank of the river are likely to be piled. Boreholes have been drilled at the locations of the abutments of both saddle options and the seismic survey over the river section has been continued onto land, to allow correlation with the borehole information. Test pits have been excavated at approximately 150 m centres to assess the ground conditions below the embankment.

The ground conditions in this section are summarised in Table 18 and the laboratory results are given in Table 19.

Table 18 Soil Profile Ch 6150-6650

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.2 m - 0.25 m	Brown sandy SILT/CLAY, contains roots, loose-soft
0.2 m - 0.25 m	Alluvial	0.25 m - 0.35 m	Brown silty SAND, medium dense
0.45 - 0.60 m	Alluvial	0.65 m - 1.2 m	Brown sandy CLAY, firm to stiff, medium plasticity
1.25 - 2.65 m	Pedogenic	3.10 m - 3.75 m	Grey sandy SILT (SILCRETE), cemented, dense to very dense
5.0 m	Alluvial	2.9 m (BH-112N) to 14.5 m (BH-112S)	Grey sandy SILT, loose to medium dense (occasional thin layers of stiff grey silty CLAY)
14.50m (BH-211)	Weathered Rock	15.60m	Red, completely weathered, Sandstone, medium dense
7.90 m (BH-112N) to 19.38 m (BH-112S) to 31.10m (BH-211)	Bedrock	-	Interbedded SANDSTONES and SILTSTONES, medium strength

Table 19 Laboratory Test Results Ch 6150-6650

TP/BH	Depth	NMC	LL	PI
TP-118S	0.6	27	69	45
TP-118S	0.5	22	22	3
TP-118S	0.2	15		
TP-213	0-0.4	18		
TP-213	0.4-1.1	20.1	35	19
TP-214	0.2-0.9	24.6	64	43
TP-214	0.9-1.25	18.5	42	22
TP-215	0.3-0.95	32	59	29

The aerial photographic analyses show that a drainage channel runs from the northern saddle to the southern abutment. It is this ancient channel which has deposited the soft alluvial sediments found in BH-112S. These soft sediments may lead to increased differential settlements between the rigid piled abutment and the motorway embankment. This differential settlement will not be as pronounced on the northern saddle option due to the reduced thickness of soft alluvial sediments (refer to Figure 3c-d, BH-211). The moisture condition and plasticity of soils east of the river are shown in Figure 7 and Figure 14.

Test pits have been excavated along the two alternative alignments from the riverside to the cut areas at the saddles. The pits indicate similar material to be present along both alignments, however rock is at a shallower depth in the pits on the northern option. This would reduce the settlements due to the consolidation, although more excavation in rock will be required closer to the saddles. Stability of the embankment is less likely to be problematic on the northern alignment due to the stronger subsoils and lower embankment height.

BH-212 was drilled as part of the Phase 2 investigations. This borehole encountered rock at a depth of 4.25 m, and was overlain by sandy clay of intermediate plasticity. Settlements in this area are anticipated to be in the range of 15-50 mm under embankment loading

Table 20 Soil Profile (Embankment section of alignment)

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.15 m - 0.4 m	Sandy clayey SILT, organic, roots, peaty, loose
0.15 m - 0.40 m	Colluvial / Alluvial	0.60 m – 2.05 m (TP-213 to TP-216)	Brown silty sandy CLAY and clayey SILT, firm, medium to high plasticity
0.95 m - 1.50 m	Pedogenic	3.1 m - 3.75 m adjacent to abutments (not present in TP-121N or TP-121S)	Grey sandy SILT (SILCRETE), dense, medium plasticity
5.0 m (only present in abutment boreholes, test pits refused in overlying pedogenic material)	Alluvial	2.9 m (BH-112N) to 14.5 m (BH-112S)	Grey sandy SILT, loose to medium dense (occasional thin layers of stiff grey silty CLAY)
1.40 m - 19.38 m	Weathered Bedrock	-	Interbedded SANDSTONES and SILTSTONES in BH-212, BH-112N and BH-112S, DACITE and TUFF within pits from Ch 6500

7.12 Chainage 6650-6900, Saddle Cut

This section covers the cuts through the saddles east of the Karuah River on both alignments. The investigations included two boreholes on each alignment, one being at the crest of the saddle and the other being at the eastern end of the cut. Down-hole geophysical techniques have been utilised in all four of these boreholes, to gain more detailed information on the quality of the rock mass and the orientation and nature of the discontinuities in the rock material. Due to the thin soil cover, no laboratory tests were carried out on the soils.

The ground conditions observed in this section are summarised in Table 21.

Table 21 Soil Profile Ch 6650 - 6900

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Residual	0.15 m - 1.65 m	Brown sandy CLAY, soft to firm, medium plasticity
0.15 m - 0.65 m	Bedrock	-	Interbedded RHYOLITE, TUFF, AGGLOMERATE, DACITE, ARENITE, low to high strength

The original alignment showed the depth of cut to be approximately 17.5 m at the deepest point on both alignments. In both BH-113S and BH-113N approximately 20 m of rock core was recovered. Rhyolite, lithic arenites, agglomerates and microgranites were encountered in BH-113S. The quality of the rock is "quite poor", with most of the core runs having rock quality designations (RQD) less than 50% (average RQD was 41%), even at depths below 10 m. This reflects the closely spaced jointing of the core. In contrast BH-113N produced core with RQD generally greater than 50% (average RQD for the hole was 78%), reflecting a more widely

spaced joint pattern. The rock strengths as determined from point load strength index tests on core from BH-113N are also greater than BH-113S.

The boreholes at the east of the cut areas were drilled to depths of approximately 10 m. Tuffs and tuffaceous sandstones were encountered in BH-114S. The RQD values were generally in excess of 50% for the upper 5 m of core and 100% for the core runs below 5 m. RQD values for BH-114N were generally less than 50% over the entire core length, due mainly to a closely spaced, steeply dipping joint set.

BH-213 was drilled in the same hole as BH-113N, and extended to a depth of 34.4 m. The down-hole geophysical survey was not carried out in BH-213, however relative core orientation was carried out to assess the relative angles between bedding and joints. This was then compared to discontinuity orientation data from the geophysical information and showed good correlation. This would indicate that the bedding and joint orientations are similar at depth within the cut.

Appropriate slope angles and bench spacings are provided in Section 2. Joint orientations from the down-hole geophysical survey are shown in Figures 4d and Figure 4f (stereoplots for the southern saddle option are also included as Figure 4e and 4g). The slope has been analysed for planar, toppling and wedge failure. Wedge failure is the critical mode in this cut. The dominant joint set is bedding which dips at 20 degrees towards the southwest (ie 17/200). There are also two steep joint sets (ie 78/093 and 65/037), and several minor joint sets. The bedding does not intersect the steep joints within the wedge failure envelope. However three minor sets do intersect within this envelope. This would indicate that minor wedge failures may occur, depending on the persistence of the joint sets. On this basis, the slope has been designed with benches at 7 m intervals and a verge at the base. Some spot bolting may be necessary for isolated wedges.

The quality of rock mass within the northern saddle will involve extremely hard ripping and blasting, as the fracture spacing and lack of weak interbeds will not allow easy ripping.

Rock core samples from both saddles have been examined under a petroscopic microscope to assess the mineralogy. The rock in each of the samples appeared to be of volcanic origin, with similar mineralogy. The rock is dominantly composed of plagioclase, with K-feldspar and quartz being the other dominant minerals. There are minor amounts of biotite mica and some chlorite as a secondary weathering product. This type of mineralogy will be suitable for use as general fill and could also be suitable for road base material provided additional testing indicated that the material met pavement specifications. Design stage investigations should consist of further investigations of the mineralogy of the rock, and also assess the slake potential of the rock upon exposure.

7.13 Chainage 6900-8050, AMP Embankment II

Over this section the alignment is again in fill. The embankment has a maximum height of 5 m where the alignment crosses the Mosquito Creek at Ch 7400. Both of the route options have been investigated in this area. Boreholes and test pits have been excavated as follows:

- BH-115
- TP-124S, TP-125S, TP-126S, TP-127S, TP-128 and TP-129
- TP-124N, TP-125N, TP-126N, TP-127N

The ground conditions observed in this section are summarised in Table 22 and the laboratory results are given in Table 23 and Table 24.

Table 22 Soil Profile Ch 6900 - 8050

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.15 m - 0.45 m	Black sandy SILT, medium plasticity, loose
0.2 –0.6	Residual	0.25 – 0.50m	Brown, sandy CLAY, firm-stiff, medium plasticity
0.15 m - 0.45 m (except TP-127S)	Residual	0.2 m - 0.4 m	Grey silty SAND or sandy SILT, loose
0.45 m (TP-127S only)	Alluvial	3.60 m	Firm to stiff sandy CLAY and silty SAND, medium dense
0.60 - 1.50 m	Weathered Bedrock	- (Drilled from 0.63m to 4.95m in BH-115)	Grey weathered RHYOLITE, RHYODACITE, TUFF, medium strength

Table 23 Laboratory Test Results (Southern Saddle)

TP/BH	Depth	NMC	LL	PI	Classification
TP-124S	0.5	10			
TP-125S	0.8		NP	NP	
TP-127S	0.3	20	23	6	CL
TP-127S	1.9	19	34	19	CL
TP-127S	4.0	19	40	20	CI
TP-128	1.0	15			SC
TP-129	0.5	20	43	28	CL
TP-129	0.9	7			GP

Table 24 Laboratory Test Results (Northern Saddle)

TP/BH	Depth	NMC	LL	PI	Classification
TP-125N	0.85	22	23	7	GC
TP-126N	0.8 - 1.5	29	70	39	CH
TP-126N	1.5 - 1.95	20	45	23	CI
TP-127N	0.4 - 0.95	29	52	31	CH

Rock generally occurs at shallow depth in this section (1.5 m BGL). It is overlain by loose sandy silt topsoil and loose silty sand (or sandy silt). Greater depths of stiff/medium dense sandy clay and silty sand occur on the southern alignment in the vicinity of TP-127S.

Plasticities and moisture contents are generally higher for the northern saddle than the southern saddle. The moisture content and plasticity ranges are indicated in Figures 8 and 12.

BH-115 indicated the presence of tuff and tuffaceous sandstone in the vicinity of the bridge at the Mosquito Creek. An allowable end bearing pressure of 3.5 MPa and shaft adhesion of 250 kPa may be assumed for this material.

In view of the generally shallow soils in the section, embankment stability is unlikely to be an issue after removal of topsoil and isolated unsuitable material.

7.14 Chainage 8050-8500, AMP Cut I

The alignment in this section is in cut. The maximum thickness of cut is approximately 10 m at Ch 8300. Test pits have been excavated at 150 m centres and three boreholes have been drilled using rotary coring techniques. Down-hole geophysical survey was carried out in BH-116.

The ground conditions in this section are summarised in Table 25 and the laboratory results are given in Table 26.

Table 25 Soil Profile Ch 8050-8500

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.15 m - 0.20 m	Brown silty clayey SAND, loose
0.15 m - 0.20 m	Alluvial	0.15 m - 0.35 m	Grey silty SAND, loose
0.3 m - 0.5 m	Residual	0.3 m - 0.50 m	Brown sandy CLAY, firm to stiff, medium plasticity
0.5 m - 1.00 m	Weathered Bedrock	-	AGGLOMERATE/DACITE, TUFF, low strength

Table 26 Laboratory Test Results Ch 8050-8500

TP/BH	Depth	NMC	LL	PI	Classification
TP-130	0.5	19	40	23	SC
TP-130	0.7	5			GP
TP-131	0.7	9	NP	NP	Rock
TP-132	0.5	16	42	25	CI
TP-133	0.6	28	67	45	CH

The plastic indices suggest that the clays encountered in this section be of medium to high plasticity.

The stereographic plot of jointing within BH-116 (refer to Figure 4h) indicates that the majority of the joints are shallowly dipping bedding planes which are generally tight and irregular. It would therefore be expected that planar failure is unlikely. Limited wedge failure is possible, and these could be stabilised with a local rock bolts and

anchors where necessary. The full wave form sonic information was quite poor (refer to Down-hole Geophysical Report, Volume 3), and this indicated the presence of occasional open bedding planes at medium spacing (approximately 600 mm apparent thickness)

The maximum depth of cut in this area is 10 m. Down-hole geophysical techniques have been used to determine the orientation of joints and defects. The stability of joints has been modelled using the DIPS program and also by rock mass classification. The rock in the boreholes within this section is of good quality with RQDs in excess of 50%. The rock material is generally strong to very strong dacite and microgranite. The fracture spacing is generally closely to medium spaced. The bedding dip appears to vary from 20° to 40°. Toppling failure is unlikely with these bedding dip angles. Planar sliding is possible on the northern face of the cutting, though this will be the low side of the side-cutting. Some small wedge failures may be possible. These will best be assessed during construction, and should be stabilised using rock bolts or, more likely, rock anchors. The cuts within this area may be designed to batter angles as per Table 3, in Section 2. Previous experience on road projects, such as the Bulahdelah to Coolongolook section of the Pacific Highway (refer to Volume 5), suggests that batter angles of 2:1 are preferable to 1:1, in terms of practicalities of blasting.

The soils in this section of the alignment are shallow and variable, ranging from silty sand in the alluvium to medium to high plasticity residual clay soils. The materials are suitable for re-use in fills after removal of the topsoil.

The rock is suitable for use as a general fill and may also be used as a road base material pending further testing. The mineralogical composition is similar to that of BH-117 which contains plagioclase, quartz and k-feldspar, with minor chlorite, biotite. No expansive clays were identified, however this may be checked by further testing (XRD mineralogical analysis) and possibly slake durability.

7.15 Chainage 8500-8900, AMP Embankment III

This section of the alignment is in shallow fill with a maximum fill height of 3 m. The investigations in this section consisted of three test pits, each of which refused in shallow bedrock

The ground conditions in this section are summarised in Table 27 and the laboratory results are given in Table 28.

Table 27 Soil Profile Ch 8500 - 8900

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.15 m - 0.35 m	Black silty clayey SAND, loose, organic
0.15 m - 0.35 m	Alluvial	0.20 m - 0.35 m	Grey silty SAND, loose
0.35 m - 0.50 m	Residual	0.35 m - 1.05 m	Brown sandy CLAY, stiff, medium plasticity
0.85 m - 1.40 m	Weathered Bedrock	-	Lithic ARENITE/TUFF (ignimbrite), medium strength

Table 28 Laboratory Test Results Ch 8500 - 8900

TP/BH	Depth	NMC	Classification
TP-134	0.3	16	SM
TP-134	0.6	17	CH
TP-134	1.0	10	GP

The soils in this section of the alignment are shallow and variable, ranging from alluvial silty sand to medium to high plasticity residual clay soils. These materials are described as stiff where cohesive, and medium dense where dominantly granular.

The materials are suitable as a foundation for use as fill after removal of the topsoil and isolated unsuitable material, and compaction of the in situ subgrade. Due to the generally shallow depth to rock and competent soils overlying the rock, embankment stability is not expected to be an issue in this section of the alignment.

7.16 Chainage 8900-9500, AMP Cut II

In this section, the alignment is in shallow cut. The maximum depth of cut is 5 m at Ch 9025 however, the cut depth is generally between 3 m to 4 m. A borehole has been drilled at Ch 9125 (BH-118), and four test pits have been excavated at a frequency of approximately 150 m intervals along the centre line.

The ground conditions in this section are summarised in Table 29 and the laboratory results are given in Table 30.

Table 29 Soil Profile Ch 8900-9500

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.20 m - 0.30 m	Black clayey SILT, loose, organic
0.20 m - 0.30 m	Residual	0.20 m - 0.50 m	Brown sandy CLAY, stiff, medium plasticity
0.5 m - 1.80 m (TP-138 only)	Residual	1.30 m	Grey clayey SAND, medium dense to dense, slightly cemented
0.70 m - 1.80 m	Weathered Bedrock	-	IGNIMBRITE/RHYODACITE, medium strength

Table 30 Laboratory Test Results Ch 8900 - 9500

TP/BH	Depth	NMC	LL	PI	Classification
TP-135	0.2	21	49	29	CI
TP-136	0.5	21	49	29	CI
TP-136	0.8	2			Rock
TP-139	0.6	21	40	21	CI
TP-139	1.9	13	NP	NP	Rock

The plastic indices of the residual sandy clays are in the range 21 to 29. Natural moisture contents are approximately 21%.

The cut will be in rock, and the rock is of "very good" quality. The rock material is high to very high strength and the bedding spacing is close to medium. The RQDs within this material range from 65%-92%. The rock mass classification of the material suggests a batter angle of 4:1 (vertical:horizontal) would be acceptable.

The rock material in this section is medium bedded, high strength rock. The dominant joint set is the shallow bedding. It will therefore be very hard ripping or marginal blast (preblast).

The test pits indicate the presence of a thin sandy alluvial layer, which is water bearing. This layer though thin, will allow seepage down the rock face. Drainage measures, such as lined drains should be installed to intercept this flow to prevent instability above the rock.

7.17 Chainage 9500-9950, Branch Lane Embankment

At the eastern end of the AMP property, the alignment changes to embankment again. The maximum depth of fill is 7 m at Ch 9750. Within this section, the road will cross the swampy area at the junction of the Branch Lane and the Pacific Highway. The investigation within this area has comprised test pits and one borehole, as the survey and alignment details had not been completed. The alignment will ultimately require an overpass/underpass, and a borehole investigation for the foundations of this structure is recommended.

Table 31 Soil Profile Ch 9500-9950

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.15 m - 0.30 m	Black silty SAND, loose, rootlets
0.15 m - 0.30 m	Alluvial	0.20 m - 0.60 m	Grey silty SAND, loose
0.60 m - 0.90 m	Residual	To end of pits	Grey, silty SAND, dense, slightly cemented
6.9	Bedrock	-	Red DACITE, MICROGRANITE, high strength

Table 32 Laboratory Test Results Ch 9500 - 9950

TP/BH	Depth	NMC	LL	PI	Classification
TP-140	0.5	15			CI
TP-140M	1.0	27			CH
TP-140	3.7	16			SC
BH-216	1.1	20.2	22	7	ML
BH-216	2.6	17.4	27	13	SC

7.18 Chainage 9950-10500, Pacific Highway Re-entrance

Over this section, the alignment is nearly at grade. The test pits within this section have been excavated on the south of the existing Pacific Highway, as it is likely that the existing highway pavement will be utilised on the northern side. Four test pits have been excavated and are described in the tables below.

Table 33 Soil Profile Ch 9950 - 10500

Depth to Top of Layer in Test Holes	Soil Origin	Thickness	Description
0 m	Topsoil	0.30 m - 0.40 m	Black silty SAND, organic, loose
0.30 m - 0.40 m	Alluvial	0.40 m - 1.30 m	Brown sandy silty CLAY, stiff, medium plasticity (dense where granular)
0.90 m (TP-141 only)	Pedogenic	To end of pit	Grey sandy SILT (SILTCRETE), dense, slightly cemented
1.80 m - 2.30 m	Weathered Bedrock	-	Grey, low strength RHYOLITE/RHYODACITE

Table 34 Laboratory Test Results Ch 9950 - 10500

TP/BH	Depth	NMC	LL	PI	CBR	OMC	MDD
TP-142	1.0	15	38	22	6	21.5	1.59
TP-143	1.0	22	76	52	3	16.0	1.74
TP-144	0.8	17	53	36	3.5	17.0	1.69

Plastic indices for the clays sampled in this section are variable, ranging from 22 to 52. This suggests that the alluvium can be classified as medium to high plasticity clay.

Natural moisture contents are also variable, ranging from 6% below OMC to 6% above.

Maximum dry densities are in the range 1.59 t/m^3 to 1.74 t/m^3.

8. REFERENCES

1. Arup Geotechnics, Preliminary Geotechnical Assessment, May 1997
2. Engel BA, Geology of the Bulahdelah – Port Stephens District NSW, Journal and Proceedings Royal Society of New South Wales, V 95 pp 197-215, 1962.
3. Mathei LE (DLWC), Soil Landscapes of the Newcastle 1:100,000 Sheet, 1995.
4. DUAP/EPA, Acid Sulphate Soils – Assessment and Management Guidelines, 1997.

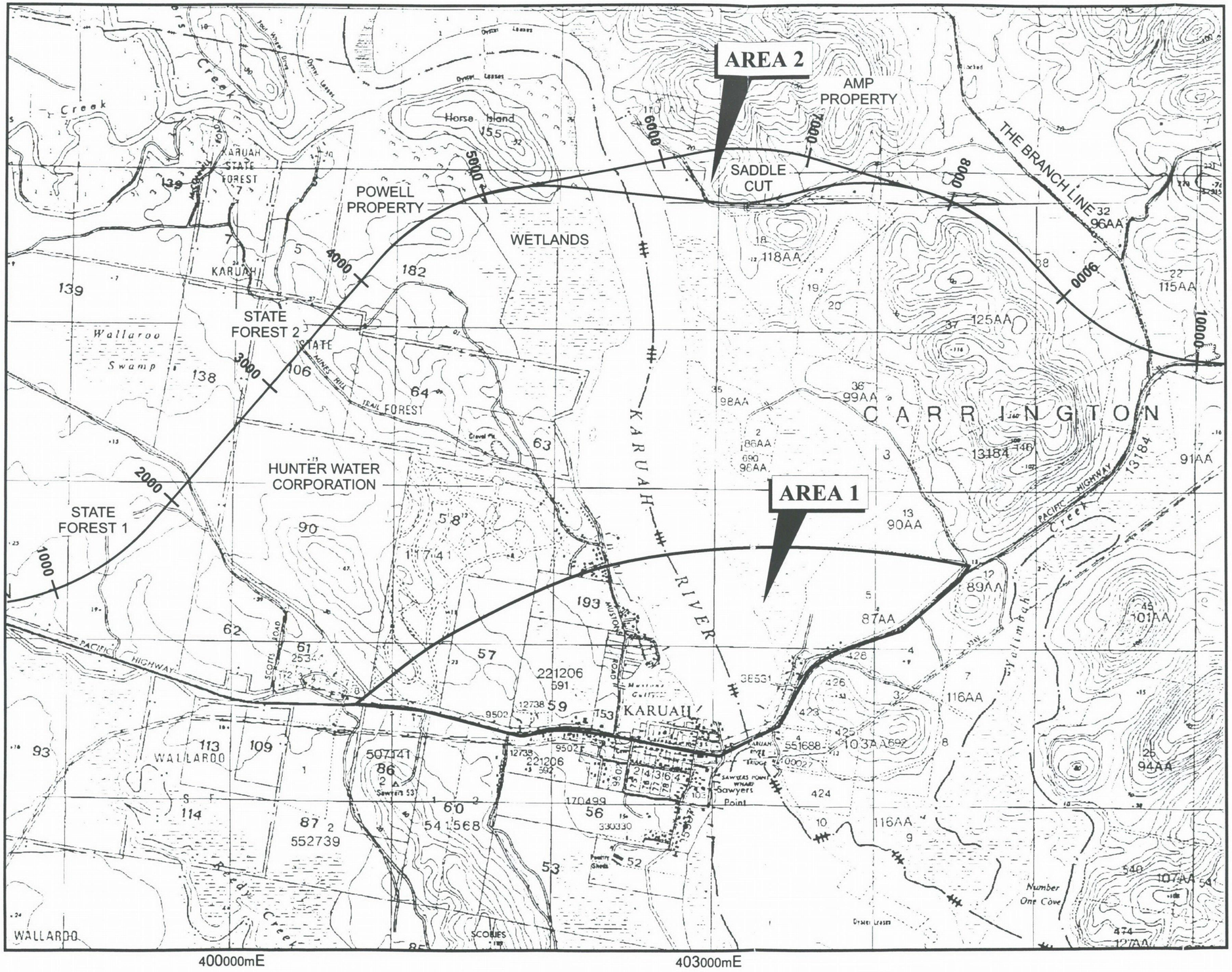
Test Pit and Borehole Coordinates and Levels

Location	Northing	Easting	Reduced Level (m AHD)
BH-101	386214.9	1386056	8.155
BH-102	387203.3	1386727	24.972
BH-103	387339.0	1386898	16.232
BH-104	387411.2	1386998	11.671
BH-105	387653.8	1387299	10.281
BH-106	388020.1	1387779	31.72
BH-107	388194.4	1388002	35.206
BH-108	388633.7	1388446.0	17.36
BH-109	388633.7	1388447	19.364
BH-110	389149.6	1388676	9.968
BH-111	389370.5	1388715	0.819
BH-112	390345.3	1388636	3.353
BH-113	390881.2	1388962	53.214
BH-114	390965.8	1388978	31.08
BH-115	391569.7	1388659	3.02
BH-116	392275.3	1388529	28.564
BH-117	392355.8	1388482	27.294
BH-118	392928.2	1387928	21.708
TP-105	386216.7	1386056	8.152
TP-106	386778.7	1386267	18.925
TP-107	387204.7	1386726	24.909
TP-108	387338.4	1386889	16.233
TP-109	387412.8	1386998	11.655
TP-110	387654.8	1387300	10.276
TP-111	388049.6	1387815	31.129
TP-112	388158.1	1387956	37.423
TP-113	388267.9	1388089	20.719
TP-114	388333.7	1388165	13.605
TP-115	388491.3	1388339	10.423
TP-116	388917.2	1388602	12.797
TP-117	389130.8	1388674	12.213
TP-118	390309.9	1388772	5.225
TP-119	390408.8	1388807	7.765
TP-120	390567.0	1388826	9.465
TP-121	390691.5	1388903	15.739
TP-122			
TP-123			
TP-124	391057.4	1388955	22.319
TP-125	391229.6	1388908	18.135
TP-126	391366.9	1388874	19.252
TP-127	391498.3	1388805	8.864
TP-128	391870.3	1388699	7.473
TP-129	391936.7	1388653	10.733
TP-130	392172.4	1388577	22.43
TP-131	392269.4	1388531	28.533
TP-132	392381.6	1388464	23.62
TP-133	392512.8	138860	19.857
TP-134	392659.8	1388215	21.966
TP-135	392857.9	1388003	26.408
TP-136	393000.0	1387859	16.636
TP-137	392709.6	1388160	22.648

Location	Northing	Easting	Reduced Level (m AHD)
TP-138	393065.6	1387760	14.392
TP-139	393237.3	1387680	7.92
TP-140	393357.1	1387640	3.215
TP-141	393441.2	1387537	1.496
TP-142	393593.5	1387573	5.095
TP-143	393754.0	1387555	9.917
TP-144	393918.9	1387532	10.115
BH-201	390180.7	1388857	-5.92
BH-202	390130.2	1388848	-9.22
BH-203	390079.4	1388838	-6.52
BH-204	390028.6	1388828	-5.22
BH-205	389977.0	1388819	-3.82
BH-206			-3.82
BH-207	389925.9	1388809	-2.92
BH-208	389878.1	1388800	-3.22
BH-209	389832.6	1388791	-2.92
BH-210	390052.1	1388833	-4.92
BH-211	390258.8	1388872	5.931
BH-212	390585.4	1388934	15.102
BH-213	390876.1	1388952	53.197
BH-214	391601.5	1388780	4.184
BH-215	392257.3	1388546	26.244
BH-216	393335.9	1387670	4.137
BH-217	389204.5	1388683	0.617
BH-218	387078.5	1386633	26.082
TP-201	386555.5	1386105	8.765
TP-202	386499.2	1386163	8.836
TP-203	386588.3	1386208	11.212
TP-204	386873.9	1386413	22.232
TP-205	386980.1	1386520	23.579
TP-206	387488.2	1387099	10.33
TP-207	387553.1	1387176	10.35
TP-208	387613.3	1387254	10.319
TP-209	387856.9	1387564	14.055
TP-210	389443.1	1388732	5.382
TP-211	389499.7	1388742	9.627
TP-212	389541.3	1388749	12.253
TP-213	390288.8	1388878	6.703
TP-214	390382.1	1388896	8.674
TP-215	390480.3	1388914	10.77
TP-216	390585.4	1388934	15.102

ARUP
Geotechnics

STUDY LOCATIONS



N

SCALE

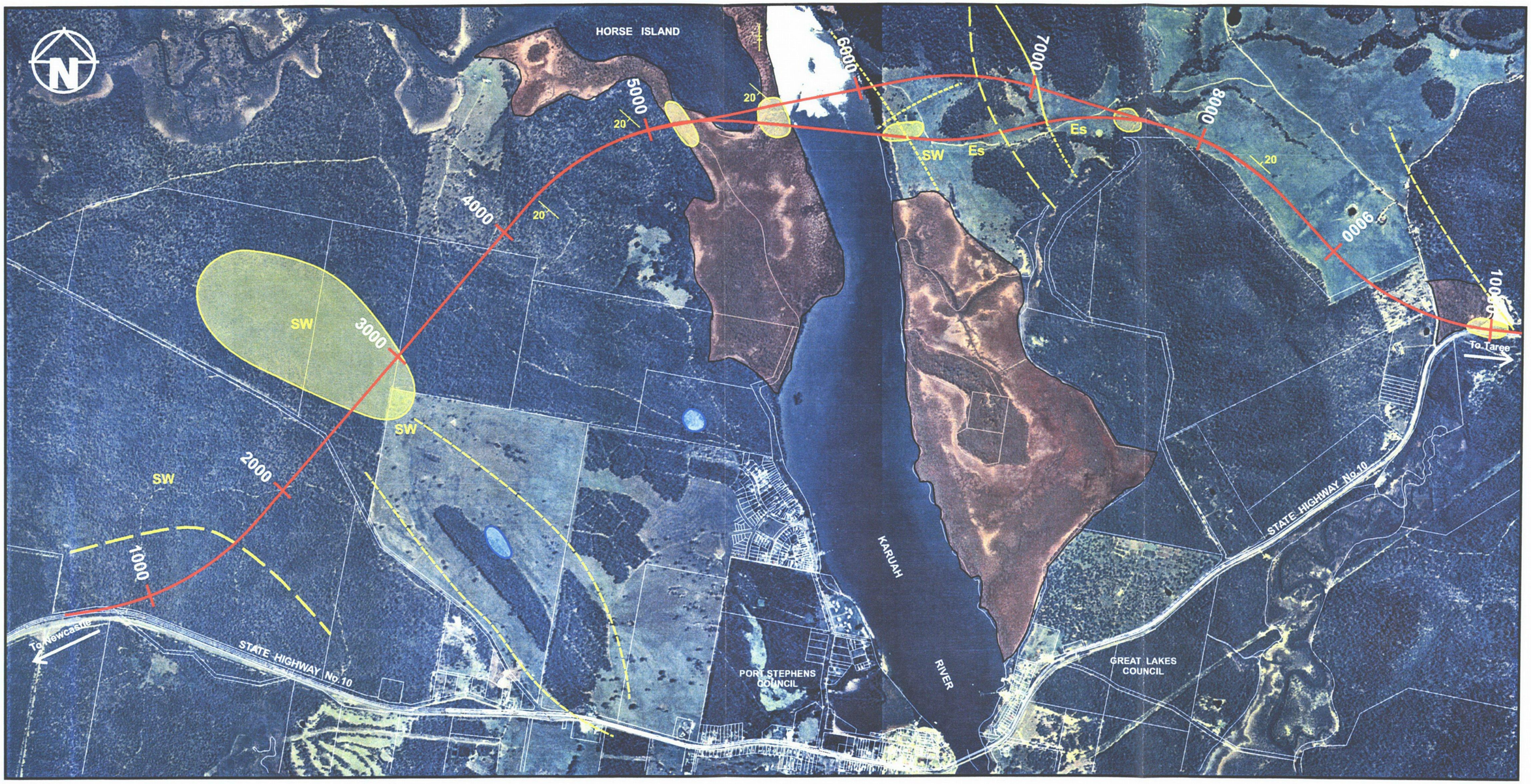
0 0.5 1.0km

26 August 1999\inf\9809\510\gjm-0001.cdr

FIGURE: 1a JOB: 9809/510

ARUP
Geotechnics

GEOTECHNICAL MAP



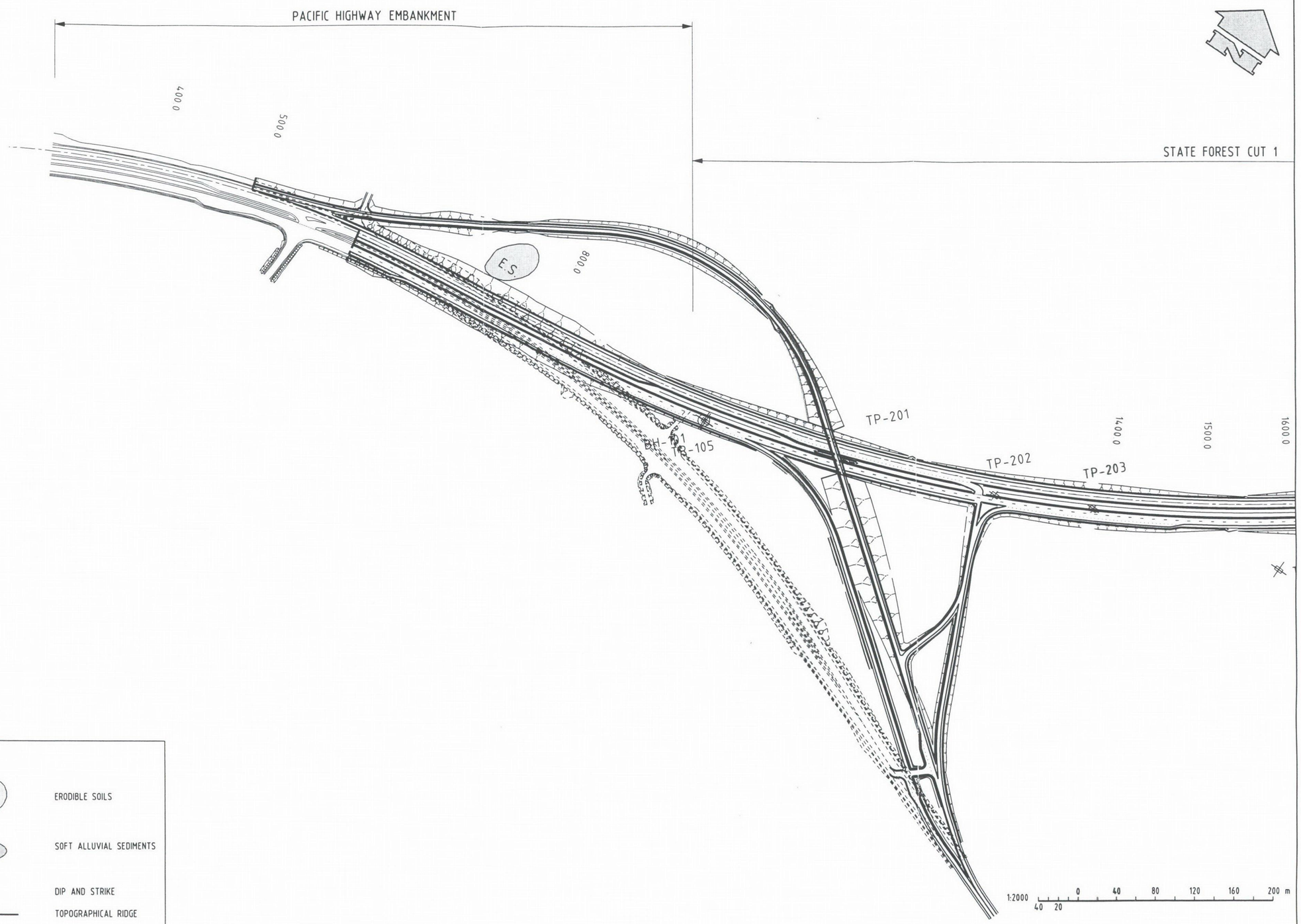
LEGEND

- Rock Outcrop
- Topographical Ridge
- Fault
- Inferred Fault
- Anticline Fold Axis
- Vertical Joint
- Dip & Strike of Bedding
- Dip & Strike of Joints
- SW — Standing Water
- Es — Erosive Soils
- Soft Alluvial Sediments
- SEPP 14 Wetlands

Scale 1 : 28,000

27 August 1999\inf\9809\510\gjm-0003.cdr

FIGURE: 1b JOB: 9809/510



LEGEND

- ROCK OUTCROP
- NATURAL CLIFF
- EROSION GULLY
- QUARRY
- E.S. — ERODIBLE SOILS
- SOFT ALLUVIAL SEDIMENTS
- 20 — DIP AND STRIKE
- TOPOGRAPHICAL RIDGE
- FAULT
- INFERRED FAULT
- S.W. — STANDING WATER

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

- BH-121 — BOREHOLE DRILLED IN PHASE 1 INVESTIGATION
- BH-211 — BOREHOLE DRILLED IN PHASE 2 INVESTIGATION
- TP-110 — TEST PIT

Issue	Description	By	Date	Issue	Description	By	Date
1	PRELIMINARY ISSUE	AH	24.6.99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 00.0 Km - 1600.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 1 of 7
Drawing No 9809/S02/FIG 2A	Issue 1

STATE FOREST CUT 1

WOLLAROO SWAMP EMBANKMENT

WALLAROO SWAMP

S.W.

1500.0 1600.0 1700.0 1900.0 2000.0 2100.0 2200.0 2500.0 2600.0 2700.0 2800.0 2900.0 3100.0

TP-106 TP-204 TP-205 BH-218 TP-107 BH-102 TP-108 BH-103 BH-104 TP-109 TP-206 TP-207 TP-208 TP-110 BH-105

ES

LEGEND

ROCK OUTCROP	ERODIBLE SOILS
NATURAL CLIFF	SOFT ALLUVIAL SEDIMENTS
EROSION GULLY	DIP AND STRIKE
	TOPOGRAPHICAL RIDGE
	FAULT
QUARRY	INFERRED FAULT
	STANDING WATER

1:2000 0 40 80 120 160 200 m
40 20

BH-121 BOREHOLE DRILLED IN PHASE 1 INVESTIGATION

BH-211 BOREHOLE DRILLED IN PHASE 2 INVESTIGATION

TP-110 TEST PIT

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date
1	PRLEMINARY ISSUE	AH	24.06.99

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

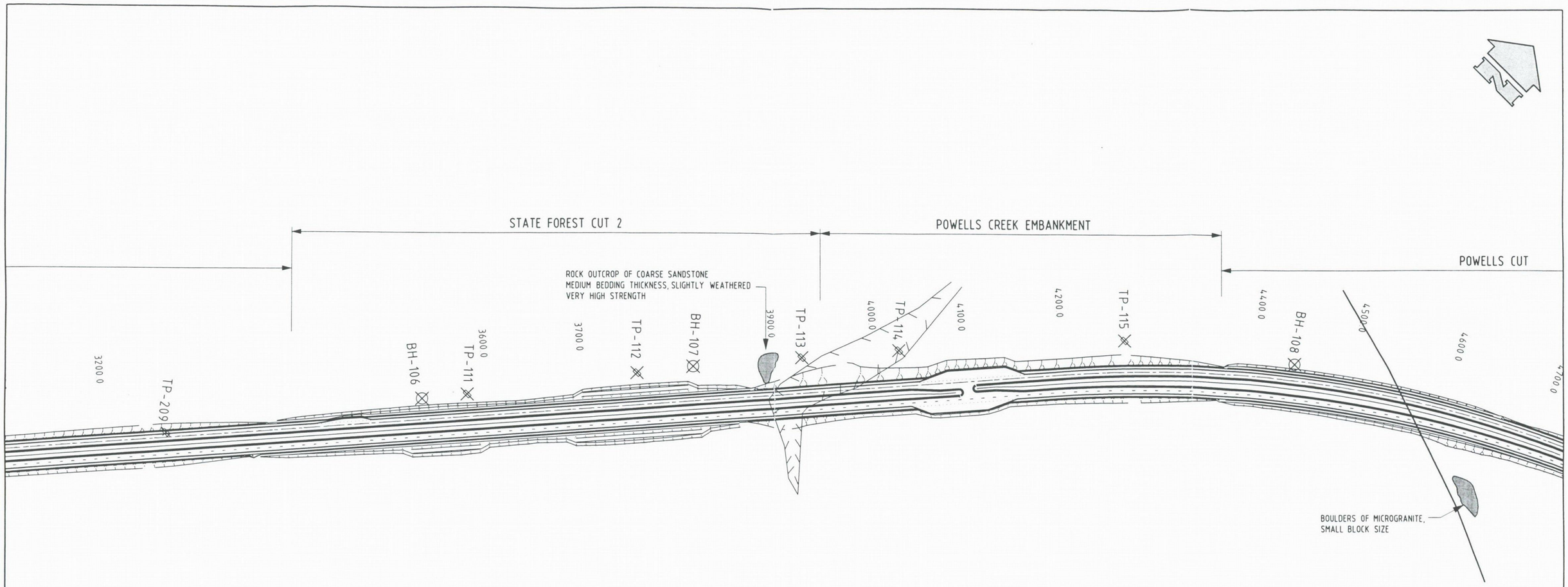
Ove Arup & Partners Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 1500.0 Km - 3100.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 2 of 7
Drawing No 9809/S02/FIG 2B	Issue 1



LEGEND

- ROCK OUTCROP
- NATURAL CLIFF
- EROSION GULLY
- QUARRY
- E.S. — ERODIBLE SOILS
- SOFT ALLUVIAL SEDIMENTS
- 20 — DIP AND STRIKE
- TOPOGRAPHICAL RIDGE
- FAULT
- INFERRED FAULT
- S.W. — STANDING WATER

1:2000 0 40 80 120 160 200 m
40 20

- BH-121 BOREHOLE DRILLED IN PHASE 1 INVESTIGATION
- BH-211 BOREHOLE DRILLED IN PHASE 2 INVESTIGATION
- TP-110 TEST PIT

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date
1	PRELIMINARY ISSUE	AH	24 06 99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners
Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

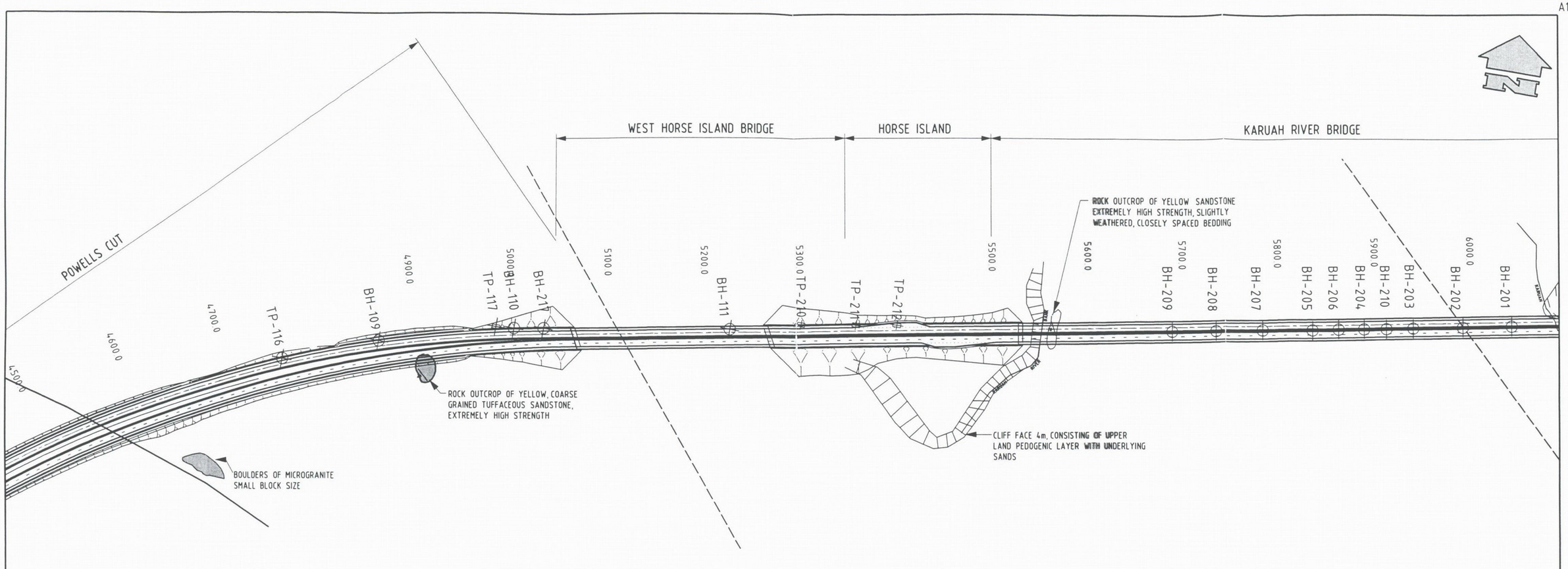
ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 3200.0 Km - 4700.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 3 of 7
Drawing No 9809/S02/FIG 2C	Issue 1

A1



LEGEND

- ROCK OUTCROP
- E.S. — ERODIBLE SOILS
- NATURAL CLIFF
- SOFT ALLUVIAL SEDIMENTS
- EROSION GULLY
- 20 — DIP AND STRIKE
- TOPOGRAPHICAL RIDGE
- FAULT
- QUARRY
- INFERRED FAULT
- S.W. — STANDING WATER

1:2000 0 40 80 120 160 200 m (40 20)

- BH-121 BOREHOLE DRILLED IN PHASE 1 INVESTIGATION
- BH-211 BOREHOLE DRILLED IN PHASE 2 INVESTIGATION
- TP-110 TEST PIT

NOTE : FOR LEGEND AND NOTES REFER DRAWING No. 201.

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date
1	PRLEMINARY ISSUE	AH	24.06.99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners
Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

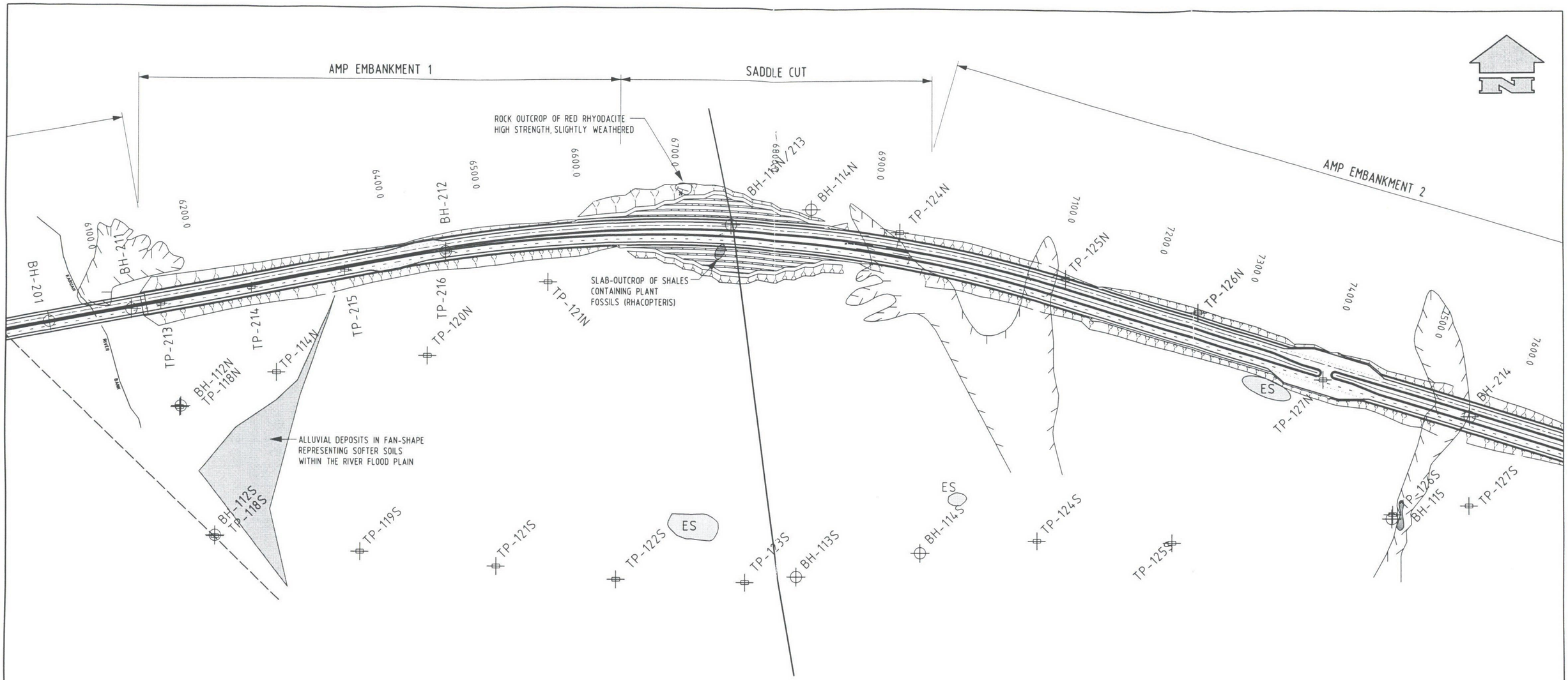
ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 4500.0 Km - 6000.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 4 of 7
Drawing No 9809/S02/FIG. 2D	Issue 1

A1 0 100 200mm on original



LEGEND

- ROCK OUTCROP
- NATURAL CLIFF
- EROSION GULLY
- QUARRY
- E.S. — ERODIBLE SOILS
- SOFT ALLUVIAL SEDIMENTS
- 20 — DIP AND STRIKE
- TOPOGRAPHICAL RIDGE
- FAULT
- INFERRED FAULT
- S.W. — STANDING WATER

1:2000 0 40 80 120 160 200 m (40 20)

- BH-121 — BOREHOLE DRILLED IN PHASE 1 INVESTIGATION
- BH-211 — BOREHOLE DRILLED IN PHASE 2 INVESTIGATION
- TP-110 — TEST PIT

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date
1	PRLEMINARY ISSUE	AH	24.06.99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

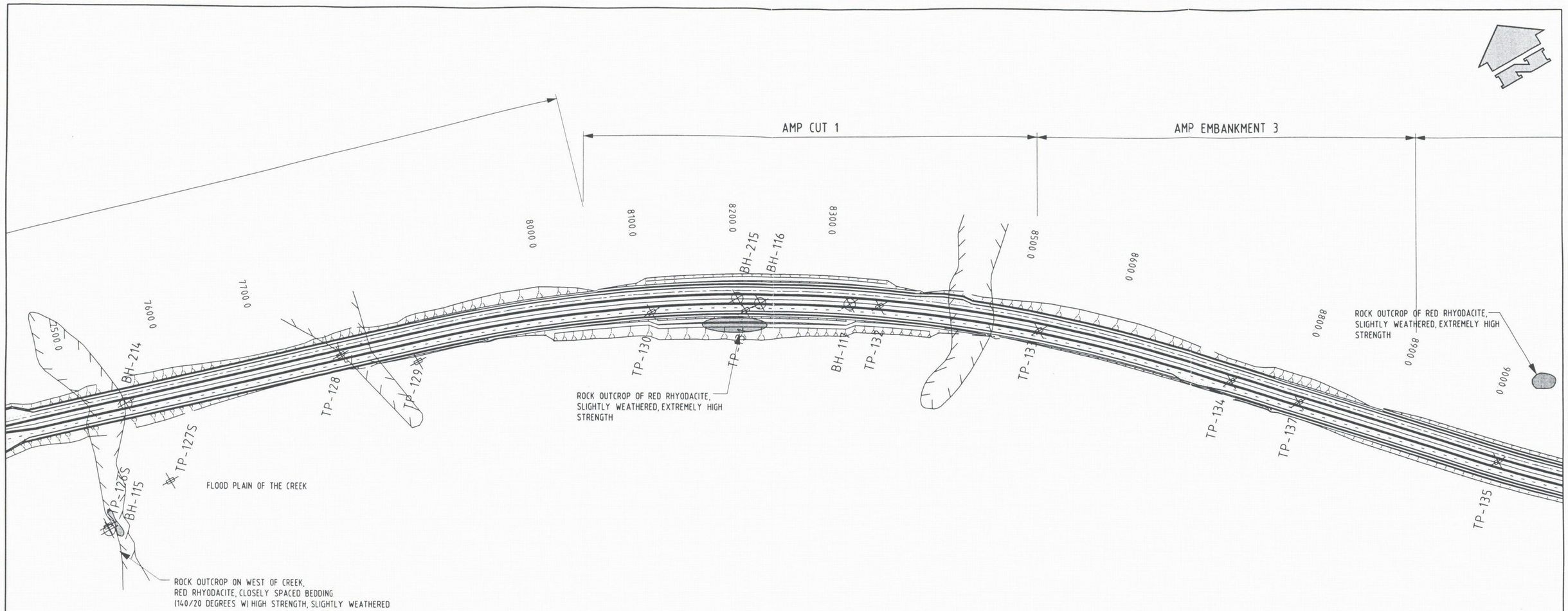
Ove Arup & Partners Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION AND GEOTECHNICAL MAPPING
(CH. 6000.0 Km - 7500.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 5 of 7
Drawing No. 9809/S02/SK(R)FIG. 2E	Issue 1



LEGEND

- ROCK OUTCROP
- E.S. — ERODIBLE SOILS
- NATURAL CLIFF
- SOFT ALLUVIAL SEDIMENTS
- EROSION GULLY
- 20 — DIP AND STRIKE
- TOPOGRAPHICAL RIDGE
- FAULT
- QUARRY
- INFERRED FAULT
- S.W. — STANDING WATER

1:20000 0 400 800 1200 1600 2000 m
400 200

- BH-121 — BOREHOLE DRILLED IN PHASE 1 INVESTIGATION
- BH-211 — BOREHOLE DRILLED IN PHASE 2 INVESTIGATION
- TP-110 — TEST PIT

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date
1	PRLEMINARY ISSUE	AH	24.06.99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESTIGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 7500.0 Km - 9000.0 Km)

FILE No. 10/362.1475 REGN. No. 0010.362.RC.MP21

Designed AH	Authorised for issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 6 of 7
Drawing No. 9809/S02/SK(R)FIG. 2F	Issue 1

AMP CUT 2

BRANCH LANE EMBANKMENT

PACIFIC HIGHWAY RE-ENTRANCE

8900.0

9000.0

9100.0

9200.0

9300.0

9400.0

9500.0

9600.0

9700.0

9800.0

9900.0

10000.0

10100.0

10500.0

10600.0

ROCKY OUTCROP OF RED RHYODACITE, EXTREMELY HIGH STRENGTH, SLIGHTLY WEATHERED

RED, BROWN, RHYODACITE, DACITE AND RHYOLITE SLIGHTLY TO MODERATELY WEATHERED, HIGH STRENGTH CLOSELY SPACED JOINTS, SMALL BLOCK SIZE. HIGH ANGLED FAULT OBSERVED IN SOUTH OF QUARRY

KARUAH RED QUARRY

ROAD CUTTING TO 2.5m IN RHYOLITE AND RHYODACITE AT 45 DEGREES, CLOSELY SPACED JOINTS, SOME EROSION OF ROCK PROFILE

WETLAND AREA WITH SOFT SOILS AND STANDING WATER

TP-135

BH-118

TP-136

TP-138

TP-139

BH-216

TP-140

TP-141

TP-142

TP-143

TP-144

LEGEND

	ROCK OUTCROP	E.S.	ERODIBLE SOILS
	NATURAL CLIFF		SOFT ALLUVIAL SEDIMENTS
	EROSION GULLY	20	DIP AND STRIKE
			TOPOGRAPHICAL RIDGE
			FAULT
	QUARRY		INFERRED FAULT
		S.W.	STANDING WATER

1:2000 0 40 80 120 160 200 m
40 20

BH-121 BOREHOLE DRILLED IN PHASE 1 INVESTIGATION

BH-211 BOREHOLE DRILLED IN PHASE 2 INVESTIGATION

TP-110 TEST PIT

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date
1	PRLEMINARY ISSUE	AH	24.06.99				

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners
Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN
CANBERRA CAIRNS PORT MORESBY AUCKLAND

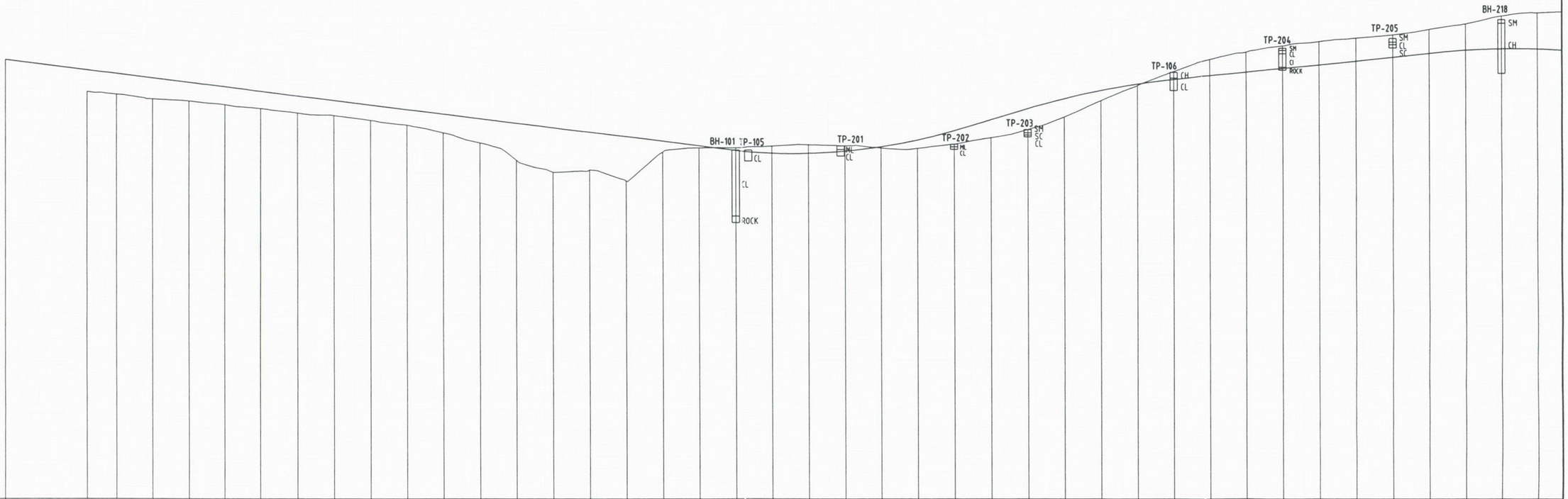
ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
CONCEPT DESIGN FOR PACIFIC HIGHWAY UPGRADE AT KARUAH
SITE INVESITGATION LOCATION AND GEOTECHNICAL MAPPING
(CH 9000.0 Km - 10500.0 Km)

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

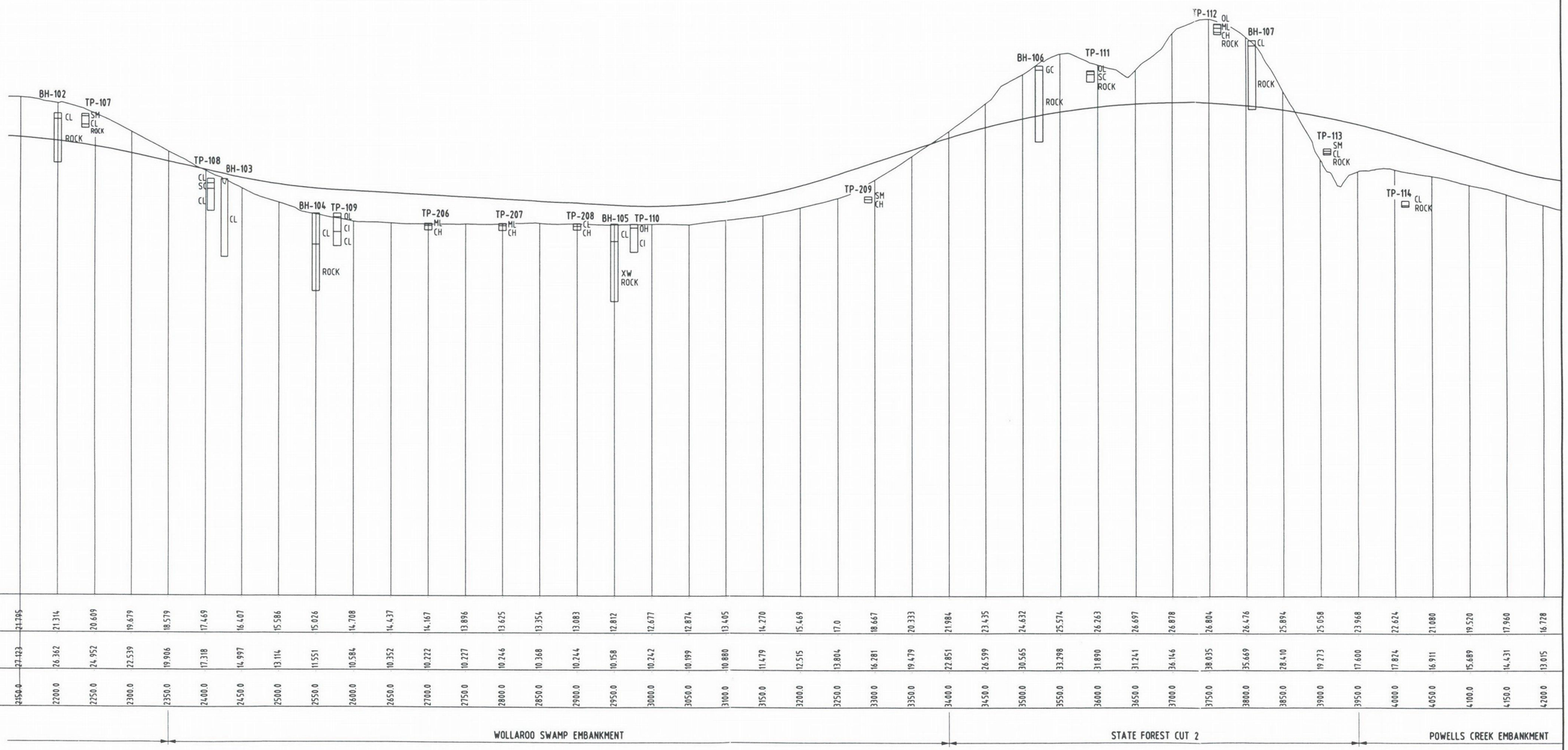
Designed AH	Authorised for Issue
Drawn AH	Scale 1:2000 AT A1
Checked	Sheet 7 of 7
Drawing No 9809/S02/SK(R)FIG. 2G	Issue 1

A0


BH-101
TP-105
CL
CL
ROCK
TP-201
ML
CL
TP-202
ML
CL
TP-203
SM
SC
CL
TP-106
CH
CL
TP-204
SM
CL
CI
ROCK
TP-205
SM
CL
SC
BH-218
SM
CH

DATUM: -40.0

| | | |

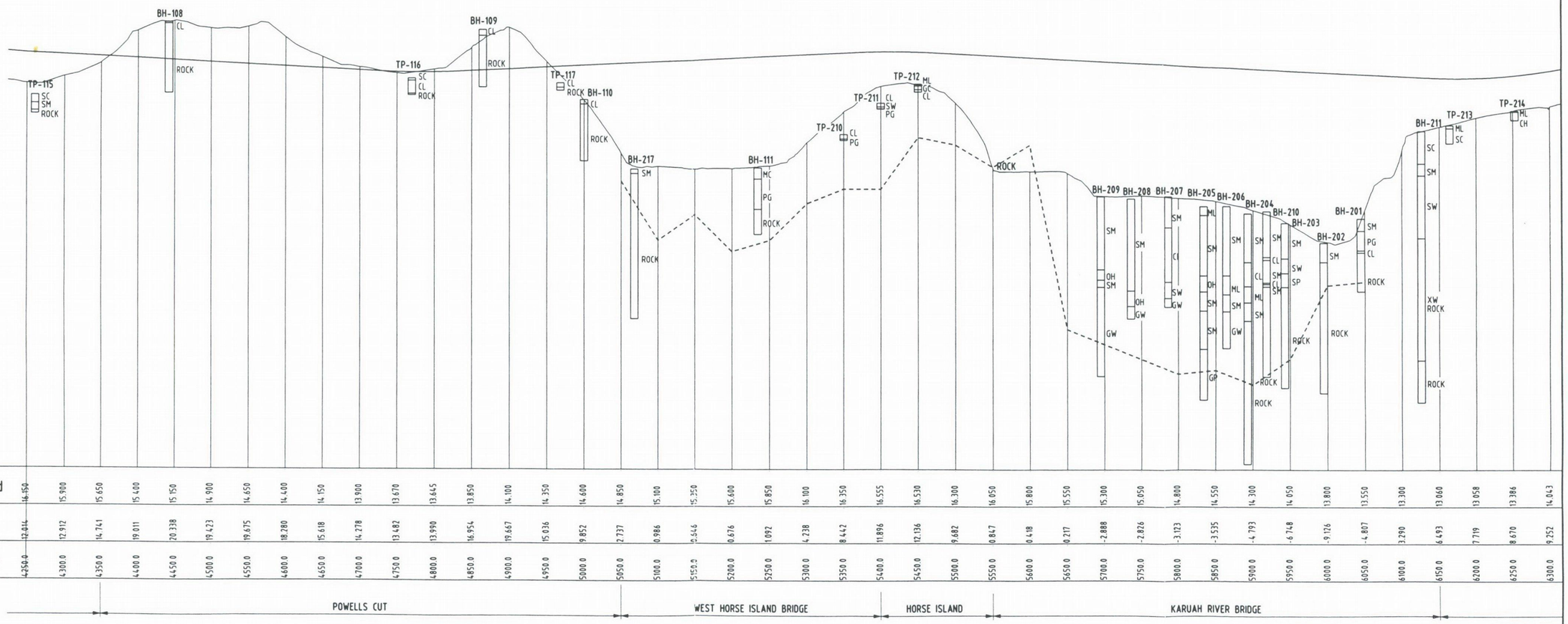

BH-102
CL
ROCK
TP-107
SM
CL
ROCK
TP-108
CL
SC
CL
BH-103
CL
BH-104
CL
ROCK
TP-109
CL
CI
CL
TP-206
ML
CH
TP-207
ML
CH
TP-208
CL
CH
BH-105
CL
XW
ROCK
TP-110
OH
CI
TP-209
SM
CH
BH-106
GC
ROCK
TP-111
CL
SC
ROCK
TP-112
OL
ML
CH
ROCK
BH-107
CL
ROCK
TP-113
SM
CL
ROCK
TP-114
CL
ROCK

DATUM=-40.000

| | | |

A0

APPROXIMATE ROCK LEVEL INTERPRETED FORM SEISMIC REFRACTION SURVEY (VOLUME 3)



CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

HORIZONTAL AT A0 1:2000 0 40 80 120 160 200 m (40 20)

VERTICAL AT A0 1:200 0 4 8 12 16 20 m (4 3 2 1)

Issue	Description	By	Date	Issue	Description	By	Date

CHECK PRINT

DOCUMENT CONTROL STATUS
UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners Consulting Engineers
477 Kent Street, Sydney NSW 2000
Telephone (02) 9320 9320 Facsimile (02) 9320 9321
SYDNEY MELBOURNE BRISBANE PERTH DARWIN CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
PACIFIC HIGHWAY UPGRADE AT KARUAH

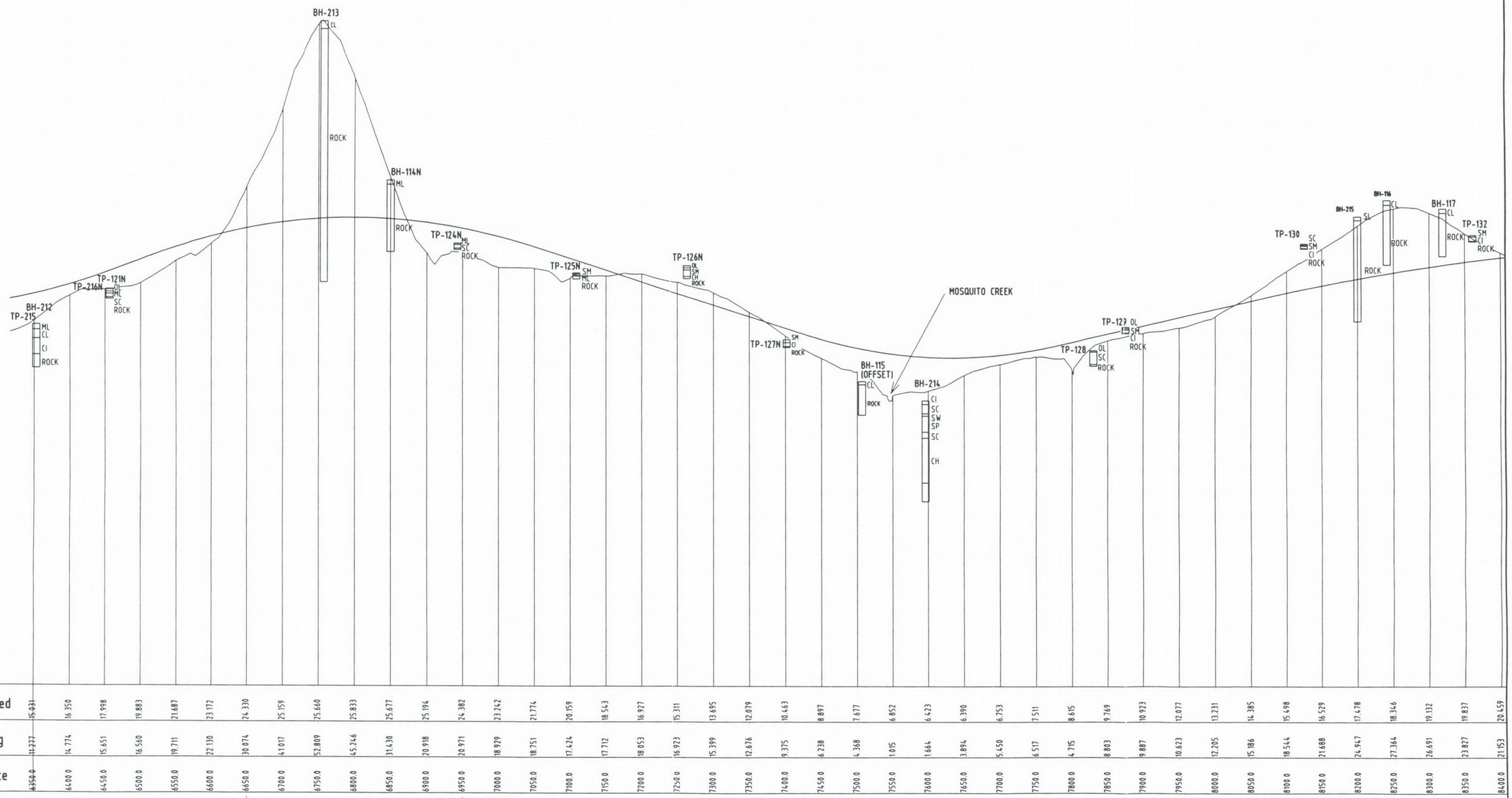
GEOTECHNICAL LONGITUDINAL SECTION

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed	CPM	Authorised for Issue	
Drawn	CL	Scale	AS SHOWN
Checked		Sheet	of
Drawing No	9809/S02/FIG 3C	Issue	1

A0 0 100 200mm on original

30 AUG 1999 14:21 g:\9809c\can dev\dgn\Ahfig_003.dgn



CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

HORIZONTAL AT A0 1:2000 0 40 80 120 160 200 m (40 20)

VERTICAL AT A0 1:200 0 4 8 12 16 20 m (4 3 2 1)

Issue	Description	By	Date	Issue	Description	By	Date

CHECK PRINT

DOCUMENT CONTROL STATUS

UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners Consulting Engineers

477 Kent Street, Sydney NSW 2000

Telephone (02) 9320 9320 Facsimile (02) 9320 9321

SYDNEY MELBOURNE BRISBANE PERTH DARWIN CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
PACIFIC HIGHWAY UPGRADE AT KARUAH

GEOTECHNICAL LONGITUDINAL SECTION

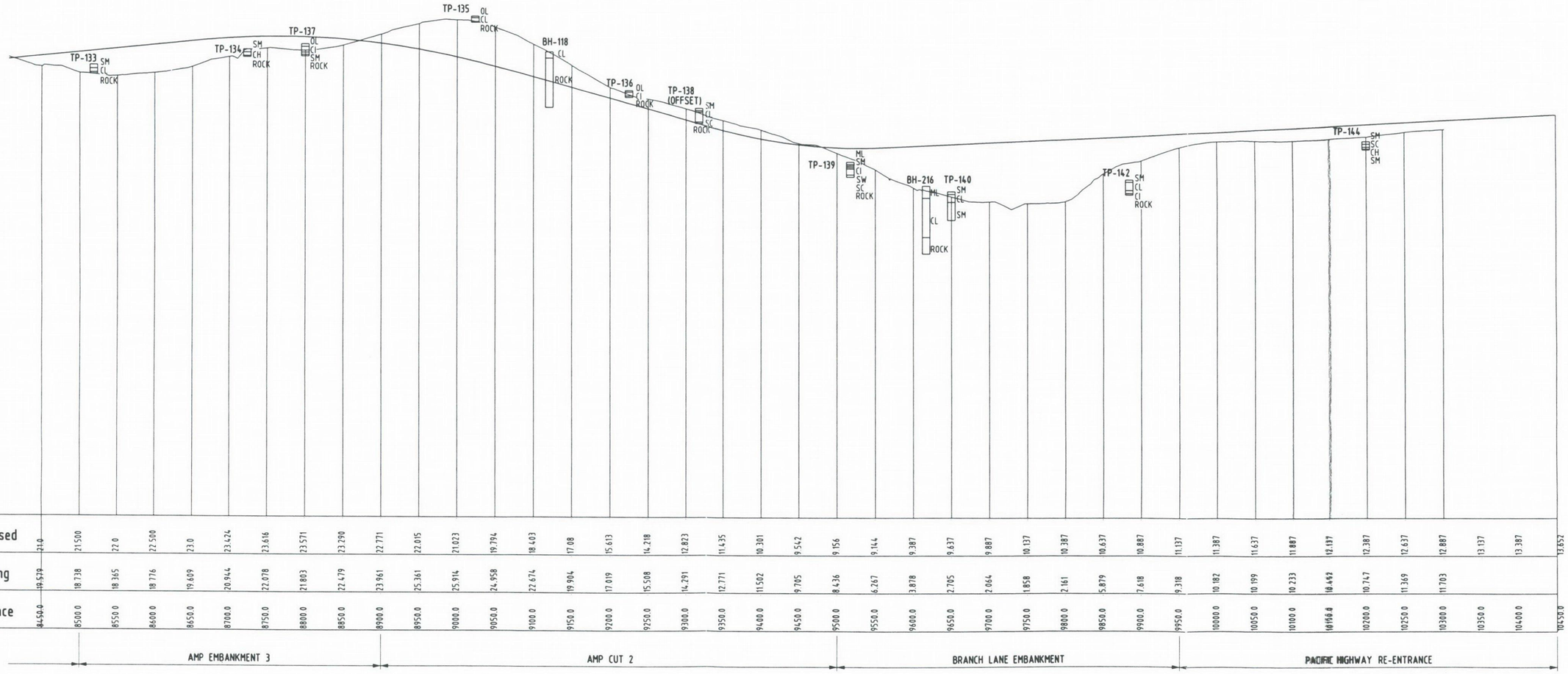
FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed CPM	Authorised for Issue
Drawn CL	Scale AS SHOWN
Checked	Sheet of
Drawing No 9809/S02/FIG 3D	Issue 1

A0

0 100 200mm on original

30 AUG 1999 14:31 g:\9809\cad\dwg\fig3d_004.dgn



Distance	Existing	Proposed
8450.0	19.579	21.0
8500.0	18.738	21.500
8550.0	18.365	22.0
8600.0	18.776	22.500
8650.0	19.609	23.0
8700.0	20.944	23.424
8750.0	22.078	23.616
8800.0	21.803	23.571
8850.0	22.479	23.290
8900.0	23.961	22.771
8950.0	25.361	22.015
9000.0	25.914	21.023
9050.0	24.958	19.794
9100.0	22.674	18.403
9150.0	19.904	17.08
9200.0	17.019	15.613
9250.0	15.508	14.218
9300.0	14.291	12.823
9350.0	12.771	11.435
9400.0	11.502	10.301
9450.0	9.705	9.542
9500.0	8.436	9.156
9550.0	6.267	9.144
9600.0	3.878	9.387
9650.0	2.705	9.637
9700.0	2.064	9.887
9750.0	1.858	10.137
9800.0	2.161	10.387
9850.0	5.879	10.637
9900.0	7.618	10.887
9950.0	9.318	11.137
10000.0	10.182	11.387
10050.0	10.199	11.637
10100.0	10.233	11.887
10150.0	10.452	12.137
10200.0	10.747	12.387
10250.0	11.369	12.637
10300.0	11.703	12.887
10350.0	10.350.0	13.137
10400.0	10.400.0	13.387
10450.0		13.652

HORIZONTAL AT A0 1:2000 (40 20) 0 40 80 120 160 200 m

VERTICAL AT A0 1:200 (4 3 2 1) 0 4 8 12 16 20 m

CHECK PRINT		
PROCESS	DATE	SIGNED
ENGINEERING CHECK		
DRAFTING CHECK		
BACKDRAFTING COMPLETE		
ENGINEERING RE CHECK		

Issue	Description	By	Date	Issue	Description	By	Date

CHECK PRINT

DOCUMENT CONTROL STATUS

UNLESS STAMPED IN RED THIS DRAWING IS UNCONTROLLED AND MUST BE VERIFIED AGAINST A CONTROLLED COPY OF THE DRAWING PRIOR TO USE TO ENSURE IT IS THE CURRENT ISSUE.

ARUP

Ove Arup & Partners Consulting Engineers

477 Kent Street, Sydney NSW 2000

Telephone (02) 9320 9320 Facsimile (02) 9320 9321

SYDNEY MELBOURNE BRISBANE PERTH DARWIN CANBERRA CAIRNS PORT MORESBY AUCKLAND

ROADS AND TRAFFIC AUTHORITY N.S.W.

S.H.10 PORT STEPHENS AND GREAT LAKES COUNCILS
PACIFIC HIGHWAY UPGRADE AT KARUAH

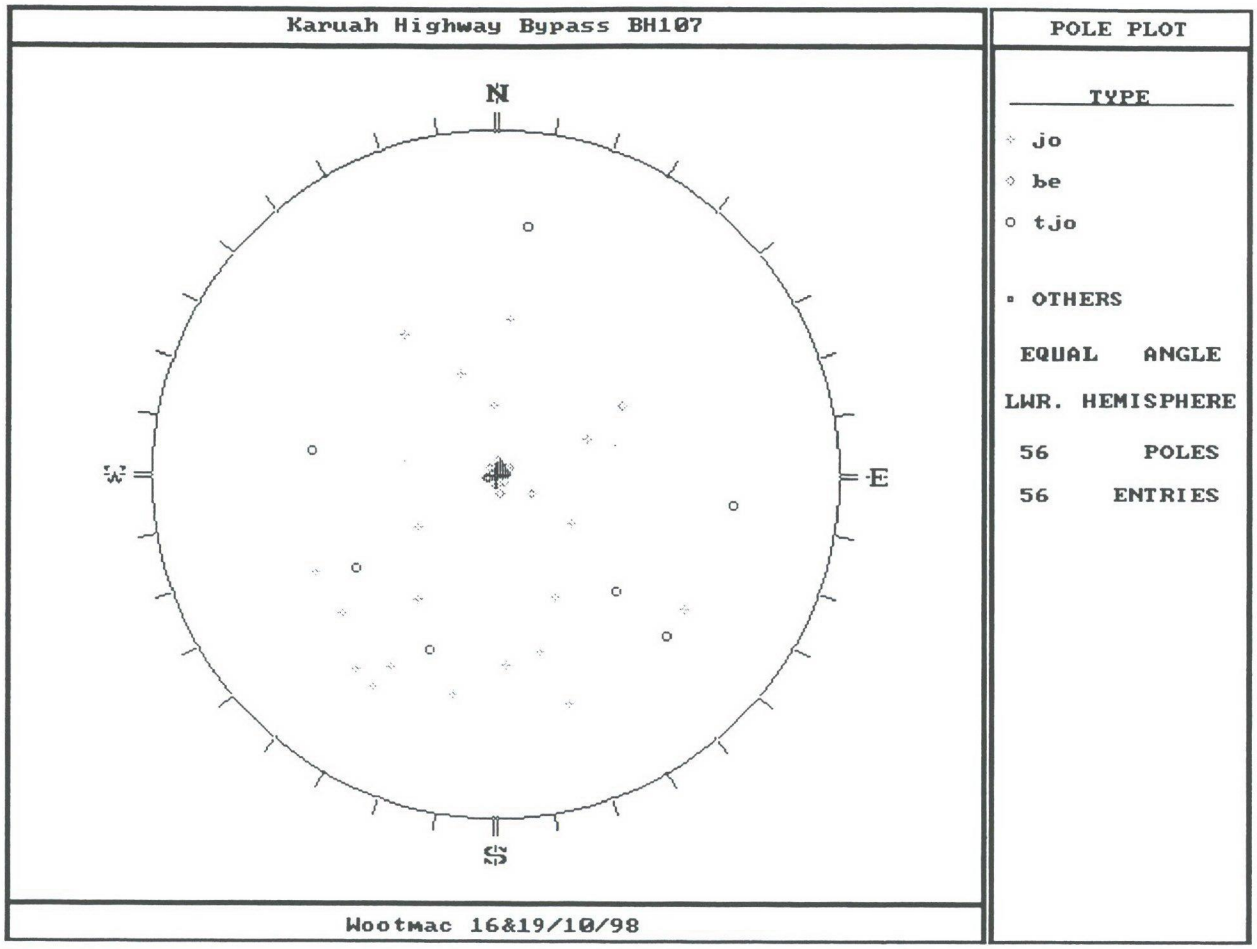
GEOTECHNICAL LONGITUDINAL SECTION

FILE No 10/362.1475 REGN. No 0010.362.RC.MP21

Designed CPM	Authorised for Issue
Drawn CL	Scale AS SHOWN
Checked	Sheet of
Drawing No 9809/S02/FIG 3E	Issue 1

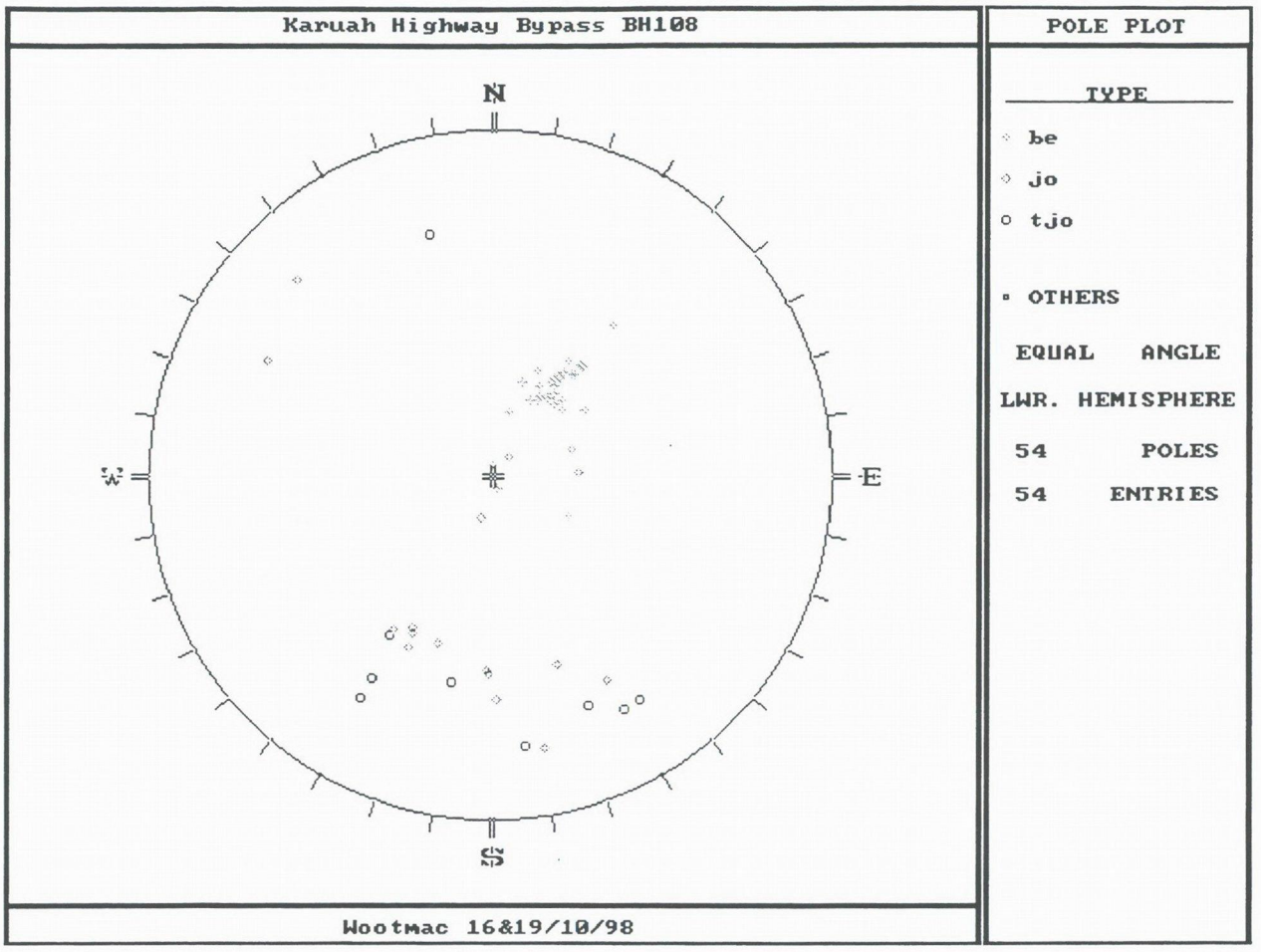
A0

0 100 200mm on original



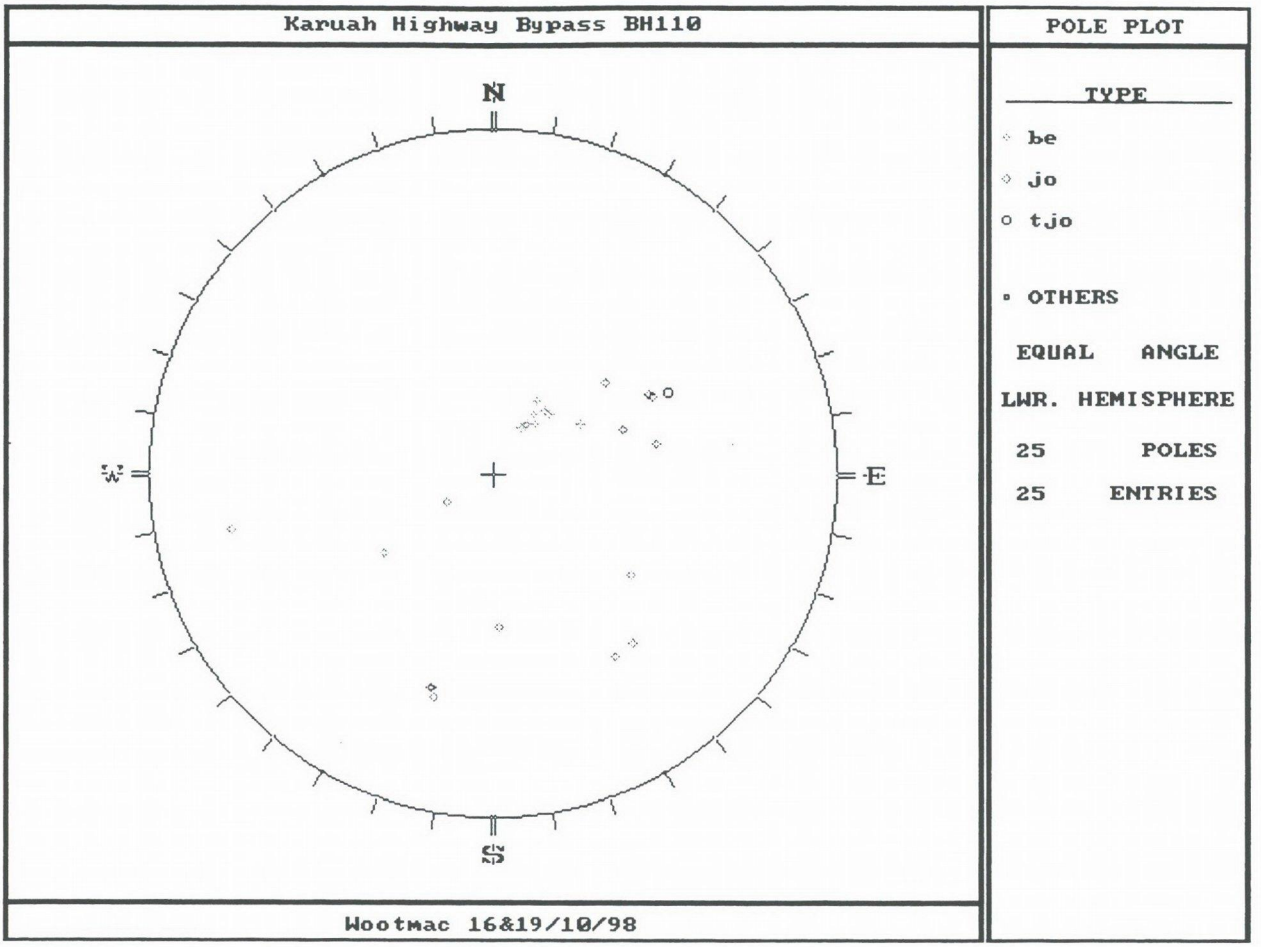
jo – joint be – bedding tjo – truncated joint

FIGURE: 4A JOB NO: 9809/510



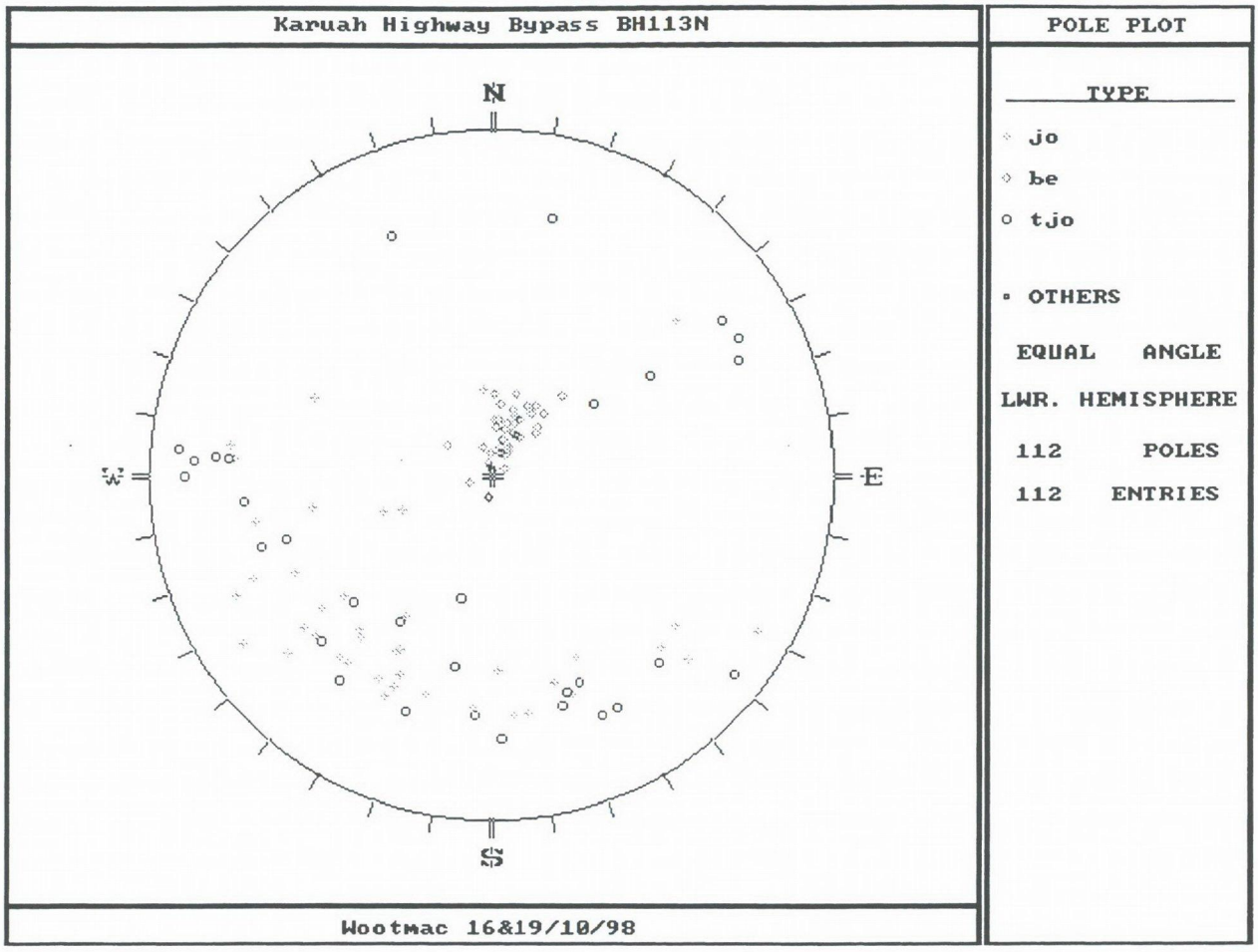
jo – joint be – bedding tjo – truncated joint

FIGURE: 4B JOB NO: 9809/510



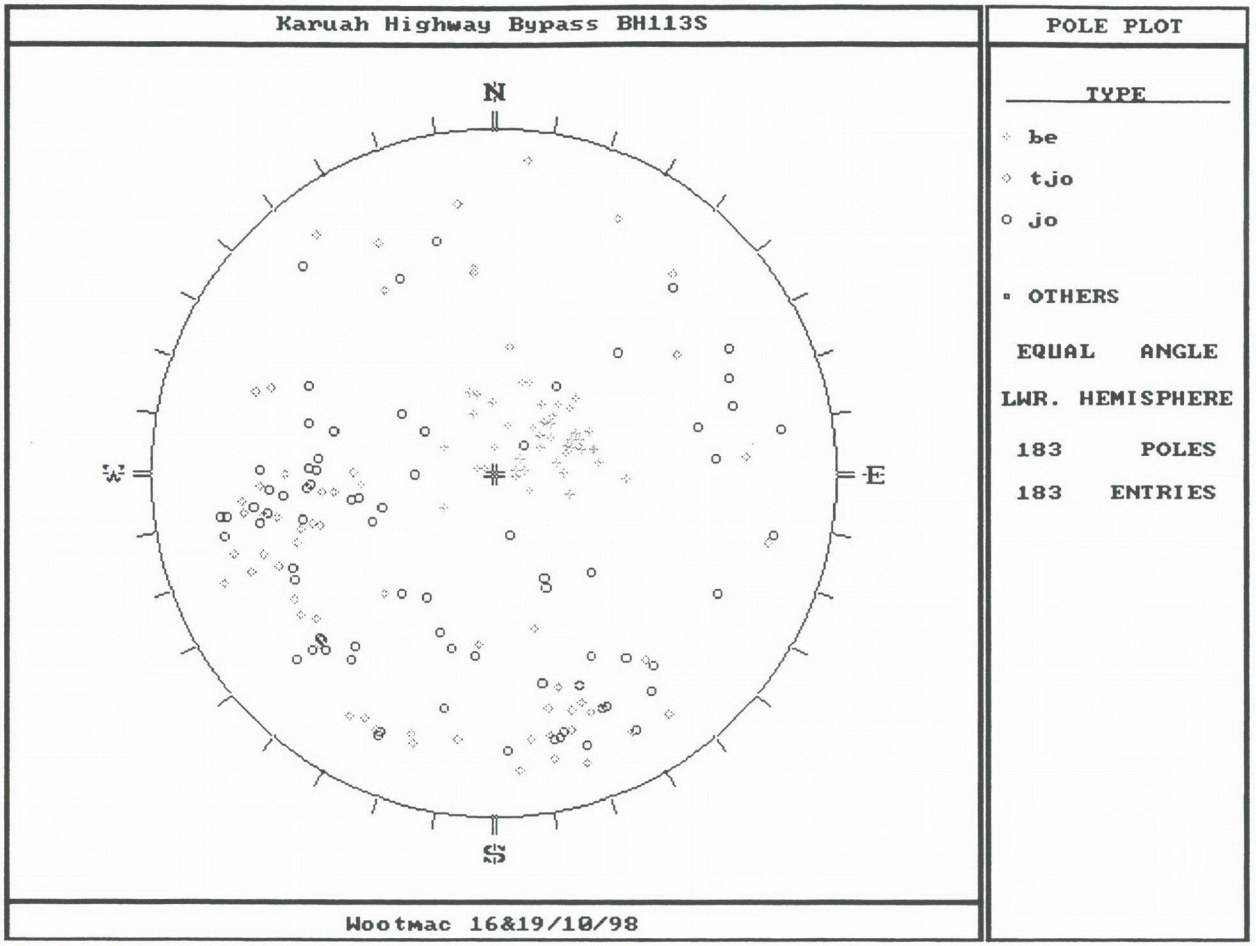
jo – joint be – bedding tjo – truncated joint

FIGURE: 4C JOB NO: 9809/510



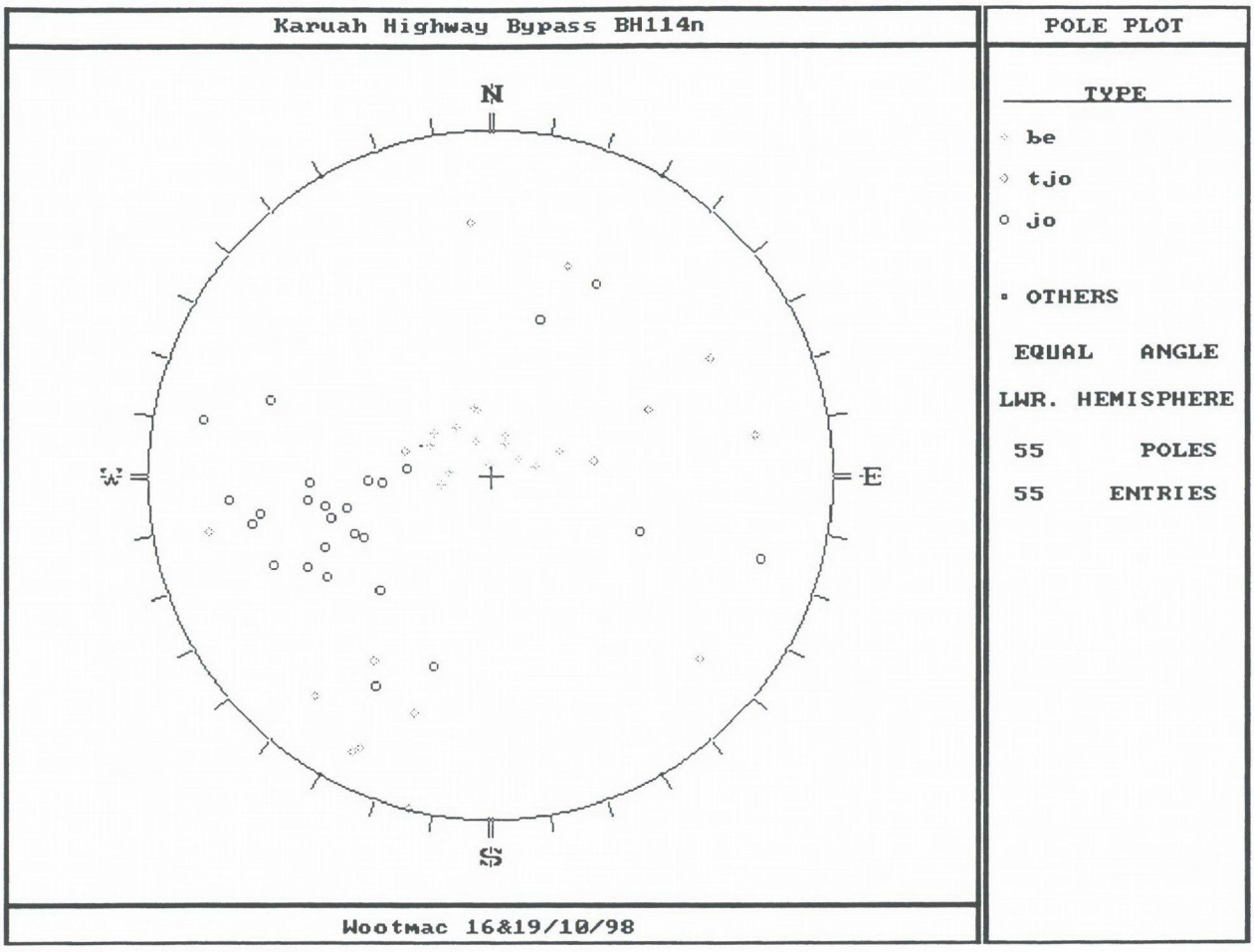
jo – joint be – bedding tjo – truncated joint

FIGURE: 4D JOB NO: 9809/510



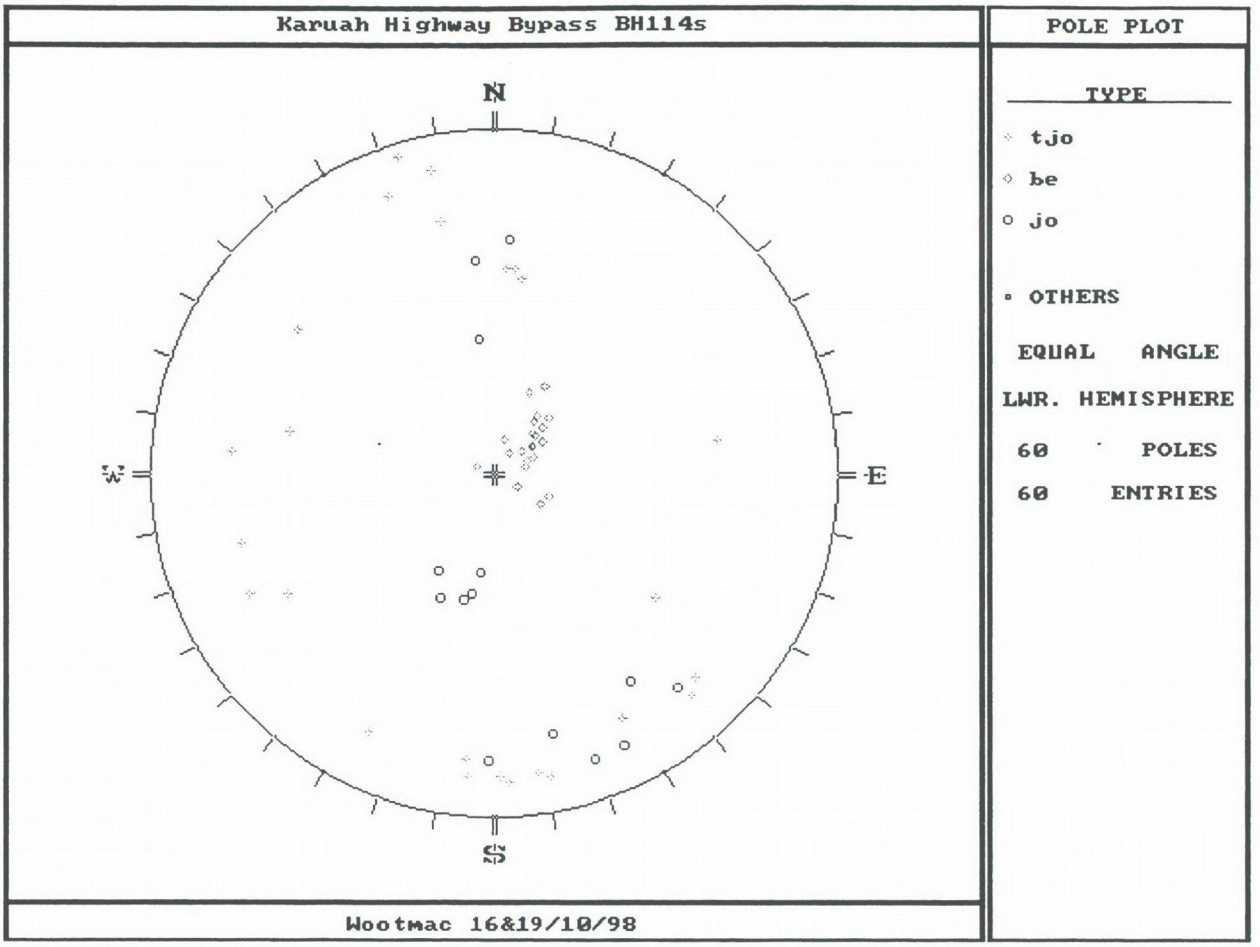
jo – joint be – bedding tjo – truncated joint

FIGURE: **4E** JOB NO: 9809/510



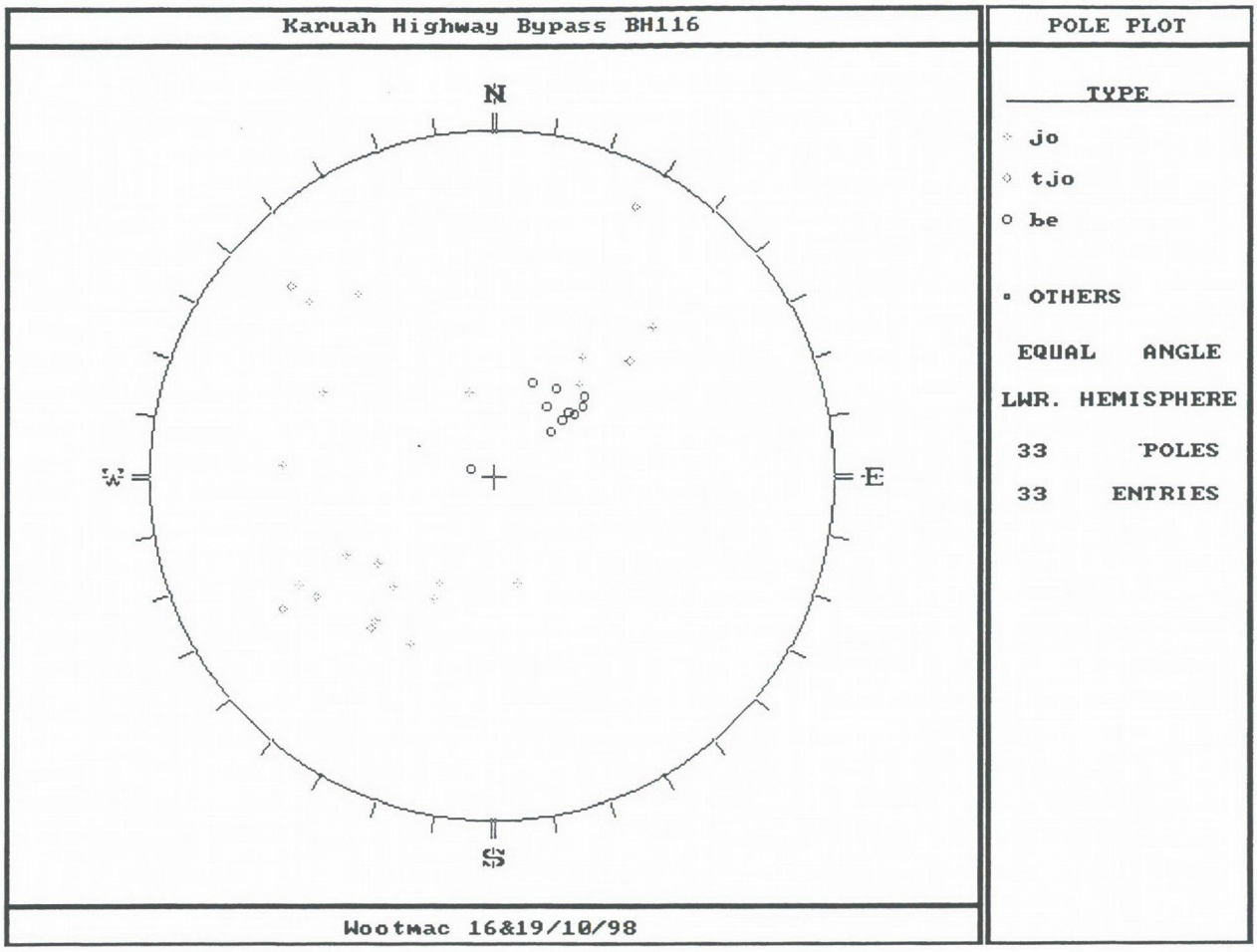
jo – joint be – bedding tjo – truncated joint

FIGURE: 4F JOB NO: 9809/510



jo – joint be – bedding tjo – truncated joint

FIGURE: **4G** JOB NO: 9809/510

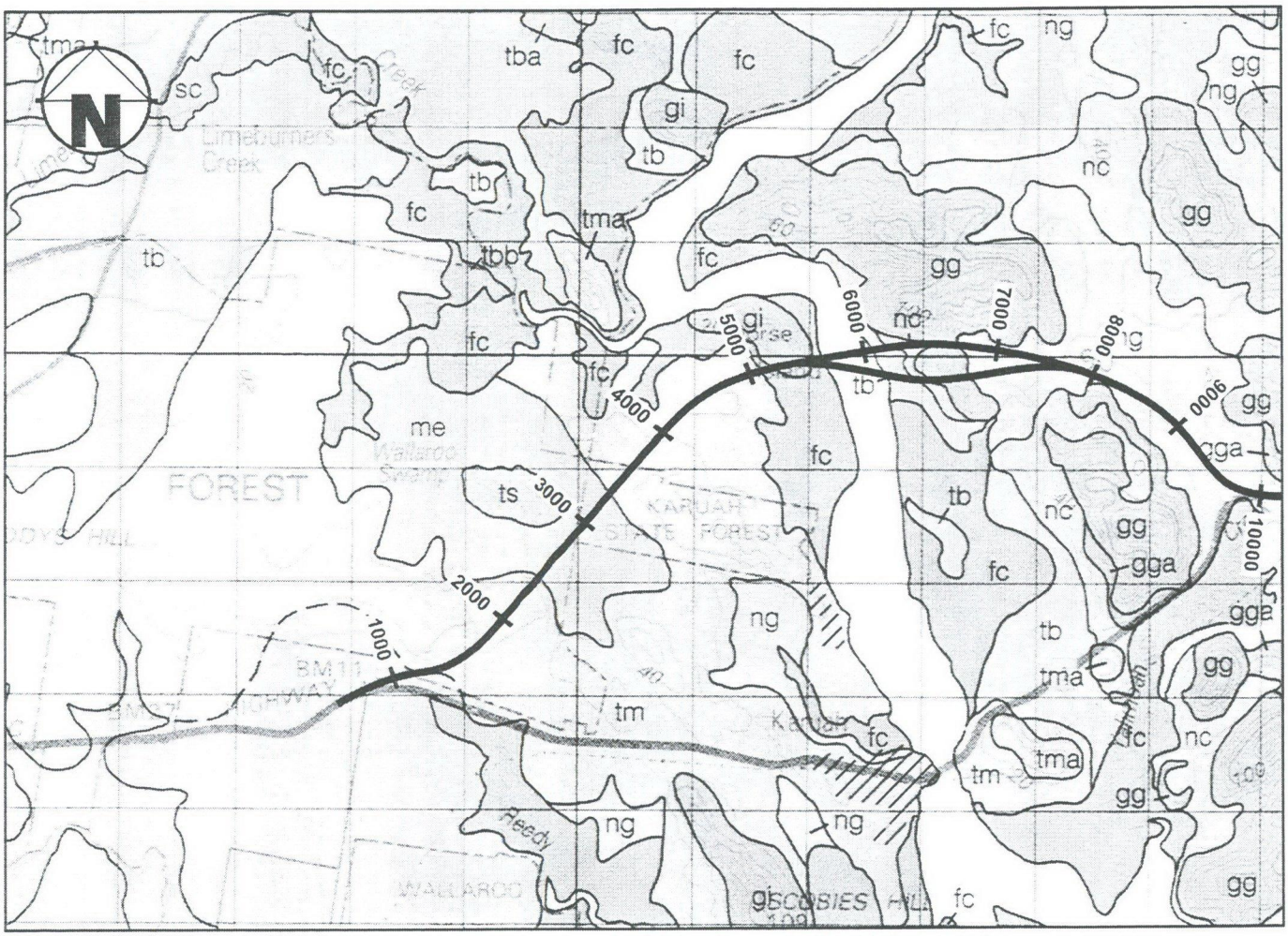


jo – joint be – bedding tjo – truncated joint

FIGURE: **4H** JOB NO: 9809/510

ARUP Geotechnics

SOIL LANDSCAPES OF KARUAH

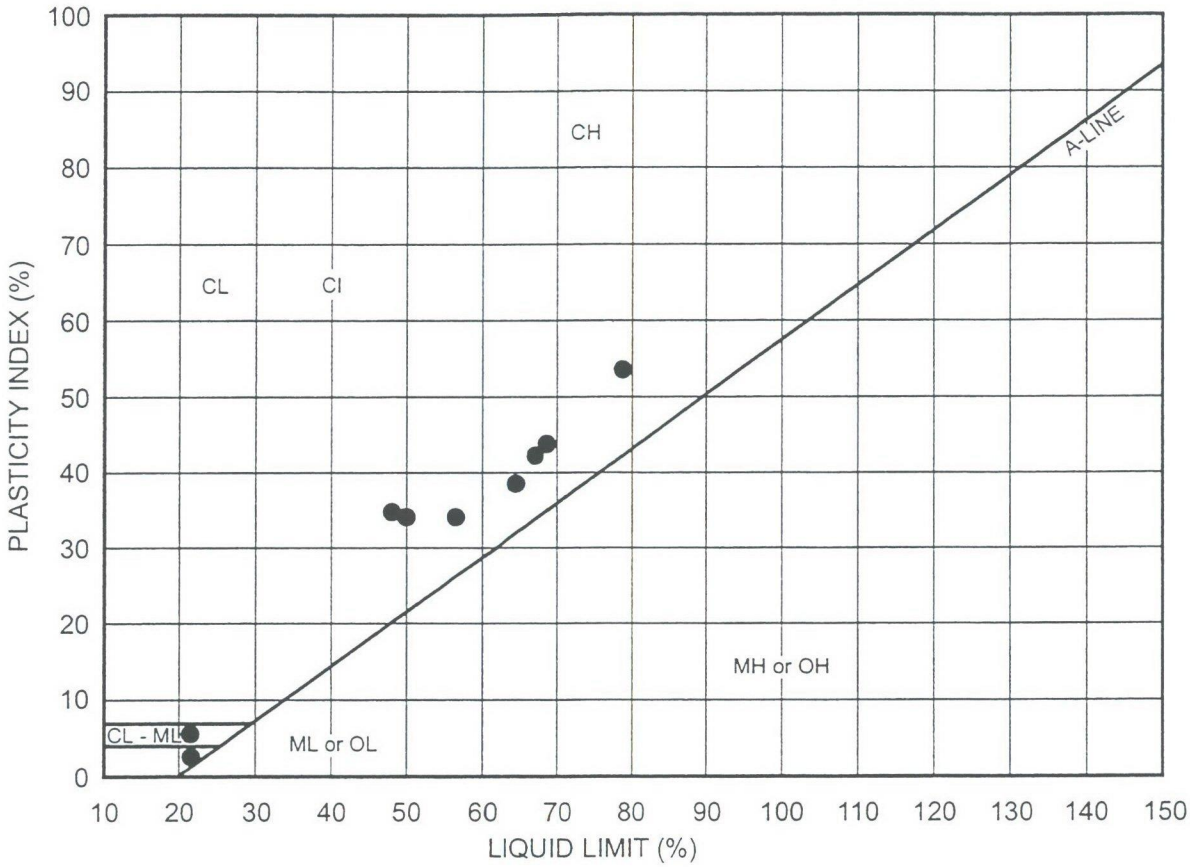


SOURCE: *Soil Landscapes Series - Newcastle, 1 : 100 000 - Sheet 9232 (DLWC, 1995).*

NOTE:
Refer to section 4.5 of the text for soil landscape units.

ARUP
Geotechnics

PLASTICITY CHART - WEST OF RIVER

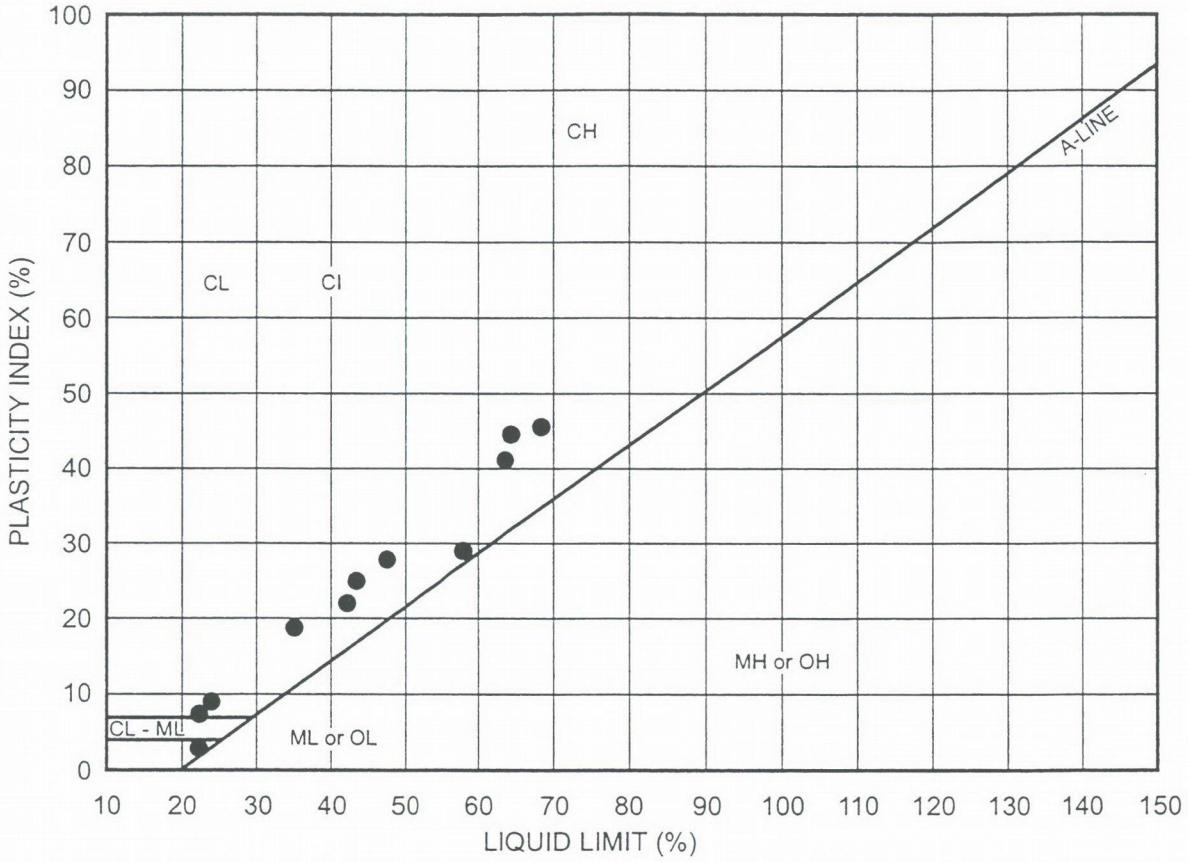


25 June 1999\inf\9809\510\gjm-0007.cdr

FIGURE: 6 JOB: 9809/510

ARUP
Geotechnics

PLASTICITY CHART
EAST OF RIVER Ch.6200 - 6800

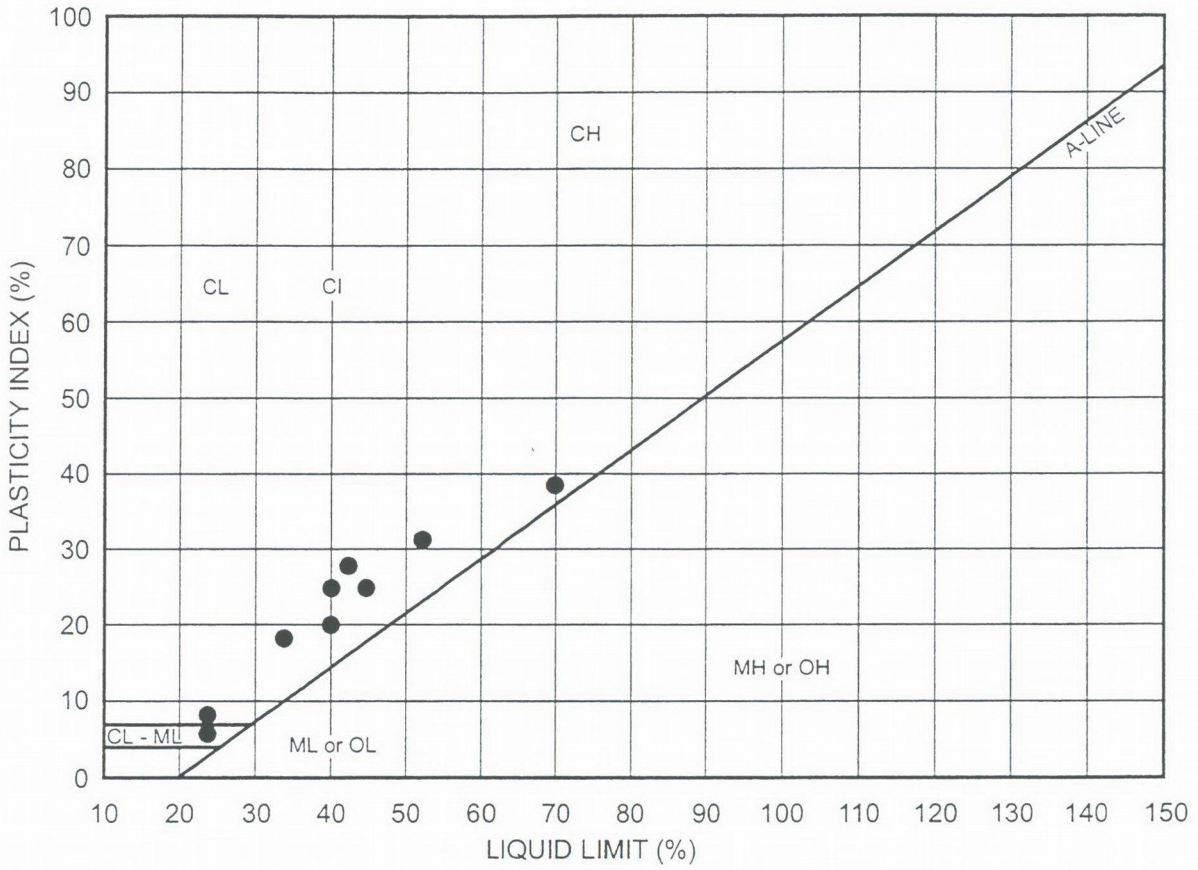


25 June 1999\inf\9809\510\gjm-0007.cdr

FIGURE: 7 JOB: 9809/510

ARUP
Geotechnics

PLASTICITY CHART
EAST OF RIVER Ch.6800 - 8050

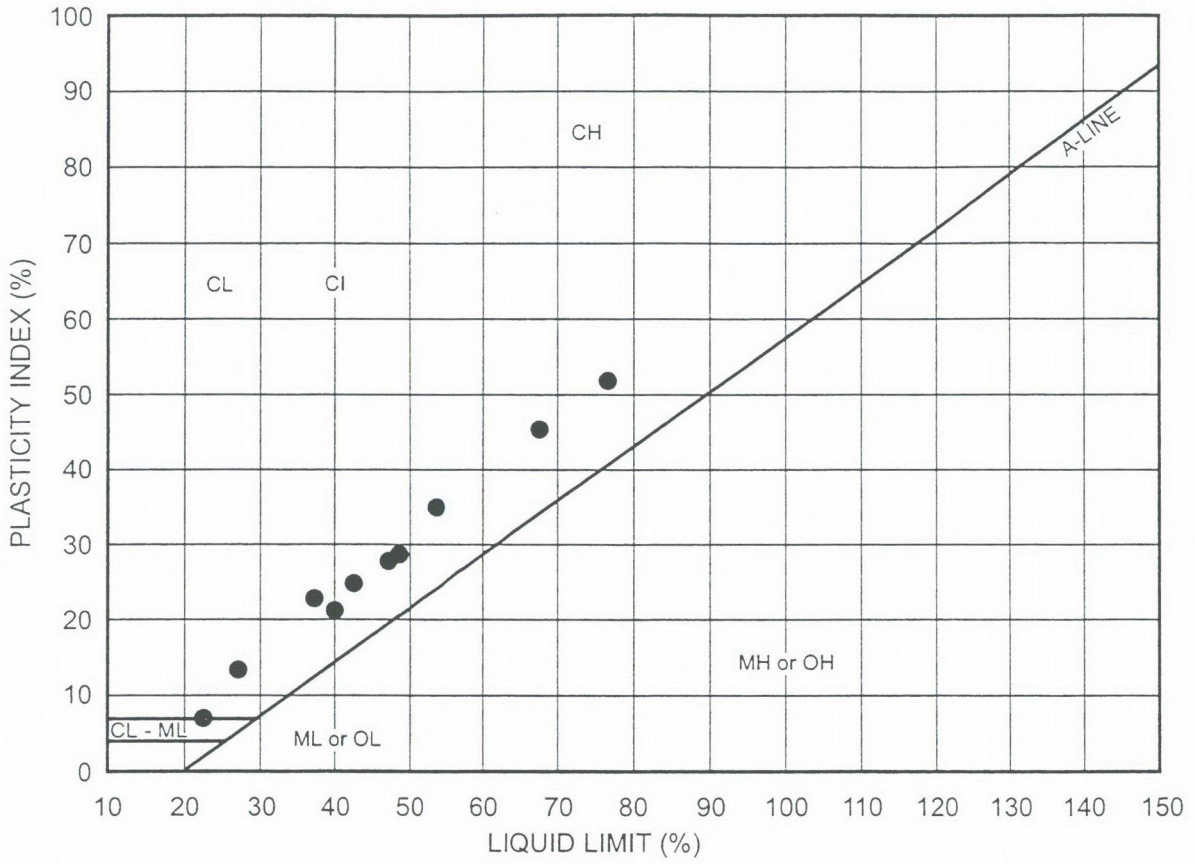


25 June 1999\inf\9809\510\gjm-0007.cdr

FIGURE: 8 JOB: 9809/510

ARUP
Geotechnics

PLASTICITY CHART
EAST OF RIVER Ch.8050 - 10500

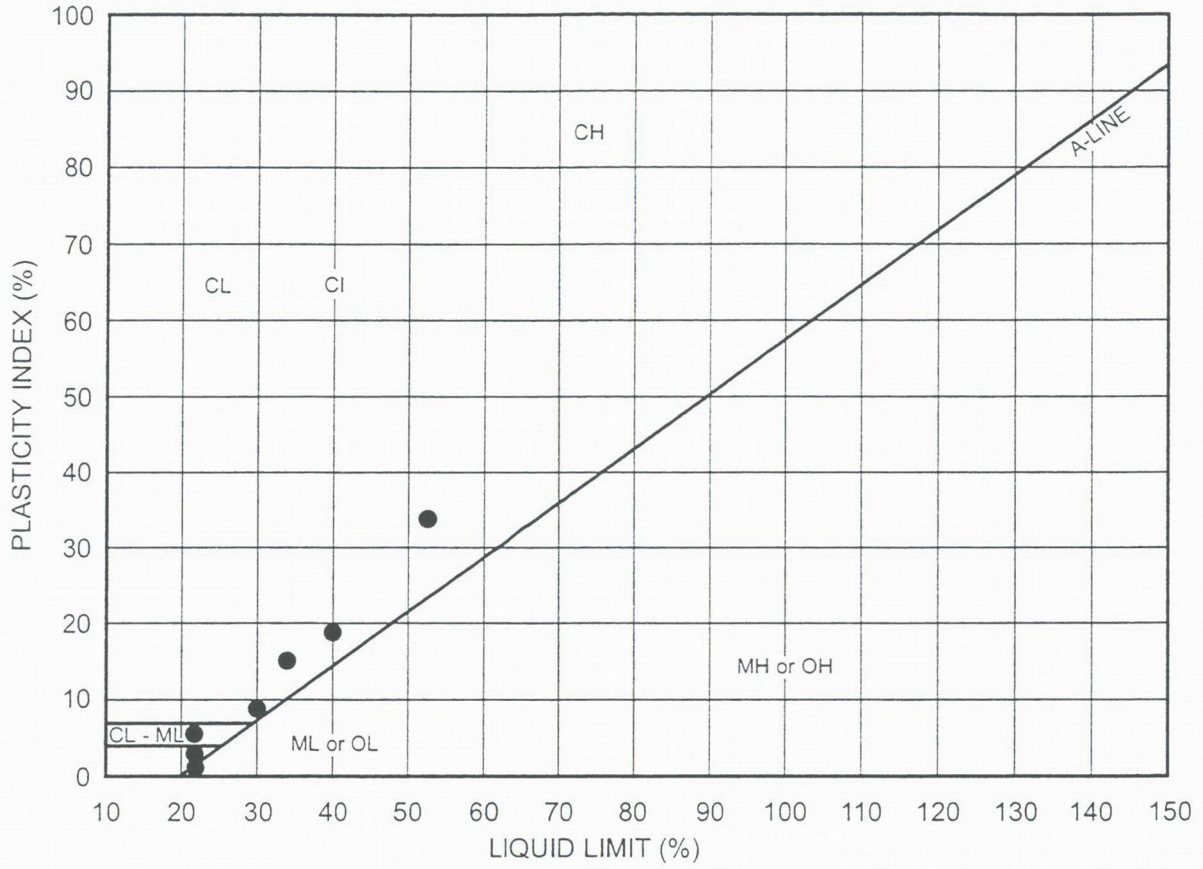


25 June 1999\inf\9809\510\gjm-0007.cdr

FIGURE: 9 JOB: 9809/510

ARUP
Geotechnics

PLASTICITY CHART
KARUAH RIVER CROSSING

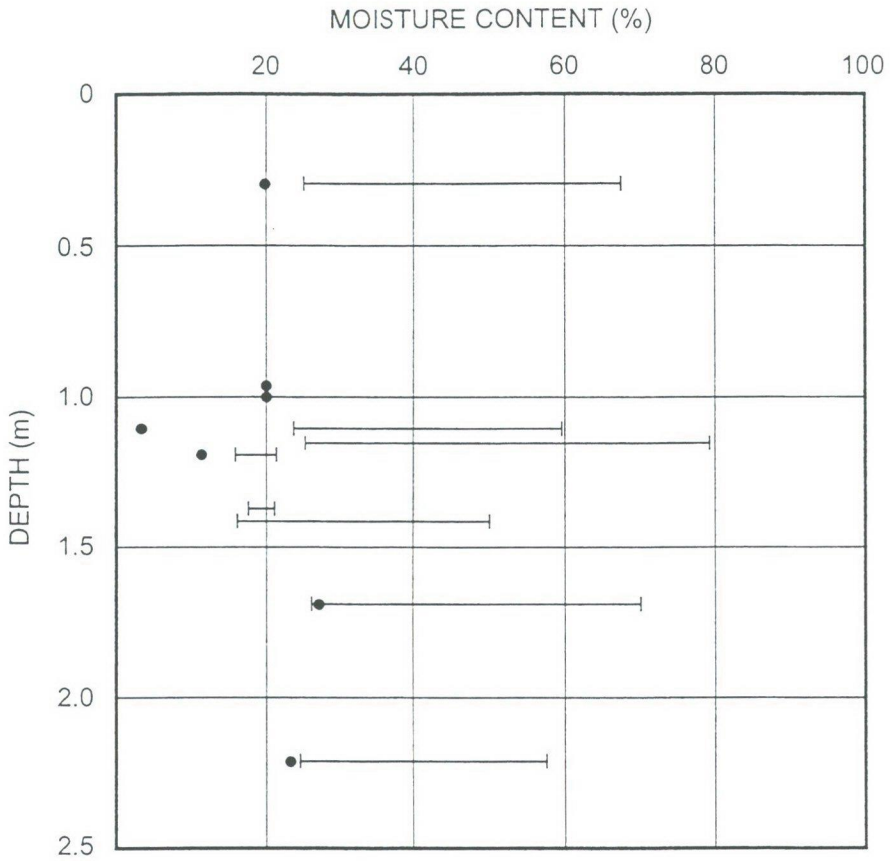


25 June 1999\inf\9809\510\gjm-0007.cdr

FIGURE: **10** JOB: **9809/510**

ARUP Geotechnics

ATTERBERG LIMITS & MOISTURE CONTENTS - WEST OF RIVER



LEGEND

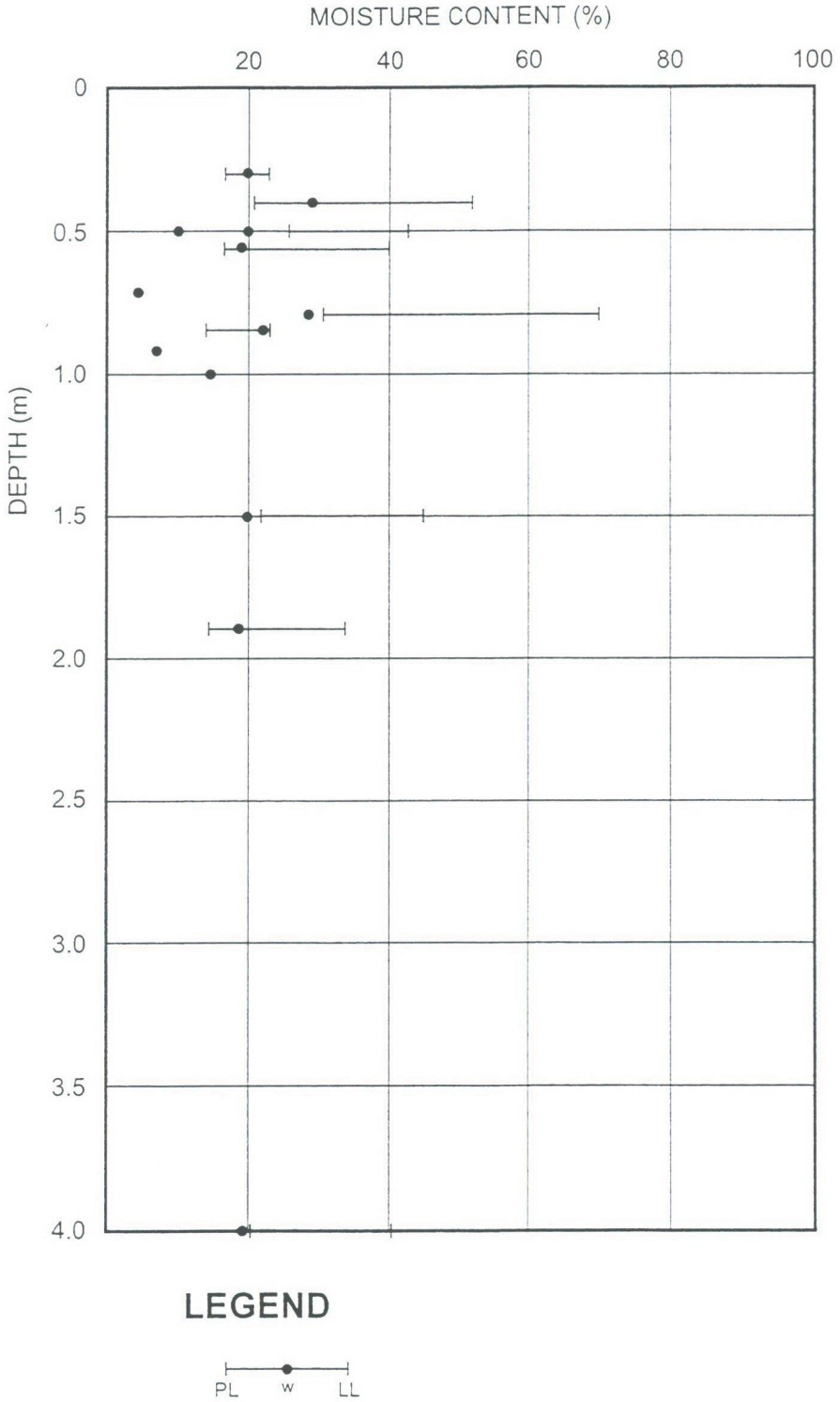


25 June 1999\inf\9809\510\gjm-0008.cdr

FIGURE: 11 JOB: 9809/510

ARUP
Geotechnics

ATTERBERG LIMITS & MOISTURE CONTENTS
- EAST OF RIVER Ch. 6800 - 8050



LEGEND

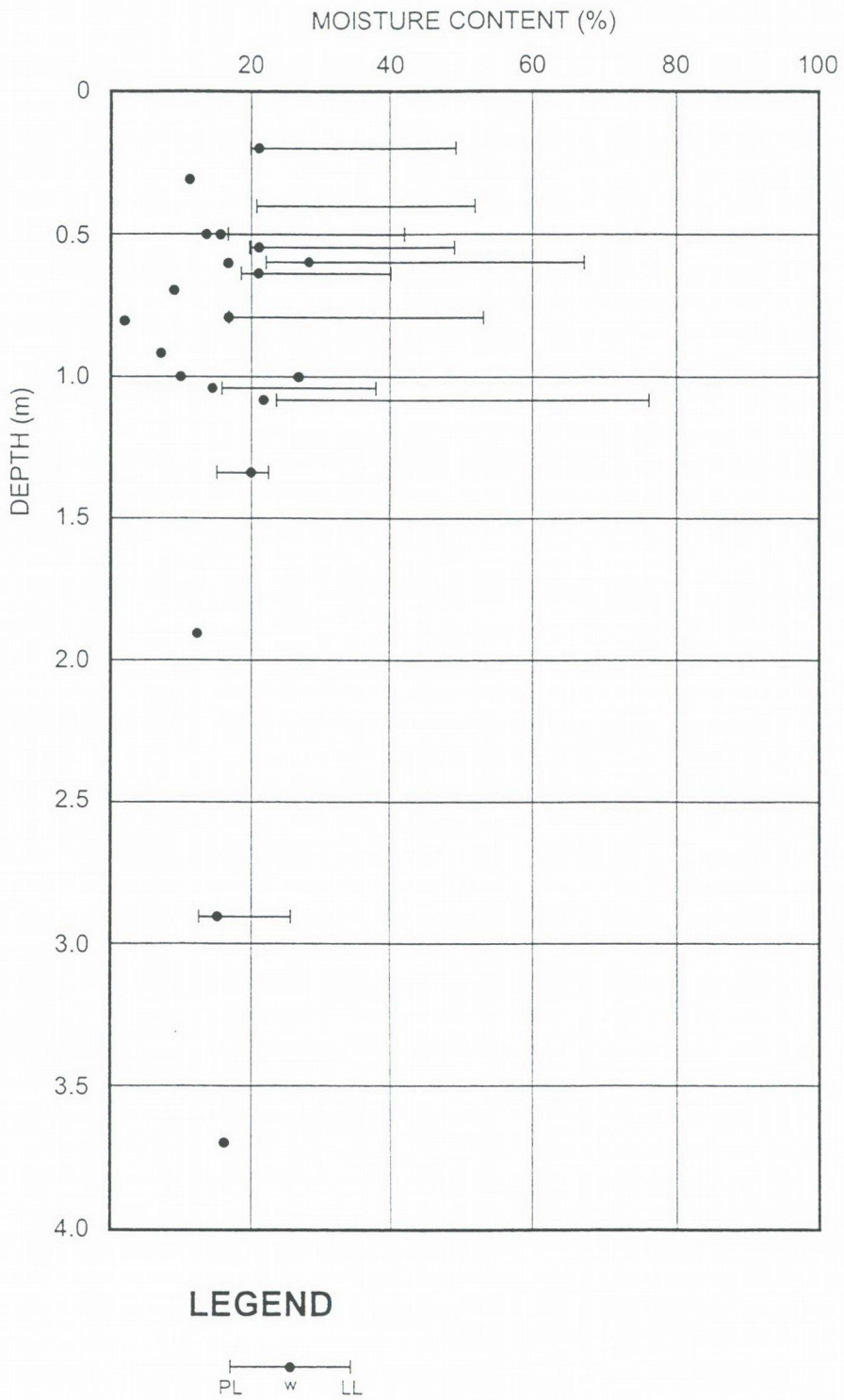
PL w LL

25 June 1999\inf\9809\510\gjm-0008.cdr

FIGURE: **12** JOB: **9809/510**

ARUP Geotechnics

ATTERBERG LIMITS & MOISTURE CONTENTS - EAST OF RIVER Ch. 8050 - 10500



LEGEND

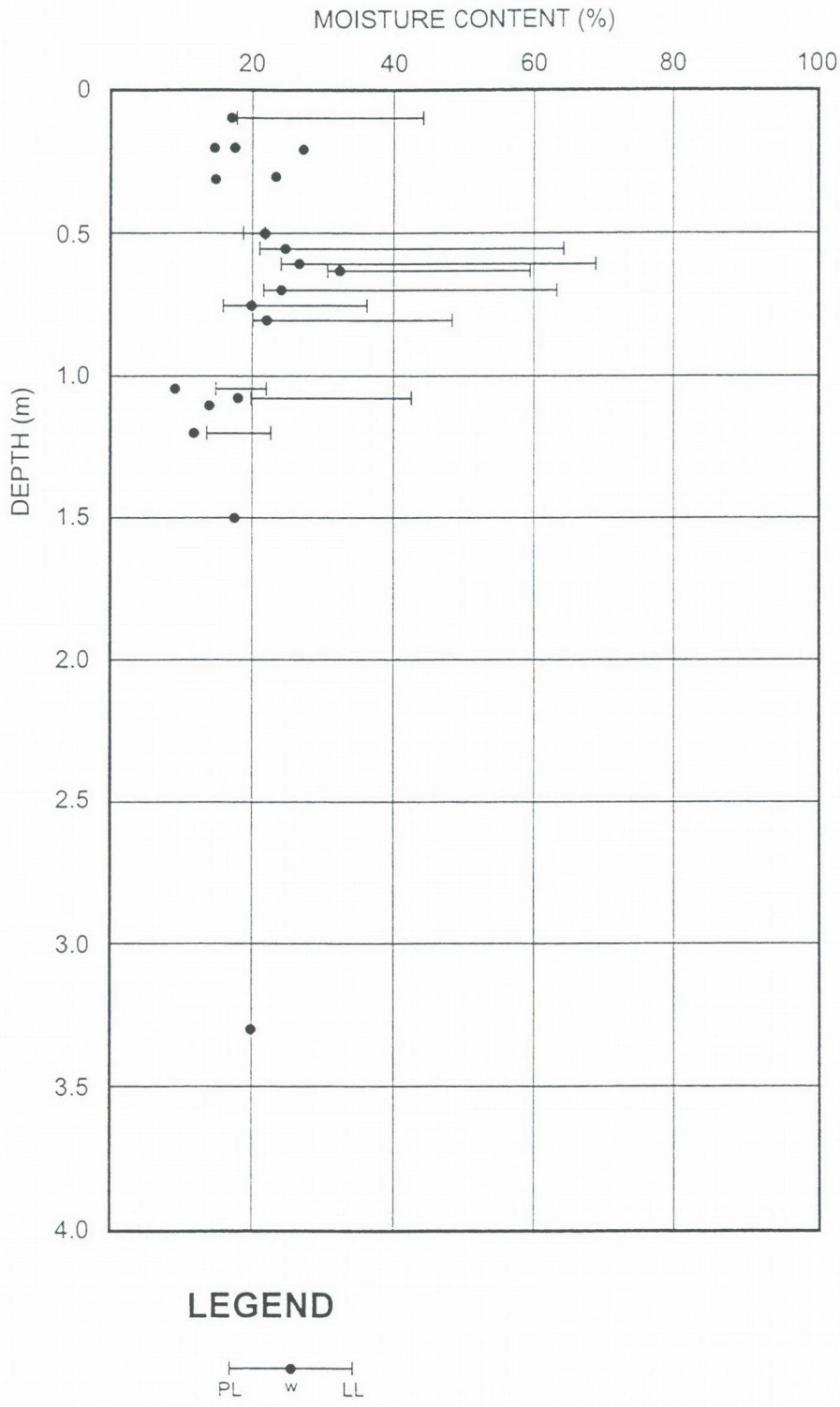
PL w LL

25 June 1999\inf\9809\510\gjm-0008.cdr

FIGURE: 13 JOB: 9809/510

ARUP Geotechnics

ATTERBERG LIMITS & MOISTURE CONTENTS - EAST OF RIVER Ch. 6200 - 6800



LEGEND

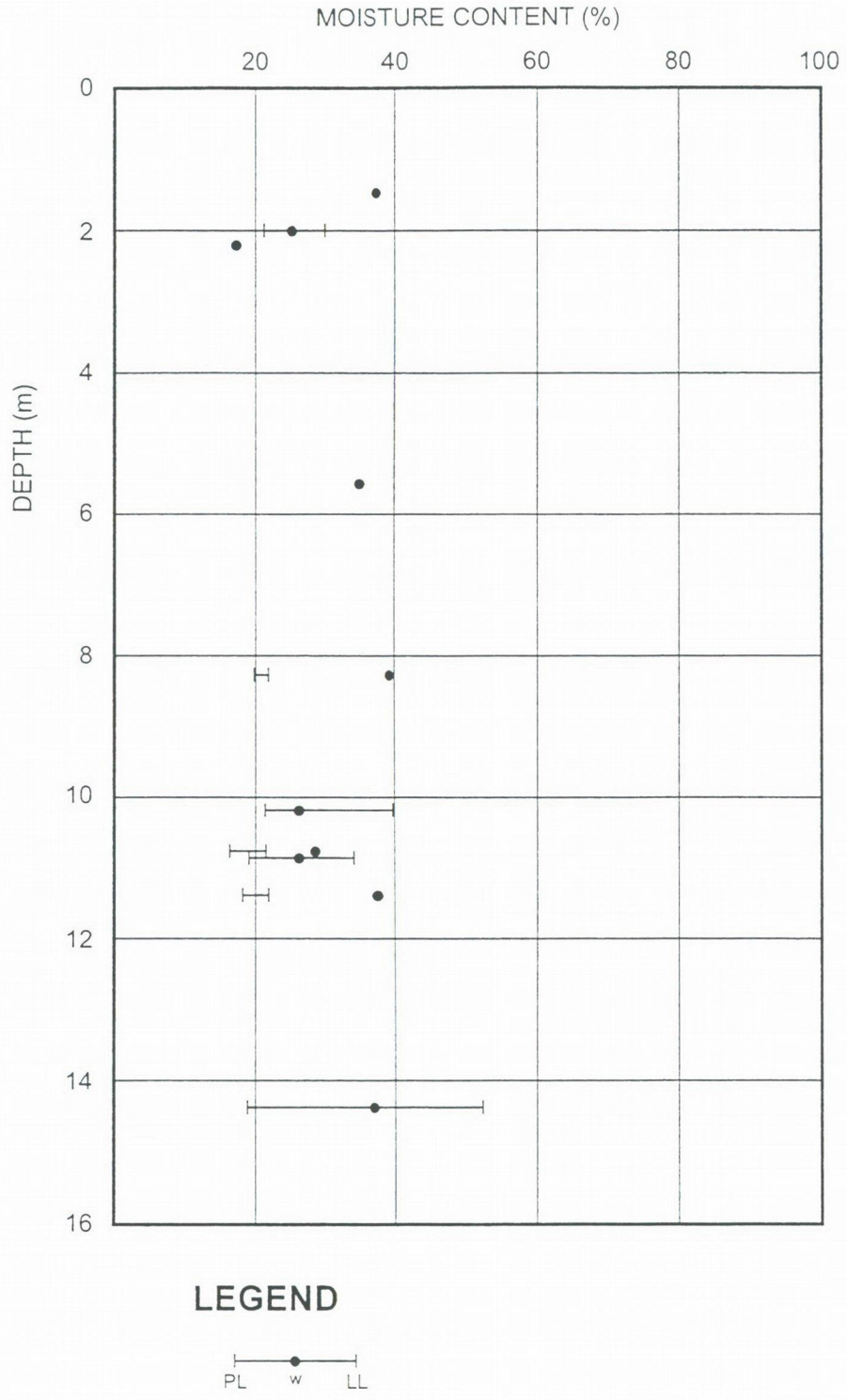
PL w LL

25 June 1999\inf\9809\510\gjm-0008.cdr

FIGURE: 14 JOB: 9809/510

ARUP
Geotechnics

ATTERBERG LIMITS & MOISTURE CONTENTS - KARUAH RIVER CROSSING

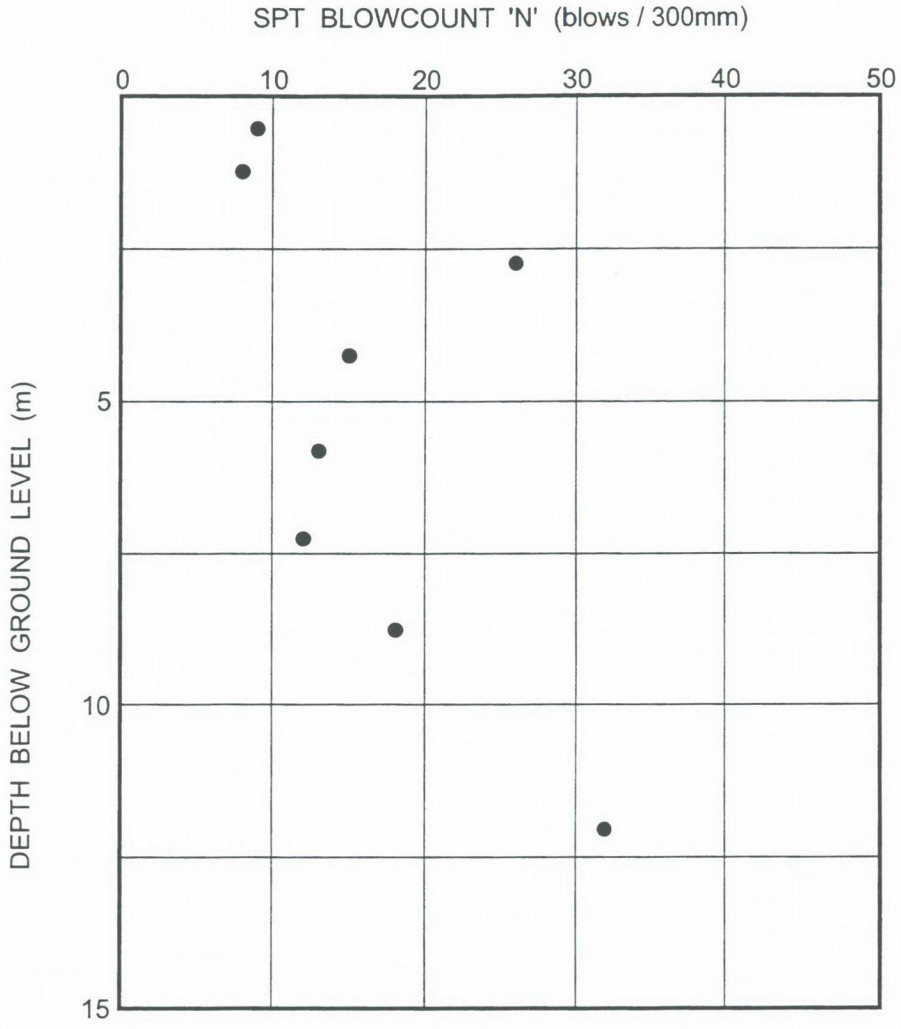


25 June 1999\inf\9809\510\gjm-0008.cdr

FIGURE: 15 JOB: 9809/510

ARUP Geotechnics

STANDARD PENETRATION TEST RESULTS PACIFIC HIGHWAY EMBANKMENT



LEGEND

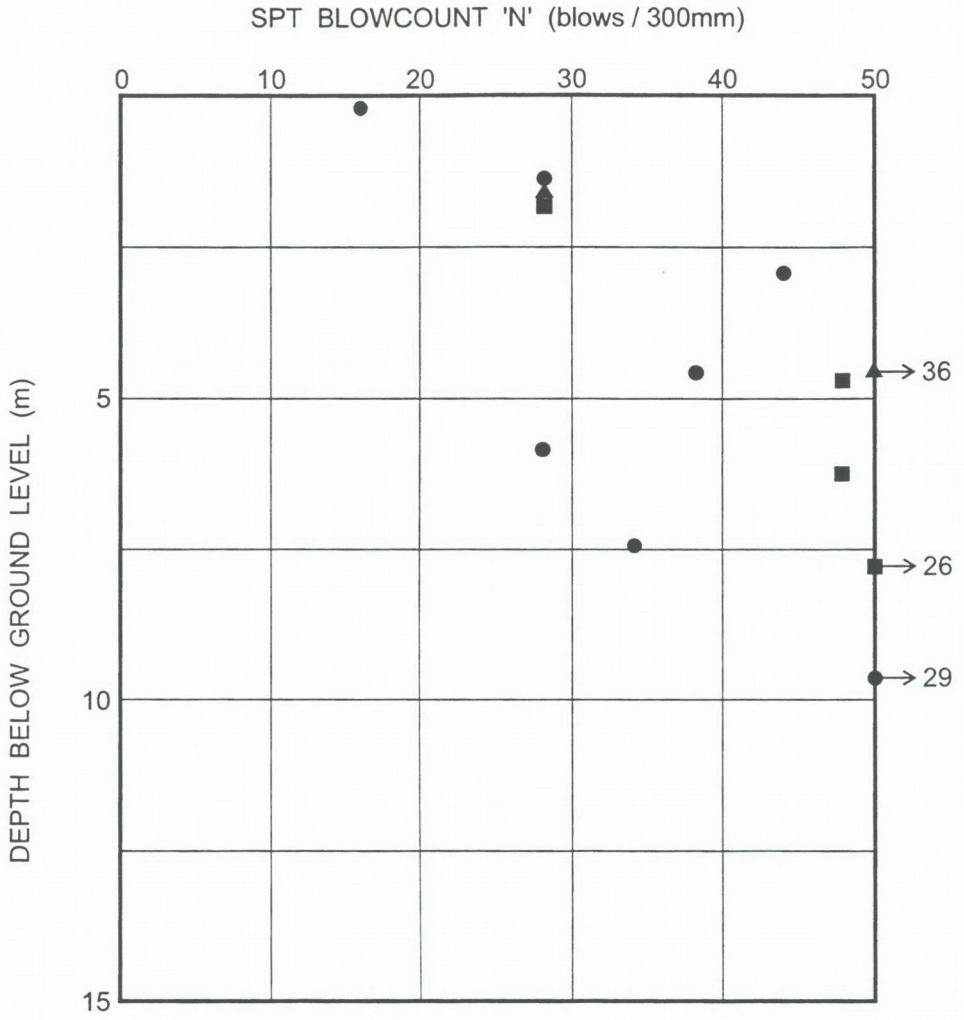
● Borehole 101

19 July 1999\inf\9809\510\gjm-0009.cdr

FIGURE: 16 JOB: 9809/510

ARUP Geotechnics

STANDARD PENETRATION TEST RESULTS WALLAROO SWAMP EMBANKMENT

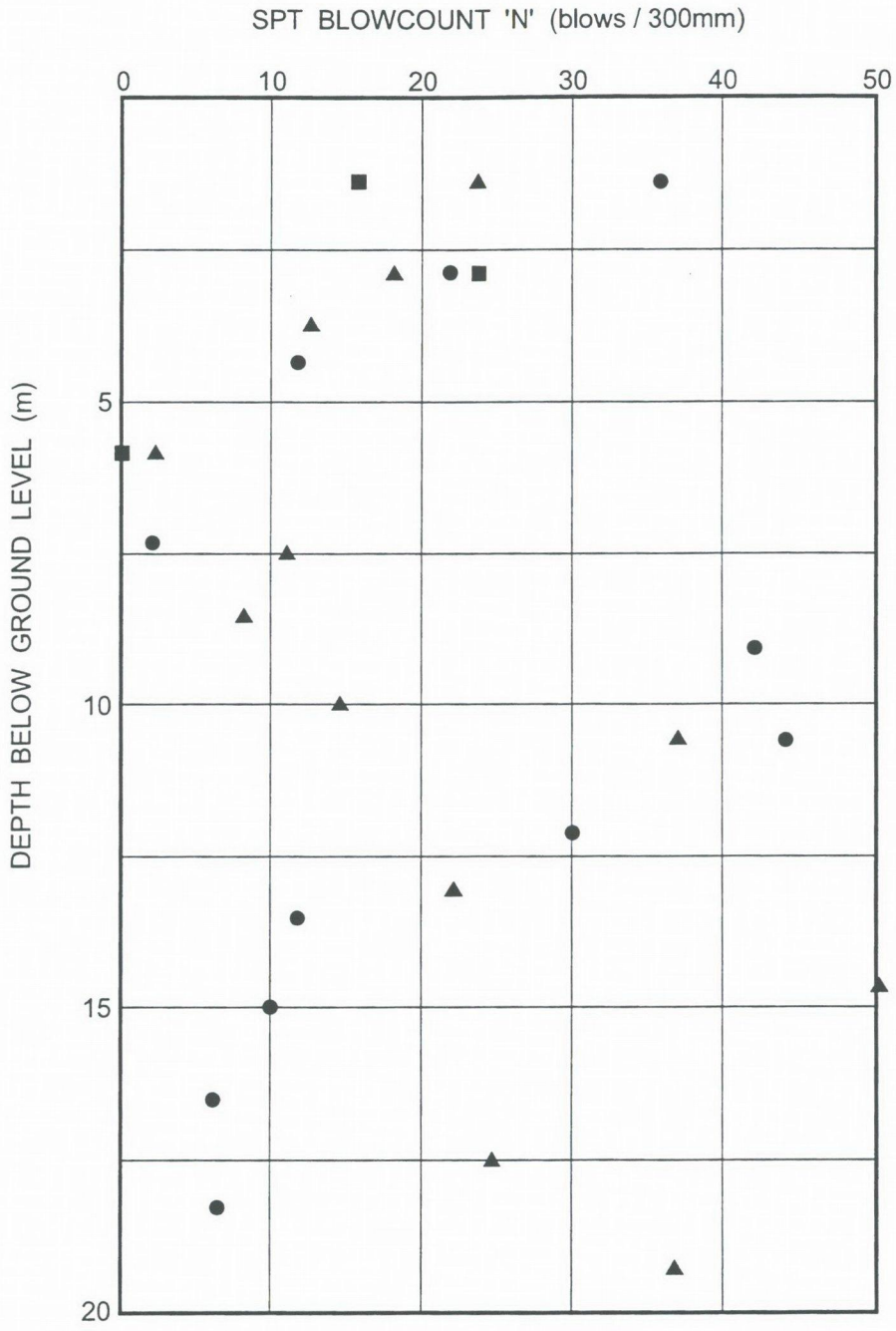


LEGEND

- ● Borehole 103
- ■ Borehole 104
- ▲ Borehole 105

ARUP Geotechnics

STANDARD PENETRATION TEST RESULTS AMP ABUTMENT



LEGEND

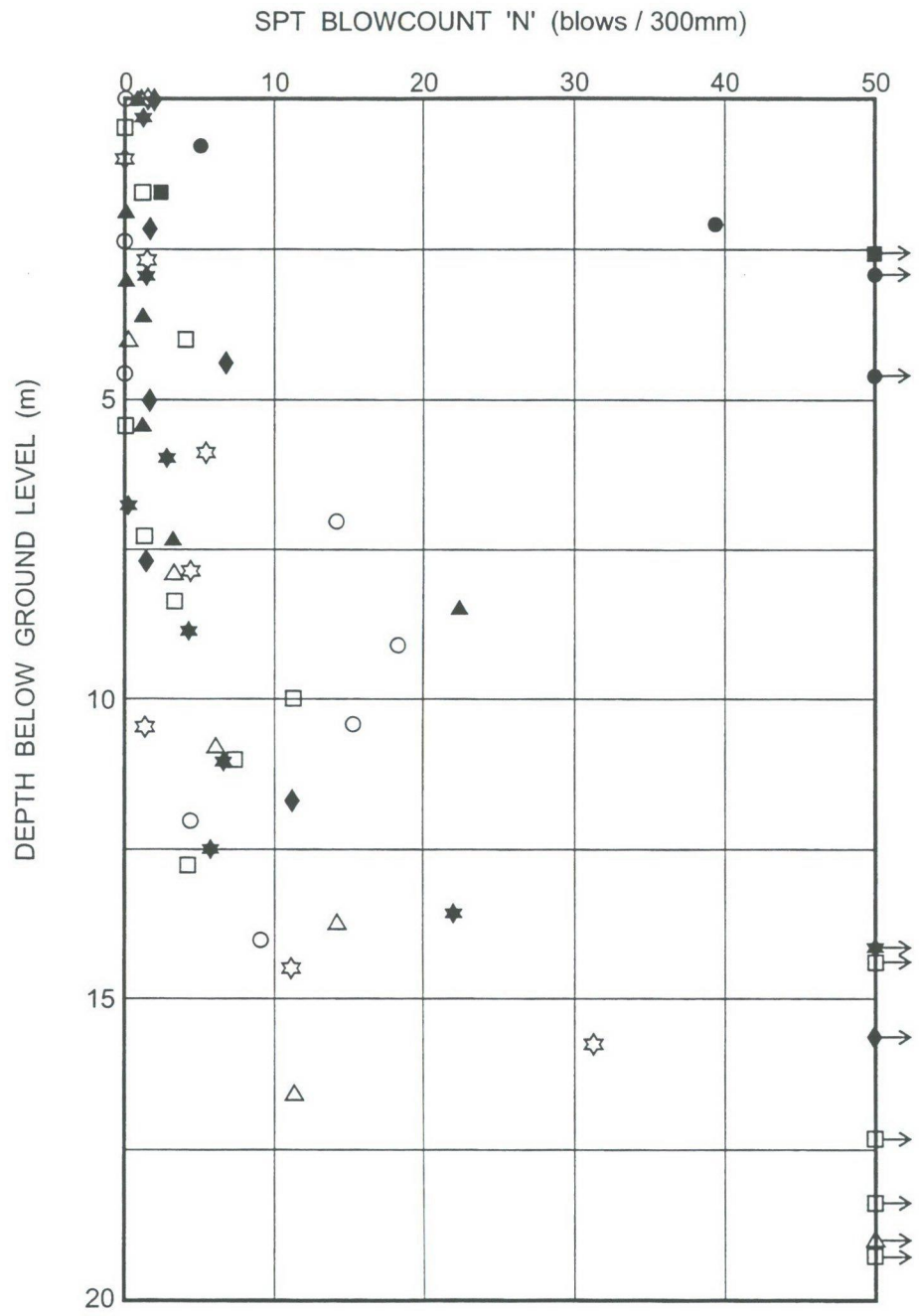
- ● Borehole 112S
- ■ Borehole 112N
- ▲ Borehole 211

19 July 1999\inf\9809\510\gjm-0009.cdr

FIGURE: 18 JOB: 9809/510

ARUP Geotechnics

STANDARD PENETRATION TEST RESULTS KARUAH RIVER CROSSING



LEGEND

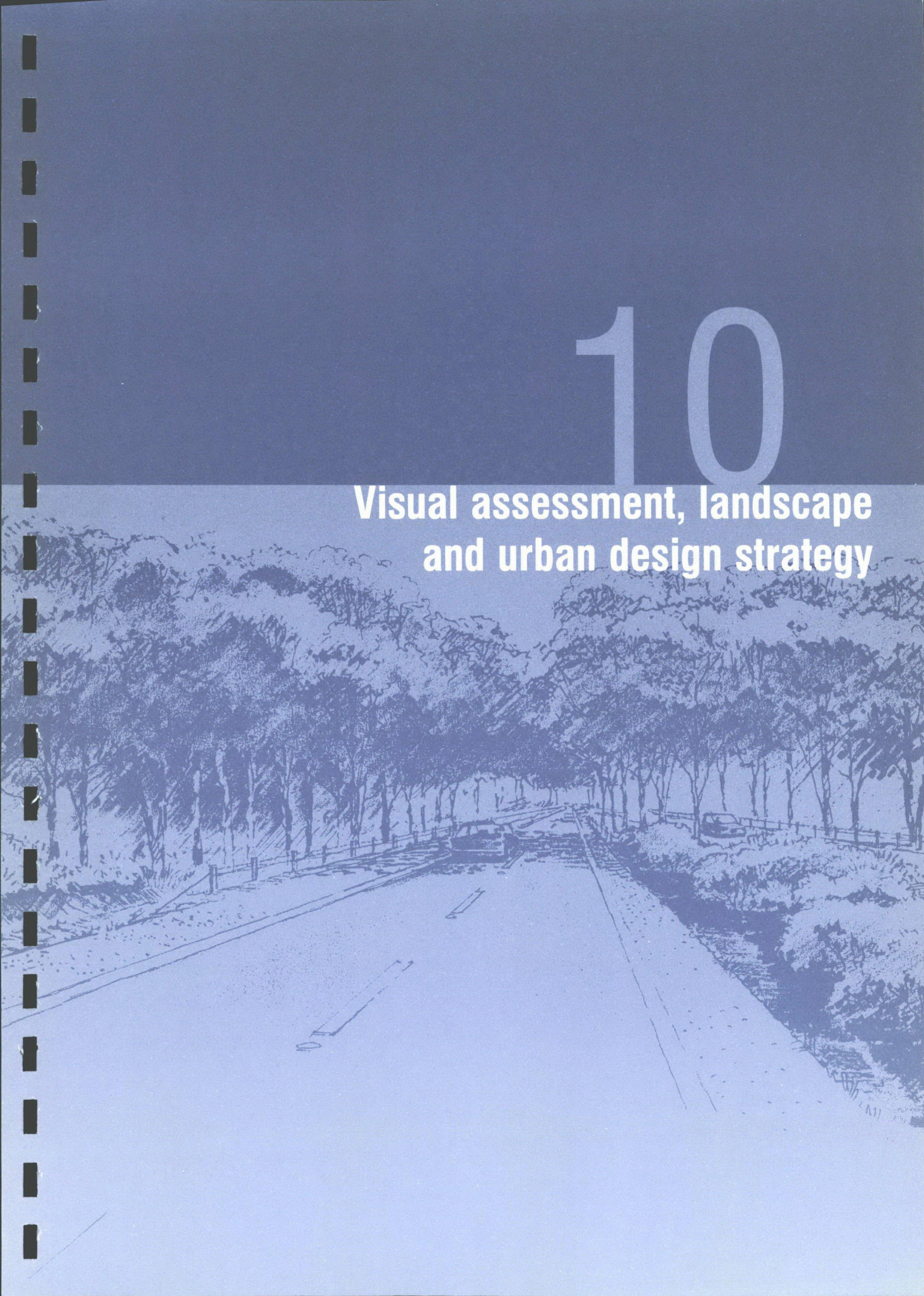
- ● Borehole 201
- ■ Borehole 202
- ▲ Borehole 203
- ○ Borehole 204
- □ Borehole 205
- △ Borehole 206
- ★ Borehole 207
- ☆ Borehole 208
- ♦ Borehole 209

19 July 1999\inf\9809\510\gjm-0009.cdr

FIGURE: 19 JOB: 9809/510

10

Visual assessment, landscape and urban design strategy



Prepared by: Environmental Partnership NSW Pty Ltd

Pacific Highway Upgrade Karuah

Visual Assessment Report



Prepared for:

ARUP

Ove Arup & Partners Consulting Engineers

September 1999

CONTENTS

SUMMARY

1.0 INTRODUCTION

1.1 Preamble

1.2 Objectives

2.0 VISUAL LANDSCAPE ENVIRONMENT

2.1 Context

2.2 Topography

2.3 Vegetation

2.4 Landuse

2.5 Patterns of population and visitation

2.6 Landscape Units

3.0 METHODOLOGY

3.1 Introduction

3.2 Visual assessment principles

3.3 Visual Quality

3.4 Visual Sensitivity

3.5 Visual Effect

4.0 VISUAL ASSESSMENT

4.1 Description of Proposed Route Alignment

4.2 Visual Quality

4.3 Visual Sensitivity

4.4 Visual Effect Summary

FIGURES

Figure 1. Landscape Units Map

Figure 2. Visual Assessment Methodology Chart

Figure 3. Visual Quality Ranking Table

Figure 4. Viewer Locations

Figure 5. Visual Sensitivity Assessment

Figure 6. Visual Effect Summary Table

SUMMARY

This Visual and Landscape Assessment Report has been prepared to assess the preferred upgrade option for the Pacific Highway at Karuah north of Newcastle, New South Wales. The report forms one part of the overall investigations for the Route Investigation Study.

Scenery or visual character of the landscape is recognised as an important resource in planning and management of the environment. Protection of the landscape qualities of the study area, in particular the SEPP 14 wetlands and intact woodland areas, is one of the key issues to be addressed.

The study area is perceived as a significant visual environment as reflected in the inclusion of the Karuah River and wooded ridgelines to the east of Karuah township in the National Trust's Port Stephens Landscape Conservation Area. This areas particular character is a function of the river environment, low lying floodplains, associated wetland vegetation and undulating rural land with a backdrop of forested hills. Views to the north from the existing Karuah Bridge are dominated by the wide expanse of the Karuah River and the predominantly intact natural ridgelines.

This report summarises the outcomes of the visual assessment. The visual quality and visual sensitivity of the study area were examined to produce a summary of visual character. The preferred corridor was then overlayed on the visual summary and evaluated. The resulting assessment determines the routes against its impact on the landscape quality and character of the study area.

Overall the implementation of the preferred route will have significant localised visual and landscape effects in the short term. This is primarily caused through the vegetation clearing and extent of earthworks required for the route alignment through the Karuah State Forest and Karuah Nature Reserve on the western side of the Karuah River, and to the steep topography of the ridgelines to the east of the river.

The longitudinal elevation of the roadway has been established to set the route into the land form reducing the potential for wider ranging visual impact, an aspect further assisted by the area's generally undulating landform. Similarly, the small number of potential viewers to the proposed route alignment limits visual exposure.

The key landscape issues arising from these visual effects will be effective landscape treatment of the steep cutting and fill batters, visual integration of impacted areas with the character of adjoining woodland and forest vegetation, and reduction of the potential visual impact of the bridge structure to local and sub regional views. Detailed responses to these issues are developed in the Landscape Concept Report that incorporates the Landscape Strategic Plan and more detailed Landscape Concept Plan.

1.0 INTRODUCTION

1.1 Preamble

The problems of traffic congestion and extended delays along the Pacific Highway Karuah have long been identified as a target area for the RTA. These issues have continued to worsen in recent years, in particular during holiday periods. The problems of pedestrian safety and long delays at Karuah are well recognised by locals and travellers alike.

Previous investigations have identified the Horse Island route as the preferred route corridor for an upgrading of the highway in the vicinity of Karuah township. The project is envisaged as a separated two lane road with shoulder cycleway/ breakdown lane.

1.2 Objectives

As part of the overall environmental assessment of the proposed upgrading, this Visual Assessment Report has been prepared to assess the preferred route option, and provide an analysis of its potential effect on the visual environment and landscape character of the surrounding area.

Objectives of the visual assessment are as follows:

- to describe the visual environment of the study area and its visual catchment in terms of the variables that are important for protection of positive existing landscape character;
- to evaluate the components of the visual character of the landscape within the visual catchment, and determine the visual quality of the landscape that the preferred route corridor traverses;
- to determine the visual sensitivity of the preferred route corridor through evaluation of views towards the route from selected viewer locations;
- to combine the results of visual quality and visual sensitivity assessment in a summary that indicates the level of visual effect along the proposed route corridor, and provides a basis for landscape mitigation and enhancement measures.

2.0 VISUAL LANDSCAPE ENVIRONMENT

2.1 Context

The study area is located north of the existing Pacific Highway and the small township of Karuah. The site incorporates the Karuah River, a tributary of Port Stephens, and its visual hinterland. The river is the area's major landscape element surrounded by an environment of low lying foreshore areas supporting wetland vegetation, and undulating rural lands with a backdrop of wooded hills and ridge lines.

The extent of the proposed route alignment lies over a large zone (8.5 kilometres west to east, and 3.2 kilometres north to south), over which a variety of landscape units with associated visual characteristics and sensitivity to change occur. The proposal traverses an undulating to moderately hilly landform including several visually dominant steep ridge lines. To the west the combination of flat to undulating landform and open forest/woodland vegetation along the corridor serves to restrict the visual catchment (locations from where the corridor can be seen) of the proposed road alignment. The Karuah River forms a dominant visual element for both recreational users and passing traffic. To the east of the river undulating footslopes are dominated by cleared rural grasslands with a backdrop of predominantly naturally forested slopes with generally natural ridge lines.

2.2 Topography

The study area can be defined as including seven distinguishable topographic types with related landform characteristics and visual implications as shown on Figure 1.:

1. Karuah River;
2. Wetland areas;
3. Steep river banks;
4. Lowland valleys;
5. Undulating footslopes;
6. Moderate slopes;
7. Steep slopes.

These are described as follows:

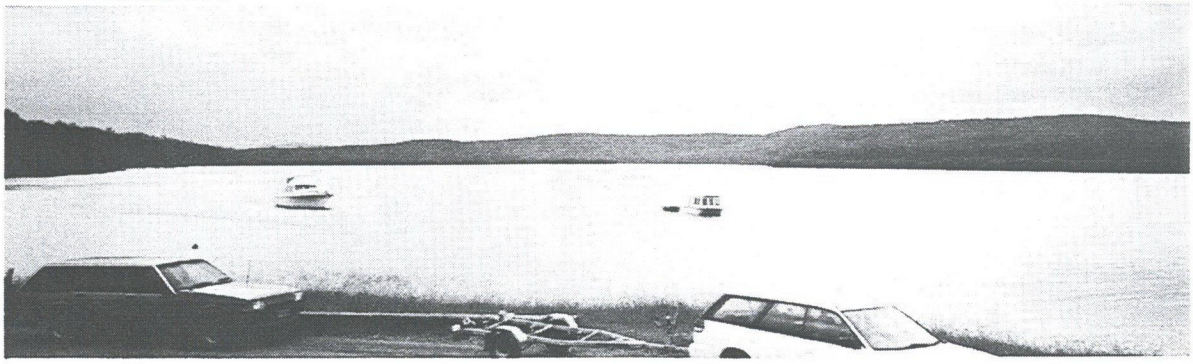
1. **Karuah River**
   The Karuah River is the dominant landscape feature in the study area. Paralleling its role as the key visual focus of the study area, the river also supports a popular role as a commercial and recreational resource for the local area. and regional community

2. **Wetland Areas**
   Wetland areas adjoining the river are extensive, covering all the low lying foreshore zones to an elevation of RL 6.0 AHD. The SEPP 14 wetland areas to the north of the town (to both sides of the river) visually merge with the forested hills beyond.

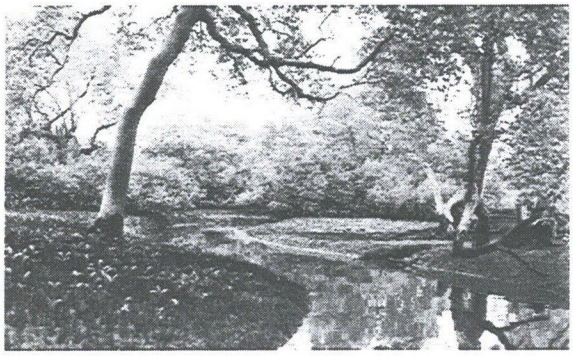
3. **Steep River Banks**
   The eastern bank of the Karuah River, opposite Horse Island, is characterised by a steep incised river bank rising up from the river. A tidal mud flat area adjoins with the eroded river bank and is vegetated by Mangroves.

4. **Lowland Valleys**
   Wallaroo Swamp is situated to the north west of the proposed road alignment. The low land valley associated with the fresh water catchment area extends further north toward Lizzies Creek and beyond. This low lying, poorly drained area is visually buffered from the town of Karuah by a ridge line to 70 metre AHD, south east of the proposed alignment characterised by predominantly rural uses with large stands of woodland vegetation.

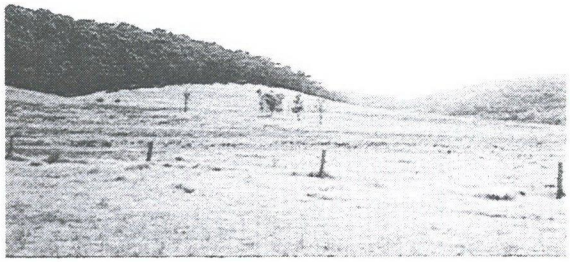
TOPOGRAPHY



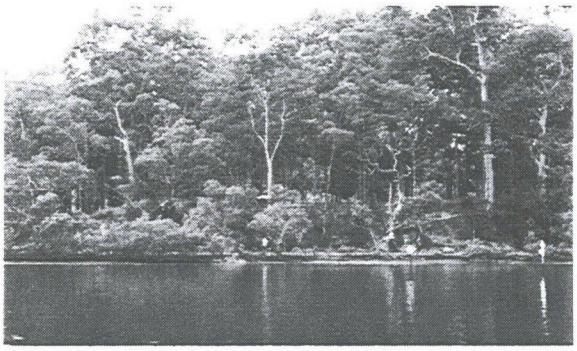
Karuah River



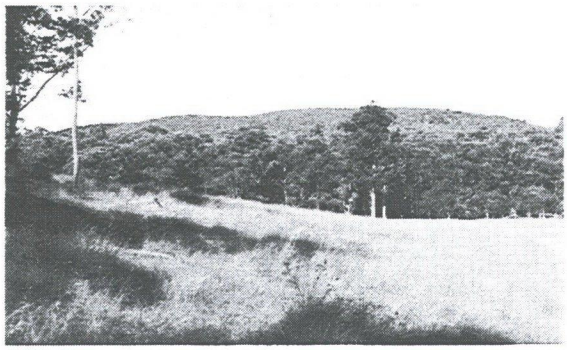
Floodplains and Wetlands



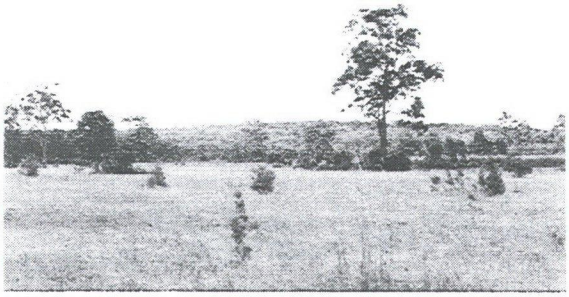
Undulating Footslopes



Steep River Bank



Moderate Slopes



Lowland Valley



Steep Slopes

5. **Undulating Footslopes**
   Adjoining the vegetated ridgelines that enclose the Karuah River are undulating footslopes of less than 1:10 gradient. Often abutted to pastoral lands the footslopes are also cleared for grazing purposes in several situations.

6. **Moderate Slopes**
   Moderate slopes are the central sections of ridgeline landforms with gradients between 1:5 and 1:10. Generally these areas remain vegetated due to their lower suitability for pastoral purposes and often poor accessibility.

7. **Steep Slopes**
   Steep slopes are those landform zones with gradients steeper than 1:5. These are centred on the northern sections of the Karuah Nature Reserve, Horse Island, the saddle landforms opposite Horse Island (to the east side of the river), and the ridgelines enclosing to the east and west the rural valley off Branch Lane east of Karuah.

Topographic Setting

Topographically, Karuah is dominated by the Karuah River and the enclosing vegetated ridgelines. To the south west of the town the partially cleared hills of Sawyers Trig (50 metres AHD) and Scobies Hill (129 metres AHD) enclose Karuah. To the west partially cleared hills to 67 metres AHD, and to the north west the wooded slopes of the Karuah Nature Reserve to 50 metres AHD, define the undulating topography that has been historically used for agricultural purposes.

To the north east of Karuah the forested ridge lines of the Carrington area and Mount George are the highest and most visually dominant topographic features. Other elevated areas to the north, west and south are buffered from the road alignment by the extent of woodland and forest vegetation.

2.3 Vegetation

Five vegetation types have been recognised for the visual assessment, based on the Flora and Fauna Assessment prepared by Gunninah Environmental Consultants (March 1999) for the proposed route corridor. Of these, the woodland and open forest community and the estuarine wetland community cover a major proportion of the study area.

The vegetation types described in the Flora and Fauna Assessment are:

1. Estuarine wetland vegetation zones,
2. Freshwater wetland vegetation zones,
3. Cleared rural zones,
4. Woodland vegetation zones,
5. Open forest vegetation zones.

1. **Estuarine Wetlands**
   The estuarine wetlands occupy the tidal and flood prone areas adjacent to Karuah River and are characterised by extensive stands of Grey Mangroves and River Mangroves, along with salt tolerant sedgeland species.

2. **Freshwater Wetlands**
   Wallaroo Swamp is located to the north east of the proposed road alignment and is a poorly drained freshwater catchment. The ephemeral swamp supports sedgeland communities surrounded by stands of *Melaleuca* sp. visually enclosing the swamp environment.

3. **Cleared Rural Zones**
   Cleared areas for grazing generally occur in the east of the study area. Much of the original woodland and open forest vegetation has been highly disturbed leaving only single or clustered native trees stands surrounded by native and exotic grasslands.

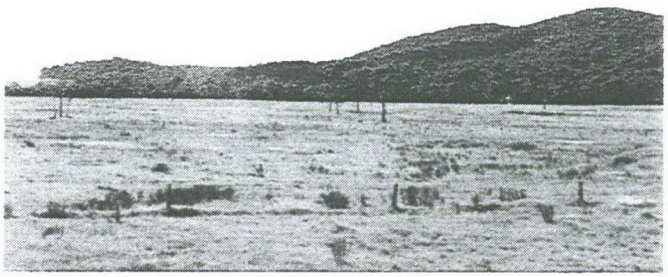
VEGETATION



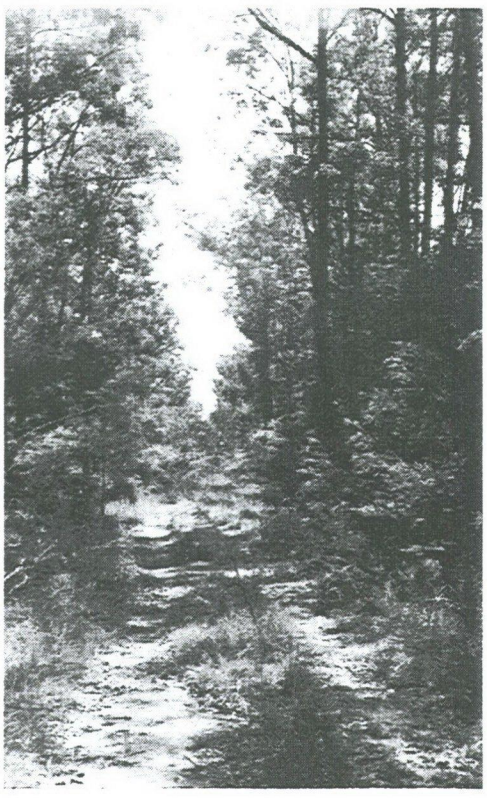
Estuarine Wetlands



Woodland



Cleared Rural



Open Forest

4. **Woodland**
   Woodland and open forest communities of *Eucalyptus* and *Angophora* species form a dominant visual character within the study area. Woodland vegetation is associated with the undulating slopes and ridge line areas of the eastern end of the proposed road alignment, merging with the open forest communities along creeklines.

5. **Open Forest**
   The open forest communities extend across much of the study area, predominantly to the north east and north of the proposed road alignment within the Karuah State Forest, to Horse Island, and on the higher slopes and ridges to the east of the Karuah River. The eastern end of the proposed road alignment is also characterised by open forest communities. Dominant *Eucalyptus* and *Angophora* species are characteristic of transitional vegetation zones with in the open forests, particularly adjacent to creeklines.

A number of native plant species have been identified within the study area by Gunninah Environmental Consultants, as having regional or state conservation concern. The only species identified under the Threatened Species Conservation Act 1995 was *Tetratheca juncea*. This small shrub has been observed in the eastern sections of the study area within open forest communities.

Species of regional conservation concern include *Hakea bakeriana*, Christmas Bell *Blandfordia grandiflora*, and Swamp Mahogany *Eucalyptus robusta.* The Christmas Bell is found in the woodland vegetation zones, along with the *Hakea sp.* The Swamp Mahogany has been identified in the poorly drained moist areas of the open forest communities.

2.4 Landuse

Within in the study area a range of land uses are evident. These uses will experience varied levels of impact by the proposed corridor due to the level of users they generate and their physical location in relation to the corridor. These include:

1. State Forestry,
2. Nature Reserve,
3. Rural Pastoral,
4. Highway,
5. River front parkland,
6. Karuah River,
7. Existing township,
8. Residential.

1. State Forestry
The dominant land use to the west of Karuah both north and south of the existing highway id State Forestry. Karuah, Wallaroo and Medowie State Forests incorporate much of the wooded hinterland of hills and ridges to the west of the town. Human activities involve intermittent access for maintenance and management purposes.

2. Karuah Nature Reserve
The Karuah Nature Reserve incorporates the wooded ridgelines and slopes to the north of Karuah township on the western side of the river. The nature reserve provides for conservation of native flora and fauna, and appropriate recreational use (eg. bushwalking). Existing trails provide access to the western section of the reserve, however trails are strongly enclosed by tree and understorey canopy and are subject to infrequent usage. The Nature Reserve is managed by the National Parks and Wildlife Service.

3. Rural / Pastoral
Rural landuses within the area are important factors shaping the study area's visual character. The grazing lands east of Karuah River visually integrate with the character of the river floodplains and adjoining forested areas. Cleared grazing paddocks with intermittent dams extend across the undulating foot slopes, with scattered rural residences located on prominent hills.

4. Highway
The proposed highway corridor will provide the greatest source of users to the study area. The by passing of Karuah township will maintain vehicular speeds of 110 kilometres per hour along the corridor, through which users will pass through a variety of landscape settings from woodland enclosure on both sides to the panoramic views of the Karuah River Bridge.

5. River front parkland
Parkland areas to the western foreshores of the Karuah River adjacent to the existing Karuah Bridge have frequent current levels of usage by highway motorists for rest stops and lunch etc. Despite being degraded in character with poor quality facilities the park areas do have attractive views out across the river and hinterland to the north. Potential views from these areas to the proposed road corridor are discussed later.

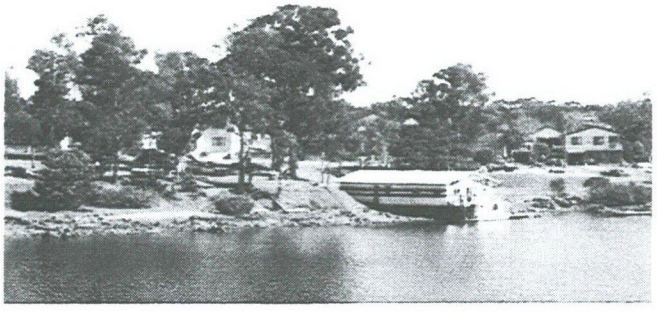
However with bypassing of the township by the proposed highway upgrade it is expected that this usage will significantly decline to some local use, and use by persons accessing the adjacent boat ramp and boat hire facilities.

6. Karuah River
Karuah River has recreation value for locals and visitors to the area. Boating and fishing are common uses. The river shallows support oyster leases along both shore lines.

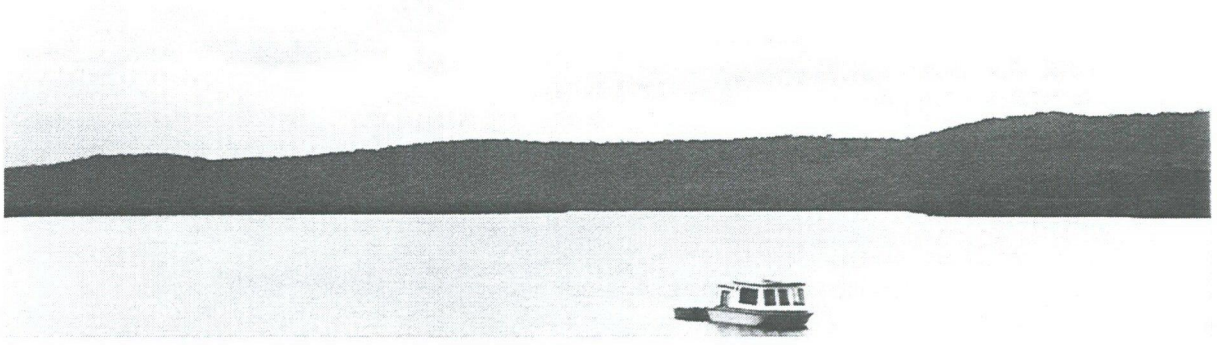
LANDUSE



State Forestry



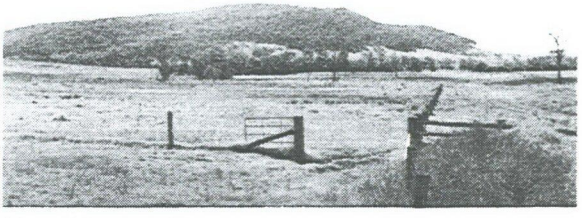
Riverfront Parklands



Karuah River



Residential



Rural/Pastoral

7. Existing Township

Karuah township is a small commercial strip adjoining the existing highway with typical vehicle services and food outlets serving highway users and the local population of approximately 1000 persons.

Highway generated use will naturally decline with the bypassing of the town.

8. Residential

Low density residential development extends to the north and south of Karuah township and the existing highway.

Located to the north of the Mustons Gully wetland area is the Karuah Aboriginal Community with a further residential subdivision adjoining the southern edge of the Karuah Nature Reserve. These permanent residential areas are between 2.2 and 3.5 kilometres from the river crossing of the proposed highway alignment.

Single rural residential areas are also located on the rivers eastern foreshores 500 metres to the north of the proposed river crossing, and in the vicinity of Lizzies Creek to the north of the corridors alignment through the Karuah Nature Reserve.

2.5 Patterns of Population and Visitation

The Karuah township with its related residential areas immediately north and south of the existing highway provides the bulk of the population living within the study area. Additional residential areas are located along the western foreshores of the Karuah River to Mustons Road (including the Karuah Aboriginal Community), along with housing to the eastern foreshores facing north west just off the existing highway. Although not extensive in numbers, sections of these established residential areas penetrate the foreshore vegetation to overlook the river and visual hinterland to the north of the town.

Visitors to Karuah are predominantly generated through the highway traffic which tends to be concentrated to the existing highway for services activities. Memorial Park also receives a regular visitation for highway user rest stops, having toilet and picnic facilities available. Beyond these areas activities appear to be more locally focussed, related to rural, fishing, and bushland recreational activities.

The proposed highway alignment will (as stated previously) provide the source of the greatest number of users through the study area. This will primarily be within vehicles in transit, with some stopover/rest visitation maintained to Karuah township.

2.6 Visual Landscape Units

The proposed road alignment traverses approximately nine kilometres of terrain through varied landscape types. Based on the topographic, vegetation, and landuse characteristics twelve Visual Landscape Units can be identified as described following, and as specified on Figure 1. - Landscape Units Map.

Unit 1 - Woodland Slopes

Moderate slopes / Woodland vegetation / State Forest

This unit incorporates the Karuah State Forest and is located to the west of Karuah township. The moderate slopes provide gradients from 1:15 to 1:25, with aspects ranging from south west to south east.

The Woodland vegetation of the State Forest ranges in height from 12 - 18 metres, with dominant species including Smooth-barked Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Brown Stringybark *Eucalyptus capitellata*, and Bastard Mahogany *Eucalyptus umbra*.

Views are available toward this area from the top of Scobies Hill to the south east and from the existing highway alignment, with some visual penetration potentially available from the low lying areas of Wallaroo State Forest to the south (but limited by vegetation and gentle topography).

Unit 2 - Woodland Valley
Low land valley / Woodland vegetation / State Forest
The undulating valley landform around Wallaroo Swamp provides gradients from 1:12 to 1:60 with the valley fringes supporting the Woodland vegetation of the Wallaroo State Forest as described for Unit 1.

Sub-unit 2A is located on the south side of the valley with a north easterly aspect. The area would potentially be glimpsed through vegetation from Mines Hill Trail located on the prominent forested ridge line to the north east.

Sub-unit 2B is located on the north side of the valley with a south westerly aspect. Views toward this area are available from the cleared rural lands to the south east adjoining the proposed Future Sewage Treatment Plant.

Unit 3 - Forest Valley
Low land valley / Open forest vegetation / State Forest
Unit 3 traverses the low lying valley area that drains into Wallaroo Swamp, flanked by Sub-units 2A and 2B to the south and north respectively. The gradient though gentle at 1:50 provides a generally north easterly aspect.

The Open forest vegetation that surrounds the swamp area ranges from 15 - 20 metres in height. The lower moister areas are dominated by Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea*, and Rough-barked Apple *Angophora floribunda*. The drier areas on the upper grades adjoining Sub-units 2A and 2B, support species including Smooth-bark Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Sydney Peppermint *Eucalyptus piperita*, and White Stringybark *Eucalyptus globoidea*. The vegetation throughout this unit is typified by upper level die back within the tree canopy.

The area is potentially visible from the surrounding ridge lines to the north, east and south, albeit restricted by canopy vegetation and viewing areas subject to very limited use. The cleared pastoral area to the east is subject to more direct views to the Forest Valley from its upper elevation.

Unit 4 - Southern Forest Slopes
Steep slopes / Open forest vegetation / State Forest
Unit 4 is typified by steep slopes ranging from 1:5 to 1:10 grade. Aspect is generally from the south west to north west.

The dominant tree species within the open forest vegetation (to 16-20 metres) include Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Gum *Eucalyptus punctata*, Northern Grey Ironbark *Eucalyptus siderophloia*, White Stringybark *Eucalyptus globoidea*, and Tallow-wood *Eucalyptus microcorys*.

Some visual penetration to this unit may be possible from Wallaroo Swamp and from distant low lands to the west.

Unit 5 - Northern Forest Slopes
Steep slopes / Open forest vegetation / Privately owned
Unit 5 incorporates steep slopes ranging in gradient from 1:5 to 1:10, with aspect swinging from the north east to north west. Part of the northern footslopes of the Mines Hill ridgeline (part of Karuah State Forest) the slopes incorporate an east - west running spur that encloses the wetland areas to the south of Horse Island.

The open forest community, which occurs widely in the study area, is that described for Landscape Unit 4.

Views are available toward this unit from the low lying floodplain areas of the Karuah River and the Karuah River itself to the north.

Unit 6 - Wetlands
Wetland / Estuarine wetland vegetation / SEPP 14
Unit 6 incorporates the tidal flood prone zones of the river corridor adjoining the western banks of the river enclosed and by the Mines Hill Ridgeline to the south west and Horse Island to the north.

Incorporated in the State Environmental Planning Policy (SEPP) 14 Wetland Protection Areas, the dominant vegetation type is wetland saltmarsh, including *Zoysia macranha*, *Sarcocomi quinqueflora* and *Suaeda australis*, which occurs behind the Mangrove stands along Karuah River. A fringe area of sedgeland dominated by *Juncus krausii* occurs behind the saltmarsh, within areas of infrequent tidal inundation. A band of Swamp Forest occurs along the low areas of adjacent rocky slopes dominated by *Casuarina glauca* and *Baumea juncea*.
The area is relatively protected to visual exposure due to the surrounding landform to the north, west and south, and the fringing Mangrove stands to the Karuah River to the east.

Unit 7 - Horse Island
Steep slopes of Horse Island / Open forest vegetation / Privately owned
Horse Island rises to 92 metres AHD with steep vegetated slopes of average 1:5 grade. The island forms a north west-south east ridgeline offering its steepest slopes and highest elevation to the south east adjoining Unit 6 - Wetlands. Surrounded by wetland and mudflat areas the landform is separated from the slopes and ridgelines of the Karuah Nature Reserve by a band of mudflat and a creekline running along its southern edge.

The island is well forested by a range of tree species including Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Gum *Eucalyptus punctata*, Northern Grey Ironbark *Eucalyptus siderophloia*, White Stringybark *Eucalyptus globoidea*, and Tallow-wood *Eucalyptus microcorys*. Grey Mangrove *Avicennia marina* var. *australasica* and River Mangrove *Aegiceras corniculatum* dominate the mudflats.

Horse Island is situated on a westerly bend in the Karuah River, and provides a prominent landmark viewed from the river and its foreshores to the north and south, along with the ridgeline to the east of Karuah River. The island is visible as far as 3 kilometres down river from the existing Karuah Bridge.

Unit 8 - Karuah River
Karuah River / Estuarine wetland vegetation / Recreation and oyster leases
As stated previously, Karuah River is a dominant visual feature within the study area. Its open water area ranges from between 400 to 700 metres in width between the wetland mudflat areas supporting mangrove species to the western bank, and the steeply rising eastern bank, vegetated with open forest vegetation (see Unit 9A).

Mangrove stands are dominated by Grey Mangrove *Avicennia marina, and* River Mangrove *Aegiceras corniculatum of between 5-8 metres height.*

Spectacular vistas north and north east along the river are afforded from the water and river foreshores. The wooded hills provide a natural backdrop of unbroken ridgelines that defines the river and its hinterland.

Unit 9 - Rural Footslopes and Saddle
Moderate to undulating footslopes and saddle / Cleared rural grasslands / Rural
The undulating rural footslopes to the eastern bank of the Karuah River are predominantly cleared, supporting single or small clusters of remnant and regenerating tree species, within a combination of native and exotic grasslands, and a varying gradient between 1:6 to 1:30.

Sub-unit 9A extends east from the river bank supporting a narrow foreshore band (to 20m) of remnant open forest vegetation including Spotted Gum *Corymbia maculata*. The low lying pastoral

slopes support grasslands of both native and exotic species. Aspect of the footslopes is generally south west, with dappled views available from the river and eastern foreshore through the foreshore vegetation.

Unit 9B lies within a saddle landform. The western to central zone of the saddle has been previously cleared, with the adjacent slopes vegetated by open forest communities. Intermittent regeneration has occurred through the central zone providing a partial continuation of the vegetated ridgeline when viewed from the west.

To its easterly aspect adjoining a cleared rural valley to the east, Sub-unit 9B is typified by more intact natural vegetation (in particular to the north south running creekline), making landform changes more visually subtle, when viewed from Unit 9C.
Open Forest vegetation to the easterly aspect of Unit 9B and regenerating westerly aspect includes Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea,* Rough-barked Apple *Angophora floribunda* and *Melaleuca styphelioides.*

Sub-unit 9A is limited in visual exposure to the Karuah River and the adjacent western foreshores due to the stand of foreshore vegetation which provides significant screening of the cleared lands at river level. Sub-unit 9B (the saddle landform) is partially visible to long views to the south west and east (over 1.5 kilometres) where the screening effect of foreshore vegetation is reduced. To the west Sub-unit 9B is visible from the cleared valley undulating to the east and also longer views from the vicinity of Mustons Lane below Mount George (2.5 kilometres distance).

The rural footslopes of the north west - north east running valley comprising Sub-unit 9C range from 1:7 to 1:20 grade, and drains towards the north east - south west running creek gully of Unit 10. This sub unit is subject to strong visual enclosure by vegetated ridgelines to the north and south, and the saddle landforms to the west.

Unit 10 - Creekline Gully
Creekline / Open forest vegetation / Rural
The north east - south west running creekline gully which separates Sub-unit 9C from Unit 11 drains into the SEPP 14 wetlands to the eastern foreshores of the Karuah River.

The stand of vegetation which crosses the gully and links the wooded hills to the north and south is a visually significant feature, restricting views from within these adjoining units.

Open forest vegetation to the gully includes Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea*, Rough-barked Apple *Angophora floribunda* and *Melaleuca styphelioides.*

Views toward this area available (as described) from the adjoining units 9C(west) and 11(east) from the surrounding ridgelines and cleared pastoral areas. Up to 1.5 kilometres to the east where the Mount George landform and adjoining ridgelines enclose the rural valley.

Unit 11 - Rural Valley
Undulating footslopes /Cleared grasslands / Rural
The Rural Valley comprises the cleared rural lands of the south east - north west running valley off the western side of Branch Lane. Sub-unit 11A incorporates undulating slopes (average gradient 1:15) below a prominent vegetated ridge line (to 116 AHD). Aspect is to the north and north east. Unit 11B is associated with similar graded undulating footslopes with an aspect more toward the south east.

The Rural Valley is typified by cleared paddocks with scattered water storage dams. Grasslands extend up to the open forest vegetation at the base of the ridge line, with minor stands of tree and understorey vegetation following creeklines. A rural residence is located at the transition between Sub-units 11A and 11B off Branch Lane.

Expansive rural views are available across the valley, and from the continuation of the valley to the north of Unit 10.

Unit 12 - Disturbed Forest
Undulating footslopes / Disturbed open forest vegetation / Rural
Unit 12 adjoins the existing road corridor of the Pacific Highway through previously cleared (but subject to partial regeneration) footslopes below the Carrington Hills. The undulating footslopes are characterised by grades of average 1:25.

East of Branch Lane the vegetation cover is more instant as far as the quarry site adjoining the highway. This zone provides the head of the creek gully that drains to the SEPP 14 wetlands south of the existing highway.

The disturbed open forest has been cleared of most of the understorey species (in particular to the west of Branch Lane) leaving a tree canopy. The tree canopy comprises mainly of Forest Red Gum *Eucalyptus tereticornis*, Spotted Gum *Corymbia maculata*, Broad-leaved Ironbark *Eucalyptus fibrosa*, White Stringybark *Eucalyptus siderophloia*, Grey Gum *Eucalyptus punctata*, Bastard Mahogany *Eucalyptus umbra* and Smoothed-barked Apple *Angophora costata*.

The area can be viewed from the southern section of Sub-unit 11B (south of existing farmhouse) with dappled views into the area from Branch Lane through fringing tree canopy.

Unit 13 - Existing Highway
The existing highway alignment changes in character throughout its course based on the surrounding context of landform, vegetation, and landuse. For the purposes of this assessment the comments provided are focused on the location of the western and eastern interchanges of the proposed corridor with the existing highway.

Sub-unit 13A: The Western Interchange is located on a bend in the highway that is flanked by undulating slopes (1:20 grade) to the north, and gentle slopes (1:40 grade) to the south east. The roadway falls to the west at a gradient of approximately 1:50-1:75. Subject to recent clearing and tapered profile of adjoining woodland vegetation the corridor has an open character particularly when approached from higher elevations to the east.

Sub-unit 13B: The Eastern Interchange is located on a tight bend in the highway and is strongly enclosed to the north and west by steeply sloping landform and open forest vegetation. To the south, the highway adjoins undulating topography falling gently towards the south. The SEPP 14 Wetlands extend to the edge of the road alignment at this location. The steep topography and close proximity of tall canopy trees to the corridor result in an enclosed visual character of strong visual interest.

3.0 METHODOLOGY

3.1 Introduction

Scenery or the visual character of landscape is widely recognised as a resource that must be taken into account during both planning processes and development of management programmes. Despite research during the past 25 years, no broadly implemented quantitative method has been devised to assess visual quality of landscapes, as has all other environmental variables such as soils and vegetation. It is possible that this goal is objectively unobtainable because perception of visual quality/character depends upon the culturally influenced subjective response of the observer.

The methodology for this study is inherently subjective, but it is based on the objective methodology of Australian and overseas studies used for visual assessment of landscapes, including United States Forestry Scheme (1974), Department of Planning (1988) and the Forestry Commission of Tasmania (1983).

It should be noted that all photographs (other than extended panorama views) taken were using a 50 mm lens and therefore closely parallel the image seen with the human eye.

3.2 Visual assessment principles

The methodology developed for the assessing the visual character of the landscape within the study area and impact of the proposed route alignment is:

- systematic in approach;
- consistent in application;
- based on professional value judgement related to commonly adopted and accepted criteria.

The fundamental objective of the assessment is the identification of significant visual elements of the study area that should be conserved in order to protect the existing visual and landscape character of the Karuah region.

The methodology for the visual assessment is outlined in Figure 2. The approach involves the evaluation of the visual character of the area and determination of the visual effect of the proposed road alignment.

Visual character is defined in terms of the visual quality and visual sensitivity of the landscape. Visual quality is evaluated based on the variables that combine to create visual character - landform and land cover. Visual sensitivity of the landscape is evaluated by analysing the views at selected viewer locations within the visual catchment of the proposed route alignment.

The results from these assessments culminate in the identification of visual effects which provides a basis for the development of landscape strategies based on key visual issues.

3.3 Visual Quality

Visual quality is essentially a description of the landscape character of an area and the relative dominance of that character. Visual quality can be based on assessment of the landscape components that form the visual setting. Quality measures the value by which human users appreciate and interpret the aesthetics of a landscape setting. Landform and landcover and their interaction/inter relationship are considered to be the key determinants of visual quality.

A range of research, including Wright, 1973; State Pollution Control Commission, 1981; and Colleran and Gearing, 1980, has indicated that outside of the city environments humans prefer landscape settings that are natural in character, with strong qualities of vegetation, water elements, varied topography, and contrasting visual features. Visual settings suggested to be least preferred are those that have been subject to a high level of human disturbance and/or display a low level of variation and contrast in landform and land cover.

Landform

Landform is generated by topography and landforming processes including rivers. Different landforms produce varying visual prominence, character, and indeed can shape the level of cultural impact on an area. For example, the ridgelines to the Karuah Nature Reserve, and east and west of Unit 11 - Rural Valley which predominantly define the visual catchment of the proposed road corridor are a dominant component of many views within the study area.

Landcover

Landcover is a function of vegetation and landuse. The structure of different vegetation communities produces different visual effects on the landscape. Cleared rural areas with intermittent tree canopy have a different character and resultant level of visual quality, to remnant endemic vegetation. Completely cleared and developed areas such as Karuah township itself, rely upon the quality of built form and cultural landscape to determine the level of visual quality. Vegetation can also influence views from areas - tall stands of trees can screen or buffer views between two locations including those on different elevations.

Landuse type is also important in determining the visual quality of and area, because landuse can dominate a landscape and alter previously dominant natural features. Commercial and residential areas with their associated infrastructure can also severely alter the landscape.

Summary - Visual Quality

Section 3.6 of this report defined the landscape units generated by the landform, vegetation, and landuse characteristics of the study area. The landscape units provide an effective basis to determine an assessment of visual quality for the study area.

Each unit is rated according to its visual quality within the landscape of the study area. Four ratings were established - very high, high, medium, low. Units that are composed of characteristics that are important to the visual quality of the area, such as vegetated ridge lines in an undisturbed condition, or low lying foreshore wetland areas, ranked very high. Units that are composed of characteristics that create a less favourable visual impression on the landscape, such as disturbed vegetation areas with visible human impact and little visual contrast, are rated lower.

3.4 Visual Sensitivity

Visual sensitivity is a measure of how critically a proposal will be viewed and the degree to which visual changes to the landscape arising from the proposal are likely to impact on human activities and usage of the study area. Visual sensitivity is influenced by the number of viewers, the duration of views, the distance from the proposal and the angle of views. Locations normally most sensitive to visual change are those with high and/or fixed viewing populations, relatively natural settings, and visually prominent and elevated sites. In addition, the closer the viewer to the site of change the higher the potential for impact. In terms of major road projects the highest impact will be to local or foreground views (less than 1 kilometre), with sub-regional or mid-ground views (1-5 kilometres) moderately sensitive, and regional or distant views (over 5 kilometres) the least sensitive (Queensland Department of Main Roads, 1997).

To determine visual sensitivity, the visual catchment of the proposed corridor is to be broadly defined and then viewer locations established.

Visual Catchment

Visual catchment is the area that contains all views of the proposed road corridor both when standing on the alignment route looking out to the surrounding landscape, and when standing away from the alignment looking towards the road. Its extent represents the limit of views, and for the Karuah study area is defined by the surrounding land form to the east, west and north.

Viewer locations
Various locations across the study area were considered as potential viewer locations for assessment of the visual sensitivity. Each location was analysed and if views could be gained toward the proposed road corridor have been recognised as a viewer location.

Visual Sensitivity Assessment

At each of the viewer locations, visual sensitivity is assessed using the following five sensitivity factors:

- number of observers;
- viewing duration;
- viewing distance;
- viewing angle;
- degree of landscape change.

The number of observers is to be estimated as high, medium or low being a comparative measure between all viewer locations. High indicates a relatively high number of viewers such as from the new highway alignment. Low indicates views from areas that are not likely to be visited by more than one or two persons, such as the proposed eastern bridge abutment.

Viewing duration is categorised as permanent (views of the route corridor are permanently exposed to human activities), casual (views are for part of the day, for example during working hours), or transient (views are infrequent and for short time periods). For example, views from residential areas on the foreshores of the Karuah River may be categorised as permanent, and views the eastern foreshore rural lands may be transient.

The distance between a point within the viewer location and the nearest point on the proposed road alignment is to be measured as the viewing distance. The distance is measured in metres.

The direction of the viewing distance is the viewing angle, expressed as either parallel, on angle, or perpendicular to the proposed corridor. The anticipated degree of landscape change as outlined in Section 4.5 Visual Effect, is also considered as part of the visual sensitivity summary.

3.5 Visual Effect

Visual effect is the sum of the visual impacts of the proposed route through each of the landscape units of the study area. Key aspects of visual effect are:

1. Level of Visual Change
2. Landscape Impact over time

These are outlined briefly below:

1. *Level of Visual Change*

The more the proposed highway alignment and its resultant built structures and earth forms contrast with the surrounding landscape, the higher the level of visual change to the landscape setting of the area. Aspects of change may include:

- substantial alterations to the natural landform such as earthworks cutting or fill benches;
- the introduction of built elements into a natural or rural landscape;
- visual separation of formerly continuous areas or view prevention (where broader views were formerly possible);
- segregation of adjacent locations or communities;
- loss of familiar landscape features or character.

In assessing the level of visual change the type and severity of change must be taken into account.

2. *Landscape Impact Over Time*

Related to the level of landscape change is the consideration of time and its relationship to vegetation growth and degree of visual mitigation of landscape mitigation measures.

In general terms, visual impacts are likely to be highest during road construction and immediately following completion. A progressive reduction in impact can usually be expected as planting develops and viewers become more familiar with permanent visual changes.

4.0 VISUAL ASSESSMENT

4.1 Description of Proposed Route Alignment

The proposed Karuah upgrade route (as indicated on Figure 1.) will result in a new section of dual carriageway highway to the north of Karuah township. Road construction will involve nine cuttings through ridge line and footslope landforms, and two bridge structures to cross Karuah River and the associated wetlands areas near Horse Island. Several fauna underpasses are also being considered, along with a potential fauna overpass across the saddle east of the proposed Karuah River bridge.

Grade separated interchanges would be constructed at either end of the proposed bypass. The western interchange indicates an over pass to connect with the existing Pacific Highway. An underpass is required at the eastern interchange to serve local road connections to rural areas.

The proposed dual carriageway design impacts on an immediate corridor of between 40 and 75 metres width, with a 9.5 metre wide two lane carriageway in each direction, separated by a 11 metre wide median over the majority of its length. Bridge structures would be constructed to a width of approximately 20 metres to reduce abutment structures and related impact on wetland areas below. The bridges are set at a maximum 13 metre elevation above mean high water level to reduce visual exposure to viewers of Karuah River.

4.2 Visual Quality

As identified in the introduction to this assessment report the proposed road corridor study area is partially located within the National Trust's Port Stephens Landscape Conservation Area. The Trust's listing has stood since 1977 when the areas scenic and scientific values were formally recognised as being of conservation significance.

The Trust's listing summary identifies that the dramatic coastal landform and intact natural setting of Port Stephens is a key aspect of its visual significance. Likewise, the extensive waterways of the main water body and tributaries (including Myall River, Pipeclay Creek, Tilligerry Creek and Karuah River) provide both scenic and scientific value through the quality of natural environment they support.

The listing extends to the upper reaches of the Karuah River (to approximately 14 kilometres north of Karuah township). The listing incorporates the estuarine wetland and mangrove areas to the eastern shores of Karuah River, the northern section of the Karuah Nature Reserve, Horse Island, and the areas below enclosing ridgelines to the east of the river.

The visual quality assessment following, reinforces the National Trust's listing of the visual hinterland of the Karuah River (ie. visual catchment defined by surrounding landform) as being of high scenic value. The assessment describes the physical character of the various landscape units from which is determined a rating of visual quality.

A very high rating encompasses the dominant homogeneous landscape units that are an integral part of the landscape character of the study area. These units are considered to be essential to the visual and environmental quality of the landscape, and provide the Karuah area with its dominant

character of natural wooded ridges enclosing a rural / rural residential landuse centred on the river system and its related wetland environments.

Landscape units in this category are generally areas with visually distinct or significant landform and landcover that would be particularly sensitive to development of the route corridors within them.

Landscape units identified as having high visual quality are areas significant in the landscape setting but usually with some changes to the natural landscape through human interference. For example, State Forest woodland areas that have been subject to impacts by adjoining landuses at their periphery or through the creation of access tracks and roads.

A further category of landscape unit that has been classified as high visual quality within the study area is rural landuse on undulating foothills. These areas are very much part of the local semi-rural character, and when combined with a backdrop of natural woodland with steeply undulating slopes provide an important visual component sensitive to change (eg. residential) or incursion (eg. roadway). Areas of note include the rural valley off Branch Lane to the east of Karuah and the cleared rural area and saddle landform to the eastern bank of the Karuah River.

The classification of medium visual quality encompasses landscape units where the natural landscape has been noticeably manipulated through human intervention, or where adjoining landuses and environmental factors have reduced the quality of vegetation. This will include areas previously cleared for rural purposes, areas of residential subdivision where some natural vegetation remains, and developed parks and cleared foreshore areas utilised for open space purposes.

The standard of canopy vegetation and understorey vegetation is a key factor affecting visual quality. To the woodland slopes and valley of the Wallaroo State Forest (Landscape Unit 3) intermittent canopy die back and weed encroachment are evidence of adjoining human activities, impacting on drainage and local ecosystems, and reduce the natural visual integrity of this area.

Landscape units with low visual quality rating include areas where the natural landcover has been totally altered by human usage. To the landscape units through which the proposed corridor passes, this classification does not occur, other than at the western junction with the existing highway. Other examples within the broader Karuah area include the existing highway alignment with poorly finished road shoulders, the commercial and industrial areas within Karuah township, and areas of residential housing with poor quality of built form and the landscape.

Figure 3 Visual Quality Ranking

No.	Landscape Unit	Unit Elements	Visual Quality	% of Corridor Length
1	Woodland Slopes	Undulating moderate slopes (1:15 - 1:25), Woodland vegetation , State Forest	High	24.5%
2	Woodland Valley	Low land valley (1:15 - 1:60), Woodland vegetation, State Forest	High	2%
3	Forest Valley	Low land valley, Open Forest vegetation, State Forest	Medium	6%
4	Southern Forest Slopes	Steep - Moderate slopes (1:5 - 1:10), Open forest vegetation, State Forest	Very High	4%
5	Northern Forest Slopes	Steep - Moderate slopes (1:5 - 1:10), Open forest vegetation, Privately owned	Very High	11%
6	Wetlands	Wetland, estuarine wetland vegetation, SEPP 14	High	2.5%
7	Horse Island	Steep slopes (1:5), Open forest vegetation, Privately owned	Very High	4%
8	Karuah River	Karuah River, Estuarine wetland vegetation, recreation and oyster leases	Very High	6.5%
9	Rural Footslopes & Saddle	Moderate - undulating footslopes and saddle (1:6 - 1:30), Cleared rural grasslands, Rural	High	12%
10	Creekline Gully	Creekline, Open forest vegetation, Rural	High	2%
11	Rural paddocks	Undulating footslopes (1:15), Cleared rural grasslands, Rural	High	14%
12	Disturbed Forest	Undulating footslopes (1:25), Disturbed open forest, Rural	Medium	8%
13A	Existing Highway - West	Undulating footslopes (1:25), Cleared/Disturbed woodland, Highway	Low	1%
13B	Existing Highway - East	Undulating footslopes (1:40), Cleared/Disturbed woodland, Highway	Medium	3%

Key Determinants of Visual Quality:

- preference for landscapes that are relatively natural in character -"vegetated"
- preference for dramatic or visually interesting topography and contrasting features
- role of landscape in determining the visual character of the region
- desirability of water elements
- undesirability of landscapes with high degree of human disturbance
- undesirability of landscapes with a lack of visual contrast

Summary - Visual Quality

In summary the proposed route alignment passes through landscape units of very high (25%), or high (57%) visual quality for most of its length. As such, potential for impacts to the visual quality of the corridor is high and will require consideration in the setting of alignment elevation and corridor width to reduce earthworks, and in landscape treatment to integrate the road with the surrounding landscape context.

The proposed eastern and western interchanges, connecting with the highway corridor, have differing capacities to absorb the visual impacts of the interchange system.

The western interchange location is more open in character, having been subject to recent clearing works and surrounded by moderate slopes to the north falling away to the South east. As such, the visual impact of the interchange can be absorbed without significant impact on the visual quality and character.

The eastern interchange is located in a more steeply sloping valley head, enclosed by steep ridgelines to the west and north, and adjoining SEPP 14 wetlands to the south. The enclosed character of the current highway will be significantly affected by the required interchange and will require design consideration (to reduce earthworks) and effective landscape revegetation.

4.3 Visual Sensitivity

Visual Catchment

The visual catchment of the proposed road corridor is determined by the effects of landform and vegetation that can be expected to limit the visual exposure of the new road to subregional views (views from on to five kilometres distance). The generally undulating topography of areas to the west of the Karuah River and the high ridgeline landforms to the east, play a role in restricting visual exposure. To the east the low lying alignment of the route is such that only elevated viewers would be exposed to the corridor. To the west, the high ridges of the Wallaroo State Forest serve to enclose the road alignment and restrict regional views.

The extent of the visual catchment is generally contained to the south at the existing Karuah Bridge, 3.5 kilometres from the river crossing of the proposed alignment.

Viewer Locations

Ten potential viewer locations were confirmed following site assessment. These locations are described below, and are indicated on Figure 4. - Viewer Locations.

1. Western Interchange
The existing highway alignment approximately 5.5 kilometres west of Karuah township.

2. Scotts Road Crossing
The vicinity of the Scotts Road crossing of the proposed corridor.

3. Garrett Residence/Karuah Nature Reserve
Rural residence and adjoining cleared areas to the north west of the Karuah Nature Reserve.

4. Mustons Road North
Residential areas over looking the river to the northern arm of Mustons Road.

5. Western Foreshores
Picnic areas to elevated foreshore reserve (Memorial Park) adjoining existing highway alignment at Karuah Bridge. Incorporates public boat ramp facility and boat hire establishment.

6. Eastern Foreshores
From the vicinity of residential housing on the eastern foreshores adjacent to the Karuah Bridge.

7. Skelton Residence
Rural residence on cleared foreshore lands to the eastern bank of the Karuah River, approximately 500 metres north of the proposed river crossing of the corridor.

8. Proposed Eastern Bridge Abutment
Cleared pastoral foreshore area and slopes to the eastern bank of the Karuah River .

9. Rural Valley
Cleared pastoral valley area adjoining Branch Lane to the west, in the vicinity existing farm house and dam.

10. Eastern Interchange
The existing highway alignment approximately 3 kilometres east of Karuah township.

Visual Sensitivity Assessment

Figure 5. summarises the visual sensitivity evaluation for each of the criteria (outlined earlier in Section 4.4) at the 10 viewer locations.

The rankings for visual sensitivity are based on the combination of the sensitivity criteria ratings for each location. Weighting points to enable a comparative level of visual sensitivity to be established between the locations are also noted.

Criteria	Categories	Visual Sensitivity	Weighting Points		
No. of Viewers	High	Highest Visual Sensitivity			6
	Medium				4
	Low	Lowest Visual Sensitivity			2
Viewing Duration	Permanent	Highest Visual Sensitivity			3
	Casual				2
	Transient	Lowest Visual Sensitivity			1
Viewing Distance	Local	Highest Visual Sensitivity	0-0.5	km	10
			0.5-1	km	7.5
	Sub regional		1-3	km	5
			3-5	km	3
	Regional	Lowest Visual Sensitivity	>5	km	1
Viewing Angle	Parallel	Highest Visual Sensitivity			2
	On angle				1
	Perpendicular	Lowest Visual Sensitivity			0.5
Landscape Change	Very High	Highest Visual Sensitivity			10
	High				7.5
	Moderate				5
	Low	Lowest Visual Sensitivity			2

The assessment identifies the sites from the viewer locations assessed at which the proposed route corridor is most visible, and as a consequence will require the consideration of engineering and landscape mitigation measures to reduce potential visual impacts. A ranking from one to ten is also provided identifying sensitivity relative to the other viewer locations (ie: 1 = most sensitive) based on the cumulative visual sensitivity level of the location for each criteria.

Figure 4 Visual Sensitivity

		Sensitivity Criteria							
No.	**View Location**	**No. of viewers**	**Viewing Duration**	**View Classification**	**Km**	**Viewing Angle**	**Landscape Change**	**Visual sensitivity**	**Rank, 1 = most sensitive**
1	Western interchange	Highway Users	Permanent	Local	0 km	Parallel	Low: existing open highway corridor	Low	8
2	Scotts Road Crossing	Medium	Transient	Local	0 km	Parallel	Very High: existing woodland	Very High	1
3	Garrett Residence/ Karuah Nature Reserve	Low	Permanent	Local	0.6 km	Perpendicular	Medium: existing cleared area, buffered to corridor by existing vegetation	Medium	7
4	Mustons Road North	Medium	Permanent	Subregional	2.0 km	North - perpendicular	High: view to bridge and particularly to cutting	Medium	5
5	Western Foreshores	Medium	Permanent	Subregional	3.3 km	North - perpendicular	Medium: long range views to bridge structure	Low	9/10
6	Eastern Foreshores	Medium	Permanent	Subregional	3.5 km	North east - perpendicular	Medium: long range views to bridge structure	Low	9/10
7	Skelton Residence	Low	Permanent	Local	0.5 km	South - perpendicular	High: view from cleared areas around house to bridge - house buffered to bridge by vegetation	High	3
8	Proposed Eastern Bridge Abutment	Low	Permanent	Local	0 km	Parallel & perpendicular	Very High: road construction in rural pastures /construction of major cutting	Very High	2
9	Rural Valley	Low	Casual	Local	0.4 km	On angle & perpendicular	High: road construction in rural pastures	High	4
10	Eastern Interchange	Highway users	Permanent	Local	0 km	Parallel	Medium: interchange construction to enclose road corridor	Medium	6

Viewing distance:

- Local Foreground Views < 1 km
- Subregional Midground Views 1 - 5 km
- Regional Distant Views > 5 km

Note:
The number of viewers for locations on the proposed highway alignment (eg. 1 and 10) represents motorist usage of the highway and id unable to be compared in relative terms to existing, non highway related uses.

4.4 Visual Effect Summary

Figure 6. - Visual Effect Summary integrates the preceding assessment outcomes and provides conclusions in the form of comments on Visual Effect, resulting Visual Impacts and possible landscape mitigation requirements (to be developed in the Landscape Strategic Plan and Concept Plan).

The Visual Effect Summary Chart identifies the following:

- Landscape Units: Unit number and name
- Description: General description of relationship to proposed route corridor
- Visual Quality Rating: From Section 5.2
- Visual Use: To what areas the Landscape Unit is visible
- Visual Sensitivity: The sensitivity of the landscape setting the change
- Visual Effect: Assessment of the degree of visual effect of the proposed corridor taking into account impact over time

Key issues for each Visual Landscape Unit are detailed below:

Landscape Unit 1 - Woodland Slopes
This landscape unit incorporates the western 2.6 kilometres of the proposed road alignment. The area consists of native woodland to an average 18 metres in height. The hilly landscape is typified by moderate slopes with the vegetation screening sub regional and regional views.

The construction of the proposed road alignment would involve the removal of 50 to 70 metre wide section of trees along the corridor. Major earthworks would involve cuttings)to a maximum depth of 6 metres) into the hillsides and filling (to average 1.0 metre depth) across gully areas. The exposed cutting and fill areas will require revegetation, to visually integrate with adjoining woodland slopes.

Landscape Unit 2 - Woodland Valley
This unit traverses two areas, north and south, of the low lying valley within Karuah State Forest. Sub unit 2B (northern sub unit) lies within the Karuah Nature Reserve where the woodland vegetation of the valley slopes merges with the open forests of the valley floor (Unit 3).

These areas are located within the transition between cuttings through the hills and fill areas across the valley floor and slopes(to 3 metre depth in Sub unit 2B). The proposed road upgrade would require the clearing of a 50 to 70 metre band of State Forest and Nature Reserve (Sub unit 2B). The higher topography of Sub unit 2A may create visual exposure of embankments from low lying areas to the north east. Revegetation of fill banks is required to integrate with adjoining woodland.

Landscape Unit 3 - Forest Valley
The valley floor of Karuah State Forest extends for approximately 600 metres. The open forest vegetation is to 20 metres tall.

Filled embankment s to this section of the road alignment contrast with the valley landscape considerably. Revegetation on embankments is required to reduce visual contrast and integrate with adjoining forest vegetation.

Landscape Unit 4 - Forest Slopes
This landscape unit traverses the steep slopes of the ridge line areas to the north of the forest valley. The area is vegetated with an open forest community to 20 metres tall within the Karuah Nature Reserve. The vegetation canopy screens subregional and regional views.

The construction of the proposed road alignment would involve deep cuttings (to a maximum 10 metres depth) through the ridgetop and filling works through the gully areas. Existing vegetation canopy and use of cuttings to the road alignment enable the road to be buffered from local and sub regional views to the north and north west from Karuah River. Revegetation will be required on fill banks.

Landscape Unit 5 - Forest Slopes
Crossing the steep ridgeline and slopes adjoining wetland areas, the road corridor extends through the Karuah Nature Reserve. The open forest community merges with the swamp forest and sedgelands close to the water's edge.

Deep cuttings (of average 4 metres - maximum 11 metres depth) through the steep slopes and fill (to 2 metres depth) within the gully areas will be buffered to views from Karuah River and the Garrett Residence (700 metres to the north). Embankment planting is required to revegetate exposed cut and fill areas to integrate with adjoining open forest.

Landscape Unit 6 - Wetlands
The wetlands and associated sedgeland/saltmarsh vegetation extend to Horse Island. The proposed bridge enables minimal physical intrusion into the SEPP 14 wetland area. Views of the upper section of the bridge will be available from the Karuah River (local and sub regional views) and will require consideration in bridge design and edge treatment. Bridge structure design should aim to minimise the thickness of the platform thus reducing its visual bulk and prominence. A raised handrail treatment (to 2.5 - 3.0 metres) that maintains views out for motorists whilst softening the impact of moving vehicles to local views of the bridge.

Landscape Unit 7 - Horse Island
Crossing the southern edge of Horse Island the road alignment is elevated on a fill platform with retaining wall to the southern side. Existing vegetation (to an average 15 metres) to the south side of the walled roadway will assist in buffering exposure of wall faces to views from the river and subregional views from the river's eastern foreshores. Wall face treatment should incorporate colouring (ie. dark grey) to better visually integrate with vegetation.

Landscape Unit 8 - Karuah River
This landscape unit is the most exposed to foreground and distant views, both from the river and settled foreshore areas. The proposed bridge structure (thirteen metres above mean water level) will be visible to distant views from Karuah township, over three kilometres down river to the south.

A rural residence is situated on the eastern foreshores to the north of the eastern abutment. The proposed bridge structure will be visible from the foreshore areas of this property, although views from the residence will be filtered by vegetation.

Landscape Unit 9 - Rural Footslopes and Saddle
Landscape Unit 9 extends from the eastern river bank, over undulating cleared pastures through the partially cleared saddle into a low lying gully area. Much of the land is dedicated to rural uses with cleared grassland areas supporting scattered remnant trees.

The corridor will be constructed on fill (between 2 to 5 metres depth) with the embankments being locally visible from the surrounding cleared areas and ridgetops, as well as fragmented views through the trees from the river. Cuttings (to 25 metres depth) through the saddle area will also be partially visible from the residential areas off Mustons Road. On the eastern side of the saddle the proposed road alignment hugs the slopes through cut and fill. The related embankments will be locally visible from the lower valley area of Mosquito Creek to the south.

Landscape Unit 10 - Creekline
This landscape unit crosses a small gully area at the base of which lies a creekline. Woodland vegetation covers the gully slopes. The proposed road alignment is elevated on fill (to average 7 metres depth) with the embankment areas being visible from the rural valley and surrounding ridgelines to the east and south east. Revegetation of embankment areas will be required to visually integrate with adjoining woodland vegetation.

Landscape Unit 11 - Rural Paddocks
Beyond the gully area 0f Unit 10 the proposed road alignment traverses the undulating footslopes of the dominant ridgeline east of Karuah River. The area is cleared for grazing uses and the proposed road alignment is raised above existing ground level for some of its length (chainage 8500 - 8900) where set on fill (to 2 metres maximum depth).

These fill embankments and cut embankments (chainage 8000 - 8500; maximum 17 metre depth / chainage 8900 - 9300 : maximum 6 metres depth)) will be visible from the rural residence to the east of the road corridor and from local traffic using Branch Lane.

Landscape Unit 12 - Disturbed Forest
This low lying area is exposed to the ridgelines to north and east. The proposed road alignment cuts through disturbed forest areas on fill creating embankment zones that will be visible to uses of the existing road corridor and Branch Lane as well as a the rural residence to the north.

Landscape Unit 13 - Existing Road Corridor
The transition between the existing highway and proposed bypass route occur approximately 5 kilometres west of Karuah township, returning to the existing highway approximately 3 kilometres east of the township.

The western interchange (Sub unit 13A) is surrounded by woodland vegetation across undulating slopes. The proposed road construction will result in filling works (to 6 metres maximum depth) to facilitate connection to the existing road corridor and integrate with an overpass to connect with Swan Bay Road. The wide clearing of the existing highway alignment will enable the area to visually absorb the works with less visual impact that the eastern interchange (Sub unit 13B).

The eastern interchange (Sub unit 13B) is surrounded by steep slopes and open forest vegetation. To allow for the connection of the proposed road alignment to the existing Pacific Highway raised link roads are required. The embankments to these linkages will be visible from the local roads and a nearby rural residence to the north. The enclosed character of this sub unit will result in a high level of visual change to existing character in the vicinity of the interchange. Revegetation of embankments to integrate with adjoining woodland areas is required.

Key Issues

General visual issues identified from the visual assessment which need to be considered in road design and development of landscape strategies are listed below:

- The visual sensitivity table indicates that the west and east interchanges will be critical locations due to the high number of viewers and position within the road corridor. At the western interchange the open character of the landscape will enable the roadways and related embankments to be more easily integrated with the adjoining landscape context. The eastern interchange is less easily integrated due to its more enclosed character to which the roadway and embankments will be a significant intrusion. Landscape treatments must respond to these issues.

- Viewers along the foreshores of Karuah township and residential areas to the east and west sides of the river will have sub regional views (over 3 kilometres distance) of the bridge and its abutments. The design of the bridge structure is the single most important visual consideration for the proposed corridor alignment.

  The visual sensitivity assessment identifies that the bridge crossings are most critically viewed from the western shores (residential areas off Mustons Road) of the Karuah River. Design of the bridge structure should aim to minimise the visual bulk on the bridge structure and consider high edge railings that filter the visual effect of moving vehicles.

- The proposed walled abutments that support the bridge structure either side of the river present vertical faces to 15 metres height. It is expected that the extensive mangrove stands

to the SEPP 14 Wetlands of the western shoreline will buffer the lower half of these wall faces. Colouring (eg. dark grey) of the upper sections is recommended to reduce visual contrast with vegetation. Such treatments recognise that the adjoining wetland environment will limit the scope of tree planting possible on the corridor southern side.

To the eastern shoreline the steeply rising bank and foreshore Woodland tree canopy mean that the abutment (approximately 5 metres above existing pastoral areas) is buffered to views from the south.

- The route alignment incorporates extensive sections of excavation to maintain consistent longitudinal grades and (in several locations) to recess the roadway into the adjoining landform, reducing visual exposure. This principle is most effective in low or moderately sloping landform (eg. chainages 3650-3800/4550). In steeper areas where the alignment runs parallel to the contours, the cuttings leave excavated faces potentially exposed to views from the down side direction (eg. chainages 4400-4700/ 8500-8800). Revegetation of the downslope zone of the alignment with tree canopy will buffer cuttings from views inward. Potential weathering agents applied to the newly cut rock faces would assist in reducing visual contrast of cuttings to views inwards

- Alternatively where the road alignment is proposed to be located on a filled profile, engineering design has sought to maximise the gradient of side slopes to minimise the extent of earthworks and related impact on adjacent vegetation.

Where filled profiles are over 3 metres above existing ground this treatment has the potential to visually and functionally dissect the landscape units it passes through, restricting visual continuity. As the corridor passes through vegetated areas over half of its route, particularly to the western side of the Karuah River, this impact will be lessened, however it will be important to integrate landscaping of the fill banks with the adjoining vegetation types to enhance visual continuity and ecological benefits.

- To several sections of the proposed alignment the corridor does pass through cleared pastoral areas, leaving sections of land visually and functionally isolated such as:

  - Chainage 6200-6400 - area to north side of alignment
  - Chainage 8300-9100 - area to west side of alignment

  It is preferable that these zones be landscaped to provide visual integration with the directly adjoining landscape unit, eg. wooded slopes, to consolidate the visual setting, and enhance outlooks from the highway for road users.

Figure 6. Visual Effect Summary

Landscape Unit	Description of Proposed Alignment	Visual Quality Rating	Landscape Character	Visual Sensitivity of Landscape Setting	Visual Effect*	Visual Impact/ Treatment**
1. Woodland Slopes	Bypass route from western interchange to chainage 2250, cutting into moderately sloping SE-SW slopes within Wallaroo State Forest.	High	SE-SW aspect oriented to existing highway and Karuah Golf Course. Consistent Woodland Cover on undulating slopes.	Exposed in short term to existing highway (local traffic).	Moderate: - exposed cuttings (to 2 m) to west side of roadway have limited visual exposure to surrounding areas due to predominantly undulating topography, vegetation canopy and sunken profile of road.	- Landscape treatment of cutting batters required in particular to west side. - Revegetation of fill banks required.
2. Woodland Valley	Chainage 2250 to 2600, and 3200 to 3400 through Wallaroo State Forest and Karuah Nature Reserve - filled profile 2-4 m.	High	Elevated valley slopes oriented to low lying areas around Wallaroo Swamp and adjoining cleared pastoral lands (site of future sewerage treatment plant) to east. Consistent Woodland Cover on undulating slopes.	Possible filtered visual penetration to views from walking trails ridgeline to NE (eg. Mines Hill Trail) - transient usage - screened to views from cleared pastoral lands by Woodland Vegetation.	Moderate: - 2-4 m fill batters to alignment. - limited exposure to surrounding areas due to screening effect undulating topography, and existing vegetation.	- Revegetation of fill banks required.
3. Forest Valley	Chainage 2600 to 3200 on filled profile 2-4 m, adjacent to Wallaroo Swamp within Wallaroo State Forest.	Med	Low lying undulating valley with Open Forest vegetation cover (subject to scattered die back)	Visual penetration from surrounding ridge lines to the north and south - (transient usage only) Passes adjacent to cleared pastoral lands on east side (future sewage plant) - no buffer at corner.	Low: - average 3 m depth fill platform. - exposure to viewers is minimal, with moderate impact on visual setting of fill profiles.	- Revegetation of fill banks required.
4. Southern Forest Slopes	Chainage 3400 to 3800 cutting through valley slopes in Karuah Nature Reserve to 1-12 metres.	Very High	SW to NW aspect oriented to Wallaroo Swamp and Wallaroo State Forest. Steep to moderate slopes supporting consistent open forest vegetation traversed by Mines Hill Trail	Limited visual exposure to cleared pastures to south due to undulating topography and open forest canopy vegetation. Alignment runs perpendicular to contours allowing recessing of cuts within landform	Low: - balanced cutting perpendicular to contours visually screens alignment from other than elevated views. - primary visual effect to alignment itself (12m depth cuttings)	- Cuttings to remain as exposed rock face where stable - Identified in Fauna Assessment as potential site for bat corridor. - - Reinforce through maximising tree canopy adjacent and to the centre of the roadway.
5. Northern Forest Slopes	Chainage 3800 to 5000 through valley slopes and footslopes to Karuah	Very High	NE to NW aspect oriented to wetland foreshores to north. Steep to moderate	Filtered visual penetration available from low lying floodplain/ wetland areas to	Moderate: - cut faces exposed to road users (to 7 m high).	- Revegetation of fill banks required. - Landscape treatment of rock

Landscape Unit	Description of Proposed Alignment	Visual Quality Rating	Landscape Character	Visual Sensitivity of Landscape Setting	Visual Effect*	Visual Impact/ Treatment**
	Nature Reserve. Profile varies: 3800-3900 cut - 2.5-10m 3900-4400 fill - 1-7m 4400-5000 cut - 3.5-10m.		slopes supporting consistent open forest vegetation. Lies within the Karuah Nature Reserve conservation area.	north adjoining Karuah River, and Garrett residence adjacent to Lizzies Creek	- cut face and embankment subject to minor visual penetration to the north.	cuttings desirable to reduce visual impact.
6. Wetlands	Chainage 5000 to 5200, through SEPP 14 Wetlands. Fill profile from 4 to 12.5 metres adjoining bridge structure over Lizzies Creek.	High	Floodplain landform and wetland vegetation - enclosed to north by Horse Island and south west by ridgeline of Karuah Nature Reserve.	Raised elevation (to 12 m) above floodplain landform increases visibility to south east (Karuah River) to sub regional (2 km) distance views from Karuah River. Horse Island screens visibility from river to north and north west.	High: - raised fill platform and bridge will exceed height of foreshore mangroves - upper sections visible from Karuah River and distant views (3.5 km) from Karuah eastern foreshores	- Revegetation of fill batters - Colour treatment (eg Dark Grey) of southern side of bridge to reduce visual contrast of structure with vegetation.
7. Horse Island	Chainage 5200 to 5600 - Bridge abutment to Lizzies Creek Crossing and Walled fill platform to southern edge of Horse Island from 5-13 metres height (south face).	Very High	Steep footslopes to southern edge of Horse Island and fringing wetland areas. Open Woodland Vegetation.	Raised platform (to 13 m) above wetland landform increases visibility to south east (Karuah River) to sub regional views (0.5 - 2 km distance) and to eastern foreshores (3.5 km distance).	High: - retention of existing tree canopy to lower slopes of Horse Island (south of roadway) will assist in buffering views to the wall face from the river and eastern foreshores. Visual exposure is greatest at east and west ends of the wall where tree canopy is reduced.	- Carry out reinforcement planting of adjoining vegetation types south of the roadway, to enhance visual buffer - Colouring (eg dark grey) of wall face material to reduce visual contrast with vegetation.
8. Karuah River	Bridge structure from chainage 5500 to 6200 at approximately 13 m above mean water line.	Very High	The major landscape element of the study area is the horizontal character of open water body and ridgelines to the north and east dominate views from the township. The river, adjoining wetland areas, and wooded ridgeline hinterland are significant visual and environmental resources as reflected in the listing of the Port Stephen's Conservation	Bridge visible to river users on 3.5 km stretch from Horse Island to existing Karuah Bridge, and to 1 km north of proposed bridge. Subject to distant views from residential areas on the western foreshores (from 2.2 - 3.4 km distance) with limited visibility to residences to eastern foreshore (3.5 km distance).	Very high: - bridge structure at 13 m above mean water level will significantly impact on predominantly natural views to north from river, foreshore residential areas and Karuah township.	- Coloured (dark grey) treatment of walled abutment and bridge structure to reduce visual contrast to vegetation and water.

Landscape Unit	Description of Proposed Alignment	Visual Quality Rating	Landscape Character	Visual Sensitivity of Landscape Setting	Visual Effect*	Visual Impact/ Treatment**
			Area.			
9. Rural Footslopes and Saddle	Chainage 6200 to 7500 through varied landscape sub units: 6200-6650: undulating rural pasture - fill 2-5m 6650-6850: saddle - cut 2-25m 6850-7500: undulating rural pasture - fill 2-5m.	High	Varied landform and vegetation character between cleared pastoral footslopes and partially cleared saddle landform.	Landform and foreshore vegetation to eastern banks of river buffer saddle from views other than from 1 km (approximately) - and directly from west. To the east views to the NW-NE running valley are currently buffered by creeklines vegetation to Unit 10. Highly exposed elevated fill platforms visible to users of cleared pastoral areas.	Moderate: - filtered views from river (300 – 500 m) to elevate fill platforms through cleared pastures and western shoreline. - Major visual impact of steep 25 metre cuttings to localised views, and to road users, and minor visual exposure to residences on western foreshores (2.5 km distance).	- Grassland vegetation of fill banks to integrate with adjoining pasture areas. - Cuttings to remain as exposed rock face where stable - potential treatment with weathering agent to reduce visual prominence of rock face.
10. Creekline Gully	From chainage 7500 7700 alignment traverses the creek area over fill to 4 - 5 metre depth.	High	The low lying creek area enclosed by vegetation and the surrounding ridgelines to the north and south.	Moderate - casual views from surrounding rural areas	Moderate: - few viewers within surrounding rural areas. - Extensive filling works have high visual effect on adjoining vegetation for road users.	- Revegetation of fill banks required to integrate with adjoining vegetation.
11. Rural Valley	From chainage 7700 to 9200 the alignment cuts into ridge lines with fill in gully areas, within rural lands.	High	The north easterly aspect is exposed to the rural valley to the east and associated local roads.	Moderate - casual to permanent views from the few rural dwellings within the low valley areas to the east.	Moderate: - cuttings would be visible from the rural valley area with few rural dwellings.	- Consider consolidation of Open Forest vegetation through revegetation of cutting embankments and isolated cleared rural lands. - Screening to pastoral lands and rural residences to the east required.
12. Disturbed Forest	Bypass route from chainage 9200 to 9800 on fill platforms from 0.5 - 6.5 m depth.	Med	The moderately sloping area is strongly enclosed by the ridgelines to the north and east. Previously cleared area having been subject to partial revegetation.	Moderate - permanent views from existing road alignment and local road (The Branch Lane).	Moderate: - views from existing road alignment and Branch Lane to filling banks.	- Revegetation of fill batters required to re- establish native tree canopy.
13A. Existing Highway	Transition from existing highway to bypass route west of Karuah township,	Med	Existing road corridor is flanked by undulating to gentle wooded slopes.	Moderate - permanent views from existing road alignment, overpass and local roads.	Moderate: - views from existing road alignment and cleared valley to	- Revegetation of fill areas and decommissioned road areas

Landscape Unit	Description of Proposed Alignment	Visual Quality Rating	Landscape Character	Visual Sensitivity of Landscape Setting	Visual Effect*	Visual Impact/ Treatment**
West	with connection to local roads via overpass of proposed alignment.		Views would be afforded from the proposed overpass and existing highway.		north to extensive filling works.	
13A. Existing Highway East	Transition between bypass route and existing highway east of Karuah township, local road connections passing under the proposed alignment.	Med	The existing road alignment is enclosed by steep slopes to the north and west. Open forest covers these slopes and the SEPP 14 Wetlands extends up to this location.	Moderate - permanent views from existing road alignment and local roads.	High: - views from existing road alignment to cleared areas and filling works.	Revegetation of fill areas and decommissioned road areas

**** Visual treatment**

Proposed treatments to be developed in Landscape Strategy and Concept Plan as described in Landscape Concept Report

***Visual effect**

Very High	Major effect - specific design and mitigation measures required
High	Significant effect incorporate design and mitigation measures where appropriate
Moderate	Generally minimal effect with inputs to be addressed through design and mitigation measures
Low	Minimal effect - no specific strategies required

Prepared by:

Environmental Partnership NSW Pty Ltd

Pacific Highway Upgrade Karuah

Landscape and Urban Design Concept Report



Prepared for:

ARUP

Ove Arup & Partners Consulting Engineers

September 1999

CONTENTS

1.0 INTRODUCTION

1.1 Generally

2.0 REGIONAL LANDSCAPE DESIGN STRATEGY

2.1 Regional Landscape Principles

2.2 Roadscape experience

2.3 Landscape Design Criteria for Landscape Units

2.4 Plant Species for landscape units

3.0 LANDSCAPE CONCEPT PLAN

3.1 Overview

3.2 Landscape and Urban Design Concept Plan
- 3.2.1 Area 1
- 3.2.2 Area 2
- 3.2.3 Area 3
- 3.2.4 Area 4
- 3.2.5 Area 5
- 3.2.6 Area 6
- 3.2.7 Area 7

3.3 Landscape and Urban Design Treatments
- 3.3.1 Vegetation Clearing
- 3.3.2 Plant material supply
- 3.3.3 Planting works
- 3.3.4 Fill embankments and cuttings
- 3.3.5 Bridge and overpass structures
- 3.3.6 Walling
- 3.3.7 Water quality control ponds
- 3.3.8 Fauna Crossings
- 3.3.9 Signage, vehicle barriers and lighting
- 3.3.10 Gateway treatments

3.4 Landscape Management and Maintenance

3.5 Detailed Design

LIST OF FIGURES

Figure 2.1 Landscape Strategy Plan

Figure 2.2 Landscape Units Plan

Figure 3.1 Layout of Area Concept Plans

Figure 3.2 Landscape Concept Plan - Area I

Figure 3.3 Landscape Treatments Cross Section - A

Figure 3.4 Landscape Treatments Cross Section - B1 / B2

Figure 3.5 Landscape Concept Plan - Area II

Figure 3.6 Landscape Treatments Cross Section - C / D

Figure 3.7 Landscape Concept Plan - Area III

Figure 3.8 Landscape Treatments Cross Section - E

Figure 3.9 Landscape Treatments Cross Section - F1 / F2

Figure 3.10 Landscape Concept Plan - Area IV

Figure 3.11 Landscape Treatments Cross Section - G / H

Figure 3.12 Landscape Treatments Cross Section - I / J

Figure 3.13 Landscape Concept Plan - Area V

Figure 3.14 Landscape Treatments Cross Section - K / L

Figure 3.15 Landscape Concept Plan - Area VI

Figure 3.16 Landscape Treatments Cross Section - M

Figure 3.17 Landscape Treatments Cross Section - N1 / N2 / N3

Figure 3.18 Landscape Concept Plan - Area VII

Figure 3.19 Landscape Treatments Cross Section - O / P

1.0 INTRODUCTION

1.1 Generally

This report describes the schematic landscape design proposals for the Pacific Highway upgrade project at Karuah. The proposals respond to the visual issues identified in the Visual Assessment Report and aim to ameliorate visual and landscape impacts of the road development in addition to enhancing the road experience for users. The proposals also build upon the principles outlined in the Urban Design Assessment which examined the key urban design factors to be addressed in both the regional context and detailed setting of the road development.

The majority of proposals contained herein build upon the general principles and strategies as outlined in the RTA's Roadscape Guidelines (1998). It is recommended that these guidelines form a complementary strategies and procedural resource in subsequent design development of the proposals.

The report is structured in two principal sections:

Section 2.0 Landscape Strategy Plan
Identifies the broad landscape principles developed to guide the landscape concept and ongoing design development. Outlines the key strategic design responses that arise from the application of these principles on the 1:10,000 Landscape Strategy Plan and describes the design responses necessary to integrate the development which the varied landscape settings (Landscape Units) through which it passes.

Incorporates a summary of the plant species identified on the site in the flora and fauna investigation by Gunninah Consultants (March 1999), and the landscape units and conditions to which these species should be applied.

Section 3.0 Landscape and Urban Design Concept Plan
Describes the application of the landscape and urban design principles and strategies to the route alignment on the 1:4000 Concept Plan. Incorporates the extent and type of landscape and urban design treatment required to mitigate visual and landscape impacts and enhance the visual and environmental integration of the new road with adjoining landform and vegetation settings.

2.0 REGIONAL LANDSCAPE DESIGN STRATEGY

2.1 Regional Landscape Principles

The integration of the road development and related structures with the regional landscape setting is the key objective of landscape strategy development.

The following principles identify performance objectives for landscape design, implementation, and management for this project. These principles are to be carried through resolution of landscape strategies and concept proposals as developed in this report and in ongoing project implementation works.

The Landscape Strategy Plan (Figure 2.1) identifies the application of the principles listed on this page to the route corridor in the context of the areas existing vegetation communities (and the defined landscape units identified in the Visual Assessment Report).

Landscape principles for consideration in Engineering Design

- Reduce the extent of clearing and earthworks in engineering design to conserve existing vegetation communities and fauna habitat.
- Engineering design to incorporate required measures to conserve natural drainage crossings of the route alignment.
- Where possible integrate engineering elements to provide a unified design solution (eg rails and walling to bridge abutments), enhancing visual unity and clarity.
- Engineering design to enhance the potential for fauna movement corridors under and over the road alignments.

Landscape Planning and Design Principles

- Revegetate any cleared construction areas to integrate with adjoining native woodland and open forest vegetation communities.
- Revegetation to optimise opportunities for enhancement of native fauna shelter and foraging (food) habitat.
- Revegetate earthworks batters to integrate with adjoining native woodland and open forest vegetation communities, stabilise earthworks zones, and buffer edge impacts of roadway on fauna habitat.
- Landscape treatments to reinforce fauna movement corridors (eg. underpasses, and aerial crossings) through enhancement of movement and shelter qualities of crossings and their approaches.
- Provide tree planting to median at grade section of road alignment to reinforce aerial fauna corridor potential.
- Enhance the visual and environmental experience of travelling along the road corridor for users.
- Where earthworks batters are steeper than 1(v):3(h) slope and vehicular safety barrier is required, provide extension of tree canopy revegetation to within 2 metres of barrier enhancing tree canopy and adjoining roadway.
- Reinforce visual buffer provided by native vegetation to the limited local viewing points of the proposed highway (eg. river & rural residences)
- Provide headlight glare reduction and visual emphasis of directional separation of road carriageways through appropriate median strip planting.

BRIDGE STRUCTURE TO BE DESIGNED TO REDUCES VISUAL EXPOSURE TO LOCAL AND SUB REGIONAL VIEWS
- REDUCE BULK AND DEPTH OF STRUCTURE
- HIGH EDGE RAIL TREATMENT TO BRIDGE TO OPTIMISE VIEWS FOR VEHICLES

EXCAVATED BANK TO BE REVEGETATED TO INTEGRATE WITH ADJOINING OPEN FOREST

FILL BATTER TO BE REVEGETATED TO INTEGRATE WITH ADJOINING OPEN WOODLAND VEGETATION

FILL BATTER TO BE REVEGETATED TO INTEGRATE WITH ADJOINING OPEN FOREST

BRIDGE STRUCTURE TO BE DESIGNED TO REDUCE VISUAL EXPOSURE TO LOCAL AND SUB REGIONAL VIEWS
- REDUCE BULK AND DEPTH OF STRUCTURE
- EDGE RAIL TREATMENT TO BRIDGE TO OPTIMISE VIEWS FOR VEHICLES

KARUAH STATE FOREST
LIMEBURNERS CREEK
LIZZIES CREEK
OPEN FOREST
WALLAROO SWAMP
KARUAH NATURE RESERVE
WALLAROO STATE FOREST
OPEN WOODLAND
REEDY CREEK
WOODLAND
GOLF COURSE
PACIFIC HIGHWAY
SPARK BAY ROAD
SCOTTS ROAD
PORT STEPHENS COUNCIL
KARUAH
KARUAH RIVER
WALLAROO STATE FOREST
REEDY CREEK
LAKES
COUNCIL
PACIFIC HIGHWAY
YALWAL
LANE
OPEN FOREST
RAILWAY
OPEN FOREST
OPEN FOREST

LEGEND

- ESTUARINE WETLANDS
- FRESHWATER WETLANDS
- CLEARED RURAL
- OPEN WOODLAND
- OPEN FOREST
  Note: Vegetation community boundaries are indicative only based on Flora & Fauna assessment mapping
- EXISTING AND PROPOSED DEVELOPMENTS
- LANDSCAPE UNITS
- REVEGETATION OF CONSTRUCTION ZONE
- FILL BATTER REVEGETATION
- CUT BATTER REVEGETATION
- EXPOSED CUT ROCK FACE
- BRIDGE STRUCTURES
- POTENTIAL VIEW EXPOSURE TO CORRIDOR TO BE ADDRESSED THROUGH ROAD DESIGN AND LANDSCAPE TREATMENTS
- MINOR/RESTRICTED VIEW EXPOSURE TO BE ADDRESSED THROUGH ROAD DESIGN AND LANDSCAPE TREATMENTS
- VIEWS FROM ROADWAY TO ADJOINING LANDSCAPE TO BE CONSERVED
- VIEW CORRIDORS
- ROAD CORRIDOR NARROWING TO OPTIMISE BIRD AND GLIDER MOVEMENT
- PROPOSED FAUNA UNDERPASS
- RESIDENCES

0 100 200 500 1000

LANDSCAPE STRATEGY PLAN

Figure 2.1
Scale 1: 25,000
Date: 01/09/99

PACIFIC HIGHWAY **UPGRADE**, KARUAH. Dwg. 1721.LVA.01

2.2 The Roadscape Experience

The route alignment as it passes through the varied landscape units provides a sequential experience of the landscape for road users which should be recognised and enhanced in both engineering and landscape design.

A summary of the key elements of the potential roadscape experience is listed below in moving from west to east along the proposed alignment.

Western Interchange

- The junction with the existing highway occurs in a wide existing highway corridor in undulating topography. Native gateway planting and the future north bound exit overpass structure for Karuah should identify this gateway to the town.

Open Woodland

- The road alignment remains enclosed as it heads north east as a straight corridor for over 2 kilometres. The combination of the straight alignment and enclosure by landform and vegetation direct driver views along the corridor.
- Visual buffer planting provided to the proposed sewage treatment works at the eastern end of Wallaroo Swamp will in the long term continue vegetation enclosure of the corridor through this existing narrow zone of vegetation.
- Bridged overpasses of the road at the Scotts Road and Mines Hill Trail crossings will be the focus of driver views, and should be sufficiently elevated to provide a comfortable experience for drivers.
- The marginal narrowing of the road corridor will be further emphasised at the locations where the alignment lies at natural grade, and tree retention is optimised. At these points it is proposed that with supplementary planting of canopy trees and understorey aerial crossing of the corridor by birds and glider populations is encouraged.

Open Forest

- North of the Mines Hill Trail bridge, the topography provides higher enclosure to the eastern side of the road, with potential for fragmented views through understorey to adjoining cleared rural areas.
- Remaining generally enclosed by vegetation and topography, the road sweeps through the ridgeline of the Karuah Nature Reserve (exposing cut rock faces to the eastern side of the roadway), opening up to the bridge crossing at the Horse Island Wetlands.

Karuah River

- The open character of the shorter wetland bridge crossing is broken by the traversal of the southern edge of Horse Island before opening again to panoramic views of the river over the main bridge structure.
- From the Karuah River Bridge, expansive views to the south east over the Estuarine Wetlands, Karuah River, and enclosing ridgelines will be available.
- For southbound vehicles views to the creekline west of Horse Island will be short in duration at normal highway speeds. It should be noted that the quality of driver views from the bridge will be determined by the final resolution of the road safety barrier treatment and the degree of view penetration that this allows
- Although a direct view line to the northern side of the major cutting at chainage 6750 will be emphasised east of the Karuah River Bridge, this will be weakened by the open character of the pastural grasslands adjoining the road.

The Saddle Cutting

- The major cutting through the saddle landform will provide a dramatic road experience of visual interest.

Open Rural Lands

- From the cutting the alignment passes through several small cleared rural areas of moderate to steep topography and high visual interest. A sense of enclosure is still maintained by the vegetated ridgeline to the north and south.
- After passing through an elevated section of roadway enclosed either side by open forest vegetation of the Mosquito Creek gully, the alignment opens up to sweeping views of rural lands on the northern side, and enclose by ridgelines to the south.

Eastern Interchange

- From the open character of the rural valley the road makes a transition into the steeper enclosed character of the existing highway.
- Gateway planting is provided as far as the western interchange.

Summary

In summary, the road corridor in moving from west to east provides (to the west of the Karuah Bridge) a predominantly enclosed visual experience created by the adjoining woodland and open forest vegetation communities (including the Karuah Nature Reserve), the undulating natural topography, and the recessing of the road through cuttings into the landform.

The character of the visual experience is one of a semi enclosed natural setting.

These factors act to emphasise the long straight section of highway through this zone although the strong enclosure and presence of overpass structures may assist in offsetting the tendency for excessive speeds that straight roads can create.

From the Wetland Bridge and crossing of Horse Island the alignment provides more diverse of visual experiences, complemented by the more curvilinear alignment which enhances the variety of visual sight lines for motorists, and their recognition of the adjoining landscape character.

Key elements are the panoramic views over the Karuah River and the mix of views to adjoining rural lands both intimate in scale and exposure to the rural valley off the Branch Lane.

2.3 Design Criteria for Landscape Units

The proposed alignment and conceptual engineering design of the Karuah by-pass determines several typical engineering conditions along the route's length. These include:

- Cuttings;
- Fill embankments; and
- Bridge structures.

Whilst the bridge structures occur in discrete locations along the route, the cutting and fill embankment conditions occur in a range of combinations (and degree of slope) on each side of the highway, each situation having specific landscape criteria in particular in relation to the adjoining vegetation community and landscape unit.

The Landscape Strategy Plan (Figure 2.1) identifies the broad locations of the combinations of these conditions that occur along the route. Landscape treatments must respond to the indigenous vegetation communities that adjoin the road and the engineering conditions resulting from the proposed road design.

In order to restrict disturbance of the woodland and forest vegetation communities (in particular canopy trees) to the route alignment, the conceptual engineering design aims to reduce the extent of earthworks (through steepening of batter slopes adjoining quality natural vegetation) to the alignment thus limiting the extent of clearing required.

As a consequence, batters to cut areas over three metres depth preclude tree planting (and to a large extent re-vegetation generally). The existing high rock profile (two metres below surface on average) results in exposed rock cuttings to most excavated sections of the alignment.

Likewise to any fill embankments over three metres high a 1(v):2(h) gradient has been applied. Whilst this does not preclude effective landscape treatment, the issues of stabilisation of mulch materials, and difficulties of landscape installation generally must be considered in landscape design. The use of smaller sized plant material and meshing of steep banks to retain mulch are two appropriate strategies.

Further to the general principles discussed above the specific design criteria applying to the corridor through the site's landscape unit settings (see figure 2.2 on following page) are listed following:

Unit 1 - Woodland Slopes

This unit incorporates the Karuah State Forest and is located to the west of Karuah township. The moderate slopes provide gradients from 1(v):15(h) to 1(v):25(h), with aspects ranging from south west to south east.

The Woodland vegetation of the State Forest ranges in height from 12 - 18 metres, with dominant species including Smooth-barked Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Brown Stringybark *Eucalyptus capitellata*, and Bastard Mahogany *Eucalyptus umbra*.

Views are potentially available toward this area from the top of Scobies Hill to the south east and from the existing highway alignment, with some visual penetration potentially available from the low lying areas of Wallaroo State Forest to the south (but limited by vegetation and gentle topography).

Unit 2 - Woodland Valley

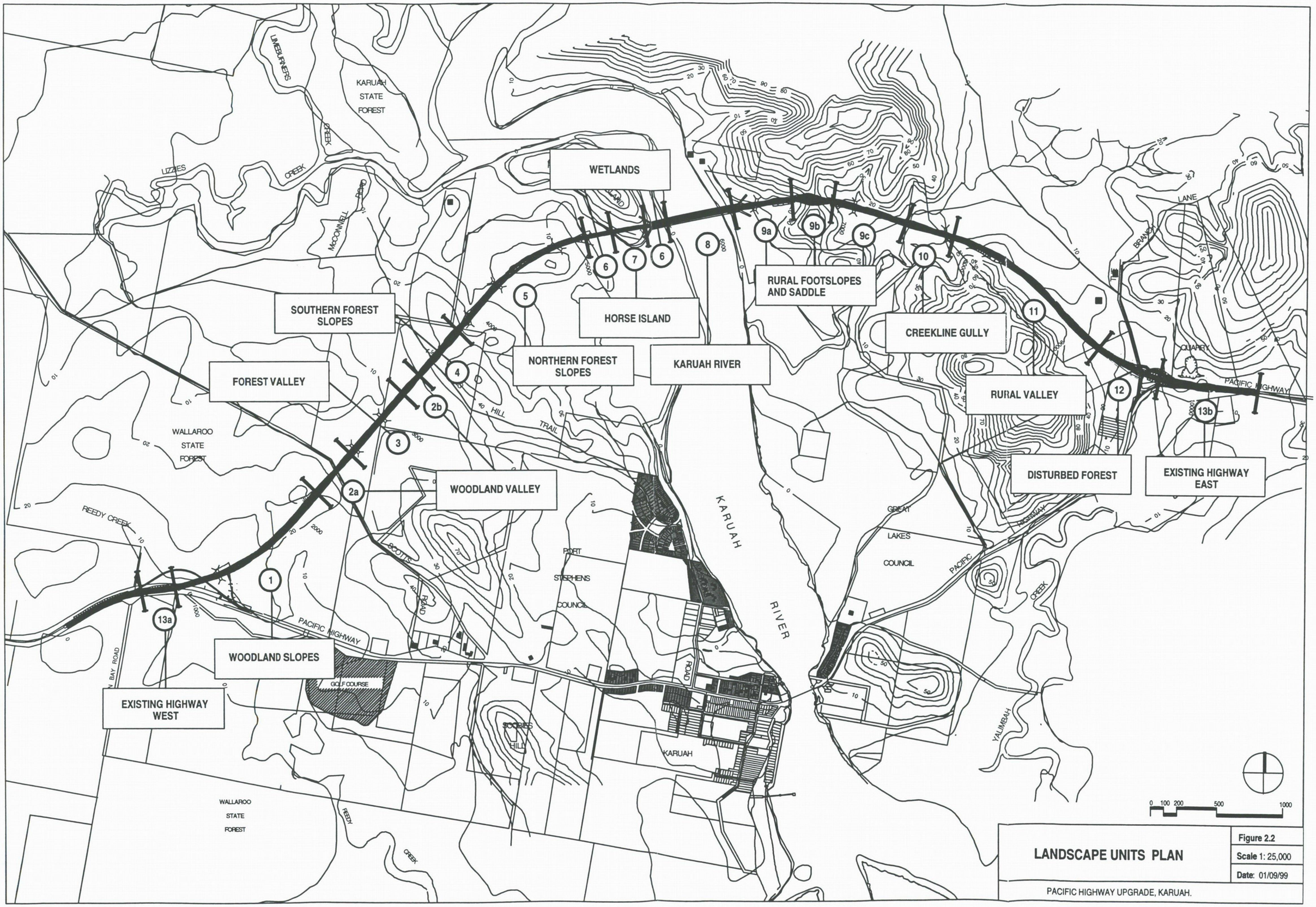
The undulating valley landform around Wallaroo Swamp provides gradients from 1(v):12(h) to 1(v):60(h) with the valley fringes supporting the Woodland vegetation of the Wallaroo State Forest as described for Unit 1.

Sub-unit 2A is located on the south side of the valley with a north easterly aspect. The area would potentially be glimpsed through vegetation from Mines Hill Trail located on the prominent forested ridge line to the north east.

Sub-unit 2B is located on the north side of the valley with a south westerly aspect. Views toward this area are available from the cleared rural lands to the south east adjoining the proposed Karuah Sewage Treatment Plant.

Unit 3 - Forest Valley

Unit 3 traverses the low lying valley area that drains into Wallaroo Swamp, flanked by Sub-units 2A and 2B to the south and north respectively. The gradient though gentle at 1(v):50(h) provides a generally north easterly aspect.



LANDSCAPE UNITS PLAN

Figure 2.2

Scale 1: 25,000

Date: 01/09/99

PACIFIC HIGHWAY UPGRADE, KARUAH.

The Open forest vegetation that surrounds the swamp area ranges from 15 to 20 metres in height. The lower moister areas are dominated by Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea*, and Rough-barked Apple *Angophora floribunda*. The drier areas on the upper grades adjoining Sub-units 2A and 2B, support species including Smooth-bark Apple *Angophora costata*, Red Bloodwood *Corymbia gummifera*, Sydney Peppermint *Eucalyptus piperita*, and White Stringybark *Eucalyptus globoidea*. The vegetation throughout this unit is typified by upper level die back within the tree canopy.

The area is potentially visible from the surrounding ridge lines to the north, east and south, albeit restricted by canopy vegetation and viewing areas subject to very limited use. The cleared pastoral area to the east is subject to more direct views to the Forest Valley from its upper elevation.

Unit 4 - Southern Forest Slopes

Unit 4 is typified by steep slopes ranging from 1(v):5(h) to 1(v):10(h) grade. Aspect is generally from the south west to north west.

The dominant tree species within the open forest vegetation (to 16-20 metres) include Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Gum *Eucalyptus punctata*, Northern Grey Ironbark *Eucalyptus siderophloia*, White Stringybark *Eucalyptus globoidea*, and Tallow-wood *Eucalyptus microcorys*.

Some visual penetration to this unit may be possible from Wallaroo Swamp and from distant low lands to the west.

Unit 5 - Northern Forest Slopes

Unit 5 incorporates steep slopes ranging in gradient from 1(v):5(h) to 1(v):10(h), with aspect swinging from the north east to north west. Part of the northern footslopes of the Mines Hill ridgeline (part of Karuah Native Reserve) the slopes incorporate an east - west running spur that encloses the wetland areas to the south of Horse Island.

The open forest community, which occurs widely in the study area, is that described for Landscape Unit 4.

Views are available toward this unit from the low lying floodplain areas of the Karuah River and the Karuah River itself to the north.

Unit 6 - Wetlands

Unit 6 incorporates the tidal flood prone zones of the river corridor adjoining the western banks of the river enclosed and by the Mines Hill Ridgeline to the south west and Horse Island to the north.

Protected by the State Environmental Planning Policy (SEPP) 14 Wetland Protection Areas, the dominant vegetation type is wetland saltmarsh, including *Zoysia macranha*, *Sarcocomi quinqueflora* and *Suaeda australis*, which occurs behind the Mangrove stands along Karuah River. A fringe area of sedgeland dominated by *Juncus krausii* occurs behind the saltmarsh, within areas of infrequent tidal inundation. A band of Swamp Forest occurs along the low areas of adjacent rocky slopes dominated by *Casuarina glauca* and *Baumea juncea*.

The area is relatively protected to visual exposure due to the surrounding landform to the north, west and south, and the fringing Mangrove stands to the Karuah River to the east.

Unit 7 - Horse Island

Horse Island rises to 92 metres AHD with steep vegetated slopes of average 1(v):5(h) grade. The island forms a north west-south east ridgeline offering its steepest slopes and highest elevation to the south east adjoining Unit 6 - Wetlands. Surrounded by wetland and mudflat areas the landform is separated from the slopes and ridgelines of the Karuah Nature Reserve by a band of estuarine wetland and a creekline running along its southern edge.

The island is well forested by a range of tree species including Spotted Gum *Corymbia maculata*, Grey Gum *Eucalyptus propinqua*, Grey Gum *Eucalyptus punctata*, Northern Grey Ironbark *Eucalyptus siderophloia*, White Stringy bark *Eucalyptus globoidea*, and Tallow-wood *Eucalyptus microcorys*. Grey Mangrove *Avicennia marina* var. *australasica* and River Mangrove *Aegiceras corniculatum* dominate the mudflats.

Horse Island is situated on a westerly right angle bend in the Karuah River, and provides a prominent landmark viewed from the river and its foreshores to the north and south, along with the ridgeline to the east of Karuah River. The island is visible as far as 5 kilometres down river from the existing Karuah Bridge.

Unit 8 - Karuah River

Karuah River is a dominant visual feature within the region. Its open water area ranges from between 400 to 700 metres in width between the wetland areas supporting mangrove species to the western bank, and the steeply rising eastern bank, vegetated with open forest vegetation (see Unit 9A).

Mangrove stands are dominated by Grey Mangrove *Avicennia marina, and* River Mangrove *Aegiceras corniculatum* of between 5-8 metres height.

Spectacular vistas north and north east along the river are afforded from the water and river foreshores. The wooded hills provide a natural backdrop of unbroken ridgelines that defines the river and its hinterland.

Unit 9 - Rural Footslopes and Saddle

The undulating rural footslopes to the eastern bank of the Karuah River are predominantly cleared, supporting single or small clusters of remnant and regenerating tree species, within a combination of native and exotic grasslands, and a varying gradient between 1(v):6(h) to 1(v):30(h).

Sub-unit 9A extends east from the river bank supporting a narrow foreshore band (to 20m) of remnant open forest vegetation including Spotted Gum *Corymbia maculata*. The low lying pastoral slopes support grasslands of both native and exotic species. Aspect of the footslopes is generally south west, with dappled views available from the river and eastern foreshore through the foreshore vegetation.

Unit 9B lies within a saddle landform. The western to central zone of the saddle has been previously cleared, with the adjacent slopes vegetated by open forest communities. Intermittent regeneration has occurred through the central zone providing a partial continuation of the vegetated ridgeline when viewed from the west.

To its easterly aspect adjoining a cleared rural valley to the east, Sub-unit 9B is typified by more intact natural vegetation (in particular to the north south running creekline), making landform changes more visually subtle, when viewed from Unit 9C.

Open Forest vegetation to the easterly aspect of Unit 9B and regenerating westerly aspect includes Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea,* Rough-barked Apple *Angophora floribunda* and *Melaleuca styphelioides.*

Sub-unit 9A is limited in visual exposure to the Karuah River and the adjacent western foreshores due to the stand of foreshore vegetation which provides significant screening of the cleared lands at river level. Sub-unit 9B (the saddle landform) is partially visible to long views to the south west and east (over 1.5 kilometres) where the screening effect of foreshore vegetation is reduced. To the west Sub-unit 9B is visible from the cleared valley undulating to the east and also longer views from the vicinity of Mustons Lane below Mount George (2.5 kilometres distance).

The rural footslopes of the north west - north east running valley comprising Sub-unit 9C range from 1(v):7(h) to 1(v):20(h) grade, and drains towards the north east - south west running creek gully of Unit 10. This subunit is subject to strong visual enclosure by vegetated ridgelines to the north and south, and the saddle landforms to the west.

Unit 10 - Creekline Gully

The south west running Mosquito Creek gully which separates Sub-unit 9C from Unit 11 drains into the SEPP 14 wetlands to the eastern foreshores of the Karuah River.

The stand of vegetation which crosses the gully and links the wooded hills to the north and south is a visually significant feature, restricting views from within these adjoining units.

Open forest vegetation to the gully includes Cabbage Gum *Eucalyptus amplifolia*, White Stringybark *Eucalyptus globoidea*, Rough-barked Apple *Angophora floribunda* and *Melaleuca styphelioides.*

Views toward this area are potentially available from the adjoining units 9C(west) and 11(east) from the surrounding ridgelines and cleared pastoral areas.

Unit 11 - Rural Valley

The Rural Valley comprises the cleared rural lands of the south east - north west running valley off the western side of The Branch Lane. Sub-unit 11A incorporates undulating slopes (average gradient 1(v):15(h)) below a prominent vegetated ridge line (to 116 AHD). Aspect is to the north and north east. Unit 11B is associated with similar graded undulating footslopes with an aspect more toward the south east.

The Rural Valley is typified by cleared paddocks with scattered water storage dams. Grasslands extend up to the open forest vegetation at the base of the ridge line, with minor stands of tree and understorey vegetation following creeklines. A rural residence is located at the transition between Sub-units 11A and 11B off Branch Lane.

Expansive rural views are available across the valley, and from the continuation of the valley to the north of Unit 10.

Unit 12 - Disturbed Forest

Unit 12 adjoins the existing road corridor of the Pacific Highway through previously cleared (but subject to partial regeneration) footslopes below the Carrington Hills. The undulating footslopes are characterised by grades of average 1(v):25(h).

East of Branch Lane the vegetation cover is more dense as far as the quarry site adjoining the highway. This zone provides the head of the creek gully which drains to the SEPP 14 wetlands south of the existing highway.

The disturbed open forest has been cleared of most of the understorey species (in particular to the west of The Branch Lane) leaving a tree canopy comprising Forest Red Gum *Eucalyptus tereticornis*, Spotted Gum *Corymbia maculata*, Broad-leaved Ironbark *Eucalyptus fibrosa*, White Stringybark *Eucalyptus siderophloia*, Grey Gum *Eucalyptus punctata*, Bastard Mahogany *Eucalyptus umbra* and Smoothed-barked Apple *Angophora costata*.

The area can be viewed from the southern section of Sub-unit 11B (south of existing farmhouse) with dappled views into the area from The Branch Lane through fringing tree canopy.

Unit 13 - Existing Highway

The existing highway alignment changes in character throughout its course based on the surrounding context of landform, vegetation, and landuse. For the purposes of this assessment the comments provided are focused on the location of the western and eastern interchanges of the proposed corridor with the existing highway.

Sub-unit 13A: The Western Interchange is located on a bend in the highway that is flanked by undulating slopes (1(v):20(h) grade) to the north, and gentle slopes (1(v):40(h) grade) to the south east. The roadway falls to the west at a gradient of approximately 1(v):50(h)-1(v):75(h). Subject to recent clearing and tapered profile of adjoining woodland vegetation the corridor has an open character particularly when approached from higher elevations to the east.

Sub-unit 13B: The Eastern Interchange is located on a tight bend in the highway and is strongly enclosed to the north and west by steeply sloping landform and open forest vegetation. To the south, the highway adjoins undulating topography falling gently towards the south. The SEPP 14 Wetlands extend to the edge of the road alignment at this location. The steep topography and close proximity of tall canopy trees to the corridor result in an enclosed visual character of strong visual interest.

It is noted that upgrading of the Pacific Highway includes duplication of the highway to the west and east. Whilst the more open character of the western interchange will absorb this change, the topographical and vegetaion characteristics of the east interchange will be altered significantly by duplication works widening the visual scale of the corridor.

2.4 Plant Species for Landscape Units

The Flora and Fauna Assessment prepared by Gunninah Consultants summarises plant species occurring within the range of vegetation communities identified on site.

Landscape proposals should look to build upon these species characteristics reinforcing the indigenous vegetation communities through which the route alignment passes whilst achieving the functional requirements of landscape revegetation of engineering roadworks. The landscape units identified in the Visual Assessment are a function of the vegetation communities and can provide the basis for this strategy to be applied. Figure 2.2 following page6 identifies the thirteen landscape units.

The following table lists species within the identified plant communities and highlights those which will be suitable for landscape revegetation works based on their horticultural performance and propagation suitability.

The chart identifies the locations in which particular species are appropriate, along with any specific comments on landscape function and use.

Figure 2.3 Plant Species for Landscape Units
(based on Gunninah Consultants Flora & Fauna Investigations of existing vegetation)

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Upper - Canopy						
Angophora costata	- Open Forest - Woodland - Cleared Rural Zones - Estuarine Wetlands	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12 - 6,7	√	√	x	Good roadside tree species- attractive form and bark
Angophora floribunda	- Open Forest - Cleared Rural Zones - Estuarine Wetlands	- 3,4,5,7 - 9,11,12 - 6,7	√	x	x	Good shade tree to area east of river.
Casuarina glauca	- Estuarine Wetlands	- 6,7	√	√	x	Adjoining low lying areas and creeklines
Corymbia gummifera	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Corymbia maculata	- Open Forest - Cleared Rural Zones - Woodland	- 3,4,5,7,13b - 9,11,12 - 1, 2	√	√	x	Good tree species as for Aug cost
Eucalyptus amplifolia ssp *amplifolia*	- Open Forest - Cleared Rural Zones - Freshwater Wetlands - Estuarine Wetlands	- 3,4,5,7 - 9,11,12 - adjacent 3 - 6,7	√	x	x	Suitable for low lying moist areas to east of river.
Eucalyptus capitellata	- Woodland	- 1,2,10,13a	√	√	x	
Eucalyptus fibrosa ssp fibrosa	- Open Forest - Woodland - Cleared Rural Zones	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12	√	√	x	
Eucalyptus globoidea	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	Generally to east of river
Eucalyptus microcorys	- Open Forest	- 3,4,5,7,13b	√	√	x	Dense foilage - good screening tree
Eucalyptus moluccana	- Open Forest	- 3,4,5,7,13b	√	√	x	
Eucalyptus piperita	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Eucalyptus propinqua	- Open Forest	- 3,4,5,7,13b	√	√	x	
Eucalyptus resinifera ssp *resinifera*	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	
Eucalyptus robusta	- Open Forest - Cleared Rural Zones - Estuarine Wetlands	- 3,4,5,7,13b - 9,11,12 - 6,7	√	x	x	endangered species
Eucalyptus siderophloia	- Open Forest - Cleared Rural Zones - Open Woodland	- 3,4,5,7,13b - 9,11,12 - 1,2	√	√	x	
Eucalyptus tereticornis	- Open Forest	- 3,4,5,7,13b	√	√	x	Generally to east of river
Eucalyptus umbra	- Open Forest - Woodland - Cleared Rural Zones	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12	√	√	x	
Syncarpia glomulifera	- Open Forest	- 3,4,5,7,13b	√	√	x	To south facing slopes
Mid - Canopy						
Acacia irrorata ssp *irrorata*		- 3,4,5,7,13b - 9,11,12	√	√	x	
Acacia longifolia	- Open Forest - Woodland - Cleared Rural Zones	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12	√	√	x	
Acacia falcata	- Open Forest	- 3,4,5,7,13b	√	√	x	
Acmena smithii	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	To minor creeks near The Branch lane
Allocasuarina littoralis	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Allocasuarina torulosa	- Open Forest	- 3,4,5,7,13b	√	√	x	
Breynia oblongifolia	- Open Forest	- 3,4,5,7,13b	√	√	x	
Callistemon salignus	- Open Forest	- 3,4,5,7,13b	√	√	x	to minor creeks near The Branch lane

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Mid - Canopy (cont'd)						
Casuarina glauca	- Freshwater Wetlands - Estuarine Wetlands	- adjacent 3 - 6,7	√	x	x	
Ceratopetalum gummiferum	- Open Forest	- 3,4,5,7,13b	√	√	x	to minor creeks near The Branch lane
Exocarpos cupressiformis	- Open Forest	- 3,4,5,7,13b	√	√	x	
Glochidion ferdinandi ssp *ferdinandi*	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	
Exocarpos cupressiformis	- Open Forest	- 3,4,5,7,13b	√	√		
Hakea dactyloides		- 1,2,10,13a	√	√	√	Attractive to nectar feeding birds
Leptospermum polygalifolium ssp *polygalifolium*	- Open Forest	- 3,4,5,7,13b	√	√	x	
Leptospermum trinervium	- Woodland	- 1,2,10,13a	√	√	x	
Melaleuca decora	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	
Melaleuca linariifolia	- Open Forest - Freshwater Wetlands - Estuarine Wetlands	- 3,4,5,7,13b - adjacent 3 - 6,7	√	x	x	
Melaleuca nodosa	- Open Forest - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 9,11,12 - adjacent 3	√	x	x	
Melaleuca sieberi	- Open Forest - Freshwater Wetlands	- 3,4,5,7,13b - adjacent 3	√	x	x	
Melaleuca styphelioides	- Open Forest - Freshwater Wetlands - Estuarine Wetlands	- 3,4,5,7,13b - adjacent 3 - 6,7	√	x	x	
Persoonia levis	- Woodland	- 1,2,10,13a	√	√	√	Difficult to propagate
Persoonia linearis	- Woodland	- 1,2,10,13a	√	√	√	
Syzygium oleosum	- Open Forest	- 3,4,5,7,13b	√	√	x	
Shrub Layer						
Acacia falcata	- Open Forest - Freshwater Wetlands	- 3,4,5,7,13b - adjacent 3	√	x	√	
Acacia linifolia	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Acacia myrtifolia	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	Good median strip planting - hardy species
Acacia suaveolens	- Woodland	- 1,2,10,13a	√	√	√	
Acacia terminalis	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Acacia ulicifolia	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Banksia serrata	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Banksia spinulosa var *collina*	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Banksia spinulosa var *spinulosa*	- Woodland	- 1,2,10,13a	√	√	√	
Boronia polygalifolium	- Woodland	- 1,2,10,13a	√	√	x	Difficult to propagate small shrub
Bossiaea heterophylla	- Open Forest	- 3,4,5,7,13b	√	√	√	Attractive shrub
Bossiaea obcordata	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	" "
Breynia oblongifolia	- Open Forest	- 3,4,5,7,13b	√	√	x	
Bursaria spinosa var *spinosa*	- Open Forest	- 3,4,5,7,13b	√	√	√	
Comesperma ericinum	- Woodland	- 1,2,10,13a	√	√	x	
Daviesia squarrosa	- Woodland	- 1,2,10,13a	√	√	x	
Daviesia ulicifolia	- Open Forest	- 3,4,5,7,13b	√	√	x	
Dillwynia retorta	- Open Forest	- 3,4,5,7,13b	√	√	√	
Dodonaea triquetra	- Woodland	- 1,2,10,13a	√	√	x	
Epacris pulchella	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Gahnia melanocarpa	- Open Forest	- 3,4,5,7,13b	√	√	√	

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Shrub Layer (cont'd)						
Gahnia sieberana	- Open Forest	- 3,4,5,7,13b	√	√	√	
Gompholobium glabratum	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Grevillea sericea	- Woodland	- 1,2,10,13a	√	√	√	
Hakea sericea	- Open Forest	- 3,4,5,7,13b	√	√	√	
Isospogon anemonifolius	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Juncus usitatus	- Open Forest	- 3,4,5,7,13b	√	√	x	
Kunzea ambigua	- Open Forest - Freshwater Wetlands	- 3,4,5,7,13b - adjacent 3	√	√	x	To low lying moist areas
Lambertia formosa	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Leptospermum juniperinum	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	Good bird habitat
Leptospermum polygalifolium ssp *polygalifolium*	- Woodland	- 1,2,10,13a	√	√	x	
Leucopogon attenuatus	- Woodland	- 1,2,10,13a	√	√	x	
Leucopogon juniperinus	- Open Forest	- 3,4,5,7,13b	√	√	x	
Lomatia silaifolia	- Open Forest	- 3,4,5,7,13b	√	√	x	
Melaleuca nodosa	- Open Forest - Estuarine Wetlands	- 3,4,5,7,13b - 6,7	√	√	√	
Mirbelia rubiifolia	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Oxylobium ilicifolium	- Woodland	- 1,2,10,13a	√	√	√	
Ozothamnus diosmifolius	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Pimelia linifolia ssp *linifolia*	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Platysace linearifolia	- Woodland	- 1,2,10,13a	√	√	x	
Pomaderris lanigera	- Open Forest	- 3,4,5,7,13b	√	√	x	
Pultenaea villosa	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Groundcover						
Adiantum aethiopicum	- Open Forest	- 3,4,5,7,13b	√	√	x	
Alternanthera denticulata	- Open Forest	- 3,4,5,7,13b	√	√	x	
Aristida ramosa	- Open Forest	- 3,4,5,7,13b	√	√	x	
Baumea juncea	- Estuarine Wetlands	- 6,7	x	x	x	
Billardiera scandens	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Bossiaea heterophylla	- Woodland	- 1,2,10,13a	√	√	x	
Bothriochloa decipiens	- Open Forest - Woodland - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12 - adjacent 3	x	x	x	
Brachycome augustifolia var *augustifolia*	- Cleared Rural Zones	- 9,11,12	√	√	√	
Brunoniella australis	- Open Forest	- 3,4,5,7,13b	√	√	x	
Calochilus campestris	- Woodland	- 1,2,10,13a	√	√	x	
Cassytha glabella	- Woodland	- 1,2,10,13a	√	√	x	
Centella asiatica	- Open Forest - Freshwater Wetlands	- 3,4,5,7,13b - adjacent 3	√	x	x	
Cheilanthes sieberi	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Chionochloa pallida	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Crinum pedunculatum	- Estuarine Wetlands	- 6,7	x	x	x	
Cyathochaeta diandra	- Open Forest	- 3,4,5,7,13b	√	√	√	
Cymbopogon refractus	- Open Forest - Freshwater Wetlands	- 3,4,5,7,13b - adjacent 3	√	√	x	
Cynodon dactylon	- Cleared Rural Zones - Estuarine Wetlands	- 9,11,12 - 6,7	√	x	x	

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Groundcover (cont'd)						
Dampiera stricta	- Woodland	- 1,2,10,13a	√	√	x	
Danthonia tenuior	- Woodland	- 1,2,10,13a	√	√	√	
Dianella caerulea var *producta*	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Dianella longifolia var *longifolia*	- Open Forest	- 3,4,5,7,13b	√	√	√	
Dichondra repens	- Open Forest - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 9,11,12 - adjacent 3	√	x	x	
Dipodium punctatum	- Woodland	- 1,2,10,13a	√	√	√	
Echinopgon caespitosus var *caespitosus*	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	
Entolasia marginata	- Open Forest - Woodland - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12 - adjacent 3	√	x	x	
Entolasia stricta	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Epaltes australis	- Open Forest	- 3,4,5,7,13b	√	√	x	
Eragrostis brownii	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Eustrephus latifolius	- Open Forest	- 3,4,5,7,13b	√	√	x	
Gahnia melanocarpa	- Open Forest	- 3,4,5,7,13b	√	√	x	
Gahnia sieberana	- Estuarine Wetlands	- 6,7	x	x	x	
Gleichenia dicarpa	- Open Forest	- 3,4,5,7,13b	√	√	x	
Glochidion ferdinandi	- Freshwater Wetlands	- adjacent 3	x	x	x	
Gompholobium minus	- Woodland	- 1,2,10,13a	√	√	x	
Gonocarpus tetragynus	- Woodland - Freshwater Wetlands	- 1,2,10,13a - adjacent 3	√	x	x	
Gonocarpus teucrioides	- Open Forest	- 3,4,5,7,13b	√	√	√	
Goodenia hederacea ssp *hederacea*	- Woodland	- 1,2,10,13a	√	√	√	
Goodenia heterophylla ssp *heterophyll*	- Open Forest	- 3,4,5,7,13b	√	√	√	
Hardenbergia violacea	- Open Forest - Woodland - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12 - adjacent 3	√	√	√	Not to be planted with trees and shrubs due to vigorous habit-groundcover to banks only
Hibbertia diffusa	- Woodland	- 1,2,10,13a	√	√	x	
Hovea linearis	- Woodland	- 1,2,10,13a	√	√	x	
Hypericum gramineum	- Open Forest	- 3,4,5,7,13b	√	√	√	
Hyposis hygrometrica	- Woodland	- 1,2,10,13a	√	√	x	
Imperata cylindrica var *major*	- Open Forest - Woodland - Cleared Rural Zones - Freshwater Wetlands - Estuarine Wetlands	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12 - adjacent 3 - 6,7	√	x	x	
Isolepis nodosus	- Estuarine Wetlands	- 6,7	x	x	x	
Juncus kraussii	- Estuarine Wetlands	- 6,7	x	x	x	
Juncus usitatus	- Open Forest	- 3,4,5,7,13b	√	√	x	
Kennedia rubicunda	- Woodland	- 1,2,10,13a	√	√	x	Not to be planted with trees and shrubs due to vigourous habit groundcover to banks
Laxmannia gracilis	- Woodland	- 1,2,10,13a	√	√	x	
Lepidosperma lineare	- Open Forest	- 3,4,5,7,13b	√	√	x	
Lindsaea linearis	- Woodland	- 1,2,10,13a	√	√	x	
Lindsaea microphylla	- Woodland	- 1,2,10,13a	√	√	x	
Lomandra filiformis ssp *filiformis*	- Open Forest	- 3,4,5,7,13b	√	√	x	
Lomandra glauca	- Open Forest	- 3,4,5,7,13b	√	√	x	
Lomandra longifolia	- Open Forest - Freshwater Wetlands - Estuarine Wetlands	- 3,4,5,7,13b - adjacent 3 - 6,7	√	√	√	

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Groundcover (cont'd)						
Lomandra obliqua	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Opercularia varia	- Open Forest	- 3,4,5,7,13b	√	√	x	
Oplismenus aemulus	- Open Forest	- 3,4,5,7,13b	√	√	x	
Oplismenus imbecillis	- Open Forest	- 3,4,5,7,13b	√	√	x	
Patersonia glabrata	- Woodland	- 1,2,10,13a	√	√	√	
Phragmites australis	- Open Forest - Estuarine Wetlands	- 3,4,5,7,13b - 6,7	x	x	x	
Pomax umbellata	- Open Forest - Woodland - Cleared Rural Zones	- 3,4,5,7,13b - 1,2,10,13a - 9,11,12	√	x	x	
Phragmites australis	- Estuarine Wetlands	- 6,7	x	x	x	
Pratia purpurascens	- Open Forest - Cleared Rural Zones - Freshwater Wetlands	- 3,4,5,7,13b - 9,11,12 - adjacent 3	x	x	x	
Pteridium esculentum	- Open Forest - Cleared Rural Zones	- 3,4,5,7,13b - 9,11,12	√	√	x	
Ptilothrix deusta	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	x	
Samolus repens	- Estuarine Wetlands	- 6,7	x	x	x	
Schizaea bifida	- Woodland	- 1,2,10,13a	√	√	x	
Schoenus imberbis	- Woodland	- 1,2,10,13a	√	√	x	
Schoenoplectus mucronatus	- Open Forest	- 3,4,5,7,13b	√	√	x	
Senecio diaschides	- Open Forest	- 3,4,5,7,13b	√	√	x	
Sporobolus virginicus var *minor*	- Estuarine Wetlands	- 6,7	x	x	x	
Stipa pubescens	- Woodland	- 1,2,10,13a	√	√	√	
Themeda australis	- Open Forest - Woodland	- 3,4,5,7,13b - 1,2,10,13a	√	√	√	
Thysanotus tuberosus	- Woodland	- 1,2,10,13a	√	√	x	
Typha orientalis	- Open Forest	- 3,4,5,7,13b	√	√	x	
Viola hederacea	- Woodland	- 1,2,10,13a	x	x	x	
Xanthosia pilosa	- Open Forest	- 3,4,5,7,13b	√	√	x	
Xanthosia tridentata	- Woodland	- 1,2,10,13a	√	√	x	
Zoysia macrantha	- Estuarine Wetlands	- 6,7	x	x	x	
Aquatic species						
Azolla filiculoides	- Freshwater Wetlands	- adjacent 3	x	x	x	
Azolla pinnata	- Freshwater Wetlands	- adjacent 3	x	x	x	
Nymphoides geminata	- Freshwater Wetlands	- adjacent 3	x	x	x	
Potamogeton tricarinatus	- Freshwater Wetlands	- adjacent 3	x	x	x	
Vallisneria gigantea	- Freshwater Wetlands	- adjacent 3	x	x	x	
Sedges and Rushes			x	x	x	
Baumea articulata	- Freshwater Wetlands	- adjacent 3	x	x	x	
Cyperus difformis	- Freshwater Wetlands	- adjacent 3	x	x	x	
Eleocharis acuta	- Freshwater Wetlands	- adjacent 3	x	x	x	
Eleocharis sphacelata	- Freshwater Wetlands	- adjacent 3	x	x	x	
Gahnia melanocarpa	- Freshwater Wetlands	- adjacent 3	x	x	x	
Juncus polyanthemus	- Freshwater Wetlands	- adjacent 3	x	x	x	
Juncus prismatocarpus	- Freshwater Wetlands	- adjacent 3	x	x	x	
Juncus usitatus	- Freshwater Wetlands	- adjacent 3	x	x	x	
Lomandra longifolia	- Freshwater Wetlands	- adjacent 3	x	x	x	
Philydrum lanuginosum	- Freshwater Wetlands	- adjacent 3	x	x	x	
Typha orientalis	- Freshwater Wetlands	- adjacent 3	x	x	x	
Schoenoplectus mucronatus	- Freshwater Wetlands	- adjacent 3	x	x	x	
Villarsia exalata	- Freshwater Wetlands	- adjacent 3	x	x	x	

Species	Vegetation Community	Landscape Unit	Treatment			
			Slopes <1:3	Slopes >1:3	Medians	General Comments
Mudflats						
Aegiceras corniculatum	- Estuarine Wetlands	- 6,7	x	x	x	
Avicennia marina var *australasica*	- Estuarine Wetlands	- 6,7	x	x	x	
Saltmarsh and sedgeland						
Baumea juncea	- Estuarine Wetlands	- 6,7	x	x	x	
Bolboschoenus caldwellii	- Estuarine Wetlands	- 6,7	x	x	x	
Cotula coronopifolia	- Estuarine Wetlands	- 6,7	x	x	x	
Isolepis nodosus	- Estuarine Wetlands	- 6,7	x	x	x	
Juncus kraussii	- Estuarine Wetlands	- 6,7	x	x	x	
Phragmites australis	- Estuarine Wetlands	- 6,7	x	x	x	
Sarcocornia quinqueflora	- Estuarine Wetlands	- 6,7	x	x	x	
Selliera radicans	- Estuarine Wetlands	- 6,7	x	x	x	
Sporobolus virginicus var *minor*	- Estuarine Wetlands	- 6,7	x	x	x	
Suaeda australis	- Estuarine Wetlands	- 6,7	x	x	x	
Triglochin striata	- Estuarine Wetlands	- 6,7	x	x	x	
Zoysia macrantha	- Estuarine Wetlands	- 6,7	x	x	x	

3.0 LANDSCAPE AND URBAN DESIGN CONCEPT PLAN

3.1 Overview

The Landscape and Urban Design Concept Plans illustrate the key landscape proposals developed incorporating the principles outlined earlier in this report.

Each of the following Area Concept Plans identifies:
- the extent of existing vegetation cover;
- extent of cut and fill earthworks embankments;
- extent and type of landscape revegetation;
- location of landscape cross sections A-P

The Concept Plans provide the basis for design development of landscape and urban design treatments in ongoing implementation of the project and are outlined in the following descriptions under the key issues of:

- ***Engineering Design Requirements:***
  Civil Engineering design issues having correlation with landscape objectives and design approach

- ***Landscape and Urban Design Proposals***
  Construction and planting works proposed in application of landscape and urban design principles

- ***Key Issues for Ongoing Design Developed***
  Significant aspects of the landscape scheme requiring further design resolution in ongoing development of the project.

The Concept Plans also incorporate a listing of recommended plantings based on the site indigenous vegetation communities relevant to the particular area. The listing categorises species within their vegetation type (eg canopy trees/shrubs etc) and the landscape treatment in which they are most appropriately used.

Figure 3.1 on the following page indicates the location of the Area Concept Plans as described on the following pages.

Area I

Area II

Area III

Area IV

Area V

Area VI

Area VII

0 100 200 500 1000

LAYOUT OF AREA CONCEPT PLANS

Figure 3.1

Scale 1: 25,000

Date: 01/09/99

PACIFIC HIGHWAY UPGRADE, KARUAH.

3.2 Landscape and Urban Design Concept Plan

3.2.1 AREA 1

(refer figures 3.2, 3.3 & 3.4)

Engineering Design Requirements

- Western interchange incorporates future bridged flyover for northbound Karuah exit. Vegetation removal to be controlled to protect existing woodland canopy.
- Vegetation clearing generally to be controlled and limited within the extent of earthworks, filling and excavation.
- Predominantly fill embankments of average 2 metres depth (max. 6m) - gradient varies with opportunity for tree planting to edge of roadway where bank gradient of steeper than 1(v):3(h) requires safety barrier.
- Cut embankments in rock after chainage 1600 (average height 2m) preclude substantial soft landscape treatment.

Landscape and Urban Design Proposals

- To highway alignment at Western interchange, revegetation of fill embankments with open woodland tree, shrub and ground cover planting is required.
- To consolidate woodland community, revegetate existing open areas that remain as infill zones between existing vegetation and revegetated stands.
- Adjoining local road and interchange road intersections, native grass revegetation should be provided to maintain vehicle sight lines.
- Landscape zones to median strips within Area 1 are generally of 8 metres width and provide the opportunity to establish a substantial vegetative buffer zone between carriageways of a mix of site frangible indigenous shrub and ground cover material, and other selected native species (proven in similar landscape situations).
- Provide break as required (for engineering/safety considerations) in native shrub planting to median strip at Karuah exit flyover bridge.
- North of chainage 1300, landscape treatments are focussed on revegetation of cut and fill embankments and provision of median strip shrub planting to buffer headlight glare and visually separate north and south bound carriageways.
- Fauna underpass provided at chainage 1400.
- Aerial fauna crossing zone provided between chainage 1500-1570 where minimal earthworks are required and tree retention can be optimised. Safety barriers to enable tree planting up to 2 metres from barrier.
- Revegetate existing highway corridor with native grassing, and intermittent native tree planting (rural character).
- Gateway avenue planting of *Angophora costata* adjacent bypass interchange and northern exit with understorey of native grasses - consider uplighting of tree canopy to enhance gateway effect.

  Angophora species reflect natural qualities of local environment and offer the best sculptural qualities of the locally indigenous species range.

Key Issues for Ongoing Design Development

- Establishment of sight lines in defining the extent of vegetation clearing and revegetation to exit/entry ramps and local road intersections at the western interchange.
- Design of water quality ponds at chainage 1250 and 1450 to respond to located topography and vegetation patterns.
- Recognition of drainage characteristics to island area of existing vegetation at chainage 1220. Drainage works to incorporate retention of existing drainage pattern as far as possible.

RECOMMEMDED PLANTINGS - Landscape Concept Plan Area I - Landscape Units 1&13a Open Woodland

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES		SHRUBS		GROUNDCOVERS	
Species	**Treatment**	**Species**	**Treatment**	**Species**	**Treatment**
Upper Canopy Trees		*Acacia myrtifolia*	T1, M, H	*Billardiera scandens*	T1, H
Angophora costata	T1, T2, H	*Acacia suaveolens*	T1, T2, M, H	*Dampiera stricta*	T1
Corymbia gumifera	T1, T2, H	*Banksia serrata*	T1, T2, H	*Dianella caerulea*	T1, T2, H
Eucalyptus fibrosa spp	T1, T2	*Banksia spinulosa*	T1, M, H	*var producta*	
fibrosa		*var collina*		*Gompholobium minus*	T1
Eucalyptus piperita	T1, T2	*Banksia spinulosa*	T1, M, H	*Hardenbergia violacea*	T1
		var spinulosa		*Hibbertia diffusa*	T1
Mid-Canopy Trees/ Shrubs		*Boronia polygalifolium*	T1	*Imperata cylindrica*	T1, T2, M,
Acacia longifolia	T1, H	*Bossiaea obcordata*	T1, M	*var major*	H, G
Hakea dactyloides	T1, H	*Dillwynia retorta*	T1, M, H	*Kennedia rubicunda*	T1, H
Leptospermum trinervium	T1, T2, H	*Grevillea sericea*	T1, M, H	*Lomandra obliqua*	T1, H
		Isospogon anemonifolius	T1	*Lomandra longifolia*	T1,T2,M,H,G
		Lambertia formosa	T1	*Patersonia glabrata*	T1,T2,M,H,G
		Leptospermum juniperinum	T1, H	*Stipa pubescens*	T1,T2,M,H,G
		Leptospermum polygalifolium	T1, H	*Themeda australis*	T1,T2,M,H,G
		Ozothamnus diosmifolius	T1	*Xanthosia tridentata*	T1, M
		Pimelia linifolia	T1, M, H		

KEY

- Existing vegetation to be retained/ protected
- New woodland revegetation - Tubestock planting
- New woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip frangible shrub tubestock planting
- Native grasses hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Avenue Planting of *Angophora costata* with native grass understorey
- Water quality pond

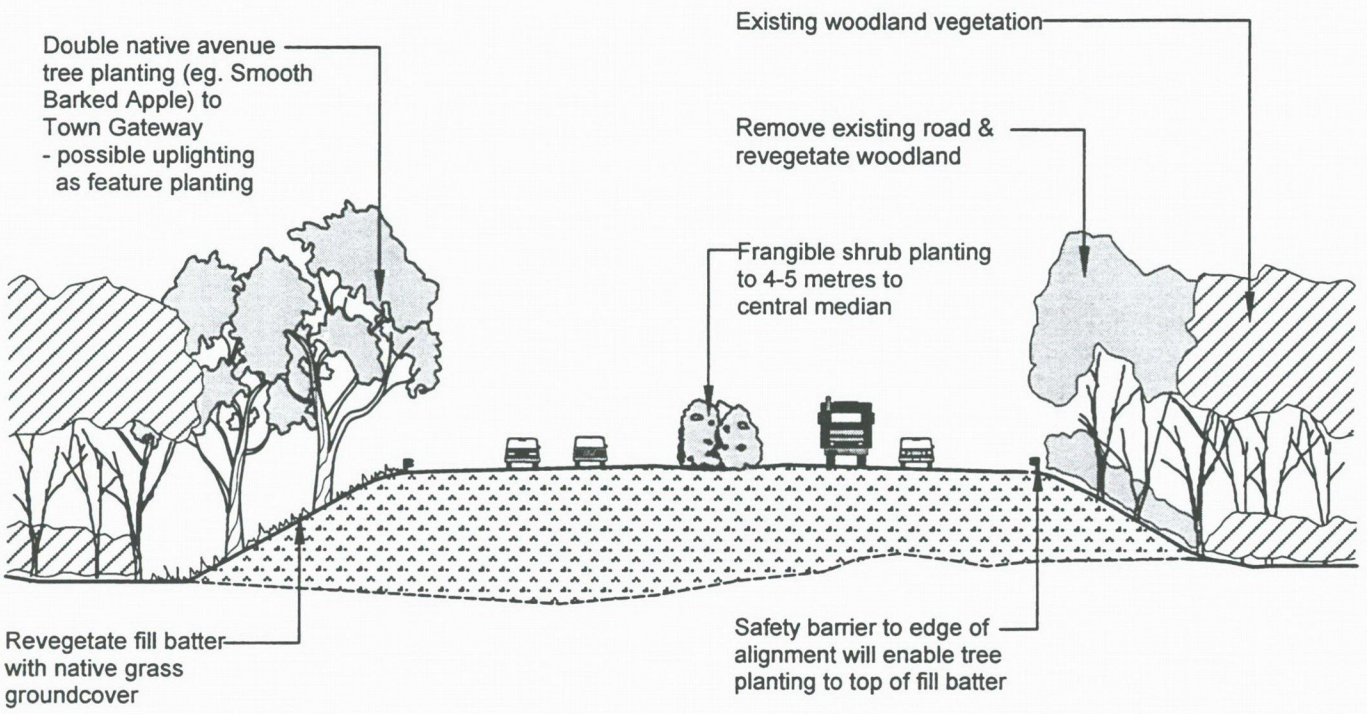
Landscape Unit 1
B2
SCOTTS ROAD
30
Landscape Unit 2
Adjoins Concept Plan Area II
B2
Ch: 2000
20
Lay by provided to southbound carriageway at chainage 1850
Woodland revegetation to cut embankment
Median strip shrub planting
B1
Tree planting to median to reinforce aerial fauna corridor amenity
Vehicular safety barrier provided to edge of carriageway
Ch: 1500
B1
Fauna underpass
Future connection (stage 2) to northbound flyover exit
Revegetate stage 1 temporary access road alignment with completion of flyover bridge
Native grass revegetation to shoulders of access trail
Existing Pacific Highway Alignment
10
Design of flyover bridge to recognise potential gateway visual role
Future Flyover (stage 2 works) exit to Karuah
Native grass revegetation to shoulders of access trail
Protect and retain existing open woodland canopy and understorey vegetation
Avenue planting of *Angophora costata* to bypass interchange and southern exit to mark town gateway
Landscape Unit 13a
A
A
A
Ch: 1000
Extend Open Woodland hydroseeding to buffer local road from Highway
Local resident access
Native grass hydroseeding of existing road corridor
10
0 10 20 50 100

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN Area I

Figure 3.2
Scale 1: 4000
Date: 01/09/99

PACIFIC HIGHWAY UPGRADE, KARUAH.

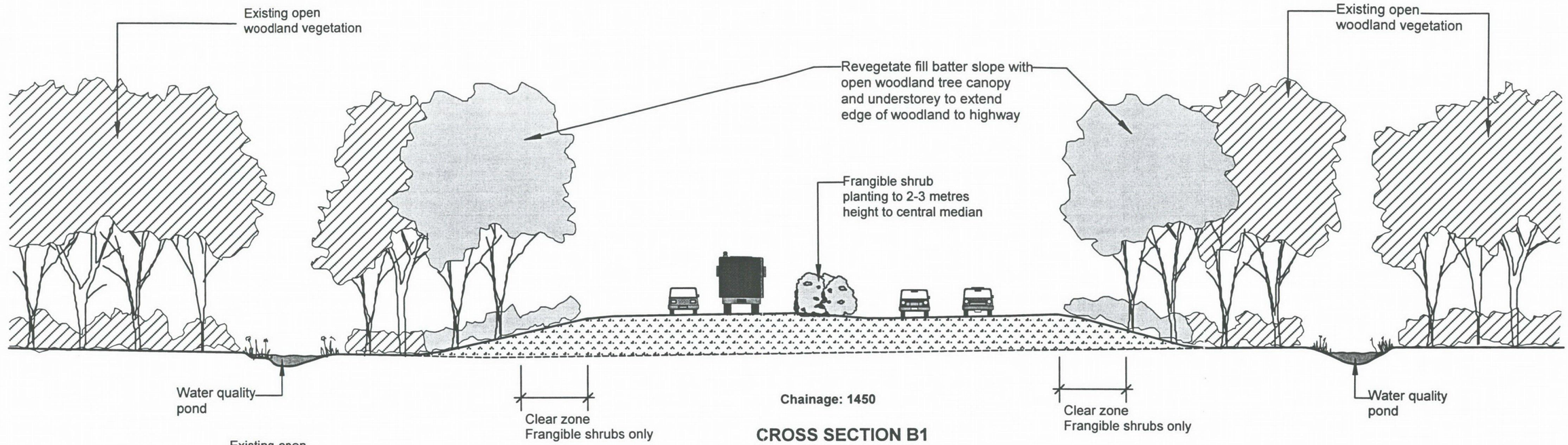
Figure 3.3



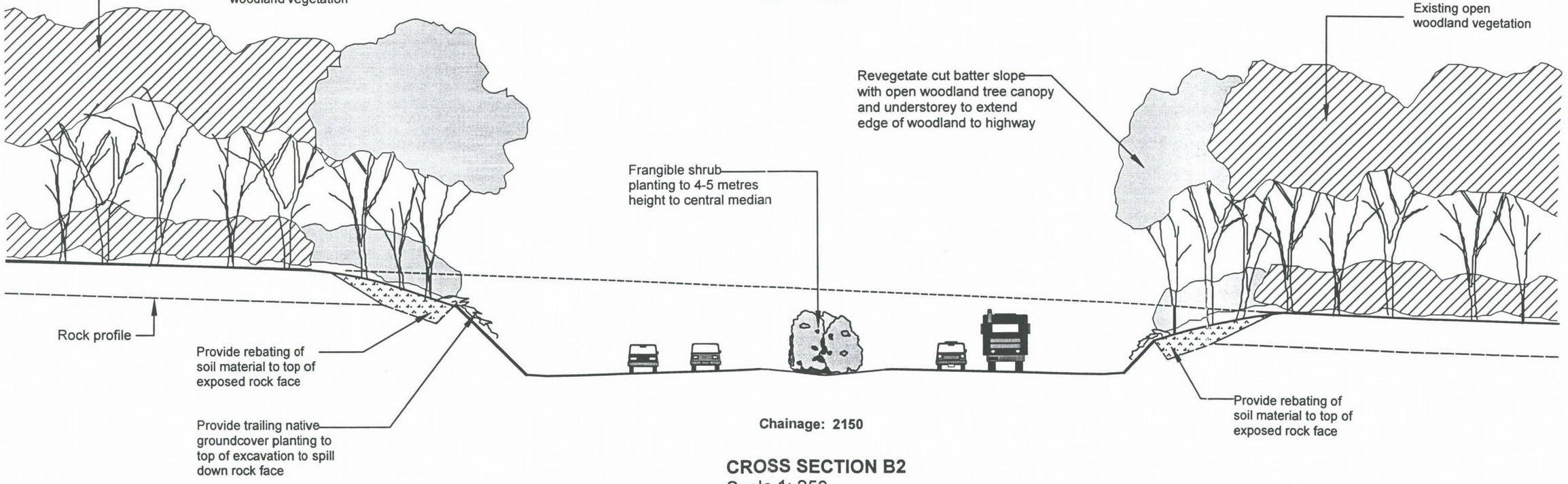
Chainage: 800

CROSS SECTION A
Scale 1:400

Figure 3.4



CROSS SECTION B1
Scale 1: 250



CROSS SECTION B2
Scale 1: 250

3.2.2 - AREA II (refer figures 3.5, 3.6)

Engineering Design Requirements

- Predominantly fill embankments at average 2.5 metres height (max 4 metres) - batter slopes maintained at steeper than 1(v):3(h) (to reduce extent of earthworks) with tree planting possible to top of bank with safety barrier provision.
- Vegetation clearing to be controlled within the extent of earthworks filling and excavation.
- Scotts Road bridge crossing provided at location south of existing road where excavated road alignment provides natural bridge abutments and visually integrates bridge with adjoining land form.

Landscape and Urban Design Proposals

- Revegetation of fill embankments to highway comprises principle landscape strategy to Area 2
- Median strip planting of mixed site understorey (woodland/open forest) and other functional shrub and groundcover planting to meet functional and aesthetic requirements (as identified for Area 1) provided to 8 metre width planted zone.
- Between chainages 2350 to 2450, it is proposed to enhance aerial fauna movement potential. This is made practical at this and other locations due to the limited extent of earthworks required for road levels and the resulting potential to conserve existing tree canopy and understorey vegetation.

  Tree specimens to the median will be retained where levels permit, however an immediate programme of advanced tree stock planting will be undertaken in the median zone to reinforce the aerial fauna corridor function. Vehicular safety barriers will be required at this point to facilitate median tree planting and tree planting in close proximity to the road shoulders to the west and east. Where existing tree canopy does not afford adequate tree cover adjoining the roadway, the provision of temporary "refuge poles" (steel post with resting box/artificial branches) should be considered.
- At chainage 2850 adjoining the cleared rural area to the east, it is proposed that the fill embankment be revegetated with native grasses and intermittent tree planting to maintain glimpses to the adjoining open pastures.
- Fauna underpasses at chainages 2640, 2960, and 3250.

Key Issues for Ongoing Design Development

- Confirmation of the scope of tree retention in close proximity to road alignment at the proposed aerial fauna crossings will be required upon preparation of detailed site survey information.
- Develop detail landscape planting proposals in consultation with National Parks and Wildlife Service to ensure consistency with the Plan of Management for Karuah Nature Reserve.

3.2.3 AREA III
(refer figures 3.7, 3.8 & 3.9)

Engineering Design Requirements

- Varied excavation and fill conditions to alignment - filled embankments provide maximised batter slopes of steeper than 1(v):3(h) (to reduce extent of earthworks), with subsequent safety barrier provision enabling tree adjacent roadway planting to top of embankment adjacent roadway.
- Vegetation clearing to be controlled with the extent of earthworks filling and excavation.
- Cutting faces to be excavated to natural bedding planes where possible to provide informal character.
- Mines Hill Trail bridge crossing (at chainage 3530) integrated into excavated road alignment.

Landscape and Urban Design Proposals

- To filled embankments open forest revegetation to be provided with tree planting extended to the edge of road shoulder
- Median strip planting of mixed site understorey (open forest) and other functional shrubs and groundcover plantings to meet functional and aesthetic requirements (as identified for Area 1) provided to 8 metre width planted zone.
- To excavated rock faces to the southern side of corridor adjoining clearing at chainage 4780, it is recommended that revegetation comprise pasture grass hydroseeding to visually integrate with the adjoining area and maintain views to open pastures from highway.
- Aerial fauna crossing zone between chainages 3340 to 3400 and 3820 to 3880.
- Fauna underpasses at chainages 3950 and 4270.

RECOMMEDED PLANTINGS - Landscape Concept Plan Area II - Landscape Units 2 - Woodland / 3 - Open Forest

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES			SHRUBS			GROUNDCOVERS		
Species	**Unit**	**Treatment**	**Species**	**Unit**	**Treatment**	**Species**	**Unit**	**Treatment**
Upper Canopy Trees			*Acacia myrtifolia*	2	T1, M, H	*Billardiera scandens*	2,3	T1, H
Angophora costata	2,3	T1, T2, H	*Acacia suaveolens*	2	T1, T2, M, H	*Dampiera stricta*	2	T1
Corymbia gumifera	2,3	T1, T2, H	*Banksia serrata*	3	T1, T2, H	*Dianella caerulea*	2,3	T1, T2, H
Eucalyptus fibrosa spp	2,3	T1, T2	*Banksia spinulosa*	2	T1, M, H	*var producta*		
fibrosa			*var spinulosa*			*Gompholobium minus*	2	T1
Eucalyptus piperita	2,3	T1, T2	*Boronia polygalifolium*	2	T1	*Hardenbergia violacea*	2,3	T1
			Bossiaea obcordata	2,3	T1, M	*Hibbertia diffusa*	2	T1
Mid-Canopy Trees/ Shrubs			*Dillwynia retorta*	2,3	T1, M, H	*Imperata cylindrica*	2,3	T1, T2, M,
Acacia longifolia	2,3	T1, H	*Grevillea sericea*	2	T1, M, H	*var major*		H, G
Allocasuarina littoralis	3	T1, T2, H	*Hakea sericea*	3	T1	*Kennedia rubicunda*	2	T1, H
Allocasuarina torulosa	3	T1, T2, H	*Isospogon anemonifolius*	2,3	T1	*Lomandra obliqua*	2,3	T1, H
Hakea dactyloides	2	T1, H	*Lambertia formosa*	2,3	T1	*Lomandra longifolia*	2,3	T1,T2,M,H,G
Leptospermum trinervium	2	T1, T2, H	*Leptospermum juniperinum*	2,3	T1, H	*Patersonia glabrata*	2	T1,T2,M,H,G
Melaleuca nodosa	3	T1, H	*Leptospermum polygalifolium*	2	T1, H	*Stipa pubescens*	2	T1,T2,M,H,G
			Ozothamnus diosmifolius	2,3	T1	*Themeda australis*	2,3	T1,T2,M,H,G
			Pimelia linifolia	2,3	T1, M, H	*Xanthosia tridentata*	2,3	T1, M

KEY

- Existing vegetation to be retained/ protected
- Existing open grassland
- Existing Estuarine Wetland areas
- Woodland revegetation - Tubestock planting
- Woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip vegetation - Tubestock planting
- Native grass hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Water quality pond

Landscape Unit 2b

Landscape Unit 3

Landscape Unit 4

Adjoins Concept Plan Area III

MINES HILL TRAIL

Tree planting to median to reinforce aerial fauna corridor amenity
Vehicular safety barrier provided to edge of carriageway

Fauna underpass

Landscape Unit 2b

Lay by provided to southbound carriageway at chainage 3130

KARUAH NATURE RESERVE

Fauna and drainage underpass

Ch: 3000

Wallaroo Swamp Freshwater Wetland environment

SCOTTS ROAD

Fauna and drainage underpass

Batter planting to Karuah sewage treatment works (by NSW Public Works)

Landscape Unit 2

Lay by provided to northbound carriageway at chainage 2520

Scotts Road aerial fauna crossing - see insert A this sheet

Landscape Unit 3

Ch: 2500

Bridge overpass to Scotts Road - located in cutting to provide natural abutments. Provide revegetation of cleared areas adjoining roadway

Bridge structure to be thematically linked to Mines Hill and west interchange (future) overpasses. Bridge to incorporate central pier with "lightweight" bridge platform

Promote aerial fauna corridor at grade section of alignment
Carry out supplemental planting of advanced tree stock

Adjoins Concept Plan Area I

Landscape Unit 1

Tree planting to median to reinforce aerial fauna coridor quality
Vehicular safety barrier provided to edge of carriageway

Revegetate existing Scotts Road alignment to be made defunct

B2

30

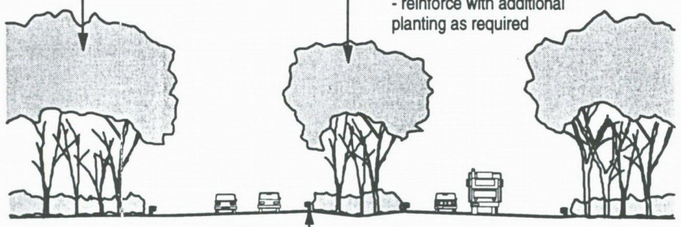
Landscape Unit 2

B2

20

Retain margin tree canopy and understorey adjoining the road corridor - reinforce with additional plantings

Retain tree and understorey planting to central median - reinforce with additional planting as required



Vehicular safety barrier provided to edge of carriageways to enable retention of tree canopy in close proximity to roadway enhancing aerial fauna movement amenity

Control of clearing to ensure that existing tree and understorey canopy are retained - reconfigure earthworks and consider walling where required to maintain drainage patterns and levels at base of trees

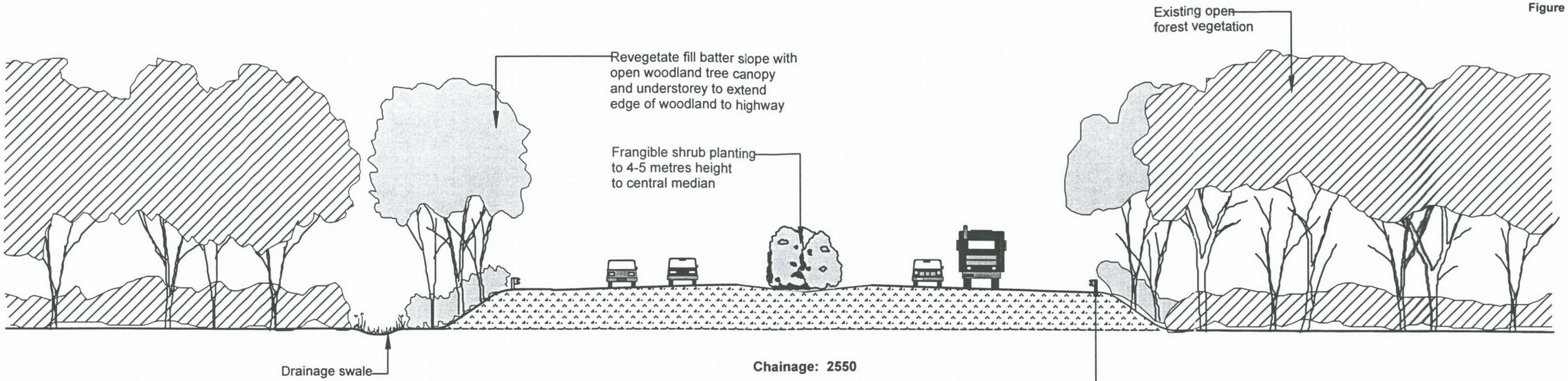
Inset A - Scotts Road Aerial Fauna Crossing
Scale: 1:1000

0 10 20 50 100

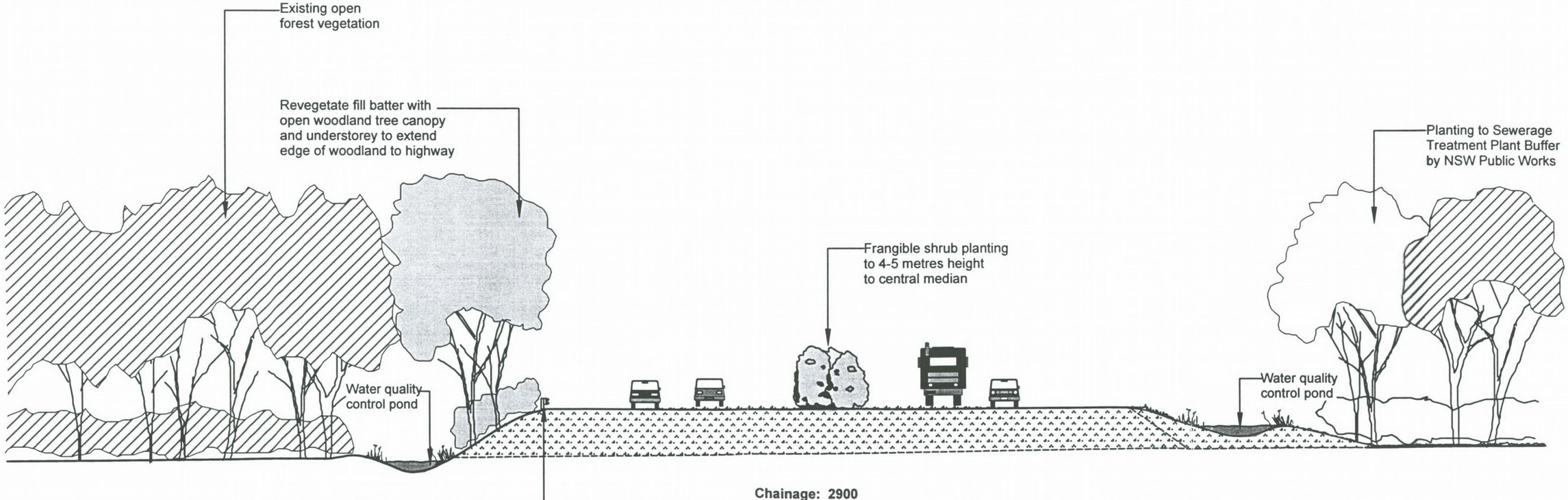
LANDSCAPE AND URBAN DESIGN CONCEPT PLAN Area II

Figure 3.5
Scale 1: 4000
Date: 01/09/99

PACIFIC HIGHWAY UPGRADE, KARUAH.



CROSS SECTION C
Scale 1: 250



CROSS SECTION D
Scale 1: 250

RECOMMEDED PLANTINGS - Landscape Concept Plan Area III - Landscape Units 4 & 5 Open Forest

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES		SHRUBS		GROUNDCOVERS	
Species	**Treatment**	**Species**	**Treatment**	**Species**	**Treatment**
Upper Canopy Trees		*Acacia falcata*	T1	*Billardiera scandens*	T1, H
Angophora costata	T1, T2, H	*Acacia myrtifolia*	T1	*Chionochloa pallida*	T1, T2, H
Corymbia gumifera	T1, T2, H	*Banksia serrata*	T1, T2, H	*Dianella caerulea*	T1, T2, H
Eucalyptus fibrosa spp	T1, T2	*Banksia spinulosa*	T1, H	*var producta*	
fibrosa		*var collina*		*Goodenia heterophylla*	T1, H
Eucalyptus microcorys	T1, T2, H	*Bossiaea obcordata*	T1, M	*Hardenbergia violacea*	T1
Eucalyptus moluccana	T1, T2	*Dillwynia retorta*	T1, M, H	*Hypericum gramineum*	T1
Eucalyptus piperita	T1, T2	*Hakea sericea*	T1, M, H	*Imperata cylindrica*	T1, T2, M,
Eucalyptus umbra	T1, T2, H	*Kunzea ambigua*	T1, M	*var major*	H, G
Syncarpia glomulifera	T1, T2	*Lomandra longifolia*	T1,T2,M,H,G	*Lomandra obliqua*	T1, H
		Persoonia levis	T1, M	*Pteridium esculentum*	T1,T2,M,H,G
Mid-Canopy Trees/ Shrubs				*Themeda australis*	T1,T2,M,H,G
Acnema smithii	T1, H			*Xanthosia pilosa*	T1, M
Callistemon salignus	T1, H				
Ceratopelatum gummiferum	T1				
Melaleuca nodosa	T1, H				
Melaleuca styphelioides	T1, H				

KEY

- Existing vegetation to be retained/ protected
- Existing open grassland
- Existing Mangrove Woodland
- Woodland revegetation - Tubestock planting
- Woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip vegetation - Tubestock planting
- Native grass hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Water quality pond

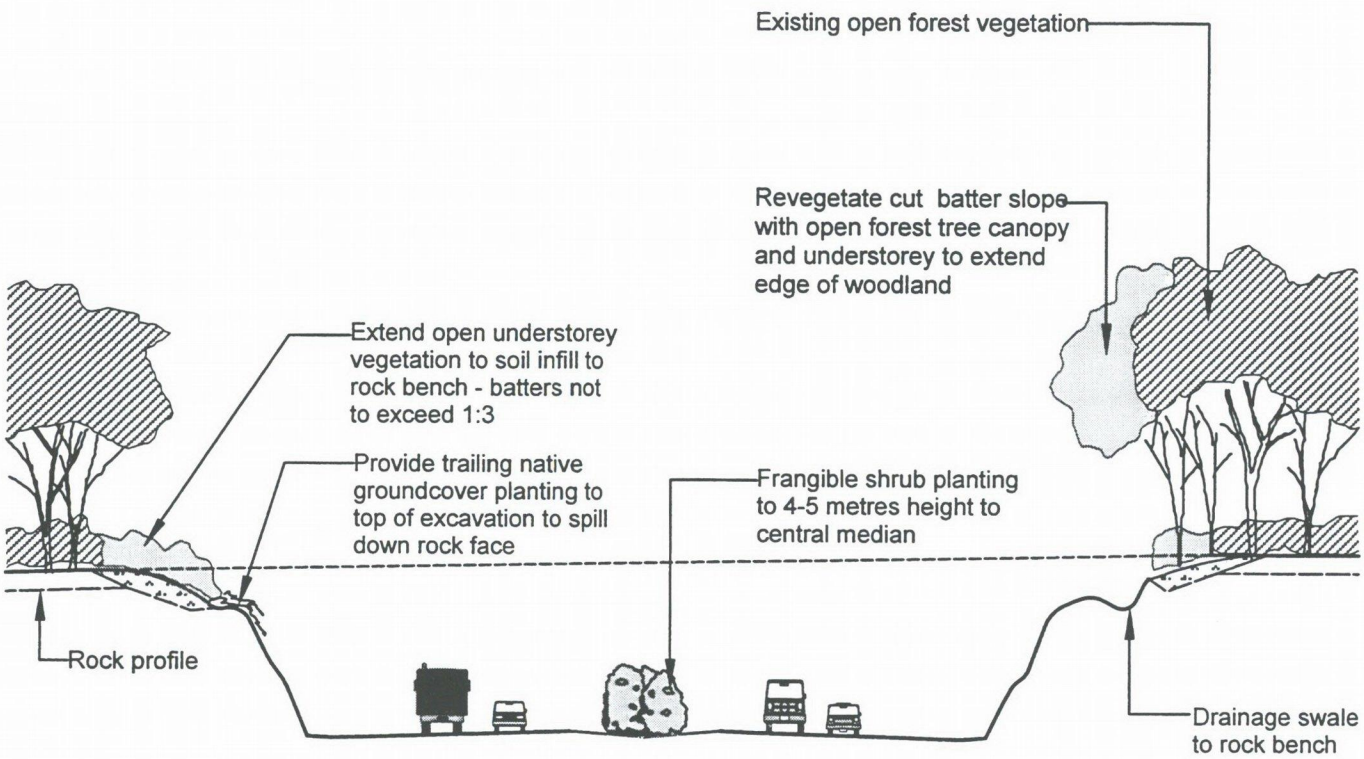
Landscape Unit 5
Culvert
10
Ch: 5000
F2
Landscape Unit 6
Dam
Adjoins Concept Plan Area IV
F2
Native grassing to cutting to integrate with adjoining open pastures
Ch: 4500
Fauna and drainage underpass
Median crossover provided at chainage 4100
Fauna and drainage underpass
Ch: 4000
Landscape Unit 4
F1
Tree planting to median to reinforce aerial fauna corridor amenity
Vehicular safety barrier provided to edge of carriageway
E
MINES HILL TRAIL
Landscape Unit 5
E
Lay by provided to northbound carriageway at chainage 3450
Ch: 3500
Tree planting to median to reinforce aerial fauna coridor quality
Vehicular safety barrier provided to edge of carriageway
Mines Hill Trail Bridge Crossing - provide landscape revegetation of bridge abutment zones
Bridge structure to be thematically linked to Mines Hill and west interchange (future) overpasses.
Bridge to incorporate central pier with "lightweight" bridge platform
Landscape Unit 2b
Adjoins Concept Plan Area II
Landscape Unit 4
KARUAH NATURE RESERVE
20
0 10 20 50 100

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN
Area III

Figure 3.7
Scale 1: 4000
Date: 01/09/99

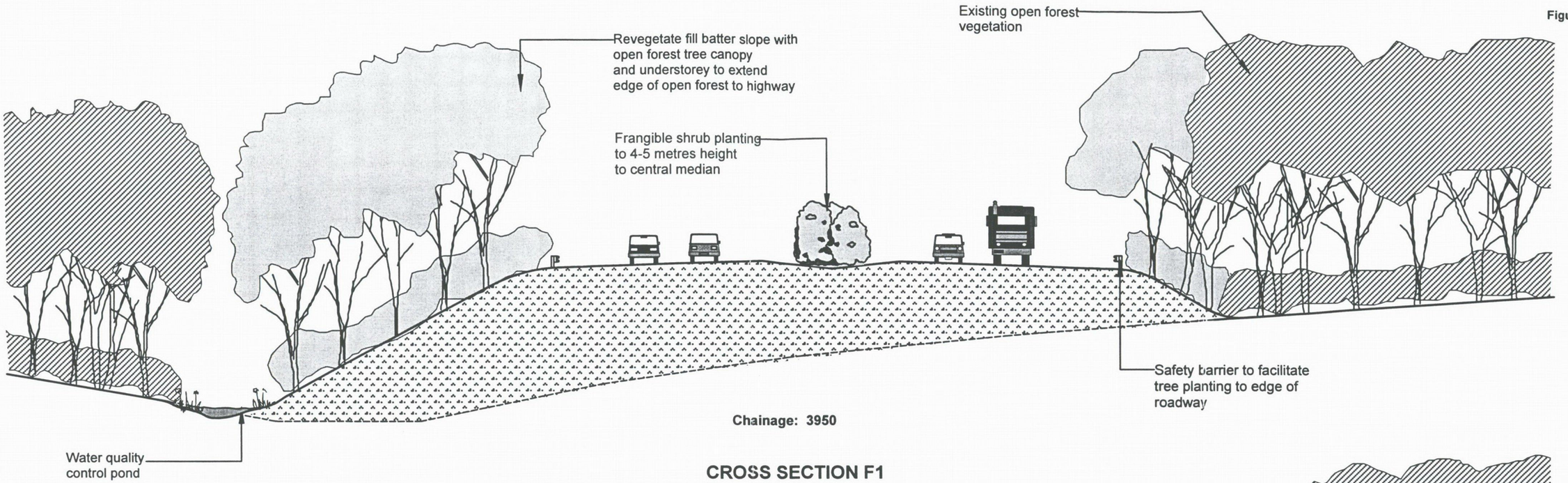
PACIFIC HIGHWAY UPGRADE, KARUAH.

Figure 3.8



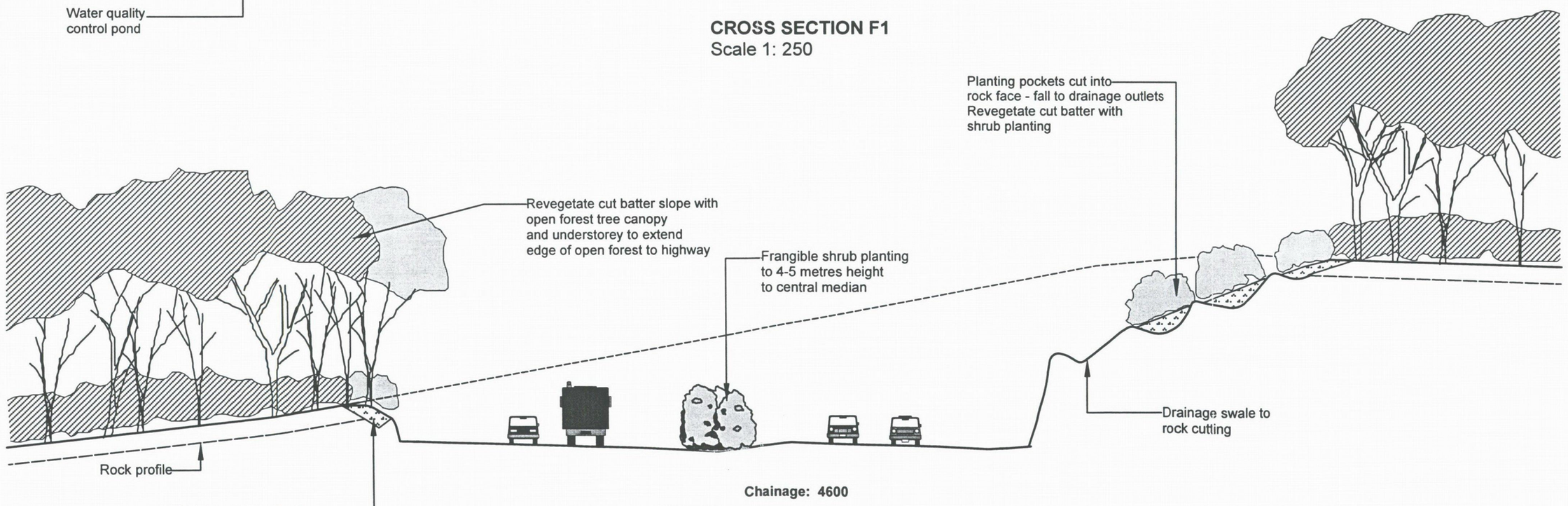
Chainage: 3700

CROSS SECTION E
Scale 1:400



Chainage: 3950

CROSS SECTION F1
Scale 1: 250



Chainage: 4600

CROSS SECTION F2
Scale 1: 250

3.2.4 - AREA IV
(refer figures 3.10, 3.11 & 3.12)

Engineering Design Requirements

- Bridge crossings across wetland areas to incorporate construction controls to limit disturbance of existing vegetation during footing and concrete pier construction.

- Vegetation clearing to relate to earthworks zones only, with protective fencing at limit of earthworks.

Landscape and Urban Design Proposals

- Fill embankments related to western abutment at Horse Island bridge (chainage 5000) are to be revegetated to integrate with adjoining open forest vegetation of the Karuah Nature Reserve. Safety barrier to embankments of steeper than 1(v):3(h) grade enables tree planting to adjacent road shoulder.

- Revegetate fill embankment slopes to crossing of Horse Island - incorporate 5 litre advanced tree stock to optimise revegetation of visually sensitive earthworks zones.

- Revegetate fill embankments to eastern side of river to consolidate strip of open forest broken by highway alignment.

Key Issues for Ongoing Design Development

- Limit extent of earthworks related to Horse Island crossing to optimise tree retention in particular to the southern side of the alignment.

3.2.5 - AREA V
(refer figures 3.13, 3.14)

Engineering Design Requirements

- Fill embankments adjoining open pastoral areas to be extended where existing trees and availability of fill material allow better integration with undulating character of adjoining areas.

- Major cutting through saddle landform (to 25 metres max depth) precludes soft landscape treatment. Drainage terraces to rock face should be retained as clean rockface due to difficulties in vegetation establishment and maintenance.

- Provide benching of rock cuttings to follow natural bedding planes where possible of rock strata to provide informal visual character.

Landscape and Urban Design Proposals

- Fill embankments adjoining pastoral grasslands to be revegetated with native grasses to provide visual integration to grassland character and maintain open views from roadway. The use of pastoral grasses should be considered at detailed design stage contingent on whether the embankment areas will be open to grazing use (with stockproof fence optionally located towards top of embankment as indicated on Cross Section K)

- To cutting embankments adjoining open forest vegetation provide revegetation to zones above exposed rock faces.

- Median strip planting of mixed site understorey (Woodland/Open Forest) and other functional shrub and groundcover plantings to meet functional and aesthetic requirements (as identified for Area 1) provided to varied width planted zones.

Key Issues For Ongoing Design Development

- The integration of native grassing to fill embankments with existing pastoral grasslands should be considered carefully to determine preferred approach to maintain visual continuity. Native grass revegetation will be appropriate where gradients exceed 1(v):3(h), a low maintenance treatment is required, and fencing to pastoral areas restricts access to embankment areas. However, to extended batters where boundary fencing is located other than at the extent of earthwork zones, the use of exotic pasture grass species to integrate with adjoining pastoral grasses will be appropriate.

RECOMMEDED PLANTINGS - Landscape Concept Plan Area IV -
Landscape Units 6,7 & 8
Open Forest and Estuarine Wetland

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES			SHRUBS			GROUNDCOVERS		
Species	**Unit**	**Treatment**	**Species**	**Unit**	**Treatment**	**Species**	**Unit**	**Treatment**
Upper Canopy Trees			*Acacia falcata*	7	T1	*Baumea juncea*	6	T1
Angophora costata	6,7	T1, T2, H	*Acacia longifolia*	6	T1	*Imperata cylindrica*	7	T1, H
Angophora floribunda	6	T1	*Acacia myrtifolia*	7	T1	*Juncus kraussi*	6	T1
Corymbia gumifera	7	T1, T2, H	*Banksia serrata*	7	T1, T2, H	*Lomandra obliqua*	7	T1, H
Eucalyptus amplifolia spp	6	T1	*Banksia spinulosa*	7	T1, H	*Sporobolus virginicus*	6	T1
amplifolia			*var collina*			*var major*		
Eucalyptus robusta	6	T1	*Bossiaea obcordata*	7	T1, M	*Themeda australis*	7	T1, H
Eucalyptus fibrosa spp	7	T1, T2	*Dillwynia retorta*	7	T1, M, H			
fibrosa			*Hakea sericea*	7	T1			
Eucalyptus microcorys	7	T1, T2, H	*Kunzea ambigua*	7	T1			
Eucalyptus mocuccana	7	T1, T2	*Lomandra longifolia*	7	T1			
Eucalyptus piperita	7	T1, T2	*Persoonia levis*	7	T1, H	**ESTUARINE WETLAND VEGETATION**		
Eucalyptus umbra	7	T1, T2, H				**Species**	**Unit**	**Treatment**
Syncarpia glomulifera	7	T1, T2						
						Mudflats		
Mid-Canopy Trees/ Shrubs						*Aegiceras corniculatum*	6	T1
Acnema smithii	7	T1, H				*Avicennia marina*	6	T1
Casuarina glauca	6	T1, T2, H				*var australasica*		
Callistemon salignus	7	T1, H						
Ceratopelatum gummiferum	7	T1				**Saltmarsh and sedgeland**		
Melaleuca linariifolia	6,7	T1, H				*Phragmites australis*	6	T1
Melaleuca nodosa	6,7	T1, H				*Sarcocornia quinqueflora*	6	T1
Melaleuca styphelioides	6,7	T1, H				*Zoysia macrantha*	6	T1

KEY

- Existing open forest vegetation to be retained/ protected
- Existing open grassland
- Existing Salt Marsh areas
- Existing Mangrove Woodland
- Woodland revegetation - Tubestock planting
- Woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Existing Estuarine Wetland vegetation to be protected
- Native grasses hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Water quality pond

KARUAH

HORSE ISLAND

Landscape Unit 8

Landscape Unit 6

Landscape Unit 7

Lay by provided to northbound carriageway at chainage 5400

Lay by provided to southbound carriageway at chainage 5460

Landscape Unit 6

Revegetate visually sensitive fill embankment slopes

Landscape Unit 5

Ch: 6000

Dam

Landscape Unit 9
Adjoins Concept Plan Area V

Landscape Unit 8

Landscape Unit 6

Foreshore Mudflat Mangrove Stands

Ch: 5000

Landscape Unit 7

Landscape Unit 6

Adjoins Concept Plan Area III

Provide supplemental spot planting of open forest tree and shrub species

Foreshore Salt Marsh

Dam

Fauna and drainage underpass

SEPP 14 WETLANDS

RIVER

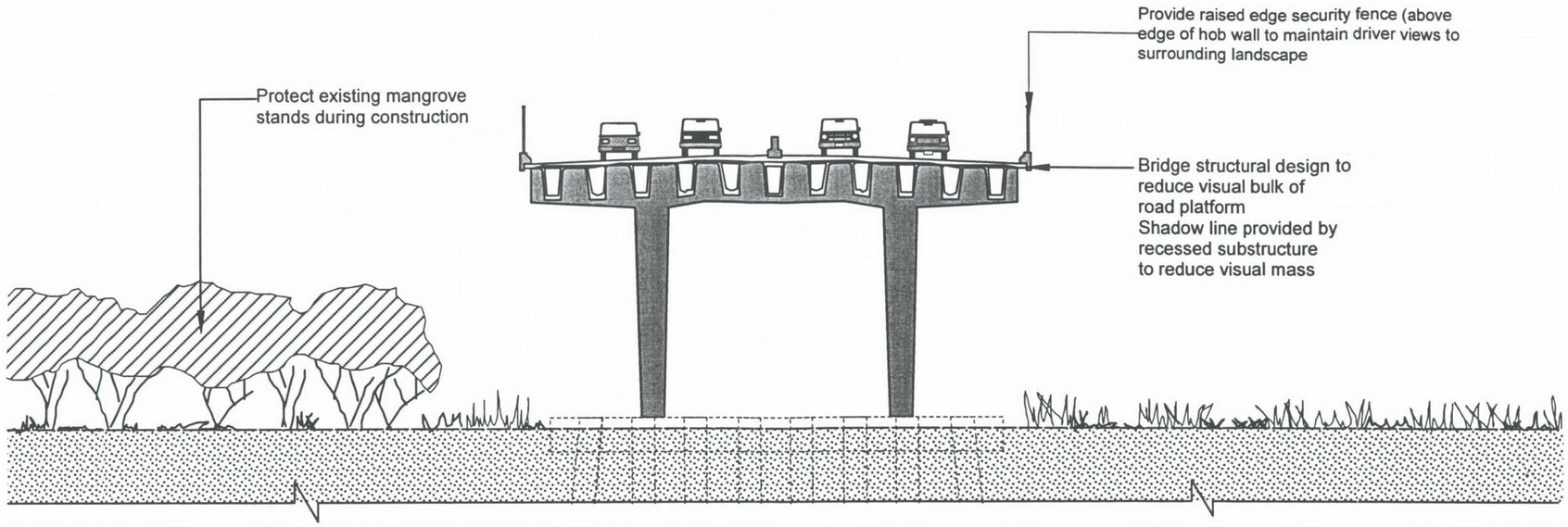
0 10 20 50 100

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN
Area IV

Figure 3.10
Scale 1: 4000
Date: 01/09/99

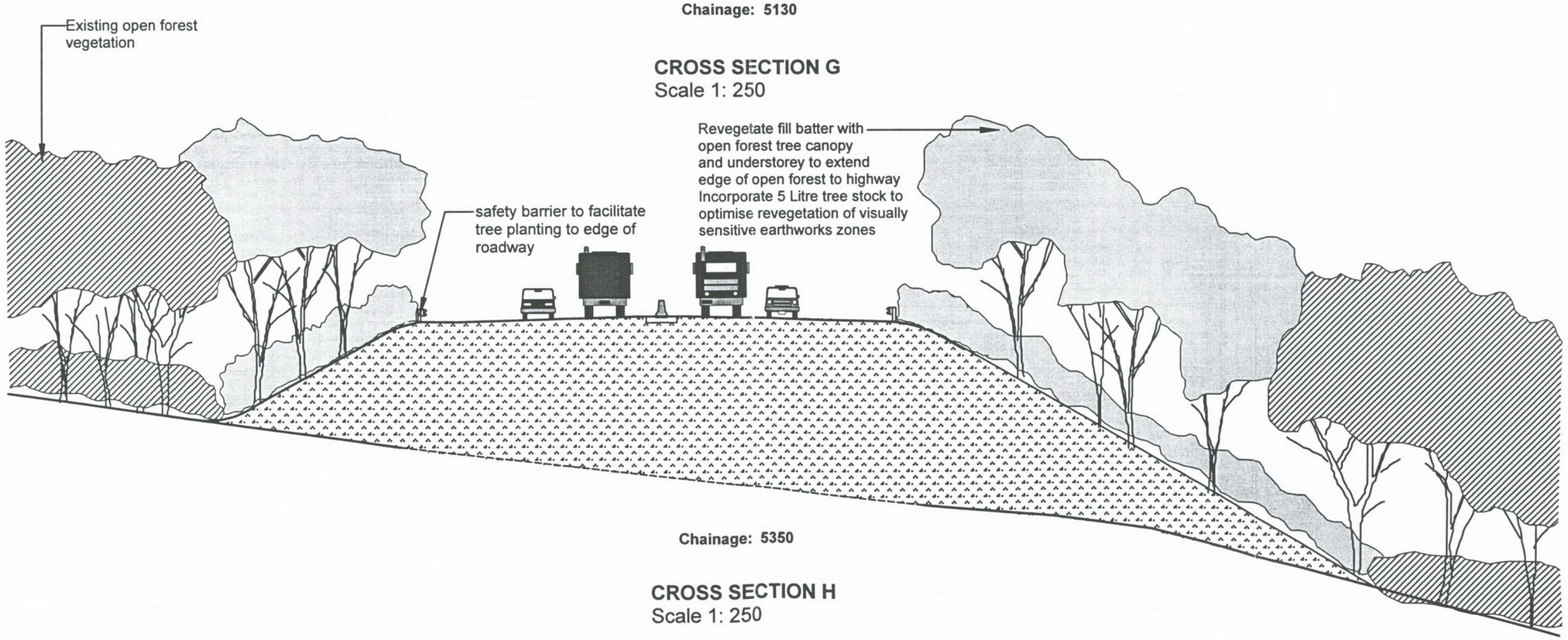
PACIFIC HIGHWAY UPGRADE, KARUAH.

Figure 3.11



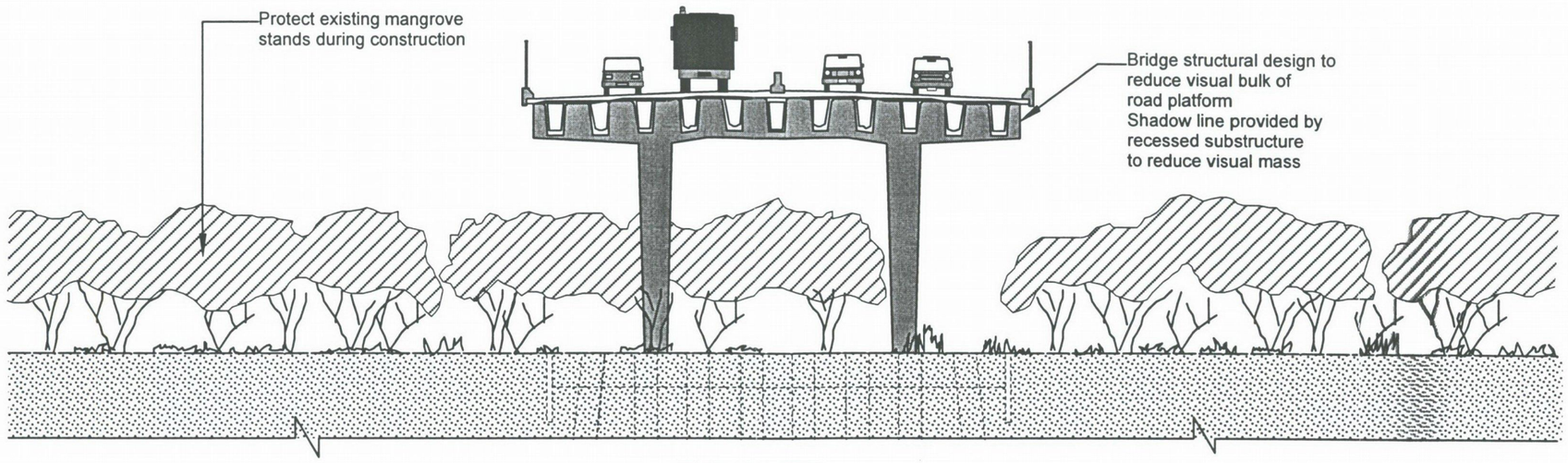
Chainage: 5130

CROSS SECTION G
Scale 1: 250



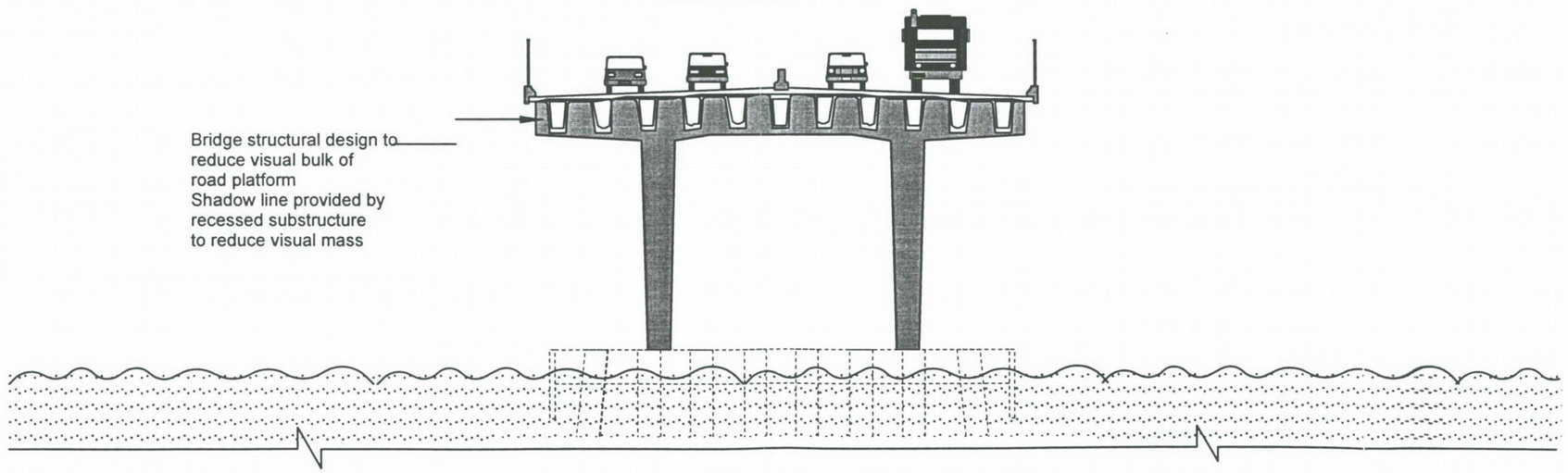
Chainage: 5350

CROSS SECTION H
Scale 1: 250



Chainage: 5560

CROSS SECTION I
Scale 1: 250



Chainage: 5800

CROSS SECTION J
Scale 1: 250

RECOMMEDED PLANTINGS - Landscape Concept Plan Area V- Landscape Unit 9 Open Forest/ Cleared Rural areas

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES		SHRUBS		GROUNDCOVERS	
Species	**Treatment**	**Species**	**Treatment**	**Species**	**Treatment**
Upper Canopy Trees		*Acacia falcata*	T1	*Billardiera scandens*	T1, H
Angophora costata	T1, T2, H	*Acacia myrtifolia*	T1	*Chionochloa pallida*	T1, T2, H
Corymbia gumifera	T1, T2, H	*Banksia serrata*	T1, T2, H	*Cynodon dactylon*	H
Eucalyptus amplifolia spp	T1, T2	*Banksia spinulosa*	T1, H	*Dianella caerulea*	T1, T2, H
amplifolia		*var collina*		*var producta*	
Eucalyptus fibrosa spp	T1, T2	*Bossiaea obcordata*	T1, M	*Goodenia heterophylla*	T1, H
fibrosa		*Dillwynia retorta*	T1, M, H	*Hardenbergia violacea*	T1
Eucalyptus microcorys	T1, T2, H	*Hakea sericea*	T1, M, H	*Hypericum gramineum*	T1
Eucalyptus moluccana	T1, T2	*Kunzea ambigua*	T1, M	*Imperata cylindrica*	T1, T2, M,
Eucalyptus piperita	T1, T2	*Lomandra longifolia*	T1,T2,M,H,G	*var major*	H, G
Eucalyptus robusta	T1, T2	*Persoonia levis*	T1, M	*Lomandra obliqua*	T1, H
Eucalyptus umbra	T1, T2, H			*Pteridium esculentum*	T1,T2,M,H,G
Syncarpia glomulifera	T1, T2			*Themeda australis*	T1,T2,M,H,G
				Xanthosia pilosa	T1, M
Mid-Canopy Trees/ Shrubs					
Acnema smithii	T1, H				
Callistemon salignus	T1, H				
Ceratopelatum gummiferum	T1				
Melaleuca nodosa	T1, H				
Melaleuca styphelioides	T1, H				

KEY

- Existing open forest vegetation to be retained/ protected
- Existing open grassland
- Existing Salt Marsh areas
- Existing mudflat mangroves
- Woodland revegetation - Tubestock planting
- Woodland revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip vegetation - Tubestock planting
- Sandstone Rockface: excavate along natural bedding planes of rock strata
- Native grass hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Water quality pond

Native grass revegetation of fill embankments

1-2 m width native shrub planting zone against safety barrier gravel surfacing of median

Organic weathering treatment to cut sandstone face

Lay by provided to northbound carriageway at chainage 6440

Lay by provided to southbound carriageway at chainage 6410

Landscape Unit 8

Landscape Unit 9a

Landscape Unit 9b

Landscape Unit 9b

Landscape Unit 9c

Bridge over Mosquito Creek

Median crossover provided at chainage 7380

Landscape Unit 9

Ch: 6500

Ch: 7000

Ch: 7500

Ch: 6000

Dam

Dam

Landscape Unit 9 Adjoins Concept Plan Area IV

Landscape Unit 10 Adjoins Concept Plan Area VI

Access road culvert underpass

ACCESS TRAIL

KARUAH RIVER

Foreshore Mudflat Mangrove Stands

Salt Marsh

90 20 30 40

0 10 20 50 100

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN Area V

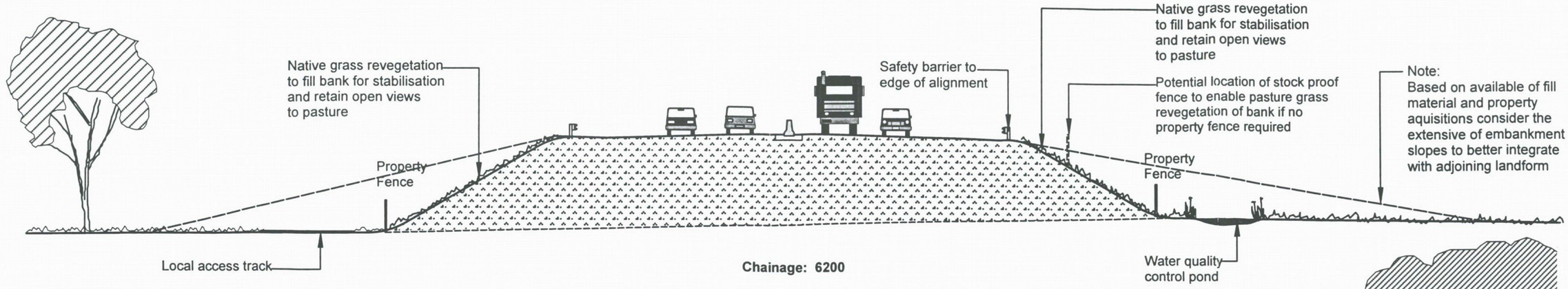
Figure 3.13

Scale 1: 4000

Date: 01/09/99

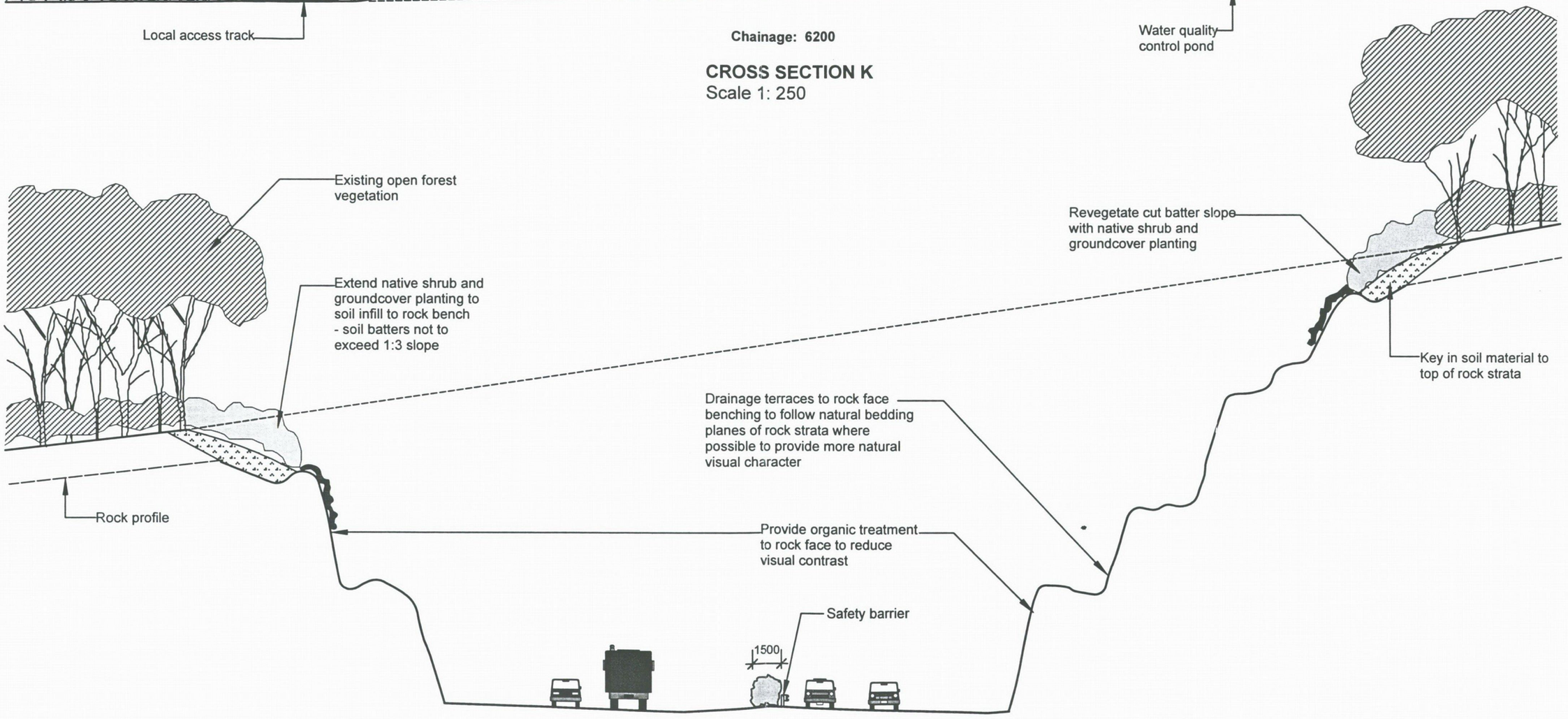
PACIFIC HIGHWAY UPGRADE, KARUAH.

Figure 3.14



Chainage: 6200

CROSS SECTION K
Scale 1: 250



Chainage: 6800

CROSS SECTION L
Scale 1: 250

3.2.6 - AREA VI
(refer figures 3.15, 3.16 & 3.17)

Engineering Design Requirements

- Extent of earthworks through open forest drainage gully of Mosquito Creek to be limited through provision of embankment slopes of steeper than 1(v):3(h) - provision of vehicular safety barriers should enable tree planting to embankment up to the road shoulder.

- Fill embankment slopes to eastern side of corridor east of chainage 7800 to be extended where existing trees, and fill material availability allow better integration of the embankment slopes with the undulating landform of the open pastures.

- Excavation embankments to west side of corridor to integrate shallow terracing to enable retention of soil pockets to maximum 1(v):3(h) gradients on bedrock that can support grass cover establishment.

Landscape and Urban Design Proposals

- Fill embankments to areas adjoining drainage gully to be revegetated with open forest species. Safety barrier to enable tree planting to top of embankment.

- Median strip planting of mixed site indigenous (Open Forest) shrub and groundcover plantings to meet functional and aesthetic requirements (as identified for Area 1).

- Fill and cut batter slopes to be revegetated with pasture grass species, where maintenance will be possible or grazing activities may extend onto earthworks zone (with the provision of appropriate stockproof fencing to roadway).

- To areas where maintenance potential/capacity is low, provide native grassing cover of low growing species to maintain visual continuity with open pastures.

Key Issues for Ongoing Design Development

- Engineering treatment of rock face to western side of corridor to facilitate soil installation and grass establishment. Consider ongoing stability (particularly in high rainfall) of soft landscaping overlain to rock based on detailed geotechnical information.

3.2.7 - AREA VII
(refer figures 3.18, 3.19)

Engineering Construction Requirements

- Extent of vegetation clearance to be controlled adjoining open forest areas at eastern interchange.

Landscape and Urban Design Proposals

- To excavated banks of corridor through partially cleared woodland provide revegetation with pasture grass species to match existing open character.

- Revegetation of fill embankments to corridor through eastern interchange to incorporate varied treatments based on embankment condition and vehicular sight line requirements:

- Open Forest Revegetation:
  to embankments adjoining open forest zones to continue vegetation corridor from south to north
- Native Grassland Revegetation:
  to embankment and graded areas where low maintenance landscape treatment maintaining sight lines adjacent vehicular intersections is required.

- Median strip planting of mixed site indigenous understorey (Open Forest) and other native shrub and groundcover plantings to meet functional and aesthetic requirements (as identified for Area 1) provided to 8 metre width planted zone.

- Gateway avenue planting of *Angophora costata* adjacent bypass interchange and northern exit with understorey of native grasses - consider uplighting of tree canopy to enhance gateway effect.

  Angophora species reflect natural qualities of local environment and offer the optimum sculptural qualities of the locally indigenous species range.

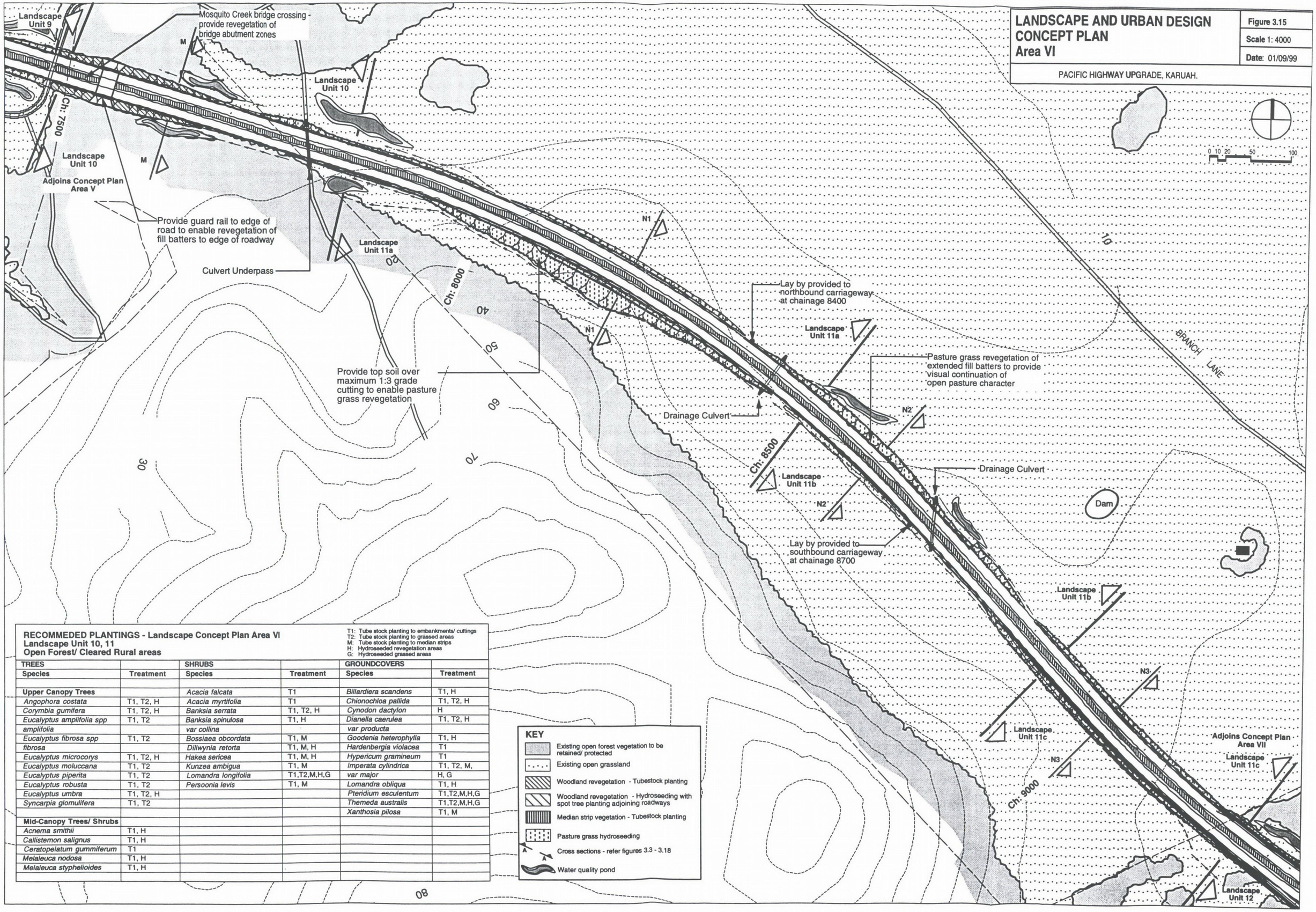
Key Issues for Ongoing Design Development

- Detailed planting scheme to respond to final intersection configuration of local access roads.

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN
Area VI

Figure 3.15
Scale 1: 4000
Date: 01/09/99

PACIFIC HIGHWAY UPGRADE, KARUAH.



RECOMMEDED PLANTINGS - Landscape Concept Plan Area VI
Landscape Unit 10, 11
Open Forest/ Cleared Rural areas

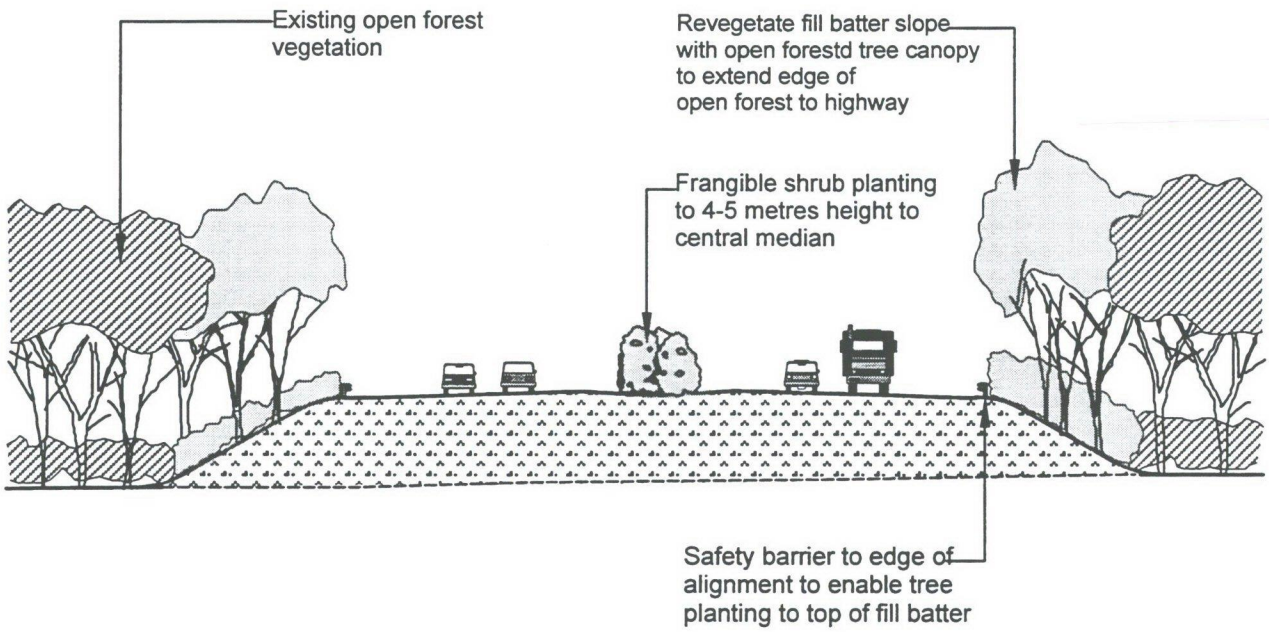
T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES		SHRUBS		GROUNDCOVERS	
Species	**Treatment**	**Species**	**Treatment**	**Species**	**Treatment**
Upper Canopy Trees		*Acacia falcata*	T1	*Billardiera scandens*	T1, H
Angophora costata	T1, T2, H	*Acacia myrtifolia*	T1	*Chionochloa pallida*	T1, T2, H
Corymbia gumifera	T1, T2, H	*Banksia serrata*	T1, T2, H	*Cynodon dactylon*	H
Eucalyptus amplifolia spp	T1, T2	*Banksia spinulosa*	T1, H	*Dianella caerulea*	T1, T2, H
amplifolia		*var collina*		*var producta*	
Eucalyptus fibrosa spp	T1, T2	*Bossiaea obcordata*	T1, M	*Goodenia heterophylla*	T1, H
fibrosa		*Dillwynia retorta*	T1, M, H	*Hardenbergia violacea*	T1
Eucalyptus microcorys	T1, T2, H	*Hakea sericea*	T1, M, H	*Hypericum gramineum*	T1
Eucalyptus moluccana	T1, T2	*Kunzea ambigua*	T1, M	*Imperata cylindrica*	T1, T2, M,
Eucalyptus piperita	T1, T2	*Lomandra longifolia*	T1,T2,M,H,G	*var major*	H, G
Eucalyptus robusta	T1, T2	*Persoonia levis*	T1, M	*Lomandra obliqua*	T1, H
Eucalyptus umbra	T1, T2, H			*Pteridium esculentum*	T1,T2,M,H,G
Syncarpia glomulifera	T1, T2			*Themeda australis*	T1,T2,M,H,G
				Xanthosia pilosa	T1, M
Mid-Canopy Trees/ Shrubs					
Acnema smithii	T1, H				
Callistemon salignus	T1, H				
Ceratopelatum gummiferum	T1				
Melaleuca nodosa	T1, H				
Melaleuca styphelioides	T1, H				

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 - refer figures 3.3 - 3.18
- Water quality pond

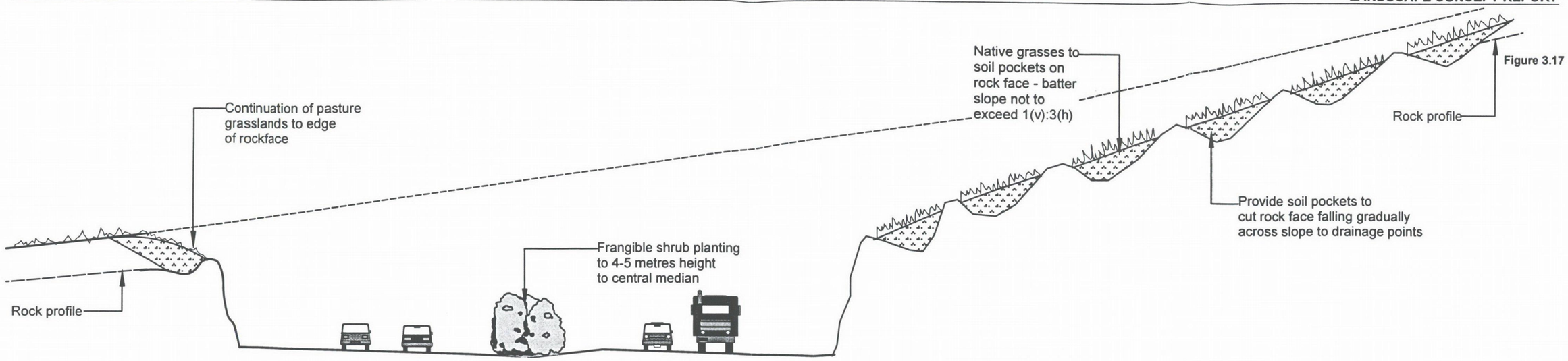
Figure 3.16



Chainage: 7600

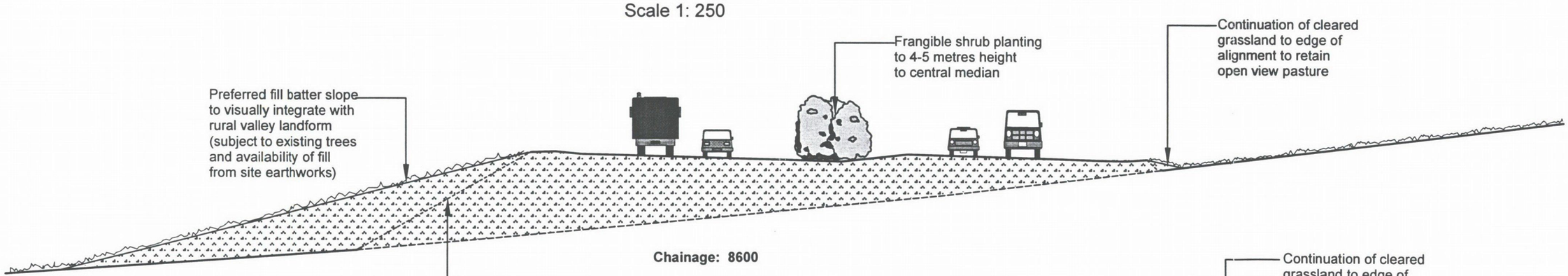
CROSS SECTION M
Scale 1:400

Figure 3.17



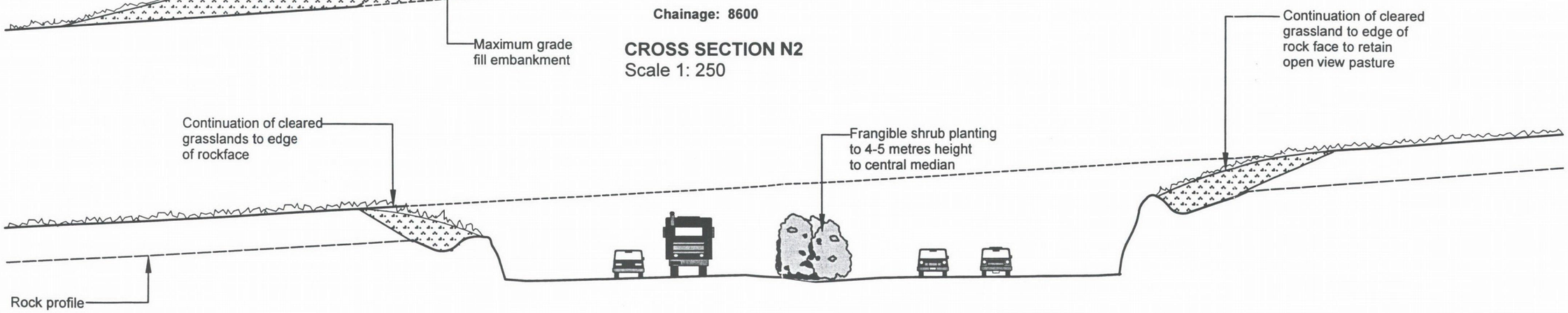
Chainage: 8250

CROSS SECTION N1
Scale 1: 250



Chainage: 8600

CROSS SECTION N2
Scale 1: 250



Chainage: 9000

CROSS SECTION N3
Scale 1: 250

RECOMMEDED PLANTINGS - Landscape Concept Plan Area VII - Landscape Units 12 / 13a Cleared Rural Areas/ Open Forest

T1: Tube stock planting to embankments/ cuttings
T2: Tube stock planting to grassed areas
M: Tube stock planting to median strips
H: Hydroseeded revegetation areas
G: Hydroseeded grassed areas

TREES		SHRUBS		GROUNDCOVERS	
Species	**Treatment**	**Species**	**Treatment**	**Species**	**Treatment**
Upper Canopy Trees		*Acacia falcata*	T1	*Billardiera scandens*	T1, H
Angophora costata	T1, T2, H	*Acacia myrtifolia*	T1	*Chionochloa pallida*	T1, T2, H
Corymbia gumifera	T1, T2, H	*Banksia serrata*	T1, T2, H	*Cynodon dactylon*	H
Eucalyptus fibrosa spp	T1, T2	*Banksia spinulosa*	T1, H	*Dianella caerulea*	T1, T2, H
fibrosa		*var collina*		*var producta*	
Eucalyptus microcorys	T1, T2, H	*Bossiaea obcordata*	T1, M	*Goodenia heterophylla*	T1, H
Eucalyptus moluccana	T1, T2	*Dillwynia retorta*	T1, M, H	*Hardenbergia violacea*	T1
Eucalyptus piperita	T1, T2	*Hakea sericea*	T1, M, H	*Hypericum gramineum*	T1
Eucalyptus umbra	T1, T2, H	*Kunzea ambigua*	T1, M	*Imperata cylindrica*	T1, T2, M,
Syncarpia glomulifera	T1, T2	*Lomandra longifolia*	T1,T2,M,H,G	*var major*	H, G
		Persoonia levis	T1, M	*Lomandra obliqua*	T1, H
Mid-Canopy Trees/ Shrubs				*Pteridium esculentum*	T1,T2,M,H,G
Acnema smithii	T1, H			*Themeda australis*	T1,T2,M,H,G
Callistemon salignus	T1, H			*Xanthosia pilosa*	T1, M
Ceratopelatum gummiferum	T1				
Melaleuca nodosa	T1, H				
Melaleuca styphelioides	T1, H				

KEY

- Existing vegetation to be retained/ protected
- Existing open grassland
- Open forest revegetation - Tubestock planting
- Open forest revegetation - Hydroseeding with spot tree planting adjoining roadways
- Median strip vegetation - Tubestock planting
- Pasture grasses hydroseeding
- Native grasses hydroseeding
- Cross sections - refer figures 3.3 - 3.18
- Avenue Planting of *Angophora costata* with native grass understorey
- Water quality pond

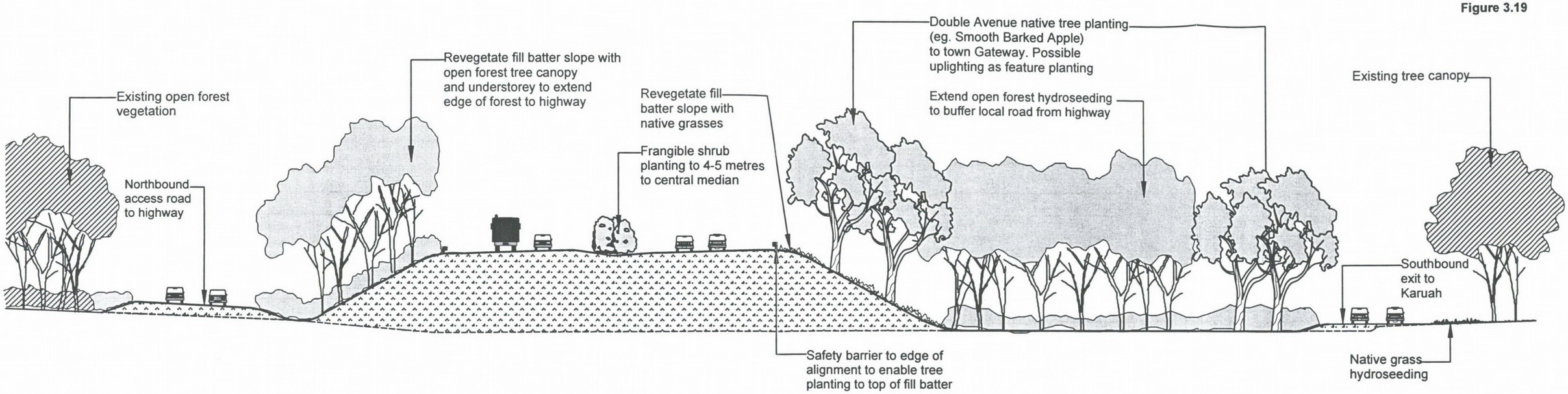
Dam
BRANCH LANE
Landscape Unit 11b
N3
Landscape Unit 11c
N3
Adjoins Concept Plan Area VI
Landscape Unit 11c
Ch: 9000
Drainage Culvert
Landscape Unit 12
Landscape Unit 12
Landscape Unit 13b
QUARRY
P
P
Landscape Unit 13b
Ch: 10000
Formal entry avenue planting of *Angophora costata* (25 Litre size) Consider potential uplighting of tree canopy
09
50
20
40
80
50
10
0 10 20 50 100

LANDSCAPE AND URBAN DESIGN CONCEPT PLAN Area VII

Figure 3.18
Scale 1: 4000
Date: 01/09/99

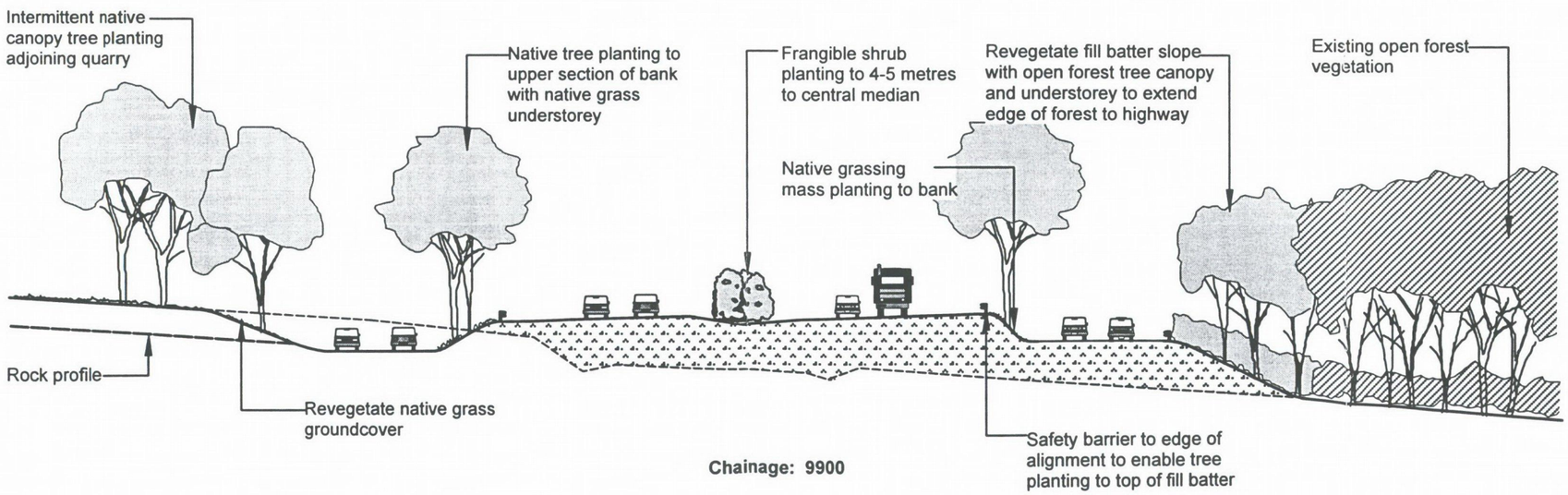
PACIFIC HIGHWAY UPGRADE, KARUAH.

Figure 3.19



Chainage: 9700

CROSS SECTION O
Scale 1: 400



Chainage: 9900

CROSS SECTION P
Scale 1: 400

3.3 Landscape and Urban Design Treatments

The following sections describe the key aspects of the preceding landscape proposals, in particular the planning, design and implementation requirements for successful realisation of landscape and urban design objectives.

3.3.1 Vegetation Clearing

As identified in the Concept Plan descriptions, due to the alignment of the corridor through extensive areas of woodland and open forest vegetation (in particular on the western side of the Karuah River), the careful definition and limitation of vegetation clearing for earthworks should be a fundamental principle of detailed engineering design.

The conservation of existing vegetation cover will assist in reducing potential environmental impact on flora qualities, in addition to protecting fauna habitat and fauna corridors through the area. The passage of the highway route through the woodland and open forest environments of Karuah will also provide a memorable experience for road users.

Suggested measures for the limitation of the extent of earthworks include:

1. Incorporate as a basic design parameter the limitation of the extent of earthworks where the corridor adjoins existing woodland or open forest vegetation.

2. Provide construction controls to define extent of earthworks including appropriate protective fencing, and erosion/soil control fencing.

3. Stage and organise construction to reduce the need for construction access off the corridor alignment, and related earthworks areas.

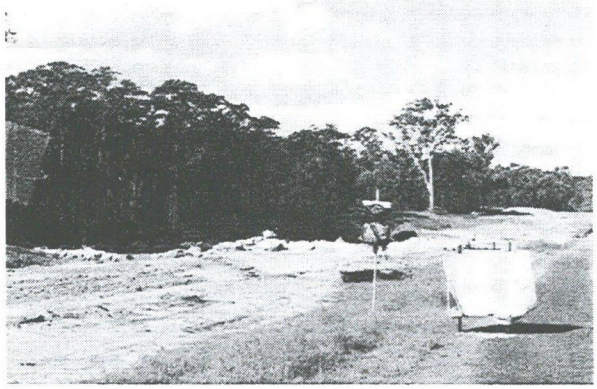
4. Final location and design of stormwater detention ponds to conserve native tree specimens wherever possible.

Engineering design must have regard to the fact that as a minimum the ground surface within the canopy (drip line) of trees should not be disturbed through either excavation or filling works. Native trees are particularly sensitive to such disturbances.

A further issue for consideration is the impact of the earthworks on natural drainage regimes both on and below the ground surface. The route runs parallel to natural contours for a high proportion of its route, and crosses natural drainage gullies in numerous locations. Native plant systems are sensitive to such impacts and measures to ameliorate the degree of change to natural drainage patterns including drainage underpasses should be incorporated.

Mulching of cleared material

Selected native plant material cleared from the corridor should be mulched on site for reuse in landscape works. Material incorporated in mulching should be carefully sorted to ensure that undesirable species (with vigorous germination and suckering habits - eg. Acacias) are not spread through the site. A mulching plan identifying suitable species should be prepared as part of the construction phase Environmental Management Plan. The plan would also identify that mulched material should be used within the vegetation community from which it originated.



Above: Road widening clearing in the vicinity of the western interchange - retention of existing tree canopy adjacent to the corridor enhances the visual quality of the road experience and reduces visual impact of construction works.



Right:

Existing vegetation to be cleared should be mulched (canopy trees and understorey) based on a specific mulching strategy incorporating suitable site species

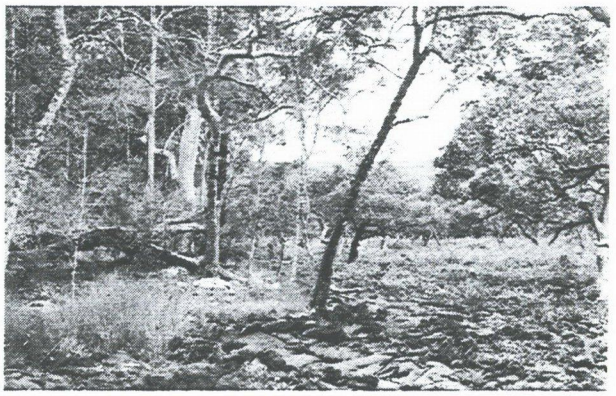
3.3.2 Plant Material Supply

A fundamental requirement of the environmental sustainability of the project should involve the protection of the biological diversity of the local ecosystem. This requires that all plant material for the project (unless justified for functional performance or safety reasons) be propagated from locally (ie. from the immediately adjoining vegetation communities) derived seed stock to protect the flora gene pool. This objective is not onerous given an adequate time frame (ideally 2 years as identified in RTA's *Roadscape Guidelines*) plant material is most effectively (both from a cost and performance perspective) propagated locally from site seed.

For a successful propagation programme, this process requires adequate coordination and programming within the overall project strategy. The process of procuring site seed and propagating tubestock and potted plant material will at the minimum require a 12 month programme. Key phases include:

- March - May — On site collection of seed;
- June - August — Storage of seed - preparation of propagation operation and production estimation, resolution of any potential supply issues; and
- September - March — Available growing season - propagation of 75mm tube stock will involve around 8 weeks, for 150mm potted material around 14 weeks.

Programming requirements should be taken into account in the planning of design development and documentation phases (where plant quantities will be confirmed). A separate plant supply contract to include seed collection, propagation, and delivery to site from a local nursery facility is the most effective approach to this process. This should be based upon an integrated strategy prepared in liaison with the local Council and the National Parks and Wildlife Service. Approval of seed collection will also be required from these management authorities.



Above: The integration of revegetation with existing plant communities is made possible through propagation of plant material from site collected seed stock.

3.3.3 Planting Works

Planting works for the Karuah Upgrade corridor will take the form of several different treatments, typical to broad scale highway corridor landscape works. Guidelines for the procurement, preparation, planting, and maintenance of plant material are provided in the RTA's Roadscape Guidelines. The detailed planting recommendations identified below should be applied in conjunction with these guidelines.

As noted in 3.3.2, programming and forward planning are critical to the success of landscape treatments. Ideally landscape works would be carried out through October-November to enable immediate establishment growth over the growing season.

Key aspects of planting treatments are described following:

1. Preparation

Following clearing, site topsoil should be stripped to a depth to be confirmed on site, and stockpiled at locations along the corridor for reuse. Ideally stockpiles should be of smaller scale at frequent locations to enable re-use in close proximity to the material's origin stockpiles should not exceed 2.5 metres in height. Subject to stockpile locations and side slopes, temporary stabilisation either through non-invasive grass seeding or covering with geotextile may be required. Soils testing should be carried out of the site stockpile to confirm soil chemistry through the various vegetation communities. However soil additives (including organic materials) should be avoided unless deemed absolutely necessary due to the potential change in physical character of the landscaped zone to the pre-existing environment.

After the completion of bulk earthworks to the corridor alignment and completion of engineering works that may affect landscape zones, site topsoil should be respread to consolidated fill and excavated areas to be planted to a minimum of 100mm. To fill batter slopes, and cut slopes above rock strata the respreading soil depth to slopes in excess of 1(v): 3(h) should be reviewed to site specific situations to maintain slope stability. Following respreading the topsoil should be ripped into fill material to 150mm depth.

2. Native revegetation tubestock planting

Planting of propagated tubestock plant material has been proposed on the Concept Plans to the embankment areas related to the corridor that directly adjoining existing Woodland or Open Forest vegetation communities. This revegetation is aimed at conserving the character of these communities and extending vegetation canopy and understorey to the edge of the highway alignment. As described in the concept masterplans, where embankment slopes exceed 1(v):3(h) grade, vehicular safety barriers should be provided enabling the planting of canopy trees to extend to the edge of the road shoulder (incorporating 2 metre clearance to barrier of tree trunks).

2. Native revegetation tubestock planting (continued)

Planting works should follow on from soil works preparation, and mulching of the planted areas with site harvested leaf and bark mulched material. Direct planting into the mulched embankment areas should follow to ensure the tubestock are not buried. Immediate watering and weekly establishment watering should be provided to a programme established to suit site conditions. The establishment of basic irrigation reticulation systems (located to the top of embankments) would be most effective in optimising plant establishment. In situations where water supply is available such provision has proven to be cost beneficial, in relation to labour intensive forms of maintenance.

Notwithstanding maintenance provision, planting layouts and spacings should account for a proportion of plant failure that is unavoidable in broad scale planting situations.

Plastic tree guards for protection from rabbit and native fauna should be provided to all tubestock and potted plantings.

3. Native revegetation hydroseeding

For cost purposes where larger areas require revegetation, hydroseeding of native seed stock should be the preferred treatment . Preparation should be carried out as for tubestock planting up to installation of topsoil. Hydroseeding of a seed mix including site indigenous tree and understorey species along with sterile "nursery crop" species should then be applied followed by hydromulching of mulch material and organic polymer binder.

Final composition of native seed to be incorporated should be carefully balanced through liaison with hydroseeding and horticultural specialist to use only species that will be viable in germination rates.

A higher level of establishment maintenance provision will be required to hydroseeded areas (than planted areas) to achieve satisfactory results. This includes watering in addition to weeding and re-sowing of areas that fail to establish.

4. Median Strip Tubestock planting

The road alignment design incorporates median strip zones that a focus on the necessity to separate and buffer (through planting) headlights of vehicles on opposite carriageways.

Planting works and follow up maintenance to median strips should be carried out as for embankment zones. Final species selection should be carried out in conjunction with the RTA's landscape specialist to agree on the preferred mix of site indigenous and other native planting that may be appropriate. Where horticulturally viable, site indigenous material will be preferred. However due to the particular functional and physical characteristics of these planting areas it is expected that some non - local native planting may be required to achieve the site specific functional and visual requirements of headlight glare reduction.

Generally median plantings (as identified in plant species list - Figure 2.3) are frangible shrub species to meet RTA's *Roadscape Guidelines* - However to proposed aerial fauna crossings where tree plantings to median are preferred (existing and new) vehicle safety barriers are required.

5. Native grass hydroseeding

To open areas between the road corridor and vegetation stands; that adjoin the road alignment, to select locations related to the corridor's interchanges and to areas adjoining open pastures where maintenance (or grazing) will not be achievable, hydroseeding of native grass species is preferred. This approach should provide (after establishment) a low maintenance treatment to areas in which rural grazing will not be carried out and more intensive native landscape treatment is not appropriate in maintaining sight lines for highway traffic.

Preparation and application of treatments would be carried out as for native revegetation hydroseeding. Once again establishment maintenance including watering weeding and fertilisation will be essential to long term quality of treatments. It should be noted that for optimum long term quality of native grass cover yearly maintenance through slashing is desirable.

The resolution of the final seed mix should incorporate site endemic species (such as *Themeda*, and *Lomandra* sp) along with an appropriate sterile nursery crop.

5. Pasture grass hydroseeding

To embankment and cleared areas adjoining open pasture areas where boundary fencing does not preclude maintenance through grazing or slashing, the continuation of pasture grass species is preferred to visually integrate with open pasture character. This treatment should incorporate a non-invasive exotic grass such as Couch species (which are present on site).

3.3.4 Fill Embankments and Cuttings

Fill embankments and cuttings occur along the road alignment to balance the required levels and alignment geometry of the engineering design (for safe and comfortable road travel) with natural landform.

The urban design assessment identified a range of principles for fill embankment and cutting slopes that included:

- Limiting the height and slope of batters adjoining cleared rural areas; and
- Limiting the extent of earthworks (fill and cutting slopes) adjoining woodland and open forest vegetation.

The objective of landscape revegetation of fill embankments and cutting slopes will include the:

- Stabilisation of slope material;
- Integration of slope vegetation cover with adjoining vegetation community to consolidate flora and fauna benefits and continue visual themes; and
- Visual mitigation of earthworks zones from views towards the roadway and from vehicles on the road itself.

Revegetation

Revegetation planting to slopes should incorporate a representative selection of the full strata of adjoining communities including canopy trees, shrub understorey, and groundcover understorey. These should be selected from the plant species last provided in this report based upon functional performance, propagation suitability and longevity.

Tree species for non frangible-shrub plantings will be subject to safety distances in accordance with the RTA's Clear Zone requirements. This will require tree plantings to nominially be set setback:

- 2 metres from the top of slopes provided with safety barriers.
- 9 metres from the top of slopes without safety barriers

To earthworks slopes in cleared pastoral settings it is appropriate that slopes are extended (made flatter) to better integrate with adjoining vegetation. Slopes should be revegetated with native or pastoral grasses to integrate with the adjoining pastoral character and maintain views from the roadway. Intermittent tree planting to continue existing patterns is also appropriate to these zones (see photo this page).



Above: Revegetation of earthworks slopes should integrate with the adjoining vegetation community or vegetation cover (eg. pastoral grass lands).

3.3.5 Bridge and Overpass Structures

Bridge structures to the road alignment occur in several situations. These are described below incorporating the key principles to be achieved in design and integration of the structures:

1. **Future flyover bridge to Western Interchange (northbound Karuah exit).**

- Marks gateway to Karuah Township - as such provides the opportunities to provide a landmark structure integrated with the raised abutments either side of the highway.

2. **Overpass bridges to Scotts Road and Mines Hill Trail**

- Located where the alignment is in cutting to better integrate with landform (ie. no fill embankments to abutments).
- Structure to be highly visible located at the focus of straight sections of road where drivers sight line will be directed.
- Need to be simple structures of "light" elevational mass to avoid distracting drivers attention and integrating with the adjoining natural setting.

3. **Wetland Bridge to Horse Island**

- Bridge structure should have themed design relationship with Karuah River Bridge to provide visual unity for motorists and for views from Karuah River.
- Provides the first major opening of views to the adjoining landscape and beyond - view access for motorists should be optimised.
- Construction should have regard to environmental management requirements for saltmarsh vegetation community and related fauna.

4. **Karuah River Bridge**

- Is the major engineered structure of the roadway, and its most visible element to the surrounding region.
- Design of elevation and support structures should be related to the strong horizontal character of the river environment. As such a level (flat) linear structure is preferred to arching structures, or those with framed or cautilevered support (refer figure 3.4.1).
- Provide panoramic views of river and adjoining hinterland - visual access for motorists should be optimised by careful design of bridge railways/barriers consistent with safety requirements.

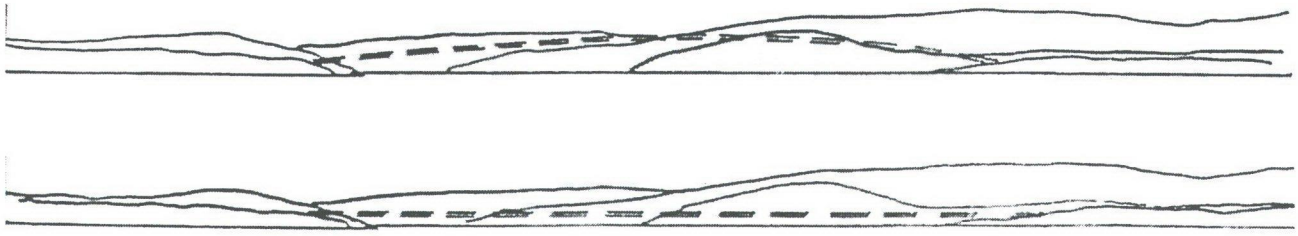
5. **Creek Bridge Crossings**

- Occur east of the Karuah River - structures will not be easily viewed however should provide a simple elegant form (eg. concrete arch).
- Wall faces over 2 metres height should be considered for some form of articulation (see figure 3.4.6) to reduce visual mass.

6. **Culvert Crossings for drainage fauna**

- Occur along the length of the corridor and whilst not heavily viewed, should integrate with the design theme of the Creek Bridge Crossings (refer figure 3.4.8 for additional detail for fauna underpasses).

Bridge forms that do not integrate with the river visual setting and horizon line will draw viewers attention and become features on the landscape



Bridge form that respond to the linear visual setting of the river will better integrate and remain objects "in the landscape"

Figure 3.4.1

3.3.6 Walls

Walls will occur on the proposed alignment in several situations:

- Bridge abutments to overpass bridges
- Bridge abutments to major bridges (eg Horse Island and Karuah River)
- Culvert underpases (drainage and fauna)

A themed treatment to walls should be provided to ensure a level of visual unity between the different situations that occur and also integrate with the design and proportions of the individual structures.

This may take the form of shadow lines to concrete facing, or the use of precast panels in a geometric arrangement to provide a coursing effect reducing the visual mass of the walls.

3.4.7 Water Quality Control Ponds

Water quality control ponds have been located to intercept runoff from the road alignment both during construction and for long term road operation. As such the ponds are located between low points in the road elevation and natural drainage lines.

As outlined in the RTA's *Roadscape Guidelines* and the Urban Design Assessment for the project it is preferred that the design of the ponds provide a natural form that integrates with the adjoining landform and vegetation.

Whilst this may mean specific design of each pond to create more linear pond shapes that relate to the position of existing trees, this process will ensure that these essential water quality management measures integrate with the adjoining landscape setting, and are not obviously man made structures.

Alternatively to the sections of the alignment adjoining cleared pastoral lands of rural character, it may be appropriate that design of ponds be more formal to visually echo rural dams as elements in the landscape.

The channels and swales that feed the ponds must also integrate with the landscape setting. Given the undulating topography of the route it is preferred in most cases that the channels be of vegetated surface (optimising filtration) and of gentle side slope and longitudinal gradient.

3.3.8 Fauna Crossings

A key aspect of road design in particular to the heavily vegetated sections west of the Karuah River is the maintenance of fauna movement corridors.

Due to the predominantly cleared nature of the alignment east of the river native fauna movement will tend to be concentrated to the forested ridgelines that run north south.

Fauna movement crossings will occur in three forms:

1. Culvert underpasses of roadway

- Occur predominantly to the alignment west of the Karuah River and double as drainage connections for natural drainage lines.
- Given their potential dual purpose, the underpasses must be of adequate scale and clearance to ensure that the crossing is not made inpassable in times of rainfall.
- The underpass should be landscaped with appropriate vegetation and rock/ timber elements to provide cover for the range of fauna habitating area. A fauna expert should be involved in the final design of these treatments (see figure 3.4.2).

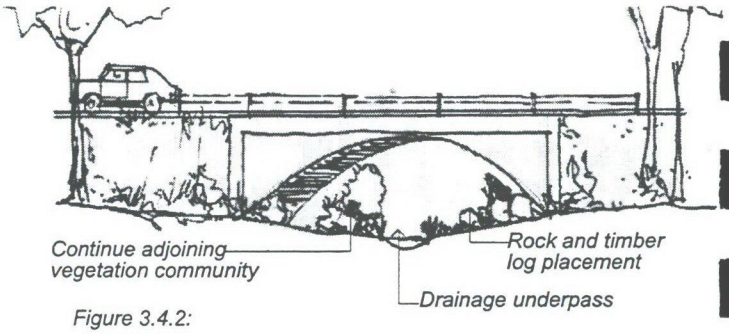


Figure 3.4.2:

2. Aerial Fauna Crossings

- Located at several points west of the Karuah River to woodland and forest areas supporting bat habitat and foraging amenity.
- Provided where road alignment is at natural grade limiting the extent of earthworks and optimising the degree of tree retention possible to the road verges and central median. With provision of safety barriers (enabling trees with 2 metres) the gaps in tree canopy created by the roadway are aimed to be limited, thus enhancing the potential for continuation of bat movement and foraging.
- Final earthworks design (incorporating tree retention) and supplementary planting should be carried out in consultation with Fauna Consultants. The provision of elemental rest/resting boxes to areas without significant existing tree canopy should be considered. Design should incorporate timber posts to provide escape routes for ground habitating fauna from predators and to assist in the movement of aerial/arboreal fauna.

3.4.9 Signage, Vehicle Barriers, and Lighting

The RTA's *Roadscape Guidelines* identify principles and design requirements for roadscape furniture that should be recognised in final design, selection and placement of these elements.

In general, the guidelines and the Urban Design Assessment for this project have identified that r oadscape furniture should form a unified palette of treatments that provide a themed approach, and (in the case of a road corridor such as Karuah through natural and semi rural environments) are low key visual elements remaining dominated by the landscape character.

Key design principles for each of the roadscape elements for the Karuah Upgrade are:

Signage:

- Signage to the road corridor should be generally reduced but where required, provided as a grouped approach to limit visual impact whilst recognising functional and safety criteria.
- Roadside advertising is not appropriate to the natural/ semi rural character of the landscape setting.

Vehicular Barriers:

- Vehicular barriers to roadside and median situations should follow one design theme (to avoid visual clutter)
- Post and wire rope barriers that are of lower visibility against adjoining vegetation are preferred to solid concrete barriers or standard W - beam guardrails.

Lighting:

- Roadway lighting should be limited to the interchange facilities (to meet RTA's Standards) to avoid disturbance of the fauna amenity of adjoining areas.
- To island areas formed at the two interchanges where formal native avenue planting is proposed, the use of subtle uplighting of the trees to provide enhancement of the gateway experience from road users may be considered.

3.3.10 Gateway Treatments

The RTA's *Roadscape Guidelines* emphasize the role of new roadway developments in recognising and enhancing gateways to towns lying either directly on, or related to road corridors.

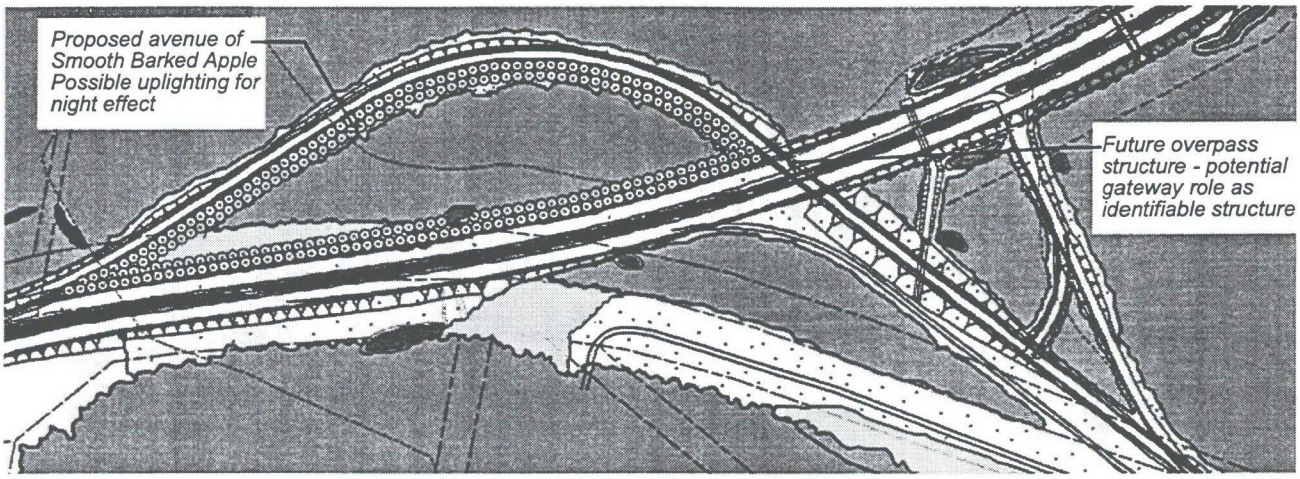
The urban design assessment for this project identified that gateway development for Karuah township should be considered in the context of other towns on the Pacific Highway in such a regional and cross regional strategy the identification of the role and hierarchy of specific towns can be relatively assessed. Whilst this should not limit the potential for individual gateways to express the identity of the township or region to which they relate, gateways should nevertheless provide a sequential road experience for drivers in the same manner as localised road design strategies.

Key aspects of the Gateway Proposals (as identified on the Concepts on the next page) are as listed:

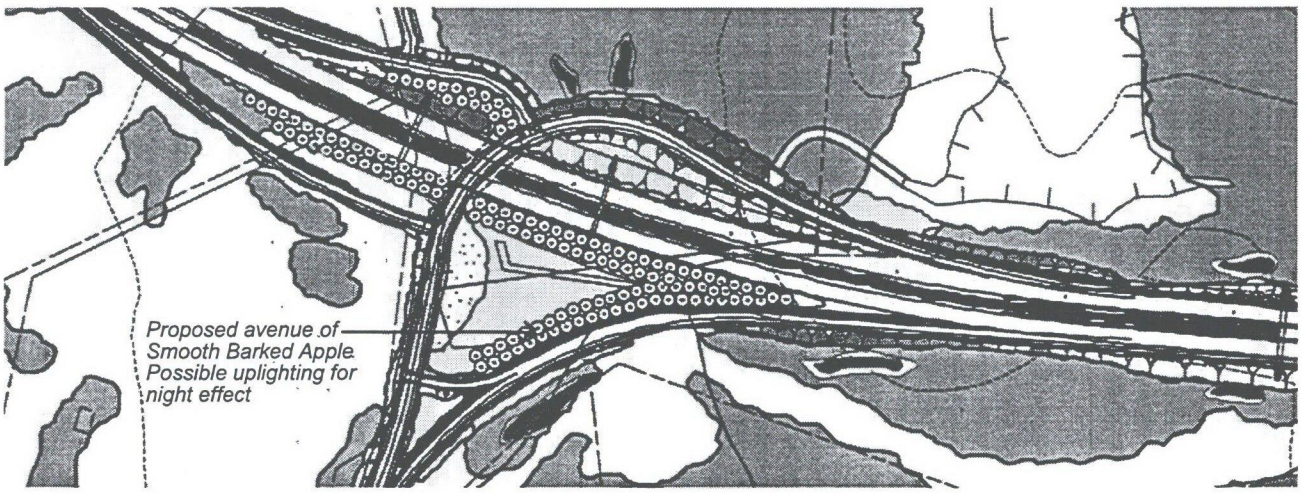
1. The development of the "island" zones created at the two interchanges by roadway construction as the location of gateway treatments.
2. The design of gateways to include the following strategies:
   - Incorporate native avenue planting of single species (eg. Smooth Barked Apple) to road edges. As a locally indigenous species the planting will integrate with adjoining vegetation whilst providing a subtle gateway theme through the formal arrangement of a single species.
   - Investigate potential for incorporation of artistic input by local Community into earthworks design through the avenue planting zones, and entry signage.
   - Consider low level uplighting of avenue planting to provide night feature of gateway.
3. The future exit flyover bridge to the western interchange should be considered for potential design theming to reinforce the Karuah Gateway (eg. Local community artwork themes to wall faces and side elevations. Note: the use of any indigenous Australian artwork themes should reflect the relevant local heritage - not generic motifs).

   A further potential gateway opportunity provided by the road development is that of the Karuah River Bridge as a major structure providing significant views to the local riverine setting.

   The bridge can potentially mark the entry to the Port Stephens areas through an appropriate signage installation and the visual impact of the dramatic entry of vehicles on the northbound carriageway to the river environment.



Western Interchange:



Eastern Interchange:

3.4 Landscape Management and Maintenance

The successful realisation of landscape strategies is inherently linked to the effectiveness of implementation management and ongoing establishment maintenance. As described in section 3.4 (Landscape Treatments) it is important that the landscape programme including plant supply is timed to allow sufficient lead times, and to ensure that completed landscape works are not disturbed once installed.

Roadscape Management Plans

The RTA's *Roadscape Guidelines* identify the importance of a coordinated approach to evaluation, planning, design, implementation, maintenance, and review of road projects to ensure that initial project objectives are realised. The guidelines identify that a preferred approach is through the preparation of a Roadscape Management Plan.

Roadscape Management Plans are "designed to:
- Help identify specific problems and issues
- Outline appropriate corrective measures
- Set out a programme for implementing improvements."

Plan development will vary for specific projects, however a base approach is provided:

Step 1 Define Scope
- Scope of the project

Step 2 Set Goals and Objectives
- Goals - long term desired outcomes
- Objectives - short term measurable steps

Step 3 Gather Information
- Identify issues and opportunities
- Review goals and objectives

Step 4 Explore Alternatives
- Planning and design options
- Objective assessment

Step 5 Choose Strategies and Actions
- Develop strategies that encourpass the project objectives for key strategic areas (eg. Visual Amenity)
- Develop actions that achieve the strategies and incorporate what actions are required, how and when they should be carried out, how they will be funded and who is responsible.

Step 6 Implement the Plan
- Review, approval, and finalisation of the Management Plan
- Physical implementation of actions (documentation; construction)

Step 7 Follow up and Control
- Monitoring and evaluation of the Management Plan against set criteria and targets
- Analysis of outcomes and implementation of any remedial actions required.

The planning and design work to date on the Karuah by-pass project comprises generally steps 1-4 and parts of step 5 of this approach.

The management plan approach is a means of prioritising and organising the tasks that are to this time carried out under a more segmented organisational process.

A document currently under preparation by the RTA entitled "*Roadside Management Plan Guidelines*" will provide a more detailed structure and rationale for the management plan approach to be broadly implemented.

Not withstanding the status of the Management Plan Structure as being "in progress" the relevance of the approach to the Karuah Project is still significant in steps 6 and 7.

Maintenance and landscape management as described following fall into the scope of step 6, whilst the provision of step 7 to this project would be of benefit to the success of other ongoing projects.

Maintenance

Following implementation a coordinated maintenance programme (recommended to be incorporated in the landscape works contract) should be initiated and followed through for a 12 month period. Maintenance should carry through the months of December and February (to optimise growing season, and avoid premature Summer exposure of planting.

Key landscape maintenance tasks should include:
- watering irrigation to a programme established to suit site conditions and seasonal requirements;
- weeding through non-residual herbicide (where possible) or hand removal;
- topping up of mulch from site stockpile;
- mowing / slashing of grassed areas;
- replacement of failed plantings;
- replacement of any damaged tree guards (and removal at end of maintenance period).

3.6 Detailed Design

This landscape and urban design concept report establishes principals for the landscape rehabilitation and enhancement of the Pacific Highway upgrade at Karuah. The next step of detailed design development must be undertaken based on detailed ground survey identifying existing tree specimens adjacent to the corridor including levels at base of trunk.

This information should be used to carry out a comprehensive coordination exercise with the project engineers to resolve which trees can be practically retained and, where appropriate, where engineering design can be adjusted to facilitate tree retention.

As identified in section 3.4 the provision of drainage strategies that maintain as far as possible natural drainage patterns is also important.

Each of the landscape and urban design treatments described in section 3.4 will require development and review to ascertain the most cost effective and horticulturally appropriate practises based on the recommendations provided in this report and in the RTA's *Roadscape Guidelines*. This will include final selection of plant material species from the planting lists provided in this report.

Prepared by: Environmental Partnership NSW Pty Ltd

Pacific Highway Upgrade Karuah

Urban Design Principles



Prepared for:

ARUP

Ove Arup & Partners Consulting Engineers *September 1999*

CONTENTS

1.0 INTRODUCTION

1.1 Generally

2.0 REGIONALURBAN DESIGN ISSUES

2.1 Existing Urban Character

2.2 Regional Urban Design Objectives

3.0 DETAILED URBAN DESIGN PRINCIPLES

3.1 Fill Embankments

3.2 Cuttings

3.3 Bridge and Overpass Structures

3.4 Water Quality Ponds

3.5 Fauna Habitat Enhancement

3.6 Signage, Vehicle Barriers, Fencing and Lighting

3.7 Gateways and Interchanges

LIST OF FIGURES

Figure 3.1.1 - Fill embankments
Figure 3.1.2 - Fill embankments
Figure 3.1.3 - Fill embankments
Figure 3.2.1 - Cuttings
Figure 3.2.2 - Cuttings
Figure 3.4.1 - Water quality control ponds
Figure 3.5.1 - Fauna enhancement
Figure 3.5.2 - Fauna enhancement
Figure 3.5.3 - Aerial Fauna Movement
Figure 3.6.1 - Vehicular barriers

1.0 INTRODUCTION

This Report supplements the Visual Assessment prepared by Environmental Partnership for the Karuah Upgrade proposals, and provides a prelude to the Landscape and Urban Design Concept Report in establishing urban design princples and strategies for the project.

Urban Design can be broadly defined as the planning and design of the built environment in which we live. In the context of road construction, urban design has a specific relationship to the integration of road structures and related elements to surrounding environment whether it be urban, rural, or natural in character.

Given the context of the proposed road corridor as it passes through forested or cleared rural lands, and crosses the Karuah River during the course of its route, urban design considerations primarily relate to the integration of the road both visually and environmentally within these non-urban settings.

The following sections identify regional issues relating to the context of the road in its regional setting, in addition to nominating detailed urban design principles that should be applied to design and construction of the road.

2.0 REGIONAL URBAN DESIGN ISSUES

2.1 Existing Urban Character

As identified in the Visual Assessment, the route corridor passes through either native woodland and open forest vegetation communities or cleared/ semi-cleared pastoral areas for most of its length.

The route bypasses the zones of urban development that adjoin the existing highway west of the Karuah River comprised by Karuah township and adjoining residential areas, along with residential development to the eastern foreshores.

Despite the potential for views of the proposed new bridge over the Karuah River from limited residential and recreational areas on the river foreshores and from the river itself, the proposed corridor does not physically impact upon existing urban development other than at the east and west interchanges with the existing highway and at the crossings of several unsealed access trails which traverse the proposed route.

The Karuah township and adjoining commercial and residential development comprise the dominant aspect of the local area's urban character. As the major focus of the town's function, the highway has tended to shape the urban development of the town as a strip service centre oriented to highway users.

To the north and south of the existing highway, residential development of varying ages and quality extends in a grid pattern along the undulating slopes and along the river foreshores.

Riverfront parkland areas are located to the north and south of the Karuah Bridge. The Memorial Park area to the north is one of unrealised open space potential with its related rocky foreshores, scattered shade trees, and boat hire uses. However, the design and quality of landscape treatments does not reflect the potential quality and outlook of the location. This is even more evident in the Carpark area on the northern foreshores overlooked by residential housing. This area is open, barren, and seemingly neglected, however it has expansive views to the north and north west of the wooded foothills framing/enclosing the Karuah River.

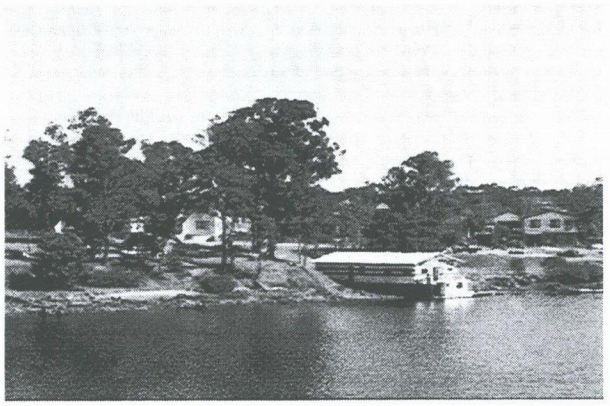
In general terms the urban fabric of Karuah township is one of utilitarian character. The image presented to motorists on the existing Pacific Highway is generally a poor one dominated by advertising signage to service stations, food outlets, and mechanical repair shops adjoining an unsealed road verge.

The urban quality of the township to a large degree appears to have been dictated by the highway corridor with no tangible provision of heritage or architectural qualities that may set the township apart from other highway settlements.

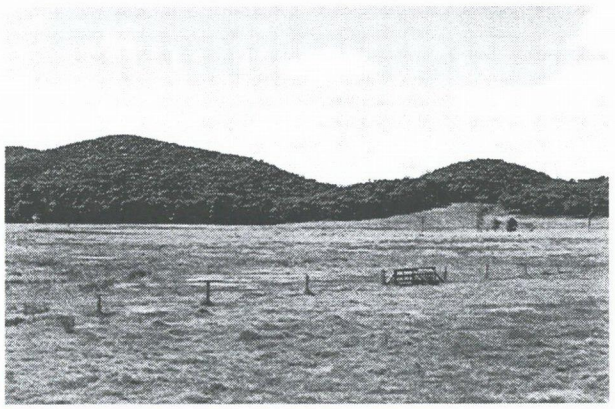
The key positive element of the town's urban character is its relationship to the Karuah River. Whilst town planning does not take full advantage of its potential planning orientation to the river, the activities that the river sustains such as fishing, boating and oyster leases, in addition to the rivers high visual quality are recognisable local images.

A secondary image of the area of regional importance is the rural landscape character of cleared pastoral areas and related grazing activities.

These two themes should be further explored in any thematic approaches to "gateway treatments" (see section 3.7) that are deemed appropriate in the overall context of the Pacific Highway route.



Above
The Karuah River is a dominant influence on the region's physical character.



Above
The area's rural imagery is also an important contributor to regional character.

2.2 Regional Urban Design Principles

The RTA has adopted urban design as a planning and design philosophy to be integrated with traditional engineering, environmental and functional parameters for road design. The urban design element of the design process involves a complementary landscape design stream which will vary in significance from project to project based on the context through which the road passes.

Several broad objectives related to good urban design practice were identified in the RTA's June 1999 edition of *"Around and About"*

The update on the RTA's Urban Design Research project identifies that "well designed roads should:

- fit into urban and rural landscapes so that they do not disrupt natural systems, landscape quality or social and economic activity and, if possible, enhance or restore them
- provide opportunities to meet the needs of pedestrians, cyclists and public transport modes through integrated design
- maintain the valuable heritage and cultural context of areas
- maintain or improve the overall noise environment, if possible, without having to resort to roadside barriers
- improve connections to the local and arterial street networks and the accessibility of communities
- respond to existing and potential landuse and development patterns in the areas through which they pass
- improve the environemnt adjacent and related public spaces and community access to them, and
- be visually pleasing in both the views to and from the facility."

Several of these broad objectives are of particular relevance to the Karuah Upgrade project, specially those relating to the integration of road developments with adjoining landscape settings, relationship to existing and potential landuses, and in ensuring road environments are visually attractive for both road users and viewers to the road corridor.

In considering the specific requirements of the Karuah Upgrade, a series of specific urban design objectives can be identified:

Objective 1

Road alignment to respond to existing topographical and drainage characteristics to enable the road construction to "fit in" to the adjoning landform

Strategies

- Road alignment to follow contours where possible
- Avoid requirement for exessive fill embankments where possible to reduce contrast to adjoining landform
- Gradient of fill and cut embankments to reflect (where possible) the gradients of adjoining landform

Objective 2

Landscape treatments to reflect the varied landscape unit settings through which the corridor passes

Strategies

- Species selection and planting patterns to incorporate adjoining vegetation community
- Site topsoil to be reused within the vegetation community zone from which it orginated to protect species distribution

Objective 3

Road alignment and structures to provide a visually pleasing composition for both road users and viewers to the corridor

Strategies

- Road alignment to provide viewing opportunities to the adjoining range of landscape settings including:
  - cleared pastoral areas
  - wetland areas
  - woodland and forested areas
  - Karuah River
- Construction and road furniture elements to be interpreted as part of an integrated theme both to the Karuah Upgrade and the Pacific Highway corridor generally.

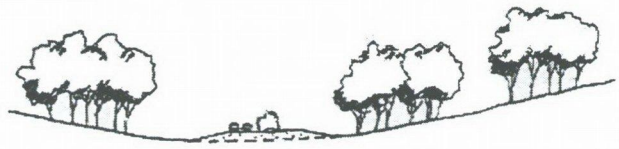
3.0 DETAILED URBAN DESIGN PRINCIPLES

3.1 Fill Embankments

Generally

Due to the undulating to steep topography of the forested and rural lands through which the proposed alignment traverses, fill and cutting embankments will be required.

Whilst landscape treatments can assist in the integration of embankment slopes with adjoining landscape character it is important that the gradient and form of fill slopes is sympathetic to adjoining landform to reduce visual contrast.



Acceptable integration of fill embankment within natural landform



Poor integration of fill embankment within natural landform

Figure 3.1.1

Design Principles

- where possible, in consideration of road geometry and alignment requirements (as identified in the RTA's Roadscape Guildelines), limit the height of fill embankments along the road corridor to reduce visual contrast to adjoining landform (refer fig. 3.1.1)
- to sections of the alignment where existing tree specimens are not significantly affected, extend fill slopes and modulate contouring to integrate with adjoining landform (refer fig. 3.1.2)
- to sections of the alignment where heavy tree canopy adjoins the corridor, limit the extent of earthworks (through the steepening of fill slopes) to limit the requirement for tree clearing (refer figure 3.1.2). Provide safety barriers to steeper fill embankment slopes where required by RTA design criteria.
- fill slopes to be revegetated with species mix and distribution pattern to integrate with adjoining vegetation communities.
- where filled sections of the alignment are open to cleared rural lands to one side with vegetation in close proximity to the other (refer figure 3.1.3 below) - consider consolidation of vegetation community to enhance habitat values and emphasie the open rural character to which views are availabl.
- Encourage regeneration of any adjopining lands (to RTA road reserve) with the relevant authorities.

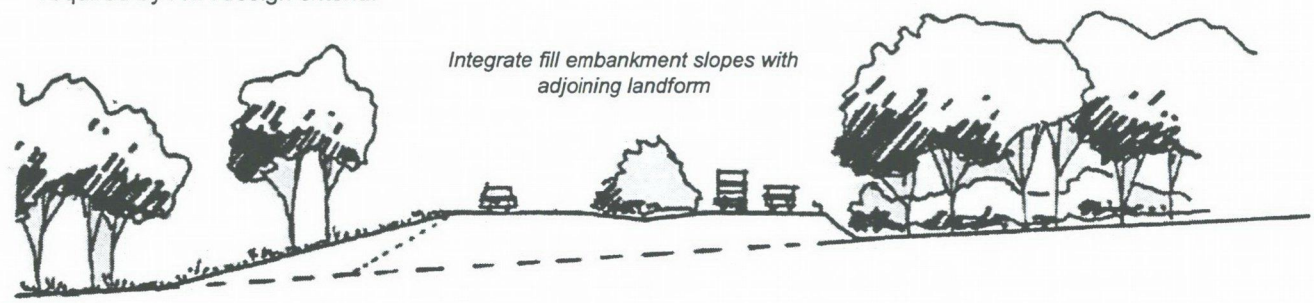


Figure 3.1.2

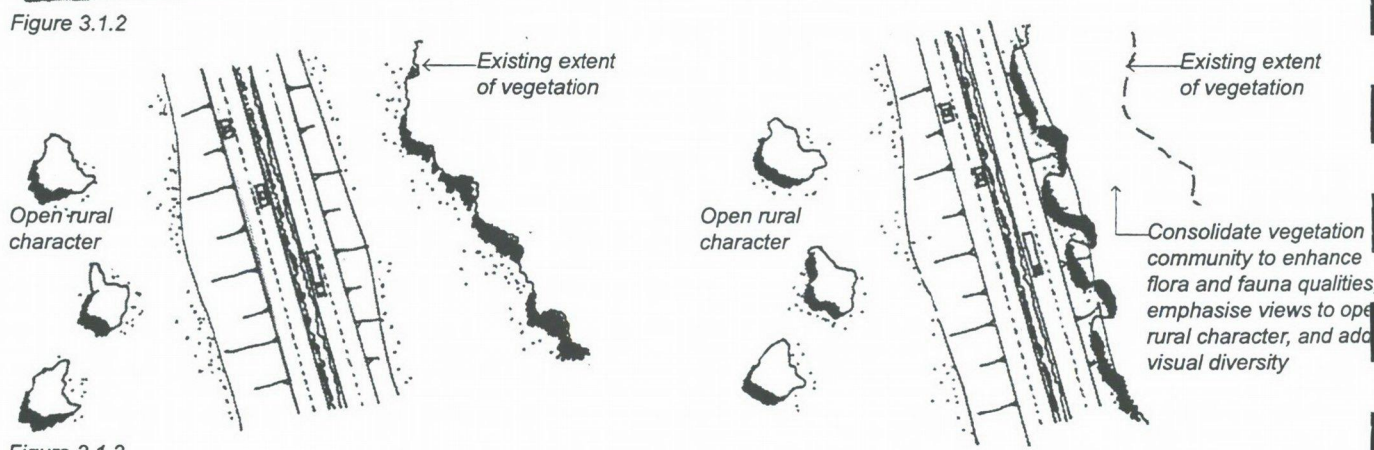


Figure 3.1.3

3.2 Cuttings

Generally

The requirement for cutting earthworks along the route corridor varies in depth from minor excavations to 26 meters depth through the saddle landform at chainage 6800.

Cuttings, whilst providing the opportunity to recess road corridors into the landform reducing the prominence of the road structure and traffic to views inwards, have the negative impact of increasing form and colour contrast to the adjoining landscape.

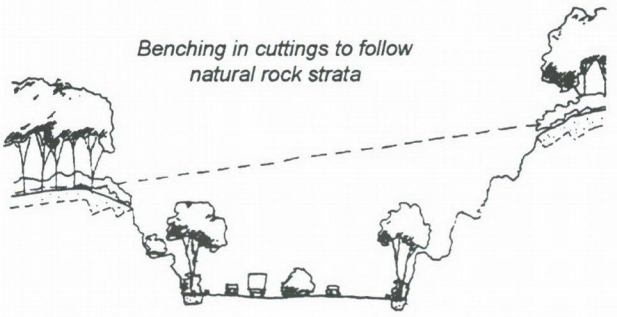
Given the limited soil depth to rock profiles to the road alignment (generally 2 metres below existing landform), cuttings over 4 metres depth will be visually prominent to both road users and potential viewers (albeit limited) to the road corridor.

However in order to minimise the level of impact on adjoining vegetation and fauna habitat, and retain the visual mitigation benefits of existing tree canopy to views to the road it is generally proposed that excavation in rock area be made as steep as possible adjoining heavily vegetated areas.

To areas where minimal vegetation canopy exists adjoining the corridor the opportunity exists to reduce the slope of rock cuttings providing the potential for development of landscape pockets suitable for grassing and intermittent tree planting.

Design Principles

- Cutting depth to be minimised through design of road levels and geometry to reduce scale and visual impact
- Cuttings into rock adjoining significant vegetation canopy to be stepped (within stability criteria) to reduce extent of vegetation clearing requirements (refer fig. 3.2.1) eg. west of Karuah River.
- Cuttings into rock adjoining cleared areas to incorporate informal benching related to natural rock strata to reduce cutting slopes and provide opportunity for development of landscape treatment to match adjoining areas.
- Cuttings in other than rock to be designed to suit adjoining landform and vegetation character:
  - In undulating landform with significant tree canopy, cutting slope to be stepped where feasible to reduce extent of vegetation clearing.
  - In undulating landform with minimal vegetation canopy flatten cut slopes to better integrate with adjoining landform (refer to figure 3.2.2).
- Large cuttings should incorporate benching to reduce scale of sheer rock faces and provide visual diversity. Cutting and benching should preferably follow natural rock strata (ie. not be engineered, regular forms) (refer figure 3.2.1).



Planting provided to benching and at road level to buffer cut rock face to situations where significant views inward are available

Figure 3.2.1

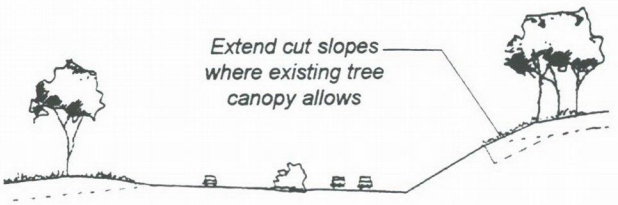
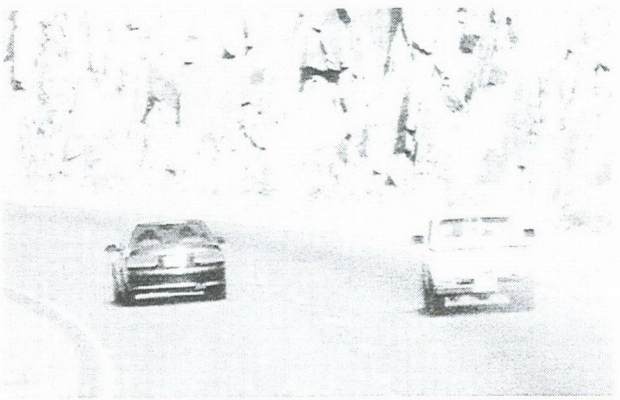


Figure 3.2.2



Above: Excavation of natural rock bedding planes provide exposed rock face of natural character

- Large cuttings in rock visible to non road users should incorporate excavated planting zones where possible to reduce visual contrast of excavated rock (refer figure 3.2.1)
- Cutting slopes in material other than rock should be designed to 1(v):3(h) maximum batter slope and revegetated to match adjoining vegetation communities.
- Where cut sections of the alignment are open to cleared rural lands to one side with vegetation in close proximity to the other - consider consolidation of vegetation community to enhance and emphasise the open rural character to which views are available (as for figure 3.1.3).

3.3 Bridge and Overpass Structures

Generally

The bridge crossing of the Karuah River is the major element of the nine kilometre road structure. Local road overpasses (to the west side of the Karuah River) of the roadway and the two interchanges with the existing highway are significant interventions in the natural and semi rural landscape settings, however the length and context of the bridge are such that integration of the structure in a sensitive visual setting of regional importance is a critical urban design requirement.

The key issue in this regard is the recognition of the strong horizontal character of the rivers and ridgelines to the surrounding hinterland.



The strong horizontal character of the Karuah River setting is an important cue for bridge crossing design

The bridge design must compliment these horizontal forms and remain integrated with landform and vegetation patterns.

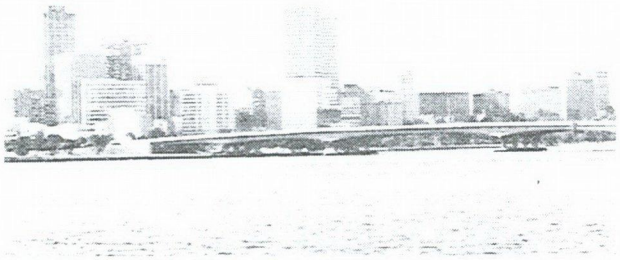
The overpass bridge crossings at Scotts Road and Mines Hill Trail are located within forested settings with a high degree of enclosure by adjoining vegetation. Motorist views will be channelled towards these structures and as such the design of the bridge elevations and abutments should avoid the creation of tunnelled or roofed visual experiences.

This will require bridges to be adequately elevated above the roadway, appear light visual appearance in elevation, and not be of excessive width.

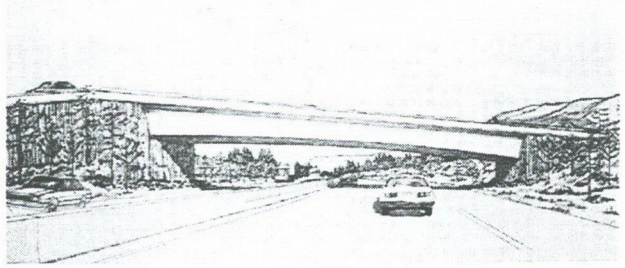
In order to provide a continuation of fauna corridor amenity to the ridgeline east of the river, it is proposed that a landbridge structure be provided over the rock cutting. Again the bridge structure must be of adequate height to integrate with the scale (proportion) of the cutting to provide a comfortable driving experience, and be of light structure appearance in elevation.

Design Principles

- Design proportions of pier structures to bridges should be in proportion to the bridge elevation (ie, not excessively wide or narrow).
- Bridge elevations should incorporate recessed edge treatments where possible to create shadow lines and reduce visual bulk of structure.
- Where underpass situations are of significant length to provide heavy over shadowing, design should incorporate openings in the central median to provide natural light access.
- Local road overpass bridges should be simple in design and materials to avoid diversion of motorists attention.
- Safety barriers to bridge structures should be simple in design and materials finishes and provide visual continuity to other road side barrier treatments. Barriers should optimise motorist views to surrounding landscape (in particular the Karuah River Bridge).



Bridge structures should remain in scale with their visual context and reflect the key aspects of the visual setting (eg. linear)



Bridge structures to natural/ semi-rural environments should not overwhelm the visual setting by their scale and mass as occurs in the above image

3.4 Water Quality

Generally

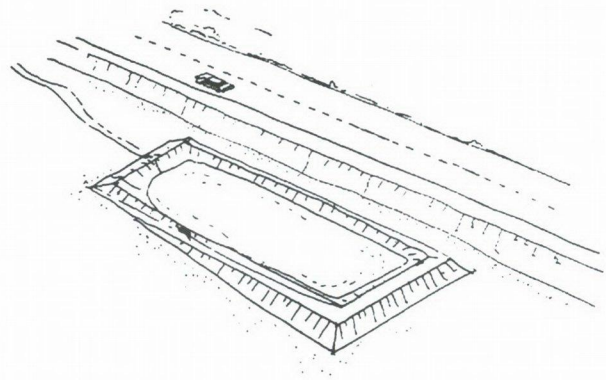
The engineering design for the road development incorporates the principle of stormwater runoff management both during construction to control erosion and siltation of creeklines, and post construction to assist in filtration of roadway runoff.

Water quality control ponds are proposed to function during the construction phase as sediment retention ponds, and will convert to planted water quality control ponds upon establishment of roadway landscape. The ponds will also function as chemical spill retention ponds.

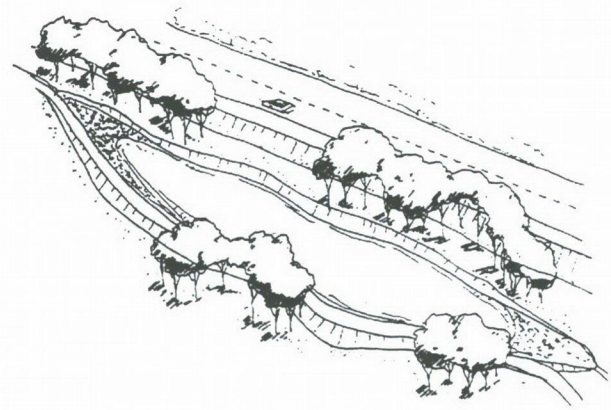
Being located so as to intercept flows from the roadway and then feed onto natural drainage lines, the ponds have the potential, in open cleared areas in particular to be of high visual impact as contrasting features in the landscape. Likewise in heavily revegetated areas an inappropriately shaped pond will also look unnatural and require a concentrated clearing of vegetation.

Design Principles

- Design of sedimentation ponds should be a site specific exercise to integrate the pond with the adjoining landform and vegetation patterns.
- Informal shaping of the pond in response to natural contours can assist in reducing visual impact. The use of subtle earthworks to direct and hold water is preferred to bulky dam walls defying natural landform.
- In sections of the road corridor which run parallel to the contours of adjoining lanform, the use of longer narrower pond profiles facilitates a linear wetland function for macrophytic planting.



Poor integration of water quality control pond with adjoining landform and character



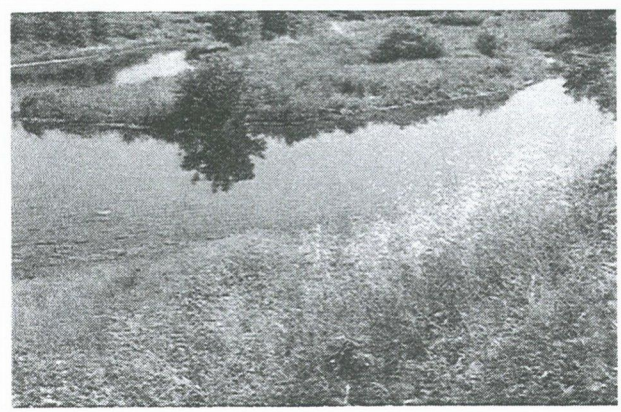
Acceptable integration of water quality control pond with adjoining landform and character

Figure 3.4.1

- In open rural areas it may be possible to design ponds to replicate (visually and functionally) rural dams, where earthworks requirements are not excessive.
- Pond layout and design of any adjoining planting should have regard to safety issue in proximity to carriageways, and in providing maintenance access.



Above: Water quality control pond in urban context providing integrated relationship with landform



Above: Water quality control pond in natural setting responding to existing landform and integrating with existing vegetation

3.5 Fauna Enhancement

Generally

The enhancement of fauna movement and habitat related to the corridor has been established as a major design objective in the Flora and Fauna componenets of the Environmental Impact Statement

Fauna enhancement will thus be promoted in several ways:

- minimisation of the extent of vegetation clearing in quality habitat areas.
- Optimistation of important fauna movement corridors across the road adjacent.

It is noted that the potential for fauna landbridge overpasses was also reviewed and discounted due to the limited fauna benefit that was affected.

In terms of built elements that must be considered as part of the roads overall urban design, the items to be addressed include:

1. Culvert underpasses at roadways
2. Potetop rest boxes for glider movement at glider crossings.

Both elements have visual implications for the road corridor and adjoining areas which can be resolved through effective use of materials and design treatments.

Design Principles

- Underpasses will generally be located in a shaded situation with drainage underpasses to:

  - maintain farm benefits of water and denser vegetation along drainage line
  - optimise clearance/depth of underpass by locating at low point in relation to roadway levels.

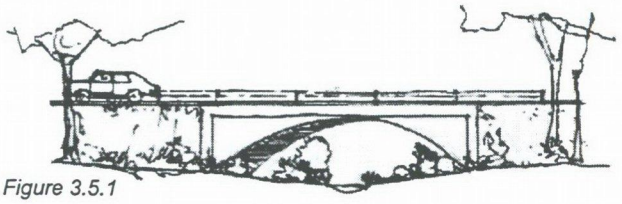


Figure 3.5.1

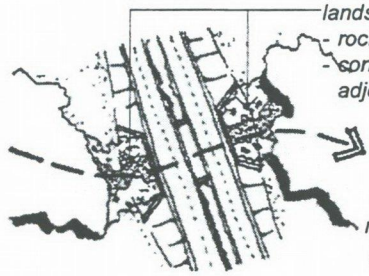
- Underpass structures will typically be provided as concrete box culverts. If strong design themes are developed for other bridge structures - these should ideally be carries through to enhancement of basic culvert forms. (See figure3.4.1/3.4.2).
- Underpasses must incorporate a variety of landscape treatments 9eg. logs, rocks, vegetation) to cater for different fauna species providing temporary protection and shelter
- Fauna underpass vegetation whilst reflecting the adjoining vegetation community should incorporate hardy species (avoid popular foraging species) to maintain vegetation cover and related fauna benefits.
- Ground surface treatments to underpasses must be provided with a stable base to prevent erosion.
- To nominated aerial crossing points of road corridor (for bird and glider populations) existiing tree retention will be optimiseddue to limited earth works (at grade level of road) and provision of vehicular satety barriers. Where site specific conditions preclude adequate existing tree canopy, consider the providion of pole top resting boxes as temporary rest popints while new tree planting s establish.

Final design requirements should be resloved with a fauna expert - basic requirements to include:

- Timer Post - to visually integrate with vegetation and provide escape for ground based fauna from predators.
- Resting box and surrogate timber branches to top of post. to provide semi protected rest/refuge point for arboreal/aerial fauna.



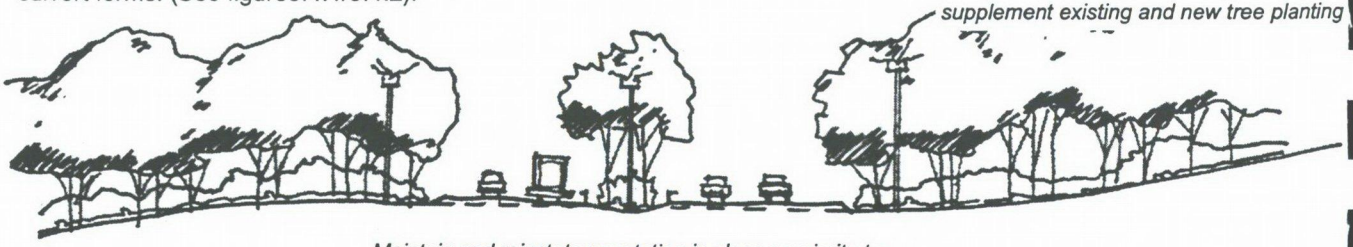
Isolation of potential fauna movement without fauna underpass



landscape treatment of underpass:
- rocks, logs etc. as shelter
- continue appropriate species from adjoining vegetation community

Conservation of fauna movement potential with provision of underpass

Figure 3.5.2



Possible resting boxes and timber "branches" installed to timber poles to supplement existing and new tree planting

Maintain and reinstate vegetation in close proximity to roadway to facilitate aerial fauna movement

Figure 3.5.3

3.6 Signage, Vehicular Barriers, Fencing and Lighting

Generally

The "road furniture" treatments including signage, vehicle barriers, and lighting for the highway development are important elements of the visual experience of the roadway.

Well designed road furniture that is part of a themed approach to both the particular project and to the greater road corridor (eg. Pacific Highway) will be functional, and of low visual impact to the adjoining landscape.

Most road furniture items have related safety functions and requirements that must be integrated and balanced with the aesthetic objectives of visual unity and low visual impact.

Design Principles for Signage

- Signage requirements for the road corridor including regulatory and safety signage should be considered as part of a coordinated plan. Key issues for review include:
  - restrict signage to that essential for safe and convenient use of the roadway
  - group signage where possible
  - apply quality design and materials to signage and supports
  - consideration of signage requirements/ implications beyond the project area to provide functional continuity
- Signage location to consider visual impact in relation to adjoining landscape setting and views (in and out). Where functional/ safety criteria can be met, locate signage in sites of lowest visual impact (ie. least visual contrast/change to landscape setting).
- The Karuah Upgrade corridor is not suitable for any forms of roadside and outdoor advertising. Advertising would be in conflict with the visual quality of the natural and semi rural character of the area.

Design Principles for Vehicle Barriers

- Safety barrier treatments must meet standard vehicle impact requirements supported by appropriate materials and design of adjoining treatments
- The use of wire rope barriers to median and road verge zones to be protected is preferred to concrete or steel barriers due to their visual permeability and less obtrusive appearance. Steel poles to wire rope treatments should be painted black, a colour which integrates well with vegetation.

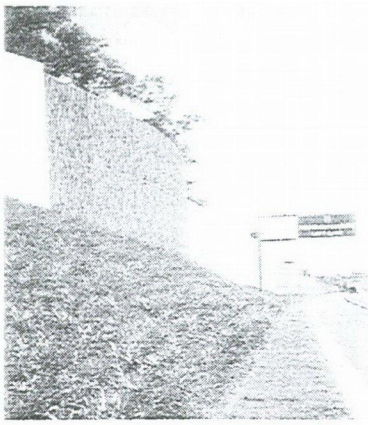
  If applicable to the project (in terms of safety considerations) the wire rope barriers should be carried through all barrier usage situations to provide a unified treatment theme.
- An option to be considered for safety barriers to bridge structures in particular to the Karuah River Bridge is the provisions of raised barriers that maintain vehicular views out to adjoining landscape (refer figure 3.6.1).
- If required to protect piers to bridge overpasses it is desirable that concrete colouring and finish matches pier concrete to be perceived as part of the one design theme. Blunt ends to barrier runs should also be avoided for safety and visual purposes. Tapering ends are preferred.

Design Principles for Fencing

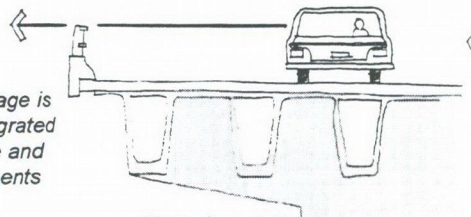
- Fencing will be provided to several situations on the corridor with related urban design requirements.
- To edge of RTA road reserve, in continuity with rural setting, fencing to road reserve to reflect rural theme of single timber post and wire stock prrof fence.
- To restrict fauna access to corridor (eg. at saddle cutting Ch 6750) provide "floppy top" fencing as described in th RTA's roadscape Guidelines.

Design Principles for Lighting

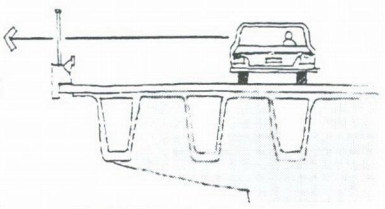
- Generally lighting should only be provided to the interchange areas of the route alignment to conserve the natural and semi-rural character of adjoining areas, and avoid disturbance of fauna habitat.
- Lighting to interchange situations should primarily meet safety and functional requirements but also have regard to urban design quality in the shape and form of lighting poles. Slender unobtrusive poles that meld into the landscape setting during the day are preferred.
- Possible feature uplighting of gateway tree plantings may be considered to provide a memorable and identifiable entry experience at the east and west interchanges.



Left:
Roadway signage is effectively integrated with landscape and structural elements



Views from bridge structure impeded by guard rail treatment



Raised edge barrier provides views to adjoining landscape and assists in providing a visual buffer to views to the bridge

Figure 3.6.1

3.7 Gateways and Interchanges

Generally

A popular aspect of urban design strategies for townships both those lying on highway corridors and those by-passed by new highway developments is the provision of symbolic gateways to the town

Gateways both enrich the travel experience as well as providing a sense of arrival and departure, in addition to reinforcing community pride and a sense of local identity.

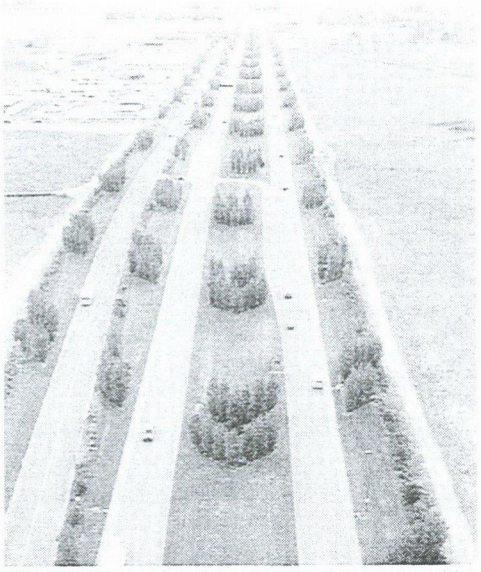
Karuah township is one of many small towns which has a relationship to the Pacific Highway, each of varying size and function, both in relation to the highway and their local area. A regional approach to planning and design of gateways to these towns, rather than a project by project basis is desirable to coordinate the hierarchy and role of townships and their related gateway treatments.

Design of gateways should however still relate to the individual town reflecting key aspects of its local physical and social identity.

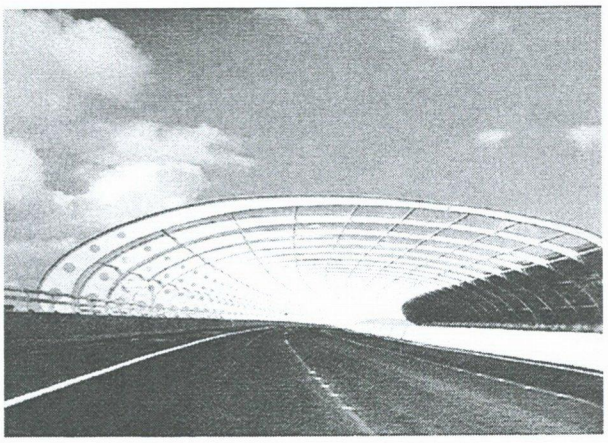
For the Karuah Upgrade the provision of gateway elements is most effectively created at the east and west interchanges to provide visual recognition of the town environs.

Design Principles

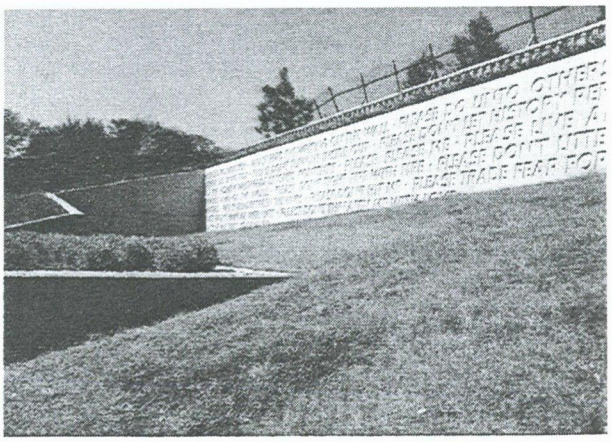
- Gateway treatments should be reviewed in the context of other townships on the highway corridor to ensure that a logical and appropriate prioritisation of towns based on functional, recreational, and social characteristics is planned.
- Gateway treatments for the Karuah Upgrade may potentially reflect the town's strong natural character of forested hills, nature reserves, and the Karuah River, and recognise the cultural characteristics of rural and fishing activities. As such the use of site indigenous plant arrangements is an effective approach to representing the natural and cultural influences on the area.
- The future flyover to the western interchanges northbound exit also represents a gateway opportunity that may be reflected in specific design treatment of that structure.
- The recognition of the local community should also be explored in design development of the gateways. This may potentially be reflected in the themed treatment of wall faces to concrete structures, the future western flyover bridge, or in the stylised design of earthworks to the two "island" landscapes created at the interchanges.
- A further gateway role that should be recognised by the road development is at the Karuah River Bridge which could be identified as the gateway to Port Stephens Shire and ..... Lakes Shire respectively.



Above: Planting theme developed to provide memorable visual experiences at Gateway location



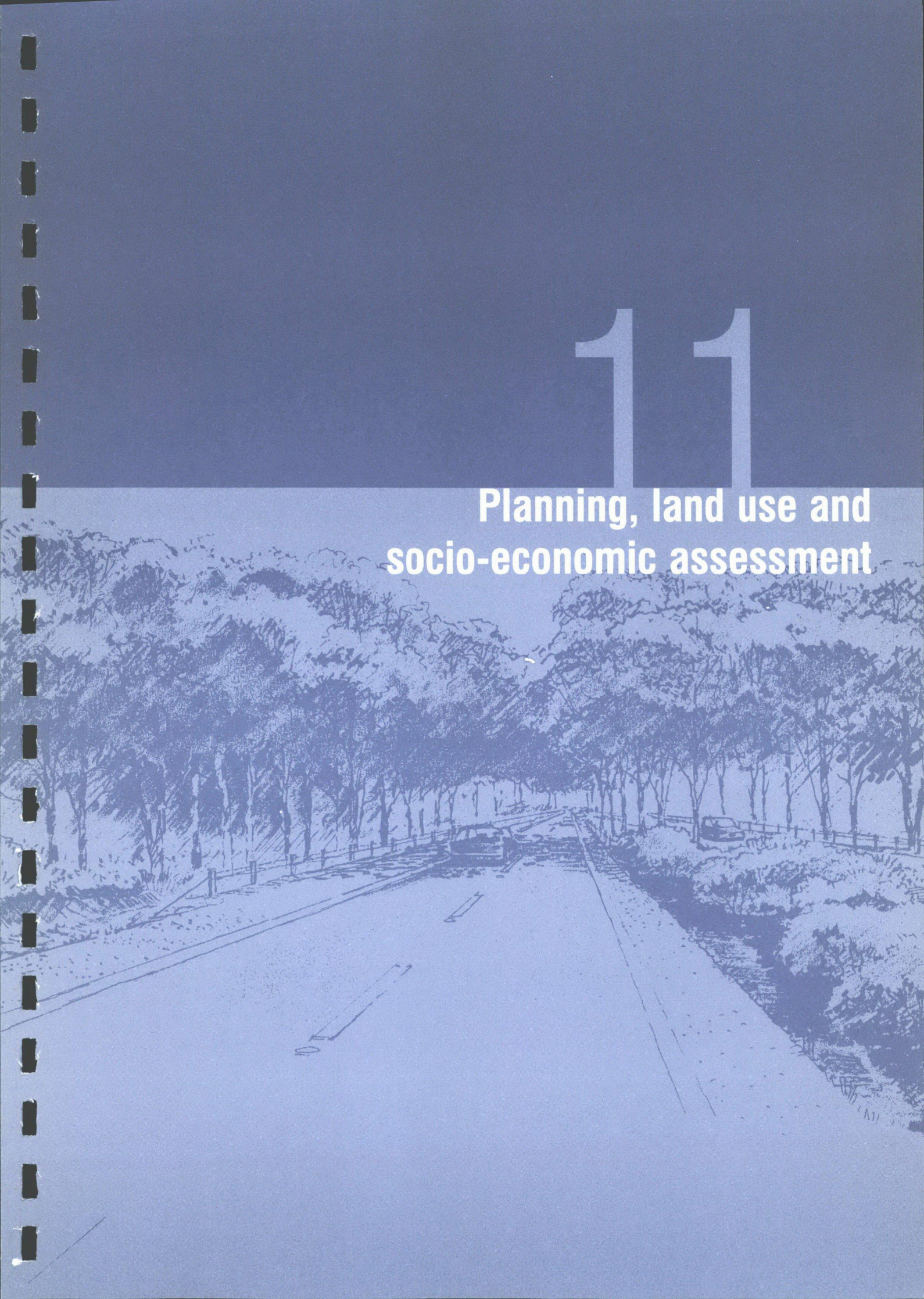
Above: Gateway structures to represent entry/exit experiences are appropriate to urban environments



Above: Signage is effectively incorporated into built structures and landform

11

Planning, land use and socio-economic assessment



PACIFIC HIGHWAY UPGRADE - KARUAH

PLANNING, SOCIAL AND ECONOMIC IMPACT WORKING PAPER

Report to

OVE ARUP & PARTNERS

Prepared by

PURDON ASSOCIATES PTY LTD
3/9 McKay Street, Turner ACT 2612
Tel: (02) 6257 1511 Fax: (02) 6248 8347
Email: purdons@dynamite.com.au

July 99

Acknowledgements

The Study Team for this project comprised personnel from Purdon Associates (Rob Purdon, Brenton Dickins, Emma Darley and Louise Fleming).

We wish to acknowledge our appreciation for the co-operation and assistance provided by Alistair Kerle (Ove Arup & Partners), Helen Weston (Environmental Affairs) and Graham Kinnear and staff of RTA.

Results of the study and conclusions drawn there from, as documented in this working paper, represent the views of the Study Team and do not necessarily reflect those of the Department.

PURDON ASSOCIATES

22 July 1999

DISCLAIMER

Any representation, statement, opinion or advice expressed or implied in this publication is made in good faith but on the basis that Purdon Associates, its agents and employees are not liable to any person for any damage or loss whatsoever which has occurred or may occur, in relation to that person taking or not taking (as the case may be) action, in respect of any representation, statement or advice referred to in this report.

Contents

Acknowledgements i

1 Introduction 1

2 Planning, Zoning and Land Use 3

2.1 Existing Land Use 3

2.2 Planning Policies 15

3 Social Impact 25

3.1 Demographic Characteristics 25

3.2 Residential Amenity 26

3.3 Local Access 27

3.4 Agriculture 28

3.5 Health and Psychological Effects 30

3.6 Social Impact Conclusion 30

4 Economic Impact 32

4.1 Business and Employment Characteristics 32

4.2 Highway Business and Employment 35

4.3 Land Acquisition and Compensation 40

4.4 Future Subdivision Potential 42

4.5 Oyster Leases 42

4.6 Economic Impact Conclusions 43

5 Conclusion 44

TABLES

Table 2.1: Distance and Estimated Travel Times from Karuah 4
Table 4.1: Principal Business Type 33
Table 4.2: Employment Numbers 34
Table 4.3: Employment by Gender and Industry (1996) 35

FIGURES

Figure 1.1: Horse Island Highway Upgrade 2
Figure 2.1: Existing Land Use 6
Figure 2.2: Agricultural Suitability Classification 10
Figure 2.3: SEPP 14 Wetlands 17
Figure 2.4: LEP Zones 22

ATTACHMENTS

Attachment A:Bibliography 47
Attachment B:Consultation Contacts 50
Attachment C:Karuah Business Survey 1997 52
Attachment D:Karuah Business Survey 1998 54

1 Introduction

The Roads and Traffic Authority of NSW (RTA) is proposing an upgrade of the Pacific Highway in the vicinity of the Karuah township, north of Newcastle and Raymond Terrace. This project is part of the $2.2 billion upgrade of the Pacific Highway between Hexham and the NSW/Queensland border over ten years being funded by the NSW and Commonwealth government. A route selection study undertaken in 1997 identified six route options. Of these options, the Horse Island Option was recommended to RTA as the preferred alignment (refer **Figure 1.1**). The Minister for Roads accepted this recommendation in mid-1998, subject to further investigation of this option through the preparation of an Environmental Impact Statement (EIS).

As part of the above investigation processes, Purdon Associates have been engaged to undertake a planning, social and economic impact assessment of the Horse Island proposal.

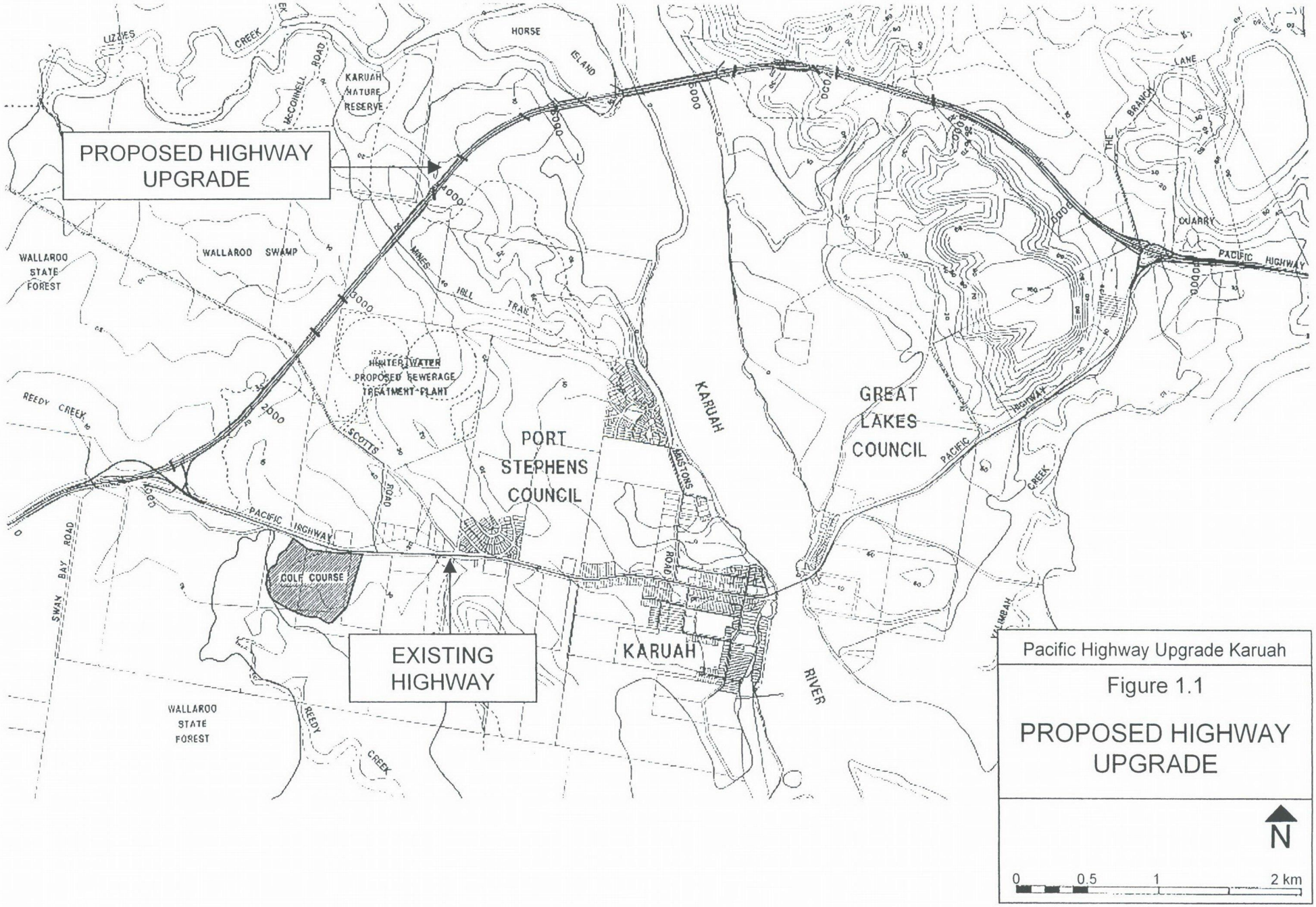
This Working Paper outlines the findings of the assessment and compares the proposed Horse Island alignment with the existing situation. Issues relating to the other five highway upgrade options were addressed in the route selection study produced by Ove Arup and Partners in 1998 and have therefore not been considered in this paper.

The assessment has been made on the basis of readily available documentation and data (refer **Attachment A**). Consultation has also been held with a number of Government Agencies (refer **Attachment B**).

This Working Paper specifically addresses the following three broad areas of interest

- Planning, zoning and land use;
- Social impact; and
- Economic and local business impact.

The local business impact also draws on two business surveys undertaken by Purdon Associates in August 1997 and December 1998 as part of the overall study (refer **Attachment C** and **D**).



Pacific Highway Upgrade Karuah

Figure 1.1

PROPOSED HIGHWAY UPGRADE

2 Planning, Zoning and Land Use

2.1 Existing Land Use

The Pacific Highway forms the principal coastal transport route between Sydney and Queensland. As a result it serves not only long distance travellers and transport but also a range of local communities and activities.

Existing and known proposed land-uses adjoining the proposed route are shown in **Figure 2.1** and summarised below. Specific social and economic impacts of the proposed Pacific Highway Upgrade on these land uses are considered further in **Sections 3 and 4**.

2.1.1 Regional Context

The Study Area is located on the north boundary of the Lower Hunter region and is the principal entry to the Hunter Valley and the Newcastle Metropolitan Area from the North Coast. Located across the boundary of Port Stephens and Great Lakes Local Government Areas (LGA), Karuah is approximately 220 kilometres from Sydney and 50 kilometres from Newcastle. These distances result in travel times of approximately 2-3 hours and 40 minutes respectively, depending on the origin of the traveller. These distances make Karuah an ideal stopping point for people travelling north.

Whilst north bound travellers form the predominant basis of Karuah's 'stop-revive-survive' role, south bound travellers also use Karuah as one of the opportunities on the Pacific Highway to break their trip. In particular, drivers of truck and freight vehicles on the Brisbane to Sydney route use the truck stop located 1.5 kilometres west of the Karuah Township (Mustons Road). However due to a greater range of stopping opportunities north of Karuah (e.g. Bulahdelah), the business from south bound traffic is considerably less than that from north bound travellers. **Table 2.1** provides a summary of distances and estimated travel times from key urban centres to Karuah.

Newcastle forms the major focus for the region in terms of employment, retail and service provision. Although the Port Stephens and Great Lakes areas have been recognised as a tourist destination for a long period of time, the area is increasingly attracting permanent residents as people migrate north from Sydney and Newcastle. Within the Port Stephens LGA, Nelson Bay and Salamander Bay are providing the principal focus of this growth.

Table 2.1: Distance and Estimated Travel Times from Karuah

Towns	Distances	Travel Time (hours)		
	(km)	Min *(1)*	Max *(2)*	Average *(3)*
Campbell Town	280	3.1	3.2	3.4
Liverpool	261	2.9	3.5	3.2
Sydney	253	2.8	3.3	3.0
Hornsby	230	2.3	2.9	2.6
Newcastle	56	0.6	0.7	0.6
Karuah	0	0.0	0.0	0.0
Bulahdelah	43	0.4	0.5	0.5
Taree	116	1.2	1.5	1.3
Port Macquarie/Wauchope	190	1.9	2.4	2.1
Coffs Harbour	353	3.5	4.4	3.9
Grafton	436	4.4	5.5	4.8
Lismore	578	5.8	7.2	6.4
Gold Coast (Southport)	709	7.1	8.9	7.9
Brisbane	784	7.8	9.8	8.7

Note:
(1) Minimum travel time calculated on the basis of an average speed of 100km/hr with 50km/hr in the Sydney Metropolitan Area
(2) Maximum travel time is calculated on the basis of an average speed of 80km/hr with 50km/hr in the Sydney Metropolitan Area
(3) Average travel time is calculated on the basis of an average speed of 90km/hr with 50km/hr in the Sydney Metropolitan Area

The tourist attraction features of this area are based largely on its natural resources including its bays and waterways, beaches, national parks, native vegetation and climate. Whilst accessing all of these features, Karuah has not developed as a significant tourist destination but rather services travellers en route to other destinations.

2.1.2 Karuah Township

The Karuah Township is located on the Karuah River near its confluence with Port Stephens. In 1996 Karuah had a population of approximately 800 persons. Located on the Pacific Highway, Karuah has played a significant highway service function and is increasingly becoming a small retirement community.

Council's Urban Settlement Strategy (originally known as Beyond 2000 Settlement Strategy) indicates that the combined Karuah/Swan Bay urban areas had a 1996 population of 1,235. It also projects that these areas have a capacity to accommodate approximately 2,000 people but that this is unlikely to be reached until some stage after the year 2021. The majority of this growth will be in Karuah.

Pacific Highway Upgrade - Karuah

Karuah has a linear commercial centre with approximately 40 businesses situated along a one kilometre stretch of the Pacific Highway on the western side of the Karuah River. This stretch of the Highway is known as Tarean Road. The principal commercial activities include:

- Petrol stations, road houses and motor vehicle repairs;
- Food stores;
- Restaurants/takeaways;
- Tourist accommodation including motels and caravan parks; and
- Clubs and one Hotel.

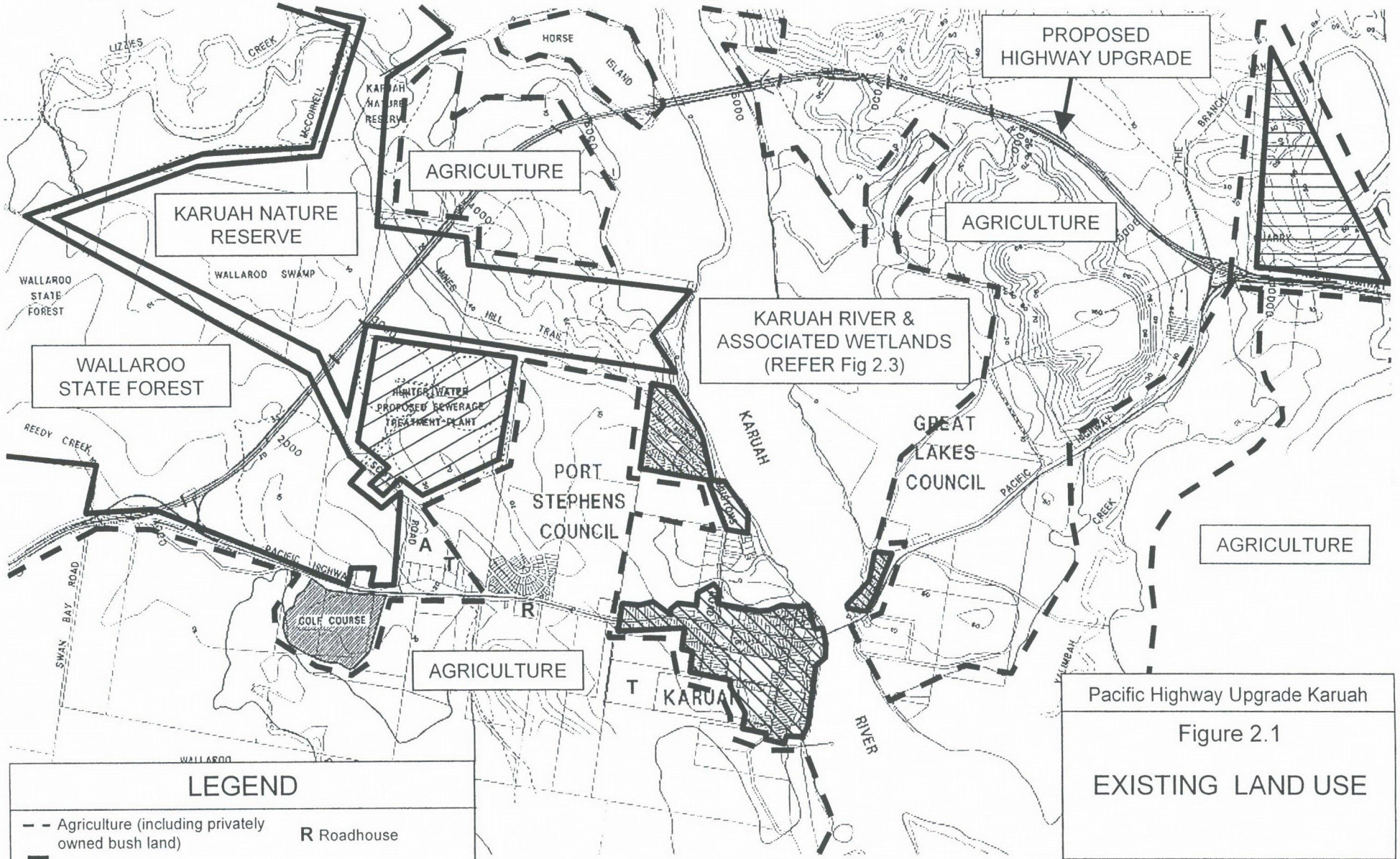
Other businesses located in Karuah include personal services, bulky goods (e.g. hardware, outdoor products and furniture repairs), recreational facilities, concrete water tanks construction, timber milling and oyster farming.

Despite four accommodation facilities, Karuah is not known as a tourist destination with these facilities generally providing overnight accommodation to the travelling public. The caravan parks also provide long stay, low cost accommodation to the retirement community.

A survey of the business community was undertaken by Purdon Associates to assess the impact of the highway upgrade on business. This survey indicated that in 1998, 41% of responding businesses (34) were either totally or substantially dependent on the highway for trade. These businesses trade significantly on the town's known 'Stop Revive, Survive' function. One of the four petrol stations in Karuah operates principally as a truck stop serving road transport and freight vehicles on the Brisbane to Sydney run.

Karuah's housing stock is of mixed age with a substantial percentage of relatively new dwellings. Residential activity is concentrated on the western side of the Karuah River. However a small development is located in Great Lakes Council on the east. Due to road design, road access to this area is difficult particularly in peak traffic periods.

On the western side of the river, residential development is divided by the highway. Residential development to the north of the highway includes the Aboriginal community and the developed portion of an old residential subdivision. This residential area is divided by landforms (including riverine wetlands associated with the Karuah River) and land ownership. The current non-urban zoning and the capacity of the approved proposed sewerage treatment plant restrict the further development westwards of the old subdivision.


PROPOSED HIGHWAY UPGRADE
AGRICULTURE
KARUAH NATURE RESERVE
AGRICULTURE
KARUAH RIVER & ASSOCIATED WETLANDS (REFER Fig 2.3)
WALLAROO STATE FOREST
PORT STEPHENS COUNCIL
GREAT LAKES COUNCIL
AGRICULTURE
AGRICULTURE
KARUAH
WALLAROO SWAMP
WALLAROO STATE FOREST
WATER PROPOSED SEWERAGE TREATMENT PLANT
REEDY CREEK
PACIFIC HIGHWAY
SWAN BAY ROAD
GOLF COURSE
KARUAH RIVER
LIZZIES CREEK
McCONNELL
HORSE ISLAND
MINES
PACIFIC HIGHWAY
LEGEND
Agriculture (including privately owned bush land)
Quarry
Urban Area (including highway services & tourist facilities)
Proposed Sewerage Treatment Plant & Irrigation Field
R Roadhouse
A Automotive
T Timber Mill
Pacific Highway Upgrade Karuah
Figure 2.1
EXISTING LAND USE
N
0
0.5
1
2 km

There are a number of community facilities scattered throughout the town, including:

- primary school;
- churches;
- cemetery;
- sports ground;
- golf course;
- tennis courts;
- community hall;
- public telephones;
- scout hall;
- BMX track;
- open space; and
- public toilets.

There is evidence of some recent investment in new and/or upgraded business activities and housing. Examples include Ampol and Mobil Service Stations, new shops near the intersection with Bundabah St and a new chemist shop. The business survey conducted by Purdon Associates for this project in December 1998 showed that about $8.1 million had been spent by or on local business in the last 5 years (refer **Attachment D)**.

The combination of the following factors have resulted in Karuah being a significant bottle neck on the Pacific Highway for long distance travellers in peak holiday periods:

- traffic lights at the intersection of the Highway (Tarean Road and Bundabah Street);
- 60 km per hour urban speed limit; and
- existing bridge over the Karuah River.

In addition to these factors, observations made by town residents and business operators indicate that other design features of the existing highway also create capacity issues in peak periods. These features include the capacity of the bridge and the location and design of overtaking lanes to the west of the town. Both require traffic to merge into one lane creating obstruction to traffic flows in peak periods.

The highway traffic also impacts on the operation of the town and the amenity of residents, particularly in the peak periods of Christmas and Easter. At these times, vehicular and pedestrian crossing of the Highway can be time-consuming and unsafe for town residents. The only controlled cross-town access is at the traffic signals at the intersection of Tarean Road and Bundabah Street.

2.1.3 Other Urban Settlements

There are a number of other small urban settlements in the vicinity of Karuah for which the proposed highway upgrade will have implications. These settlements include North Arm Cove, Carrington and Tahlee to the north of Port Stephens and to a lesser extent Swan Bay to the south. The settlements to the north-east of Karuah have a population of approximately 270 and, with the exception of some minor Council-provided community facilities in North Arm Cove, are solely residential areas accommodating permanent residents and holiday houses. These settlements currently use Karuah for convenience retailing and some motor vehicle related activities. The proposed highway upgrade will bypass Karuah and has the potential to provide improved access to businesses and services in Raymond Terrace. This impact is considered further in **Section 4**.

2.1.4 Agriculture and Fisheries

The proposed highway upgrade corridor crosses agricultural properties for approximately 4.5 kilometres or approximately 50% of its 9.5 kilometre length. This agricultural land is situated to the south west of Horse Island and to the east of the Karuah River. The majority of this land has been substantially cleared, although some areas of forest and bush land remain.

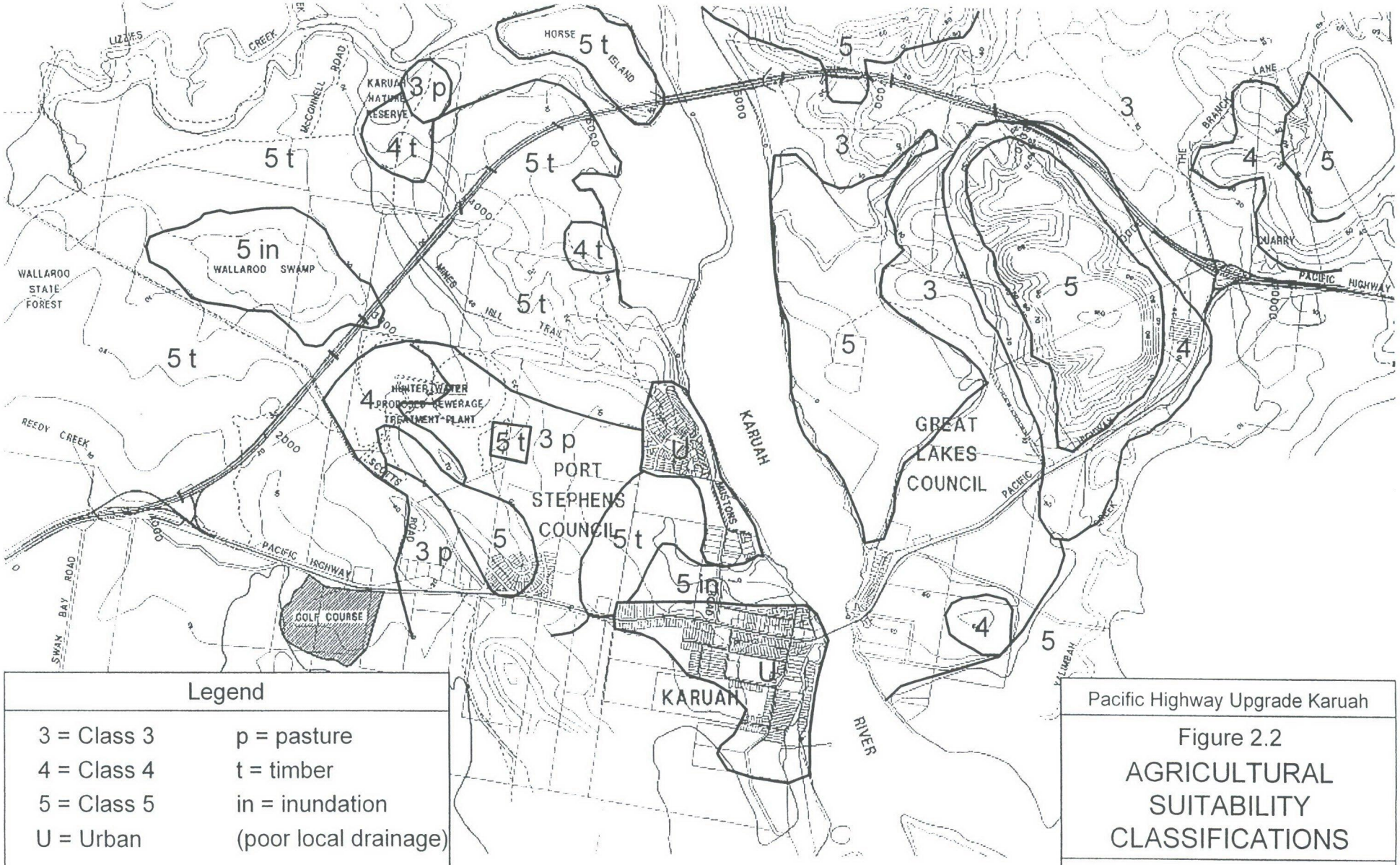
This agricultural land is in five different property holdings and is predominantly used for stock grazing. There is no local area data available on the role of these properties in the regional economy. However, statistical local area data on agriculture for the Great Lakes Council and Port Stephens areas indicates that while making significant contributions to the local economy, agriculture in these areas forms only a small percentage of total production for NSW. The main features of local agriculture include the following:

- Beef cattle represents the principal agricultural activity in both Council areas;
- Beef cattle farming has an estimated value of agricultural operations of $1.1 million in Port Stephens and $4.4 million in Great Lakes, which represents approximately 0.3% and 1.1% of NSW total for beef cattle establishments; and
- Agricultural activities in both Councils represent less than 1% of NSW agricultural establishments and land area in total.

Agricultural land capability maps prepared by the Department of Agriculture in accordance with the Rural Land Evaluation Manual (DUAP, 1988) indicate that:

- The cleared land affected by the route occurs solely within Great Lakes Council and has been classified as Class 3, agricultural suitability. This class is applied to gently-steeply sloping grazing lands which may be suited to pasture improvement. In general, they may be cultivated in rotation with pasture and have a moderate production level due to environmental constrains. These constraints mean that soil conservation or drainage works may be required. As a general principle, Class 3 lands should be protected from incompatible development (refer **Figure 2.2**);
- Small areas on both sides of the river have been classified as Class 4 agricultural suitability. The Port Stephens Maps also indicate that this area has timber cover. Class 4 land has a higher level of environmental constraints than Class 3, including slope. It is generally suitable for grazing purposes but is not suited for cultivation. Minimum tillage agricultural techniques may be appropriate but overall production will be low (refer **Figure 2.2**); and
- The remainder of the corridor is included within the Class 5 agricultural suitability classification. The Port Stephens Maps also indicate that an area adjoining and including Horse Island has timber cover, and another area associated with Wallaroo Swamp, as having poor local drainage. Due to the extremes of environmental conditions, this land is generally considered unsuitable for agricultural purposes. In the best cases, low level grazing may be appropriate (refer **Figure 2.2**).

The Karuah River and adjoining Port Stephens are important resources for the cultivation of oysters and fisheries in general. Based on the number of licensed sheds, NSW Fisheries has estimated that there are approximately twenty oyster farmers operating in the Karuah and Branch Rivers, extending upstream approximately six kilometres from Port Stephens. These operations create an estimated employment base of approximately 30 to 40 people. Due to the seasonal and family nature of such businesses, it is not possible to more accurately define employment in this industry.



Legend	
3 = Class 3	p = pasture
4 = Class 4	t = timber
5 = Class 5	in = inundation
U = Urban	(poor local drainage)

NOTE: Boundaries indicative only.

SOURCE: Dept Ag. Agricultural Capability Maps as Held by Councils.

Pacific Highway Upgrade Karuah

Figure 2.2

AGRICULTURAL SUITABILITY CLASSIFICATIONS

N

0 0.5 1 2 km

2.1.5 State Forests

The Karuah State Forest is situated north of the existing Pacific Highway to the west and north west of Karuah (refer **Figure 2.1)**. This area has recently been reviewed for its resource and conservation values with a portion being reclassified as the Karuah Nature Reserve (refer **Section 2.1.6**).

The Wallaroo Forest Area has been heavily logged in the past for a range of timber products including high value poles, girders, sawlogs and pulpwood, with particular emphasis on the supply of mine timbers. It has also been sourced for harvesting of domestic firewood for the Raymond Terrace urban area. However, the current management plans propose that this area provides a significant hardwood timber resource for the Newcastle market in the longer term. State Forests has therefore placed this area under recovery management mode with an estimated harvest date of approximately 2017. Under this regime, the following uses are allowed within the Wallaroo Forest Area:

- Occupation permits for bees and grazing;
- Military exercises;
- Telecommunication sites;
- Annual fuel management programs;
- Road/trail maintenance; and
- recreational uses (e.g. four wheel driving, horse riding and camping in designated sites).

Two saw milling operations are located adjoining the existing highway in the vicinity of Karuah. These mills source timber from the surrounding forests for the above markets. The survey undertaken by Purdon Associates indicated that these mills had 17 full and part-time employees which represents approximately 7.5% of Karuah's employment base (excluding oyster farmers).

2.1.6 Nature Reserve

In February 1999, a portion of the Wallaroo and Karuah State Forests were gazetted as a nature reserve under the control of the National Parks and Wildlife Service (NPWS). This gazettal occurred as a result of a Comprehensive Regional Assessment (CRA) process which reviewed the resource requirements of State Forests and the environmental significance of particular areas.

Karuah Nature Reserve is comprised of 2,637 hectares in four separate parcels. The core of the reserve contains two adjoining parcels in the catchments of Limeburners and Deep Creeks. The southern of these parcels runs from Limeburners Road north to Karuah River and Limeburners Creek and is affected by the proposed road corridor (refer **Figure 2.1)**.

The CRA indicated that the reserve's environmental significance lies in its diverse range of forest and habitat types. The reserve is recognised as having an important Koala population as well as high quality habitats for a number of threatened, endangered and vulnerable species. The reserve also includes Wallaroo Swamp.

The recent nature of the transfer of land management responsibilities to the NPWS has meant that to date no management plan or principles have been formally developed for this reserve.

The proposed highway corridor crosses the reserve and provisions for management and wildlife crossings of the highway will be required. The impacts of the proposed highway on the Koala population along with other relevant flora and fauna issues are covered in a separate Species Impact Statement (SIS) undertaken by other consultants as part of this EIS project.

2.1.7 Proposed Developments

A number of developments have been proposed for land in the vicinity of Karuah. The nature of these projects along with their current status and potential implications are summarised below.

2.1.7.1 Treatment Plant

Hunter Water is in the process of developing a treatment plant for Karuah. This project, being undertaken as part of the Hunter Sewerage Project, is located off Limeburners Road approximately 2 km west of Karuah township.

Stage 1 of the plant is due to be constructed and operational by mid 2000. The facility includes a treatment plant on a 1.8 ha site to the south of Scotts Road and effluent storage dam and irrigation facilities on a 100 ha site to the north. This latter area immediately adjoins the proposed highway alignment. Stage 1 of the project will serve 2,500 equivalent persons. Stage 2 is expected to increase this to 4,000 equivalent persons. However, based on current planning policy and growth patterns, threshold demand for Stage 2 is not expected to be reached until approximately 2020.

There are three potential impacts relating to this proposed development:

- Land acquisition for highway. The current RTA road proposal involves an acquisition of 0.1 ha from the north western corner of the irrigation field associated with the treatment plant. The impact of this acquisition is minimal and will not affect the plant's overall development under current proposals.
- Aerosols on highway traffic. There is potential for aerosols (i.e. airborne spray) from the irrigation facilities to impact on highway traffic in certain weather conditions. This issue is being addressed by other members of the consultant team as part of the EIS process.
- Visual amenity for travelling public. The proposed treatment plant will potentially be visible to traffic on the proposed highway upgrade and appropriate screening of this facility is being addressed as part of the landscape strategy for the highway upgrade. The treatment plant's irrigation facility will appear to the travelling public as an irrigated paddock. From a visual perspective it is not necessary for substantial screening of this facility to occur.

2.1.7.2 Golf Course Development

A proposed development by the Karuah Golf Club has been mooted on its existing site south of the current Pacific Highway, 3km west of Karuah. The proposal includes a resort development and a significant upgrade of the golf course facility. Despite discussions with Council, no development or rezoning application is being pursued at this stage.

The proposed highway upgrade is not considered to have a detrimental impact on this proposal. Whilst still visible, in the middle distance, from the proposed highway upgrade the improved amenity of the golf course and the proposed resort development will increase the overall market attractiveness of this facility and any associated upgrade. These changes in amenity will result through the highway's relocation and associated reduction in passing traffic volumes. The resort proposal also has the potential to create significant employment opportunities in Karuah and mitigate against employment loss in local businesses resulting from the highway upgrade (refer **Section 4.2)**.

2.1.7.3 Crayfish Farm

Port Stephens Council approved a development application in late 1998 for the extension of a crayfish farm on the land to the south of the western end of the proposed highway upgrade. It is not expected that the proposed Highway bypass will have any adverse affect on this development.

2.1.7.4 Quarry

Mountain Industries owns a 41 ha parcel of land at the eastern end of the proposed upgrade. A development application has recently been lodged with the Great Lakes Council for the expansion of quarrying on this site. It is understood that the material extracted from the quarry is intended for road base and fill-material. Although potentially available for use in the highway upgrade project, it is understood that no commitment has been given to the purchase of such material at this stage.

Although there will be issues of access to the site, which are being considered in the engineering concept design for the upgrade, the proposed Highway upgrade is not considered to have a significant impact on this proposal. Appropriate conditions will need to be included in any development consent to cover vehicular access and rock extraction methods.

2.1.7.5 Proposed Rural Subdivision

AMP has lodged a development proposal for consideration by the Great Lakes Council which involves the refocusing of agricultural operations on their property in The Branch Lane, away from grazing of cattle and towards forestry operations. This proposal recognises the proposed highway upgrade, but involves the creation of 12 lots with a minimum of 40 hectares adjoining the proposed highway upgrade alignment and the Karuah River. Access to the subdivision is proposed via The Branch Lane.

This proposal has the potential to increase the number of residents in proximity to the proposed highway corridor as well as increasing traffic using The Branch Lane and the proposed eastern interchange. The approval, subdivision and marketing of the subject lots will need to recognise the proposed highway corridor. It is understood that Council has requested further information from the proponent before it considers the application.

2.1.8 Land Use Conclusions

The Pacific Highway is a major inter and intra-regional transport link which performs a significant function in the State's economy as well as in the Hunter Region. The highway improves long distance access to the attractions of Port Stephens and Great Lakes Council areas, as well as improving local accessibility between settlements in areas adjacent to Karuah. The Highway also allows for interaction between residents and local business in these areas. In doing so, there is an interaction between the Highway and the existing land uses along its route.

Karuah's town structure and economy has developed with the Highway as its principal focus. The town's business community has provided one of highway service roles on the Pacific Highway to long distance travellers. This has evolved due to its location approximately 2-3 hours from the Greater Sydney Metropolitan Area. Whilst predominantly serving north bound traffic, Karuah also serves travellers heading south from Brisbane, the Gold Coast and the North Coast of NSW.

The Highway also affects the amenity of the town, with travellers recognising Karuah as a significant bottleneck on their trip north and with residents having problems in moving around the urban area in peak traffic periods.

The locality around Karuah has largely avoided intensive tourist development that characterises other parts of the two local government areas, and is largely being used for forestry, agricultural or commercial fishing purposes.

The proposed Highway upgrade will affect the existing landuses and patterns along with the nature of residents' lifestyles in the locality. These impacts are discussed further in **Section 3 and 4**.

2.2 Planning Policies

Planning policies of relevance to the proposed Pacific Highway upgrade at Karuah are drawn from three levels: State, Regional and Local. The interaction of these policies define the role of the Pacific Highway and the Karuah township, as well as defining the nature of considerations required to appropriately assess the proposed development.

These policies and their implications are summarised below.

2.2.1 State Planning Policies

The NSW Government has introduced a number of policies, which apply to two or more Local Government Areas. These take the form of either State Environmental Planning Policies (SEPP) or Ministerial Directions under Section 117(2) of the *Environmental Planning and Assessment Act 1979*. This section of the working paper summarises those policies of relevance to the current project.

2.2.1.1 *SEPP 4: Development Without Consent*

SEPP 4 permits development of certain public utilities without the need for development consent, where that development:

- is not prohibited by the Act;
- is carried out in accordance with respective development standards; and
- occurs in accordance with approvals granted under other legislation.

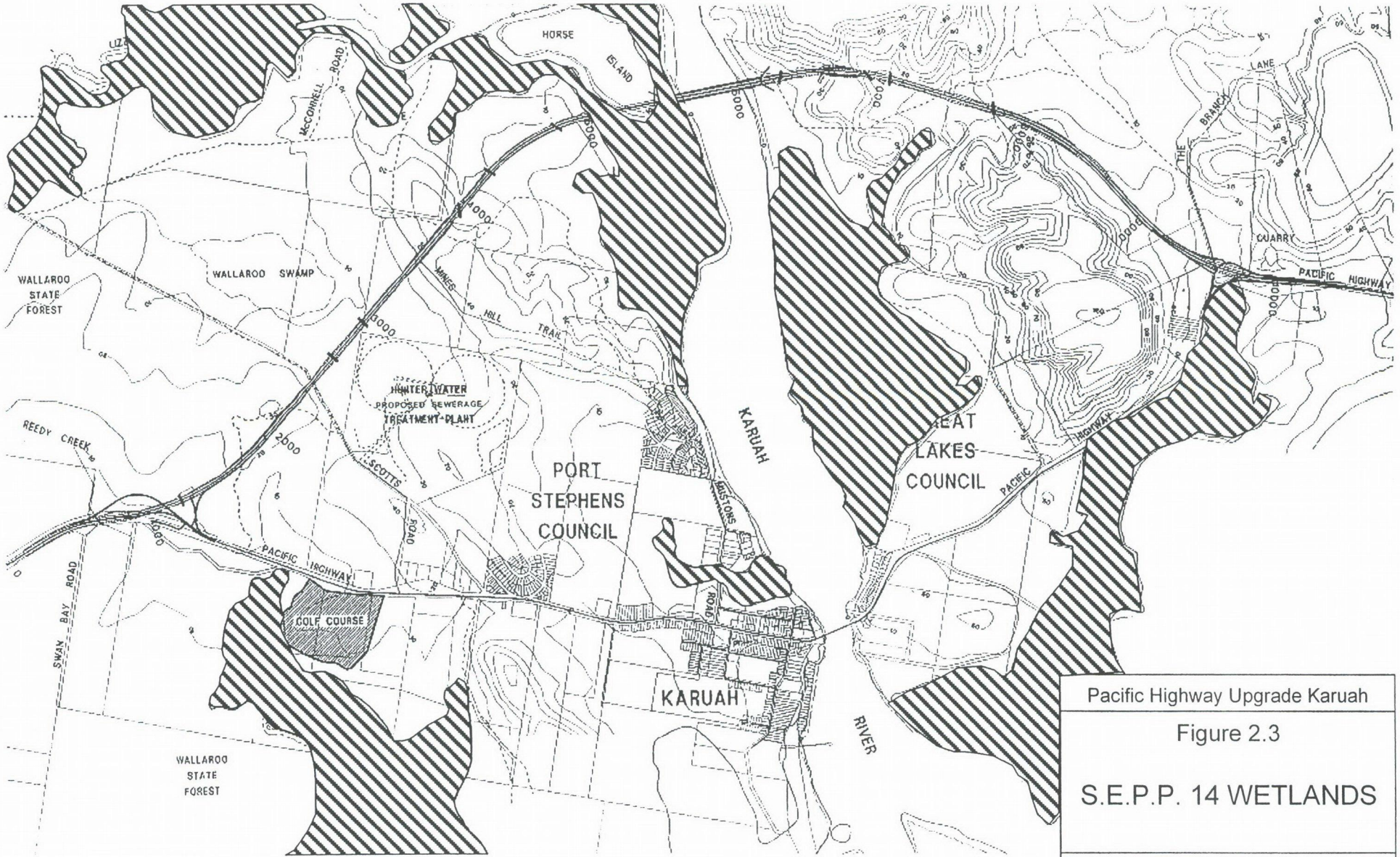
Specifically, classified roads and toll works (as defined under the Roads Act 1993) are exempted from the need to obtain development consent. However, this SEPP does not remove the need for environmental assessment under the *Environmental Planning and Assessment Act 1979*.

2.2.1.2 *SEPP 14: Coastal Wetlands*

SEPP 14 aims to preserve and protect coastal wetlands in the environmental and economic interests of NSW. The policy allows development or restoration of land affected by this policy only with the consent of the relevant Council and the concurrence of the Director of Planning. The policy outlines factors of consideration for the Director's concurrence including:

- environmental effects of proposed development;
- proposed safeguards and rehabilitation measures;
- consistency with relevant environmental policies;
- alternatives considered; and
- appropriate conditions of approval.

Three such wetlands have been identified adjoining the Karuah River and are either crossed or adjoin the route option under consideration. The Horse Island Option involves the bridging of a wetland (refer **Figure 2.3**). The impact of the proposed highway upgrade on this wetland is being considered by other consultants as part of the EIS process.


HORSE ISLAND
McCORMELL ROAD
WALLAROO STATE FOREST
WALLAROO SWAMP
HUNTER WATER PROPOSED SEWERAGE TREATMENT PLANT
REEDY CREEK
SCOTTS ROAD
PACIFIC HIGHWAY
SWAN BAY ROAD
GOLF COURSE
WALLAROO STATE FOREST
PORT STEPHENS COUNCIL
KARUAH
GREAT LAKES COUNCIL
KARUAH RIVER
THE BRANCH
QUARRY
PACIFIC HIGHWAY
Pacific Highway Upgrade Karuah
Figure 2.3
S.E.P.P. 14 WETLANDS
N
0 0.5 1 2 km

2.2.1.3 SEPP 26: Littoral Rainforest

SEPP 26 provides a mechanism for the consideration of developments that are likely to impact on littoral rainforest areas in order to achieve their preservation. It applies to recognised areas of littoral rainforest as well as land within 100 metres of SEPP 14 Wetlands. Such development can only occur with the consent of the relevant Council and the concurrence of the Director of National Parks and Wildlife.

Although there are no designated areas of Littoral Rainforest within the study area, the proximity of the proposed highway alignment to SEPP 14 Wetlands (refer **Section 2.2.1.2**) requires the consideration of the potential impact on Littoral Rainforest. Other consultants are examining this issue as part of the EIS process.

2.2.1.4 SEPP 44: Koala Habitat Protection

SEPP 44 protects native vegetation which is a core habitat for Koalas. The policy applies to all Local Government Areas specified in the policy including both Ports Stephens and Great Lakes Council areas, and to all land not included in a National Park, a State Forest and a Flora Reserve. It requires all such land to be assessed for its potential as a koala habitat and managed accordingly.

Port Stephens Council is currently preparing a Koala Plan of Management. This is not currently in a form generally accessible to the public. However, other consultants are undertaking this consideration as part of the EIS process in respect of the study corridor.

2.2.1.5 Section 117(2) Direction No. S28 – Commercial/Retail Development along the Pacific Highway

In accordance with provision of Section 117(2) of the *Environmental Planning and Assessment Act 1979*, the Minister may direct Councils to prepare Local Environmental Plan/s outlining particular policy directions.

Direction S.28 was introduced on 3 August 1998 to specifically address the nature of commercial and retail development along the Pacific Highway between the Queensland border and Hexham. This direction recognises that:

- The Pacific Highway's primary role is one of an inter and intra-regional road traffic route rather than a traffic access route to retail facilities.
- General retail activity should be located in urban areas as distinct commercial centres and any such activity located with frontage to the Pacific Highway should be designed to protect and enhance the safety and efficiency of the highway.

- Commercial and retail activities which are bypassed by the Highway should not be relocated to facilitate direct highway access.
- Highway service centres may be required to serve long distance travellers and that policies which guide the location and design of such development are appropriate.
- Existing development which adjoins the highway and fulfils a highway service function, may be allowed to expand if such expansion will help it conform with other principles of the Direction.

The implications of these guidelines for the current project are considered further in **Section 4**.

2.2.2 Regional Planning Policies

Regional planning in New South Wales is the responsibility of the Department of Urban Affairs and Planning. For planning purposes the study area falls within the Northern and Lower sub-regions of the Hunter Region. Relevant regional policies relating to the current project include:

- Hunter Regional Plan 1989;
- Hunter Coastal Urban Settlement Strategy (1994); and
- The Hunter Gateway Strategy (1998).

The **Hunter Regional Plan 1989** and **Hunter Coastal Urban Settlement Strategy (1994)** provide the regional context for planning and growth within the region. These policies recognise that the region's diverse natural environment will face increasing pressure from future population growth. They endeavour to ensure that development associated with such growth is planned and managed in an environmentally and economically acceptable manner.

Karuah does not currently play a significant role in the overall strategy. Whilst recognising the existing settlement and proposed sewerage treatment facilities, current regional planning policies do not provide for any expansion of the Karuah township, beyond infill of existing zoned areas and existing developments.

The Pacific Highway is recognised in these policies as a significant inter-regional road and that upgrading of this road is likely to occur.

The Hunter Gateway Strategy was developed by the Hunter Regional Organisation of Councils between 1996 and 1998 and was aimed at improving regional employment opportunities through the beautification and conservation of significant environments which form entrances, corridors, views and vistas in the Lower Hunter Region. The strategy is intended to serve as a model project by bringing together a number of distinct interests including conservation, employment, urban design and tourism.

Consideration of the appropriate landscape theme for the Highway between Karuah and Hexham would fit within the umbrella of the gateway strategy and could utilise the objectives and processes developed. Any landscape concepts developed and implemented for the current highway upgrade needs to be viewed within the broader context as an entrance to the Lower Hunter Region.

2.2.3 Local and Community Planning Initiatives

The proposed Pacific Highway upgrade traverses land in the Port Stephens and Great Lakes Council Areas, with the Karuah River forming the boundary. The development of the highway raises a number of issues which are affected by provisions contained in the Port Stephens Local Environmental Plan 1987 and Great Lakes Local Environmental Plan 1996. These issues include subdivision potential, highway access and the treatment of severed land.

2.2.3.1 Port Stephens Local Environmental Plan 1987

The Port Stephens Local Environmental Plan 1987 (LEP 1987) applies to the land west of the Karuah River affected by the proposed highway upgrade in either the Rural 1(a) or Rural 1(f) (Forests) zones (refer **Figure 2.5**). The principal intent of the Rural "A" zone is to provide for and protect agricultural land or land with agricultural potential. Within these zones and for the purpose of the current investigations, subdivision is only allowed:

- For those purposes permitted or permitted-with-consent under the LEP but excluding dwelling houses or duplexes;
- For public roads, minor boundary adjustments, consolidation; and
- To address severance and encroachment issues.

Although any road requires development consent in the affected zones as a public utility, LEP 1986 exempts such consent for any activity in relation to the construction or maintenance of any public road, unless the development involves:

- alterations to the design or external appearance of any buildings;
- creation or alteration to any road access; or
- widening or realignment of any road.

In these circumstances, the RTA relies on Clause 11(c) of SEPP No.4 to override the need for development consent (refer **Section 2.2.1.1**). However, assessment of the proposal is still required under the provisions of Part 5 of the *Environmental Planning and Assessment Act 1979*.

It is also noted that LEP 1987 does not currently identify any items of recognised heritage significance in the study area.

LEP 1987 also includes provisions for a Special Uses 5(c) (Proposed Arterial Roads). Consideration will need to be given to the amendment of the LEP after determination of the project by the RTA to incorporate the proposed alignment and to adequately protect it from inappropriate development until such time as the road is constructed. Once zoned Special Uses 5(c), the owner of affected land may require its acquisition by the RTA in accordance with conditions specified in the LEP. These conditions relate to:

- acquisition processes;
- RTA's 5 year works program at the time of the land owner/s request for acquisition;
- potential for interim development of the subject land and resulting costs to the RTA of such development; and
- hardship issues resulting from the RTA's inability to acquire the subject land in a reasonable time.

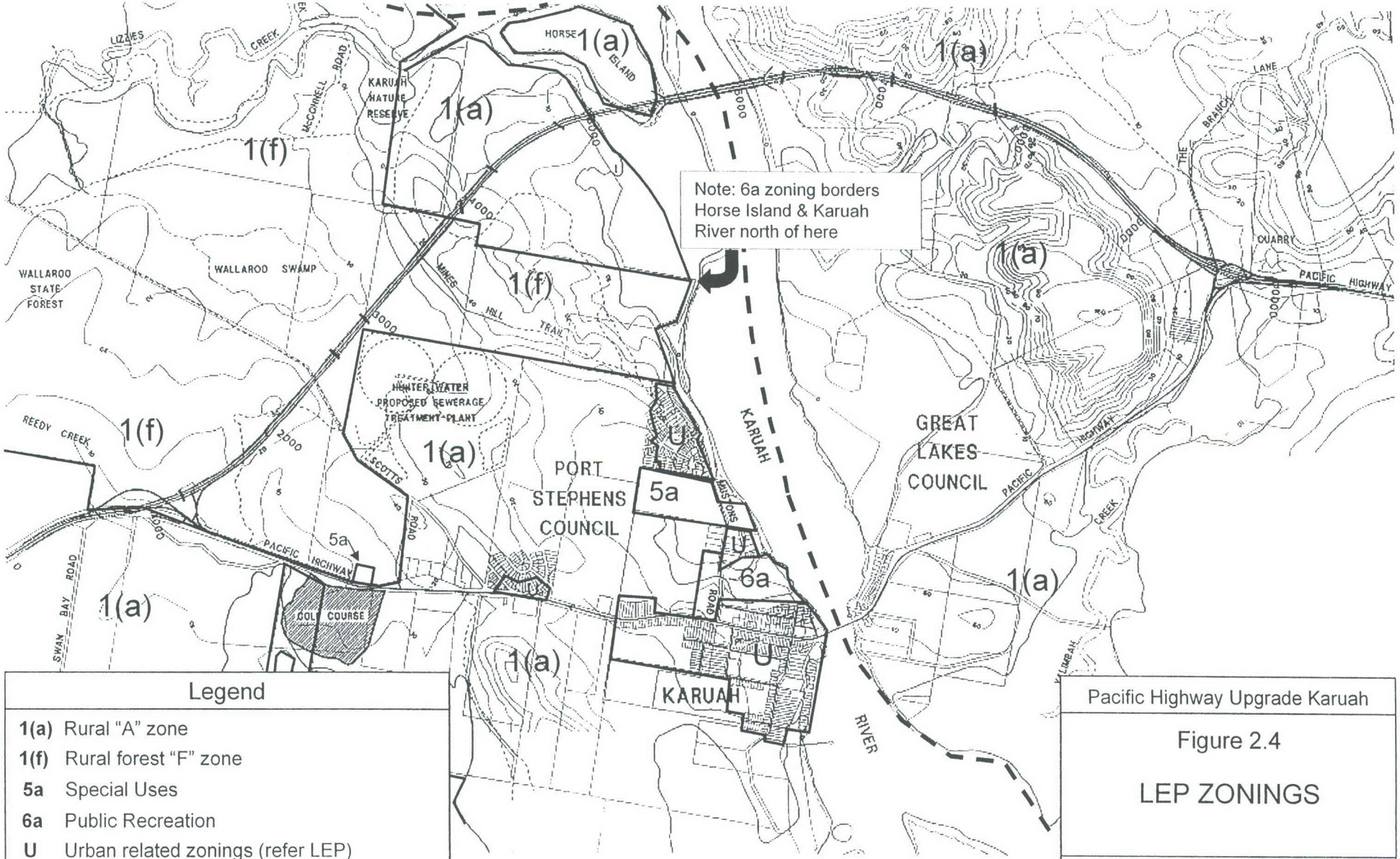
Port Stephens Council is currently undertaking a review of LEP 1987 and a draft document is expected to be on public exhibition in mid to late 1999. Although currently not in a form that could be viewed by the consultant team, it is understood that the structure of the Draft LEP simplifies the zoning principles. As a result the above Rural 1(f) Forestry Zone is to be amalgamated with the Rural 1(a) General Rural Zone. These proposals are not expected to affect the proposed highway upgrade.

2.2.3.2 Great Lakes Local Environmental Plan 1996

The Great Lakes Local Environmental Plan 1996 (LEP 1996) applies to the land east of the Karuah River and includes land affected by the proposed highway upgrade in the Rural 1(a) zone. The principal intent of the Rural "A" zone is to provide for agricultural production. Within this zone land may be subdivided, provided that the minimum allotment area created is 40 hectares. However, smaller allotments may be created to allow for minor encroachment issues or boundary adjustments.

The LEP 1996 does not require development consent for any activity in relation to the construction or maintenance of any road by Council or the RTA. However, under provisions of Part 5 of the *Environmental Planning and Assessment Act 1979*, environmental assessment is required.

It is also noted that LEP 1996 does not currently recognise any items of heritage significance in the study area.



Legend

- **1(a)** Rural "A" zone
- **1(f)** Rural forest "F" zone
- **5a** Special Uses
- **6a** Public Recreation
- **U** Urban related zonings (refer LEP)
- – – Council Boundary

SOURCE: Port Stephens LEP 1987
Great Lakes LEP 1996

Pacific Highway Upgrade Karuah

Figure 2.4

LEP ZONINGS

N

0 0.5 1 2 km

LEP 1996 includes provisions for a Special Uses 5(d) (Arterial Roads Reservation). Consideration will need to be given to the amendment of the LEP after determination of the project by the RTA to incorporate the proposed alignment and to adequately protect it from inappropriate development until such time as the land is acquired and the highway constructed. Once zoned, Council cannot consent to the subdivision of land zoned for a proposed road unless that subdivision makes provision for the creation of that road.

The owner of affected land zoned 5(d), may require its acquisition by the RTA in accordance with conditions specified in the LEP. These conditions relate to:

- acquisition process;
- RTA's 5 year works program at the time of the land owner/s request for acquisition;
- potential for interim development of the subject land and resulting costs to the RTA of such development; and
- hardship issues resulting from the RTA's inability to acquire the subject land in a reasonable time.

2.2.3.3 Karuah Strategic Management Plan

The Karuah Strategic Management Plan is a community based planning process being co-ordinated by a number of local organisations and individuals. It endeavours to focus community vision on the future of Karuah both in the lead up to and the post highway upgrade eras.

The document proposes the following vision:

> "Karuah being the Northern Gateway to Port Stephens with good access to waterways and foreshores, offers a quality experience to locals and visitors with access to wetlands, improved streetscape and Koori culture with an emphasis on youth involvement and employment opportunities".

Five strategies have been developed to guide the future development of Karuah namely:

- Business and Tourism;
- Karuah Wetland Walking Trail;
- Foreshore/Cycleway and Recreational Development;
- Koori Development; and
- Main Street Beautification.

Since the plan's completion in September 1998, a number of organisations are independently pursuing the implementation of individual strategies. Port Stephens Council has recently received a grant under the NSW Government's Mainstreet Program to facilitate improvements to Tarean Road. It is understood that these funds will be used and supplemented by Council to engage a main street co-ordinator to implement relevant strategies for Karuah and Raymond Terrace.

2.2.4 Planning Policies Conclusion

Current planning policies relating to the study area do not preclude the proposed highway upgrade and mean that the RTA in accordance with SEPP 4 is the consent authority. Provisions of Part 5 of the *Environmental Planning and Assessment Act 1979* requiring the assessment of the project's environmental impact will be met by the current investigations. However, the section of the route that traverses SEPP 14 wetland east and west of Horse Island requires assessment under Part 4 of the Act and development consent from Port Stephens Council.

Policies outlined in **Section 2.1.1** require that some specific investigations will be required as part of the current EIS. These include the following issues:

- Coastal Wetlands;
- Littoral Rainforest; and
- Koala Habitat.

Other members of the consultant team have undertaken these investigations. The results of these investigations are reported elsewhere in the EIS documentation.

On finalisation of the final route for the Pacific Highway upgrade and depending on the timetable for its construction, the RTA will need to liaise with both Councils to reserve the proposed route in the respect LEPs in order to protect it from development in the interim and to facilitate land acquisition.

3 Social Impact

This section provides a brief review of relevant demographic characteristics of the study area and assesses the social impacts of the proposed Highway upgrade.

3.1 Demographic Characteristics

The following demographic analysis is largely based on the Australian Bureau of Statistics (ABS) 1996 census. Although part of Karuah is located on the eastern bank of the river (i.e. Alicetown), the nature of data collection by ABS has meant that it is difficult to differentiate this portion of Karuah from its surrounding rural population. Unless otherwise stated the following analysis addresses only that portion of Karuah on the river's western bank, (as contained in ABS Collector District 1111108).

3.1.1 Population Characteristics

In 1996, Karuah's total population (including Alicetown) was 838 persons (ABS Jan 1998).

This population was characterised by:

- Slightly lower than average proportion of people under 15 years of age (Karuah with 20.7% compared to the Hunter region at 21.8% and NSW at 21.3%).
- Higher than average proportion of older people over 60 years of age (Karuah with 22.2% compared to Hunter region at 18.5% and NSW at 16.6%).
- A substantially higher than proportional representation of people with Aboriginal and Torres Strait Islander heritage (Karuah with 14.2% compared to Hunter Region at 0.13% and NSW at 0.12%).

These attributes reflect the choice of Karuah as a retirement destination as well as the presence of the Aboriginal Community.

Karuah is also characterised by lower than average individual incomes. About 90% of the labour force earned less than the NSW average of $610 per week, and almost 80% of the labour force earned less than $400 per week. There is also a discrepancy between male and female incomes. This is consistent with the rest of NSW. Female incomes tend to be lower because of their over representation in part-time positions associated with service stations and road houses in Karuah.

3.1.2 Housing

The 1996 Census identified a total of 374 houses in the western portion of Karuah, of which 74% (313) were occupied resulting in an average occupancy rate of 2.6 persons per household. This is higher than the occupancy rate for NSW of 2.4 persons per household.

This housing stock is dominated by detached dwellings (86%), with the remainder including either flats or units (2%), Caravans (6%) and other housing types. Caravans accommodate a higher level of Karuah's population (4%) than does similar housing forms elsewhere in the Hunter (1%) and NSW (1%).

When compared with the Hunter Region and NSW as a whole, Karuah experienced:

- A higher home ownership rate (Karuah with 43% compared with Hunter at 40% and NSW at 39%);
- A higher vacancy rate (Karuah with 16% compared with Hunter Region at 10% and NSW at 9%);
- Lower proportion of rented dwellings (Karuah with 21% compared with Hunter Region at 25% and NSW at 28%); and
- Lower levels of home purchasing (Karuah with 15% compared with Hunter Region at 21% and NSW at 21%).

These characteristics are indicative of a settled and non-transient population, combined with the provision of owner-occupied holiday dwellings.

3.2 Residential Amenity

Within the study area, the Pacific Highway provides direct frontage to approximately 60 residential properties (or about 20% of total housing stock), two motels and a caravan park. The majority of these highway dwellings have a setback of approximately eight to ten metres. This means that the amenity of these properties is currently affected by the noise of highway traffic and difficulties in gaining access to the highway, particularly during peak periods.

For the wider Karuah community, the Highway also performs a significant function as the town's commercial centre and a key element of its transport network (i.e. Tarean Road). During peak periods, residents have difficulty accessing this commercial centre and crossing their main street. The relocation of the highway away from Karuah has the potential to significantly improve the residential amenity of those properties fronting Tarean Road.

Although the majority of the proposed alignment is through forestry and agricultural land, five residential dwellings are indirectly affected by the proposal alignment. Impacts on these dwellings result from proximity to the proposed road corridor and potentially relate to traffic noise and visual effects.

One of these dwellings is affected by the current highway alignment and is located in proximity to the eastern interchange. This residence is approximately 200 metres from the existing highway and only 100 metres from the proposed corridor. Subject to detailed design, access arrangements to this property may also be affected.

The other four properties are not currently affected by the existing Pacific Highway and are located between 200 and 600 metres from the proposed corridor. One of these properties is believed to have views southwards over the Karuah River towards the Highway upgrade. These views will be substantially changed through the construction of the Karuah River Bridge at Horse Island.

The corridor will directly affect a further property located off The Branch Lane near its intersection with the existing Pacific Highway. This property contains a number of train carriages and farm sheds. However their detailed function and occupancy status is uncertain. A portion of this property will be acquired as part of the Highway proposal.

3.3 Local Access

The upgrade of the Pacific Highway to meet national highway design standard requires that access to adjoining properties be restricted. Approximately 60 properties currently have direct and unrestricted frontage to the existing Highway within the study area. These include properties both within the township and in adjoining rural areas having direct highway frontage.

The Horse Island proposal will mean that although direct access from Tarean Road (the existing highway) to these properties will not be changed, the road being accessed will no longer be the Pacific Highway. This alteration will improve direct access to individual properties particularly during peak periods, due to a reduction in traffic levels.

For properties south of the proposed alignment including the Karuah Township, access from the new road will be via the existing highway (Tarean Road) and by means of the eastern and western interchanges. It is not anticipated that travel time to and from Karuah, Raymond Terrace and other settlements in the vicinity will be significantly altered by the upgrade proposal.

Due to an expected decrease in traffic movements within the Karuah township, access across Tarean Road and within the town should be substantially improved, especially during peak holiday periods. Access arrangements within Karuah's town centre will also be improved through the reduction in traffic numbers and the change in nature of the road. The ease and safety of pedestrian movements across Tarean Road will also improve. The reduction in traffic flow also has economic implications for businesses in town (refer **Section 4**).

Properties north of the proposed route will generally have their existing access maintained. On the western side of the Karuah River, access will continue to be provided by Scotts Road and Mines Hill Trail, being an extension of Mustons Road. Bridges over the new highway are proposed to facilitate this access. In addition to provision of access to individual properties, these bridges will facilitate access for commercial and recreational users of the Karuah Nature Reserve and the Wallaroo State Forest.

For properties on the eastern side of the Karuah River, The Branch Lane will remain the principal access. However, its intersection with both the existing and proposed highways will be affected and incorporated into the eastern interchange.

3.4 Agriculture

The principal impacts on the agricultural sector resulting from the highway upgrade will include:

- impact on rural amenity;
- potential for fragmentation of properties;
- loss of cleared agricultural land (refer **Section 4.1**); and
- restriction of access to individual properties (refer **Section 3.3**).

The impacts on rural amenity result from the placement of a road in a location where no such road previously existed and include changes to rural views and the' previously peaceful rural environment.

The visual changes depend largely on the viewer's perspective. The amenity for the travelling public will be significantly changed as the journey will be relocated from the existing highway through an urban area to one through a rural environment. The new journey will also include a bridge of the Karuah River giving extensive views over the surrounding countryside.

However the quiet rural environment experienced by residents and existing users of the proposed corridor will be significantly affected. The forests and agricultural land currently located in the corridor will be replaced by a high-speed national highway standard road. Design elements reducing traffic noise and emissions will be important in mitigating this decreased amenity. Such measures will be developed as identified elsewhere through the EIS process and subsequent detail design, as appropriate. The noise and visual implications are under consideration by other team members as part of this EIS process.

In addition to the acquisition of the proposed corridor, the highway upgrade will result in the fragmentation of four privately owned agricultural properties, two properties on either side of the river. To the west of the Karuah River, the corridor will separate or sever one parcel from each of two properties. The more significant impact involves the severance of 26 hectares from the remainder of the property representing approximately 26% of the property's total area. The other severance west of the river involves less than one hectare representing about 20% of the property's area.

To the east of the Karuah River, two parcels are severed from each of two properties. The more significantly affected property has two parcels of 3.6 and 3.9 hectares which would be separated from the remainder of the property, representing approximately 5% of the total holding. Although the second holding involves larger land areas (29ha and 21ha), the larger total holding means that this represents only 3% of land area and is likely to have a smaller impact. This latter property is also the subject of a current subdivision proposal (refer **Section 2.1.7**).

In both cases, the absence of access between the principal holding and the severed parcel effectively severs the later portions from the main landholding. This situation can be mitigated by several means:

- Provision of management/stock access under or over the proposed highway; or
- Negotiated sale of the smaller portion by either affected landholder or the RTA to other adjoining landowners.

Due to their size, acquisition of these parcels by the RTA for incorporation into the road reserve is inappropriate in this case. However, the provision of appropriate management/stock access should be incorporated in the concept design.

In addition to the impact on the above private properties, fragmentation of the State Forest and Nature Reserve also occurs. Due to the Nature Reserves proximity to the State Forest and the habitat potential of this forest, the need for appropriate management and wildlife underpasses is recognised. Provision has been made in the concept design for twenty facilities or landscaping features which will facilitate fauna crossings of the proposed highway. Sixteen of these are located to the west of the river and include bridges at Scotts Road and Mines Hill Trail that will also facilitate management access.

3.5 Health and Psychological Effects

Apart from noise and road safety issues, no separate assessment of wider health or related issues has been undertaken. The issue of road safety is considered by other Consultants as part of the EIS process.

Traffic on the existing highway generates air emissions and this is likely to increase with traffic volumes, whether the upgrade proceeds or not. However, due to the rural nature of the proposed highway corridor and the anticipated traffic volumes, air emissions are predicted to be within relevant goals (Holmes Air Science 1999). Reduced traffic volumes through Karuah will also reduce the emissions within the township substantially improving the air quality along the existing highway (Tarean Road).

Several factors could lead to added stress as a result of the current proposal on some individuals in the corridor or in Karuah which will be bypassed. The process of highway upgrading, including uncertainty during the investigation and design phases, loss of land, disruptions during the construction phase, loss of business or changed business trading patterns, and subsequent adjustments to a new highway location and noise regimes may create some stress related issues for some individuals.

3.6 Social Impact Conclusion

The proposed Pacific Highway upgrade will significantly improve the residential amenity within the Karuah township in the following ways:

- Reduction in vehicle numbers along with associated reductions in vehicle emissions and noise;
- Improved vehicular access to individual properties; and
- Improved mobility and safety within the township and in particular along Tarean Road, including access to and from the local public school.

In addition to this, Pacific Highway travellers will benefit from removal of a well-known traffic bottleneck and an improved travelling experience through the rural/bushland amenity of the upgraded corridor.

These improvements will have some impact on the amenity of users and residents of land along the proposed corridor. A reduced amenity for these users and residents will result from the placement of a road in a location where no road previously existed, although it is noted that the number of people directly affected along the new route is substantially less than those in Karuah township. The impacts include:

- Increased traffic noise and emissions;
- fragmentation of rural properties;
- Proximity of several dwellings to the proposed corridor;
- Changes to access arrangements; and
- Impacts on rural views and vistas.

However the extent of these impacts are considered to be of a minor nature when compared with the substantial amenity improvements within Karuah and for the travelling public.

Mitigating measures need to be considered to reduce the above impacts. These include:

- road gradients consistent with relevant highway design standards;
- provision for appropriate local access;
- incorporation of appropriate screening, buffers and landscaping;
- provision of management/stock underpasses on agricultural properties, and in the State Forest and Nature Reserve; and
- provision of fauna crossing points in bushland areas.

4 Economic Impact

This section considers the impact of the proposed highway bypass on business turnover, investment and employment within Karuah.

4.1 Business and Employment Characteristics

The following employment analysis is largely based on the Australian Bureau of Statistics (ABS) 1996 census and the research undertaken by Purdon Associates in May 1997 and December 1998 (refer **Attachments C** and **D**).

Although part of Karuah is located on the eastern bank of the river (i.e. Alicetown), the nature of data collection by ABS has meant that it is difficult to differentiate this portion of Karuah from its surrounding rural population. Unless otherwise stated the following analysis addresses only that portion of Karuah on the river's western bank, (as contained in ABS Collector District 1111108).

4.1.1 Business Characteristics

There are approximately 35 businesses operating in the study area. The range and nature of those businesses responding to the surveys undertaken by Purdon Associates are summarised in **Table 4.1**. However it should be noted that a number of businesses listed include a mix of activities (e.g. service station/restaurant or newsagent/food/post office).

Karuah has a high percentage of local business focussed on highway service. However, the town also contains a number of other business activities which are not highway oriented. These include oyster farming, timber milling, services to the local population and services to the wider region (e.g., builders, tradesmen).

The principal types of business in Karuah, based on the number of establishments surveyed, include:

1. Petrol stations and motor vehicle repairs. This category include six (6) businesses comprised of four service stations and two motor vehicle repair workshops. One of the service stations primarily targeted at trucks. While both motor repair businesses target the local market and highway trade, one of these also acts as the local NRMA agent. The bulk of petrol and other motor products are sold by three main outlets and are heavily dependent on passing trade.

Table 4.1: Principal Business Type

Business Type	1997 Survey No.	1997 Survey %	1998 Survey No.	1998 Survey %	Comment on Difference
Petrol Station/Motor Vehicle Repairs	5	14.7%	5	14.7%	No response from 1 in '98
Food	5	14.7%	4	11.8%	1 business closed
Restaurant/cafe/takeaway	4	11.8%	4	11.8%	Part response from 1 in '98
Tourist Accommodation	4	11.8%	3	8.8%	1 declined to respond
Club/Hotel	3	8.8%	3	8.8%	
Industrial/Timber mill	2	5.9%	2	5.9%	
Hardware/Power Products	2	5.9%	2	5.9%	
Newsagent/Post Office Agency	1	2.9%	1	2.9%	
Chemist	1	2.9%	1	2.9%	
Furniture/Upholsters	1	2.9%	1	2.9%	
Hairdressers	1	2.9%	1	2.9%	
Golf Shop	1	2.9%	1	2.9%	
Boarding Kennels	1	2.9%	1	3.0%	
Medical Centre	1	2.9%	1	2.9%	
Boat Hire	1	2.9%	1	2.9%	
Newspaper	1	2.9%	0	0.0%	No response in 1998
Liquor Supplier	0	0.0%	1	2.9%	No response in 1997
Gifts	0	0.0%	1	2.9%	New
Professional Services	0	0.0%	1	2.9%	Not contactable in 97
Total	34	100.0%	32	100.0%	

Source: Purdon Survey, May 1997 & December 1998

2. Food stores. In 1998, this category includes four outlets predominantly aimed at highway service trade, tourists and the local convenience market. A further business had closed in the period since the 1997 business survey. The majority of residents appear to do weekly shopping in Raymond Terrace or Newcastle.

3. Restaurants/cafes/takeaways. Karuah has four stand alone outlets in this group, with businesses in other categories (e.g. service stations, clubs and hotels) also providing eat-in facilities.

4. Tourist accommodation. Karuah has two motels, and two caravan parks.

5. Clubs and Hotel. Karuah has two clubs and a hotel.

Other businesses located in Karuah include personal services, bulky goods (e.g. hardware, outdoor products and furniture repairs), timber milling, recreational facilities, concrete water tanks construction, and oyster farming. NSW Fisheries has estimated that there are approximately twenty oyster farmers in the vicinity of Karuah, based on the number of licensed sheds.

4.1.2 Employment Characteristics

The businesses surveyed employed a total of 227 people including the owners and/or managers. Of these, the majority (57% or 129) are employed on a part-time or casual basis, while 43% (98) are in full-time employment (refer **Table 4.2**). It is also noted that the majority (60% or 137) of those employed by local businesses are female.

In addition, NSW Fisheries estimate that the oyster industry in Karuah employs between 30-40 people. Due to the seasonal and family nature of such businesses it is not possible to more accurately define employment in this industry within the scope of the current exercise.

The inclusion of these additional jobs increases total employment in Karuah in late 1998 to between 280-290 positions.

Table 4.2: Employment Numbers

	Male No.	Female No.	Total No.	%
Full Time	61	37	98	43%
Part-time/casual	29	100	129	57%
Total	90	137	227	
	40%	60%	100%	100%

Source: Purdon Survey, December 1998

The 1996 Census identified the industry of employment by place of residency (refer **Table 4.3**). For the urban area of Karuah (located west of the river), the census indicated that the principal industrial base for employment included:

- Retail trade (26%);
- Agriculture, forestry and fishing (15%);
- Accommodation, cafes and restaurants (13%); and
- Manufacturing (11%).

Off these, retail trade and accommodation, cafes and restaurants are most likely to be affected by the highway upgrade (refer **Section 4.2**).

Whilst broadly consistent with the Purdon Surveys, discrepancies occurred due to:

- lapse in time between the sources;
- differing emphasis. The 1998 business survey was focused on place of employment while the 1996 Census is based on the place of residency; and
- marginal differences in the areas covered by the survey and census. The survey focused on all businesses within the urban and immediately adjoining areas, on both sides of the river. It included the businesses west of the township out to and including the golf course. Whilst the census excludes both the Golf Course and the Jetty Village Caravan Park.

Table 4.3: Employment by Gender and Industry (1996)

Industry	Male		Female		Total	
Agriculture, Forestry and Fishing	28	21%	6	6%	34	15%
Mining	3	2%			3	1%
Manufacture	17	13%	9	9%	26	11%
Electricity, Gas and Water supply	3	2%			3	1%
Construction	19	14%			19	8%
Wholesale trade	3	2%			3	1%
Retail trade	26	19%	34	35%	60	26%
Accommodation, Cafes and restaurants	5	4%	25	26%	30	13%
Transport and storage	6	4%			6	3%
Communication Services			3	3%	3	1%
Finance and Insurance	3	2%	6	6%	9	4%
Property and Business Services	6	4%			6	3%
Government Administration and Defence	8	6%	3	3%	11	5%
Education	6	4%	4	4%	10	4%
Health and Community Services			6	6%	6	3%
not stated	3	2%			3	1%
Total	136	100%	96	100%	232	100%
	59%		41%		100%	

Source: ABS, 1996, Census of Population and Housing, Table T19

Further detailed analysis of employment characteristics is provided in the Business Survey reports contained in **Attachments C** and **D**. The relationship of this business and employment base to the highway and the impact of the proposed highway upgrade in discussed in **Section 4.2**.

4.2 Highway Business and Employment

Recent studies of Karuah by Purdon Associates for the RTA (refer **Attachment C** and **D**) show that there is a high level of dependence on passing highway traffic. Direct linkages include at least four service stations/road houses and two motels.

Examples of indirect business linkages to the highway include those establishments that provide services or supplies (e.g. food) to the roadhouses.

The investigations undertaken include two surveys (May 1997 and December 1998) of the forty business establishments. In each, the manager or owner of each business was requested to assess the impact of the proposed highway upgrade. The 1998 survey was undertaken in light of the decision to proceed with investigations for the Horse Island Option.

The 1998 survey results (Purdon, December 1998) show:

- Approximately one third (29%) of businesses in Karuah were 'totally reliant' on the highway for trade;
- a further 12% of businesses were 'substantially reliant' on the highway for trade, principally due to their servicing of highway dependant businesses; and
- 60% of employment in Karuah was associated with businesses that were either 'totally' or 'substantially highway reliant';
- The majority (57%) of jobs in Karuah were part-time positions, with 73% of these being associated with highway reliant businesses;
- women employees occupied the majority (60%) of jobs in Karuah with 77% being in highway related businesses.

Based on this information, Karuah has a high business and employment dependence on the highway.

The survey results also recognised that the low level of expected future capital investment in the town centre is in part due to uncertainty being created by the highway upgrade proposal and an assessment of the impact of reduced traffic flow along what is the current highway.

A bypass of Karuah is expected to have a significantly adverse effect on local business and employment prospects. Approximately 35% (12) businesses are anticipating closure with a further 26% (9) businesses anticipating a decrease in trade. This impact may potentially affect up to 130 jobs or 58% of total local employment. Based on the above business characteristic, the impact of this loss of employment will affect part-time and/or female employees working in service stations, road houses and fast food outlets. This effect is consistent with evidence from other bypassed communities (Parolin & Garner, 1996).

Flow on effects may further increase this trade and employment loss. However, the Parolin & Garner 1996 report suggests that such indirect impacts will be minor and affect gross annual turnover rather than employment levels.

Some of this loss in employment will be offset by development proposals currently being considered which are unrelated to the highway upgrade (refer **Section 2.1.7**). Although specific employment numbers for these projects are not known, these new or expanded activities have the potential to generate additional employment based in the study area.

An evaluation of the *Economic Impact of Bypass Roads on Country Towns* has been conducted over recent years for the RTA (Parolin & Garner, 1996). This study included a number of towns in NSW that had been bypassed by national highways. The study concluded that whilst some short term restructuring of local business does occur, with associated business closures, there have been a number of beneficial outcomes in the medium to longer term arising from the bypass. Whilst each town responds differently to the effects of a bypass, experience has shown that employment impacts are generally not as severe as initially forecast and that there are compensating benefits from improved local residential amenity, tourist trade and convenience of local shopping. Employment loss is minimised where niche markets are developed quickly (e.g. Berrima) or where mitigating measures are incorporated in to the highway design (e.g. highway service centre at Yass).

Experience of other bypasses has shown that the travelling public tends to buy petrol, food and other services at highway service centres in preference to a detour into the local town. To date however, provision of **overnight accommodation** has been retained in the local town (Parolin & Garner, 1996). Whilst this involves a decision to break the trip, hotels/motels in towns that have been bypassed now offer accommodation that is much quieter than locations that were previously affected by highway noise. This situation is seen as a positive marketing opportunity for accommodation in Karuah. Other affected businesses may also benefit from product diversification or change marketing strategies. Such marketing initiatives will need to specifically target residents of other settlements in the locality of Karuah to ensure that these people continue to use facilities and services in Karuah rather than those located in Raymond Terrace.

The provision of a **highway service centre** site close to Karuah has been raised as a possible option for mitigating the above business impacts on the Karuah Community, particularly in respect of employment levels.

Although Council and RTA approval would be required, such a proposal would need to be investigated and developed by the private sector. No such proposal currently exists.

Such a facility could generally comply with the location and design guidelines specified in the Minister's Section 117(2) direction (refer **Section 2.2.1.5**), in that:

- facilities could be located close to Karuah (i.e. approximately 4 kilometres) at one of the interchanges of the proposed highway upgrade with the Karuah Access Road (existing highway);
- employees resident in Karuah would not need to use the highway upgrade to access the facility;
- with the exception of the Ayers Rock Roadhouse, the closest highway service facilities are located at Raymond Terrace, approximately 28 kilometres south, and Bulahdelah 43 kilometres north; and
- the range of facilities required by the long distance traveller could be located on the site.

The principal advantage of such a centre is its potential to retain some of the current local employment affected by the highway upgrade. Large highway service centres located on both sides of a national highway are generally recognised as significant employment generators employing up to 100 people in full-time, part-time and casual positions. Such a proposal in the vicinity of Karuah could substantially mitigate against the potential identified loss of 130 positions from the Karuah economy.

The benefits to Karuah that may accrued from the facility also increase particularly if the contract to operate the service centre was won by one or more of the existing roadhouse operators in Karuah. Such benefits arise from the retention of local investment and the associated multiplier effects for support businesses within the local economy.

However, the impact of such a centre on Karuah has also been questioned by the local business community. Concerns regarding the development and operation of such a facility include:

- concentration of activity in the management of one business operator rather than the current four operators;
- allocation of contracts for operation of, and support services to, the centre to an out-of-town operator thereby losing some of the economic returns to the town; and
- discouragement for the travelling public to visit the township of Karuah itself, and the associated flow-on benefits to other business outlets.

Some respondents to the Business Survey (December 1998) were concerned at the concept of a new highway service centre, commenting that Karuah could retain its highway service function if the design of the highway upgrade gave priority to traffic accessing the town rather than being directed along the bypass (refer **Attachment D**). It should be noted however, that this concept is not consistent with current RTA design practice which is considered to adequately address the issues raised.

Research undertaken by Parolin and Garner (1996) recognised the increasing role of highway service centres over town centres in provision of services to the travelling public. Whilst noting that long distance travellers do not appear to be changing their behaviour, with a return to the use of town centre based services, this research indicated that such town centres may recapture some highway trade in future due to environmental benefits resulting from being bypassed.

Improved highway signage provides another opportunity for promotion of Karuah as a 'stop-revive-survive' destination. Negotiations between Karuah and RTA regarding the placement of suitable highway signage between Sydney and the township could help boost awareness and encourage travellers to stop for a short break or overnight stay.

The highway upgrade proposal provides an opportunity for the Karuah Community to refocus and to define a new future for itself. The Karuah Strategic Management Plan (refer **Section 2.2.3.3**) goes some way to addressing the need to move Karuah away from its current role as highway service town to one as a place to live and/or visit. However during the survey period, there was an observed lack of support and confidence in these initiatives from the local business community. It will also be important for individual businesses to refocus. Such a process will need to address product diversification and target marketing. The business community will also need to ensure that it meets the needs of local residents, including those of surrounding settlements (e.g. North Arm Cove) to prevent a loss of patronage to Raymond Terrace.

Whilst not officially promoted as a **commuter town,** Karuah has the advantages of proximity (by car) to employment centres in the Lower Hunter region, relatively cheap land, and a village atmosphere with access to a range of social infrastructure including primary school, clubs, churches, and recreation facilities. Provision of a sewerage scheme will also have a positive effect on the town.

Karuah is not currently seen nor marketed as a **tourist destination** and its short to medium term potential is restricted by the lack of facilities and competition from other settlements around Port Stephens. However, its location on the Karuah River near its confluence with Port Stephens and the ease of access from the Hunter and Sydney markets, establishes a good base for future targeted tourist development. Specific opportunities could include low cost tourist accommodation, estuary and river fishing, boating facilities (including houseboat hire), and establishment of environmental and cultural education facilities.

The gradual development of these new town functions for Karuah will create new business and employment opportunities in the local area that are not dependent on highway service. Existing development proposals (refer **Section 2.1.7**) will also assist this process.

The location of the proposed highway across two local government boundaries complicates the planning of the proposed highway as well as the formulation of responses to the community's concerns. In particular, the formulation and implementation of an economic development strategy should conceivably be addressed by both Local Government Authorities (i.e. Port Stephens and Great Lakes). However, due to the location of the majority of the Karuah Township, leadership in this function will primarily fall to Port Stephens Council.

4.3 Land Acquisition and Compensation

The proposed highway upgrade will impact on a number of property owners, and require the acquisition of both government and private land by the RTA.

For the purposes of the current assessment, a corridor width of approximately 90 metres has been assumed. The proposed highway (excluding bridges) requires a land take of approximately 89 hectares from ten separate land owners. Only one property is to be totally acquired for the project. However, this property is less than 0.5ha and is currently unused.

The severity of impact on any individual property owner will be dependant on the relationship between the current property size, the amount of land acquired and the owners' current and intended use for that property. Three properties are principally affected by this acquisition. The impact on these properties range from 6% to 12% of the total property area.

With the exception of fencing and one dam, no capital improvements are affected on these properties. The quality of the land is considered generally to be of Class 4 and 5 agricultural suitability and therefore the significance of impact relates to the extent of the resumption. One property falls within a Class 3 agricultural suitability and therefore the severity of the impact is greater due to the higher quality of the agricultural land resumed.

The remaining six properties have less than 4% of their total holding resumed. The impact of this resumption (excluding severance issues as referred to in **Section 3.4**) is therefore considered to be minor. However it should be noted that within this group are the three largest single acquisitions required for the highway upgrade:

- approximately 28 hectares is required from one property east of the Karuah River. This land also falls within the Class 3 agricultural suitability and therefore has the potential for a more significant impact on the property. However due to the required land take being less than 1% of the total property, the impact is considered minor. This land is also currently the subject of a subdivision proposal, thereby lessening the impact of the highway upgrade on the property's current operations;
- approximately 21 hectares is required from the Wallaroo State Forest. Given the extent of the Wallaroo State Forest and the current status of the resource that it contains, the impact of this land take is considered to be relatively minor; and
- approximately 14 hectares is required from the Karuah Nature Reserve. This represents less than 1% of the reserve's total area. The impact of this acquisition on the reserve's significance has been assessed by other members of the consultant team.

The Roads Act 1993 authorises the RTA to acquire land affected by its proposals, while compensation for such acquisition is assessed having regard to the compensation provision of the Land Acquisition (Just Terms Compensation) Act 1991.

The RTA has estimated a total land acquisition cost for the project of approximately $1.9 million. This includes provision for compensation related issues. It should be noted that no compensation is payable by RTA for loss of business income by properties in localities that have been bypassed by the Highway.

4.4 Future Subdivision Potential

The potential for future land subdivision along the corridor as a result of the location of the proposed highway is very limited.

Pursuant to the Port Stephens LEP 1986 there are no minimum lot areas in the subject zones. However, subdivision may occur as a result of a single allotment being divided by a public road. No such provision exists in the Great Lakes Council LEP 1996, where the minimum relevant lot area is 40 hectares.

Under these provisions only two additional lots can be created. These form two of the 12 lots subdivision currently being proposed by AMP. East of the River, the RTA will need to consider provision of management access across or under the proposed highway upgrade or facilitate the sale of severed land to adjoining land owners (refer **Section 3.4 and 4.2**).

4.5 Oyster Leases

Several oyster leases are directly under the alignment of the proposed Horse Island Bridge and may be affected by the proposal. Potential impacts on these leases relate to changes in water quality and flow, both during construction and in the long term.

During construction care will need to be taken to avoid sediment flows into and within the river, through the use of appropriate mitigation measures.

Longer term impacts may result from the design of the proposed bridge impacting on water flows in the vicinity of the leases. Care will also need to be taken to ensure that road and bridge run-off does not enter the river without appropriate treatment.

However, the bulk of oyster business operations in the locality are unlikely to be affected by any gain or loss of trade as a result of the highway bypass, and will continue to provide employment in the local area.

The consultant team is currently undertaking detailed consultation with NSW Fisheries and affected lessees. This consultation will be required throughout the design and construction process to ensure impacts are mitigated. One option that may need to be considered is the resumption of the oyster leases which have the potential to be directly affected.

4.6 Economic Impact Conclusions

Karuah has a relatively small business and employment base with approximately 40% of business and 60% of jobs being either totally or substantially reliant on the existing highway. The proposed highway upgrade has the potential to impact significantly on this business and employment base. A number of mitigating actions can be taken to offset the potential loss of highway-oriented trade and employment, although there is not unanimous support within the local community for any one agreed strategy.

The development of a Highway Service Centre is seen as desirable for the retention of local employment, but its flow-on impacts on remaining businesses is seen by some business with concern. In order to maximise the benefits of such a centre the inclusion of local business owners in its development and operation is seen as desirable. However, it is recognised that such a proposal is not the responsibility of the RTA but would require the investigation and implementation by a private developer.

Improved highway signage promoting Karuah, as a 'stop-revive-survive' town would be provided by the RTA to assist in offsetting loss of trade and jobs as a result of the bypass.

The loss of employment resulting from the highway upgrade will in part be offset by employment associated with existing development proposals.

Other examples of alternative development opportunities for Karuah that need to be addressed by the local community include the town's role as a low cost tourist and recreation centre and as an expanding residential area. Individual businesses also need to assess product and service diversity as well as alternative marketing options.

In order to minimise the impact of the proposed highway upgrade on the economy of Karuah, a comprehensive economic development strategy should be prepared. The RTA, Port Stephens and Great Lakes Councils and other NSW Government agencies along with community and private sector interests all have a role in the funding, developing and implementing of such a strategy.

The upgrading of the Pacific Highway requires the acquisition of a corridor of land of sufficient width to accommodate the road and associated infrastructure. The RTA will therefore need to negotiate appropriate compensation with directly affected landowners.

5 Conclusion

The Pacific Highway is a major inter and intra-regional transport link which performs a significant function in the State's economy as well as in the Hunter Region. The highway improves long distance access to the attractions of Port Stephens and Great Lake Council areas, as well as improving local accessibility between settlements in areas adjacent to Karuah. The Highway also allows for interaction between residents and local business in these areas.

Karuah's town structure and economy has developed with the Highway as its principal focus. Not only does the town's business community provide one of the highway service roles on the Pacific Highway to long distance travellers, but the highway also affects the amenity of the town. Travellers recognise Karuah as a significant bottleneck on their trip north and residents experience problems in moving around the urban area in peak traffic periods.

On the basis of the above assessment, the principal **social and economic advantages** of the proposed Horse Island highway upgrade include:

- Improved amenity of long distance travellers using highway upgrade;
- Removal of another bottleneck for travellers using the Pacific Highway;
- Improved residential amenity residents (population 840) of Karuah Township and users of its commercial centre;
- Improved accessibility of residents to individual properties along Tarean Road;
- Improved accessibility of resident to facilities in Tarean Road during in peak traffic periods;
- Retention of non-highway reliant business and employment activities;
- Retention of local access to rural properties;
- Provision of management access to State Forests and Nature Reserve;
- Provision of fauna access across highway in State Forests and Nature Reserve; and
- Minimal impact on agricultural, forestry and fishery resources.

The principal **social and economic disadvantages** of the Horse Island highway upgrade proposal are:

- Decreased amenity of existing residents adjoining proposed highway upgrade (estimate population 15-20);
- Fragmentation of a few rural properties;

- Loss of trade to highway reliant businesses; and
- Potential loss of up to 130 jobs in highway service functions within Karuah, in the absence of mitigating measures (e.g. highway service centre).

The Highway proposal also creates a number of opportunities for the future of Karuah and surrounding areas. In order to minimise the impact of the highway upgrade proposal consideration needs to be given to:

- Provision of improved highway signage promoting Karuah;
- To establish a privately developed highway service centre in proximity to Karuah;
- The way that individual businesses respond to changing trading patterns. Changes to product range and marketing strategies need to be considered; and
- Limited opportunity to subdivide fragmented rural land east of Karuah River.

Overall the highway proposal provides the community with an opportunity to refocus Karuah away from a role of highway service town to one of residential and tourist community. The Karuah Strategic Management Plan and the recent funding under the NSW Government's 'Mainstreets' Programme go part way to achieving this change in focus.

However, a comprehensive Economic Development Strategy should be prepared for Karuah. Such a strategy needs broad-based community, business and government support and will greatly improve the ability of Karuah to achieve the above transition successfully and minimise the impact on its economic and employment base. The RTA, Port Stephens and Great Lakes Councils and other NSW Government agencies along with community and private sector interests all have a role in instigating funding, developing and implementing such a strategy.

Current planning policies relating to the study area do not preclude the proposed highway upgrade and mean that the RTA in accordance with SEPP 4 is the consent authority. However, the section of the route that traverses SEPP 14 wetland requires assessment under Part 4 of the Act and development consent from Port Stephens Council.

The RTA will also need to liaise with both Councils to reserve the proposed route in the respect LEPs in order to protect it from development in the interim and to facilitate land acquisition.

ATTACHMENT A: BIBLIOGRAPHY

Attachment A: Bibliography

Australian Bureau of Statistics, 1998, *Agriculture Australia Catelogue No. 7113.0*, Commonwealth of Australia, Canberra

Australian Bureau of Statistics, 1998, *Agriculture New South Wales Catalogue No. 7113.1*, Commonwealth of Australia, Canberra

Australian Bureau of Statistics, 1997, *1996 Census of Population and Housing – Selected Social and Housing Characteristics for Statistical Local Areas (NSW and Jervis Bay) Catalogue No. 2015.1*, Commonwealth of Australia, Canberra

Australian Bureau of Statistics, 1998, *1996 Census of Population and Housing – Selected Characteristics for Urban Centres and Localities (NSW and ACT) Catalogue No. 2016.1*, Commonwealth of Australia, Canberra

Bradley R & Holsman A, 1985, *The Impact of the Highway Bypass at Gundagai,* University of New South Wales, Sydney.

Bureau of Transport and Communication Economics (BTCE), 1994, *Working Paper 11: The Effects on Small towns of Being Bypassed by a Highway: A Case Study of Berrima and Mittagong*, BTCE, Canberra.

Community of Karuah. 1998, *Karuah Strategic Management Plan,* Community of Karuah, Karuah.

Department of Planning. 1989, *Hunter Regional Environmental Plan,* Department of Planning, Sydney.

Department of Planning, 1988, *Rural Land Evaluation,* Department of Planning, Sydney.

Holmes Air Science, 1999, *Upgrade of Pacific Highway, Karuah – Air Quality Assessment.*

Manidis Roberts Consultants, 1998, *The Hunter Gateway Strategy,* Manidis Roberts Consultants, Maitland.

Department of Planning, 1994, *Hunter's Coast – Hunter Coastal Urban Settlement Strategy,* New South Wales Government, Sydney.

Department of Planning, 1994, *Population Projections – Non-Metropolitan Local Government Areas in New South Wales 1991-2021,* New South Wales Government, Sydney.

Port Stephens Council. 1987, *Port Stephens Local Environmental Plan 1987,* Port Stephens Council, Raymond Terrace.

Port Stephens Council. 1998, *Urban Settlement Strategy, Stage II,* Port Stephens Council, Raymond Terrace.

Parolin B & Garner B, 1996, *Evaluation of the Economic Impacts of Bypass Roads on Country Towns – Final Project Report*, University of NSW and Roads and Traffic Authority of NSW, Sydney.

Purdon Associates Pty Ltd, 1999, *Pacific Highway Upgrade – Karuah Business Survey 1998,* Purdon Associates Pty Ltd, Canberra.

Purdon Associates Pty Ltd. 1997, *Pacific Highway Upgrade – Karuah Business Survey,* Purdon Associates Pty Ltd, Canberra.

University of New South Wales – School of Geography. 1981, *The Impact of a Bypass on the Yass Economy,* University of New South Wales, Sydney.

ATTACHMENT B: CONSULTATION CONTACTS

Attachment B: Consultation Contacts

Organisation	Name	Position
NSW Fisheries	Graham White	Conservation Manager
National Parks and Wildlife Service	Ashley Love	Comprehensive Regional Assessment Unit
Department of Urban Affairs and Planning (Hunter)	Rolf Fenner	Senior Planner
Department of Urban Affairs and Planning (North Coast)	Jim Clark	
Hunter Region Organisation of Council	Tracie Stinson	Executive officer
Port Stephens Council	Michele Harrison	Strategic Planning Officer
Great Lakes Council	Paul De Szell	Development Assessment Officer
State Forests	Mike Pryma	

ATTACHMENT C:
KARUAH BUSINESS SURVEY 1997

PACIFIC HIGHWAY UPGRADE

KARUAH BUSINESS SURVEY 1997

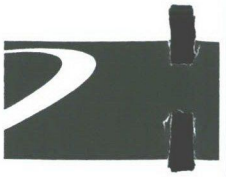
Report to

ROADS AND TRAFFIC AUTHORITY OF NSW

Prepared by

PURDON ASSOCIATES PTY LTD
3/9 McKay Street Turner ACT 2612
Tel: (06) 257 1511 Fax: (06) 248 8347

01 August 1997



ACKNOWLEDGMENTS

The Study Team for this project comprised personnel from **Purdon Associates** including Robert Purdon, Brenton Dickins, Patty Shaw, and Bianca Park.

We wish to acknowledge our appreciation for the cooperation and assistance provided by business owners and managers in Karuah.

Results of the study and conclusions drawn therefrom, as documented in this report, represent the views of the Study Team and do not necessarily reflect those of the Roads and Traffic Authority of NSW.

PURDON ASSOCIATES
August 1997

DISCLAIMER

Any representation, statement, opinion or advice expressed or implied in this publication is made in good faith but on the basis that Purdon Associates, its agents and employees are not liable to any person for any damage or loss whatsoever which has occurred or may occur, in relation to that person taking or not taking (as the case may be) action, in respect of any representation, statement or advice referred to above.

CONTENTS

1 PURPOSE 3

2 METHODOLOGY 3

3 MAIN FINDINGS 5

3.1 Business Type 5
3.2 Employee Characteristics 6
3.3 General Business Characteristics 7
3.4 Business Trade Areas 10
3.5 Reliance on Highway 12
3.6 Financial data 14
3.7 Attitude to Highway Upgrade 16
3.8 General Discussion 21
3.9 Highway Upgrade Options 23

4 CONCLUSIONS 23

ATTACHMENT A: 1

TABLES

Table 3.1: Principal Business Type 5
Table 3.2: Employment Numbers 6
Table 3.3: Residential Address of Managers and Employees 7
Table 3.4: Business Characteristics 8
Table 3.5: Reasons for Choosing Karuah 9
Table 3.6: Source of Business Supplies 10
Table 3.7: Business Trade Areas 11
Table 3.8: Reliance on Highway by Business Type 13
Table 3.9: Reliance on Highway for Employment 14
Table 3.10: Financial Data 15
Table 3.11: Attitudes to Highway Upgrade 18
Table 3.12: Summary of Attitudes 19

1 PURPOSE

The Karuah Business Survey has been undertaken by Purdon Associates as part of wider investigations for the upgrade of the Pacific Highway in vicinity of the township. The upgrade is being proposed by the Roads and Traffic Authority of NSW (RTA).

The purpose of the survey was to:

- consult directly with local traders on their attitudes to the proposed highway upgrade;
- obtain data as a basis for defining the local business profile for the study area; and
- provide a basis for assessing the impact of the proposed highway upgrade options on the local business community.

This report does not provide detailed consideration of social impact and amenity factors associated with a highway upgrade apart from reporting on the comments made by respondents during the Survey.

2 METHODOLOGY

Methodology for the Business Survey was as follows:

- businesses within Karuah were initially identified from previous visits of consultant team to Karuah, which was supplemented through a review of the local telephone directory;
- a written survey form was forwarded to all known businesses in the study area in the week commencing 12 May 1997. The Survey (refer **Attachment A**) included questions covering issues investigated recently by a study on the impact of highway bypasses for RTA. Business owners/managers were requested to complete the survey and hold it for collection by the study team; and
- businesses were advised that only aggregated survey results would be published as part of this report but privacy of individual business outlets would be maintained. Confidentiality was guaranteed with no information on individual companies to be published or given to RTA without written authorisation.

- ❑ two consultants from Purdon Associates visited Karuah in the week commencing 19 May 1997 to collect the survey forms from businesses. This also provided the consultants with the opportunity to:

  - ♦ discuss the survey with individual business people, along with their attitudes to the upgrade issue in general and Highway Upgrade options;

  - ♦ observe business operations and to draw conclusions on the likely impact of the Highway Upgrade; and

  - ♦ identify gaps in the listing of know businesses and attempt to fill those gaps by contacting those businesses identified.

- ❑ all survey results have been tabulated and analysed. The results of the survey are presented in **Section 3** with conclusions drawn in **Section 4**.

Surveys were initially sent to 32 businesses (excluding oyster farmers - see below) in the study area. During the visit of the consultants team to Karuah in respect of the survey:

- ❑ three (3) businesses were identified as no longer being active in the study area;

- ❑ a further eight (8) surveys were distributed; and

- ❑ only one (1) of the known businesses was unable to be contacted. This business is not considered to be highway related.

Where the surveys were unable to be collected, individual businesses were requested to send the form to the consultant team. Contact details were provided. Only one survey was received by this means.

In total, 34 surveys were received and analysed resulting in a response rate of approximately 92% (34 out of 37). All businesses, with the exception of a concrete tank maker, were located to the west of the bridge.

No survey or contact has yet been made with the local oyster industry. Contact with industry representatives will be made later in the investigation process. It is believed that although this industry may be temporarily affected by the construction aspects of the highway upgrade, their business operations are unlikely to be affected by any gain or loss of trade, and will continue to provide employment in the local area.

3 MAIN FINDINGS

The following discussion summarises the main findings of the Karuah Business Survey.

3.1 Business Type

Thirty four (34) of the businesses in Karuah responded to the survey and participated in discussions with the consultant team.

These business have been analysed on the basis of their principal activity. However it should be noted that the a number of these businesses include a mix of activities (eg service station / restaurant, food/videos, newsagent/food, etc).

Table 3.1: Principal Business Type

Business Type	No.	%
Boarding Kennels	1	3%
Boat Hire	1	3%
Chemist	1	3%
Club/Hotel	3	9%
Food	5	15%
Furniture/Upholsters	1	3%
Golf Shop	1	3%
Hairdressers	1	3%
Hardware/power products	2	6%
Medical Centre	1	3%
Newsagent/Post Office Agency	1	3%
Newspaper	1	3%
Petrol Station/Motor Vehicle Repairs	5	15%
Restaurant/cafe/takeaway	4	12%
Timber Mill	2	6%
Tourist Accommodation	4	12%
TOTAL	**34**	**100%**

Source: Purdon Survey, May 1997

The principal types of business surveyed in Karuah include (refer **Table 3.1**):

1. Food stores. This category includes four outlets predominantly aimed at highway service trade, tourists and the local convenience market. The majority of residents appear to do weekly shopping in Raymond Terrace/Newcastle.

2. Restaurants/cafes/takeaways. Karuah has three stand alone outlets in this group, with other activities (eg. service stations, clubs and hotels) providing eat in facilities.

3. Petrol stations and motor vehicle repairs. This category includes four service stations, one of which is primarily targeted at trucks and one which also provides motor vehicle repairs and acts as the local NRMA agent. A fifth facility is solely a motor vehicle repair centre which although principally targeting the local market does also obtain some highway trade. the bulk of petrol and other motor products are sold by three main outlets and are heavily dependent on passing trade.

4. Tourist accommodation. Karuah supports two motels, and two caravan parks.

Other business located in Karuah include a liquor store, concrete water tanks, engineering services, building contractors, and oyster farming.

The direct reliance of businesses on the highway was identified by comparing the nature of business derived from the Highway and is discussed in further detail in **Section 3.5**.

3.2 Employee Characteristics

The businesses surveyed employed 262 people including the owners and/or managers. Of these, the majority (58% or 151) are employed on a part-time or casual basis, while 42% (111) are in full-time employment (refer **Table 3.2**). From discussions it is understood that the majority of these employees are either women or youths, although details of this split were not collected.

Table 3.2: Employment Numbers

	Survey		1991 Census	
	No.	%	No.	%
Full Time	111	42%	85	31%
Part-time/casual	151	58%	176	63%
Not Stated			17	6%
Total	**262**	**100%**	**278**	**100%**

Source: Purdon Survey, May 1997
ABS 1991 Census of Population and Housing

The survey data compares with a total employed workforce resident in Karuah urban area in 1991 of approximately 280 people. However, the 1991 Census does not identify the location of the employment for these residents and some are likely to be located away from Karuah.

The differences in the full-time/part-time split between our survey and the census is believed to be primarily due to the absence of the oyster farming industry from the survey base.

The survey also indicated that the majority of owners/managers and employees resided in Karuah and the local area. These classifications represent 83% (215) of the total employed. Approximately 80% of owners and/or managers surveyed lived in Karuah (refer **Table 3.3**).

Table 3.3: Residential Address of Managers and Employees

	No.	%
Residential Location of Manager		
In Karuah	27	79%
Karuah Local Area	1	3%
Elsewhere	5	15%
Not Stated	1	3%
Sub Total	**34**	**100%**
Residential Location of Employees		
In Karuah	141	62%
Karuah Local Area	48	21%
Elsewhere	39	17%
Sub Total	**228**	**100%**
Residential Location of Managers & Employees		
In Karuah	168	64%
Karuah Local Area	49	19%
Elsewhere	44	17%
Total	**261**	**100%**

Source: Purdon Survey, May 1997

3.3 General Business Characteristics

3.3.1 General

Of the businesses surveyed, the majority (70%) had operated for less than six (6) years while 41% for less than 3 years. Only 24% of business have operated for 10 years or more (refer **Table 3.4**).

The majority of businesses also have existing highway frontage (85%), and own their own premises (56%) (refer **Table 3.4**). Of the 44% of businesses that lease their premises, 67% have less than 5 years to remain on their existing lease. This time period coincides with the stated timing of the proposed highway upgrade. Many of these businesses have indicated that their decision to renew their lease will be dependant on the outcome of Highway upgrade investigations.

Table 3.4: Business Characteristics

Item	No.	%
Length of Running Business		
Less than 1 year	4	12%
1-3 years	10	29%
3-6 years	10	29%
6-10 years	2	6%
more than 10 years	8	24%
Total	**34**	**100%**
Ownership of Business Property		
Owned	19	56%
Leased	15	44%
Total	**34**	**100%**
Length to run on Leased Property		
less than 1 year	1	7%
1-3 years	3	20%
3-5 years	6	40%
over 5 years	5	33%
Total	**15**	**100%**
Highway Frontage		
Yes	29	85%
No	5	15%
Total	**34**	**100%**

Source: Purdon Survey, May 1997

3.3.2 Business Location Decisions

The principal factors affecting the choice of location for businesses in Karuah were (refer **Table 3.5**):

- available business opportunity (71% of all businesses responding);
- high volumes of passing traffic (53%);
- lifestyle (18%);
- availability of raw materials (9%); and
- cheap land/premises available (6%).

Although not specifically differentiated within the survey, available business opportunity includes both the purchase of existing businesses and identified gaps within the Karuah market.

Table 3.5: Reasons for Choosing Karuah

Reason	No.	%
Available Business Opportunity	24	71%
High Volume of Passing Traffic	18	53%
Lifestyle	6	18%
Raw materials available	3	9%
Cheap Land/Premises Available	2	6%
Other	1	3%
Family Reasons	1	3%
Central to Market	1	3%
Tourism potential	1	3%
Location	1	3%
Local Demand for products/services	1	3%
Total Responses	**59**	
Total Establishments	**34**	

Source: Purdon Survey, May 1997

3.3.3 Source of Business Supplies

Businesses were asked to identify the source of business supplies coming from the following locations: Karuah, Newcastle and Hunter Region, Sydney, and elsewhere. The results are summarised in **Table 3.6**.

The principal source of supplies for businesses operating in Karuah is the Newcastle and Hunter Region, with 94% of all business obtaining some supplies from this area. Almost two-thirds (61%) of businesses get some supplies from the Karuah area, 58% from Sydney and 45% from elsewhere.

Conversely approximately 40% of businesses get no supplies from the Karuah area.

Of those businesses obtaining supplies from Karuah, only seven (7) businesses (37%) get more than 50% of their supplies from the Karuah area. While thirteen (13) business (or 44%) get more than 50% of their supplies from Newcastle and the Hunter.

Table 3.6: Source of Business Supplies

% of Supplies	Karuah		Newcastle/ Hunter		Sydney		Elsewhere		
	No.	%	No.	%	No.	%	No.	%	
1-10%	6	32%	6	21%	8	44%	5	36%	
11-20%	4	21%	2	7%	2	11%	5	36%	
21-30%	1	5%	3	10%	2	11%	1	7%	
31-40%	1	5%	3	10%	1	6%	1	7%	
41-50%	0	0%	2	7%	2	11%	1	7%	
51-60%	1	5%	0	0%	0	0%	1	7%	
61-70%	1	5%	2	7%	1	6%	0	0%	
71-80%	2	11%	5	17%	0	0%	0	0%	
81-90%	1	5%	3	10%	2	11%	0	0%	
91-100%	2	11%	3	10%	0	0%	0	0%	
Total	**19**	**100%**	**29**	**100%**	**18**	**100%**	**14**	**100%**	**31**
	61%		**94%**		**58%**		**45%**		**100%**
0%	12	39%	2	6%	13	42%	17	55%	
Total Responses	**31**		**31**		**31**		**31**		
Not Stated	3		3		3		3		
Total Establishments	34		34		34		34		

Source: Purdon Survey, May 1997

3.4 Business Trade Areas

Businesses were asked to allocate the source of trade to the following categories:

- Local residents;
- Hunter Region;
- Passing Highway Trade;
- Indirect Highway Trade;
- Holiday Makers in Karuah;
- Other NSW Areas; and
- Interstate and Overseas.

A number of business had difficulties distinguishing between some of these categories and in particular the 'Passing Highway Trade' and 'Holiday Makers'. As a result, they assumed that trade was directly associated with the Highway traffic unless obviously noted otherwise. A strong reliance on highway traffic is therefore stated. The results are summarised in **Table 3.7**.

Table 3.7: Business Trade Areas

% of Trade	Local Residents		Hunter Region		Passing Highway Trade		Indirect Highway trade		Holiday Makers		Other NSW		Interstate/OS		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
1-10%	7	23%	9	50%	8	28%	4	50%	10	63%	4	80%	4	100%	
11-20%	8	27%	3	17%	4	14%	1	13%	2	13%	1	20%			
21-30%	1	3%	3	17%	2	7%			1	6%					
31-40%	3	10%	1	6%	4	14%	2	25%	1	6%					
41-50%	3	10%	1	6%	1	3%			1	6%					
51-60%	1	3%			1	3%	1	13%							
61-70%	3	10%			3	10%			1	6%					
71-80%	1	3%	1	6%	1	3%									
81-90%	2	7%													
91-100%	1	3%			5	17%									
Total	**30**	**100%**	**18**	**100%**	**29**	**100%**	**8**	**100%**	**16**	**100%**	**5**	**100%**	**4**	**100%**	**32**
	94%		**56%**		**91%**		**25%**		**50%**		**16%**		**13%**		**100%**
0%	3	9%	15	45%	4	12%	25	76%	17	52%	28	85%	29	88%	
Total Responses	33	100%	33	100%	33	100%	33	100%	33	100%	33	100%	33	100%	
Not Stated	1		1		1		1		1		1		1		
Total Businesses	34		34		34		34		34		34		34		

Source: Purdon Survey, May 1997

Based on the results of the survey, the principal source of trade for businesses operating in Karuah was passing highway traffic. This classification was identified by 91% (29) of businesses as filling some component of their trade. In particular, five (5) businesses, including the motels and major service stations indicated that over 90% of their trade was reliant on this source. A further five (5) including restaurants, service stations and food shops indicated that passing traffic formed between 50% and 80% of their trade. Only sixteen (16) businesses indicated that passing traffic represented less than 20% of their trade of which four (4) indicated that they received no trade from the highway.

These figures compares with 94% of all businesses who obtained some trade from 'local residents'. Although marginally greater proportion of businesses than 'passing highway trade', this classification represented a smaller proportion of trade for individual businesses, with three quarters (76%) indicating that this source represented less than 50% of their overall trade and approximately 55% (18) indicate it was less than 20% of trade.

3.5 Reliance on Highway

Karuah's reliance on the Highway can be assessed through a number of issues separate from the issues of a bypass. Comparison was drawn between the amount of trade individual businesses received for passing or highway traffic (refer **Section 3.4**) and a number of criteria. Four broad reliance categories were prepared based on the following characteristics:

- ❑ Total reliance on Highway Traffic = 81% to 100% of Total Turnover derived from this source
- ❑ Substantial reliance on Highway Traffic = 51% to 80% of Total Turnover derived from this source;
- ❑ Partial reliance on Highway Traffic = 21% to 50% of Total Turnover derived from this source; and
- ❑ No reliance on Highway Traffic = 0% to 20% of Total Turnover derived from this source.

These categories were compared with:
- ❑ type of business;
- ❑ total employment;
- ❑ length current owner ran the business; and
- ❑ property ownership.

3.5.1 Business Type

Of the 34 businesses in Karuah, five (5 or 15 %) businesses are totally reliant on the highway traffic for their trade. These include Petrol Station/Motor Vehicle Repairs and Tourist Accommodation. A further five (5 or 15 %) businesses are substantially reliant on the highway and include Restaurants, Food, Petrol Station/Motor Vehicle Repairs and the Hotel. (refer **Table 3.8**).

The majority (47%) of businesses are not reliant on the highway for their trade. However, it should be recognised that this broad breakdown only reflects the direct relationship between a business and highway traffic. It does not reflect the interrelationships between businesses within Karuah. For example the butcher selling meat to the service station restaurants or the service stations acting as agents for the newsagency.

Table 3.8: Reliance on Highway by Business Type

	Businesses Reliance on Highway				
	Total Reliance No.	**Substantial Reliance No.**	**Partial Reliance No.**	**No reliance No.**	**Total Businesses No.**
Food		1	3	1	5
Petrol Station/Motor Vehicle Repairs	3	1		1	5
Restaurant/cafe/takeaway		2	2		4
Tourist Accommodation	2			2	4
Club/Hotel		1	1	1	3
Timber Mill			1	1	2
Hardware			1		2
Newsagent/Post Office Agency				1	1
Hairdressers				1	1
Golf Shop				1	1
Newspaper				1	1
Chemist			1		1
Boat Hire				1	1
Boarding Kennels				1	1
Furniture/Upholsters				1	1
Medical Centre				1	1
TOTAL	**5**	**5**	**9**	**15**	**34**
	15%	**15%**	**22%**	**46%**	**100%**

Source: Purdon Survey, May 1997

3.5.2 Total Employment

Employment is relatively evenly split between those business with a total or substantial reliance on the Highway (53% of all employment identified in the survey) and Partial or no reliance on the highway (47% of all employment identified in the survey) (refer **Table 3.9**). Again this does not recognise the interrelationship between businesses.

Table 3.9: Reliance on Highway for Employment

Reliance on Highway	Employment	
	No.	%
Total reliance	103	39%
Substantial Reliance	37	14%
Partial Reliance	28	11%
No reliance	94	36%
Total Employment	262	100

Source: Purdon Survey, May 1997

3.5.3 Length of Business Ownership

There is no apparent relationship between the degree of reliance on the highway and the length of business ownership.

3.5.4 Nature of Property Ownership

There is no apparent relationship between the degree of reliance on the highway and nature of property ownership.

3.6 Financial data

Business were requested to provide data on:

- Gross Annual Turnover for the 1995/96 and 1996/97 years;
- Wages and Salaries for the 1995/96 and 1996/97 years; and
- Capital Investment made in the business over the past five years.

Concerns regarding confidentiality resulted in a lower response rate for these questions than the remainder of the survey. The results are shown in **Table 3.10.**

Table 3.10: Financial Data

	Total	No. of Responses	Average	Not Stated	Total Establishments
Gross Annual Turnover					
1995/96	$4,083,430	15	$272,229	19	34
1996/97	$4,260,426	15	$284,028	19	34
Wages & Salary Bill					
1995/96	$2,433,502	20	$128,079	14	34
1996/97	$2,449,302	20	$128,911	14	34
Capital Investment					
	$11,755,000	22	$534,318	12	34

Source: Purdon Survey, May 1997

Attempts have been made to obtain comparable data from the Australian Bureau of Statistics. However due to differing catchment boundaries and collection techniques, any comparisons drawn are rendered meaningless. These comparisons have therefore not be made.

3.6.1 Gross Annual Turnover

Fifteen (15) businesses provided details of Gross Annual Turnover ranging from $20,000 to $800,000 in 1996/7. This represents a response rate of only 45%, but resulted in Gross Annual Turnover for the responding businesses of $4.1 million in 1995/96 and $4.3 million in the 1996/97 year to date. This represents an average of approximately $270,000 and $280,000 per business for the respective years.

Based on these average figures, it is estimated that 37 businesses identified in the study area (excluding oyster farms) generate a total Gross Annual Turnover of approximately $10.4 million. This figure is a conservative estimate only as those businesses who did not respond include three of the four service stations as well as the timber milling activities. It is estimated that these activities would experience the larger turnovers of businesses in Karuah.

It has not been possible to obtain comparable data from the ABS regarding business activity in the Study Area.

3.6.2 Wages and Salaries

Twenty businesses provided details of Wages and Salaries for the 1995/96 and 1996/97 years respectively, resulting in a response rate of 61%. The combined Wages and Salaries generated were $2.4 million for each of the 1995/96 and 1996/97 years and involved employment of 183 people on a full-time and part-time basis. Those businesses not responding to this question where primarily owner/operators whose wages salaries would be drawn from the profit of the business and/or who do not employ additional staff and therefore do not have a specific wages/salaries bill.

In 1996/97 this represents an average of $130,000 per business for the respective years and average income of $13,400 per employee. This data has been compared with information form the 1991 Census which has been inflated to 1996 values. This information indicates and average individual income for the Karuah Urban Area of $14,700. The survey results therefore represent an under estimation.

Based on these average figures both from the survey and the census, it is estimated that the 259 people employed by the 34 businesses surveyed earned a total in annual wages and salaries within the range of $3.5 million to $3.8 million.

3.6.3 Capital Investment

A total of 22 businesses responded to this question. Over the past five years, respondents indicated that they had made a total capital investment in their business of $11.8 million with an average of $530,00 per business. Of the total investment made, approximately two thirds was made by 3 individual companies. This reduces the average investment for the remaining businesses to $210,000 per business over the 5 year period or $42,000 per year. This annual figure represents approximately 15% of the Average Gross Annual Turnover referred to in **Section 3.6.1**.

A number of the business are awaiting the outcome of the Highway upgrade investigation before proceeding with additional investment.

3.7 Attitude to Highway Upgrade

The impact of a Highway upgrade through Karuah or a bypass of Karuah was also assessed through the survey. Business were asked to speculate on the potential impact of two conceptual options to gauge the initial reaction of the business community. At the time of the survey no route concepts or alignments had been prepared.

The **Highway upgrade** was described as an 'upgrade through town, with a closed median strip and 80km speed limit'. A number of businesses had difficulties conceptualising this proposal in terms of the implications for individual business access, but related it to the existing road form in the vicinity of 'Heatherbrae' or 'Motto Farm' south of Raymond Terrace.

A **highway bypass** of Karuah was the second option included in the survey but a possible route definition or the potential for a highway service centre was not mentioned.

Business owners/managers were requested to provide a quantitative estimate of the impact on trade and employment for the two broad concepts as well as making

qualitative comments on the negative and positive aspects of each option. The quantitative results are discussed below and summarised in **Table 3.11.**

3.7.1 Impact on Trade

Thirty two (32) businesses responded to the questions on the impact on trade of the Highway upgrade and Bypass. A total of 28% respondents indicated that the **Highway upgrade** would have **no effect on trade** and 16% indicated that the **Bypass** would have no effect on trade.

However, 66% of businesses indicated that they would experience a **decrease in trade** as a result of an **upgrade scenario**, while 81% would experience a decrease in trade as a result of a **bypass**.

Of those facing a decrease in trade under the **upgrade proposal**, almost two thirds (13 out of 21) indicated a decrease in trade of less than 30%, while a third (7 out of 21) indicated a decrease in excess of 40%. No business believed that they would be faced with closure.

The impact of the **bypass proposal** was seen to be much more severe on local businesses. Almost 70% (18 of 26) of all businesses facing a decline in trade believed that it would be in excess of 40%, with ten or one-third of all businesses surveyed indicating that they would be faced with closure.

3.7.2 Impact on Employment

Survey responses indicated that the impact of a bypass on existing employment in Karuah would be more severe than an upgrade proposal.

Under the upgrade scenario 63% of business believe that there will be **no change** in employment levels compared to 39% of businesses under a highway bypass.

Table 3.11: Attitudes to Highway Upgrade

Subject	Upgrade				Bypass			
	No.	%			No.	%		
Effect on Business								
No Effect	9	28%			5	16%		
Closure					10	31%		
Decrease	21	66%			16	50%		
Increase	2	6%			1	3%		
Total	32	100%			32	100%		
Not Stated	2				2			
Total Establishments	34				34			
Size of Change	**Decrease**		**Increase**		**Decrease**		**Increase**	
10% or less	5	24%			4	15%	1	100%
11-20%	5	24%	1	50%	1	4%		
21-30%	3	14%			2	8%		
31-40%	1	5%			1	4%		
41-50%	5	24%	1	50%	2	8%		
More than 50%	2	10%			6	23%		
100%					10	38%		
Total	21	100%	2	100%	26	100%	1	100%
Not Stated	1				2		2	
Change in Employees								
No change	19	63%			12	39%		
Decrease	9	30%			19	61%		
Increase	2	7%						
Total	30	100%			31	100%		
Not Stated	4				3			
Size of Change in Employees								
Decrease	-26				-135			
Increase	20							
Total	-6				-135			

Source: Purdon Survey, May 1997

31% of businesses anticipated that the upgrade proposal would result in a decrease in employment of up to 26 jobs. However this would be largely balanced by an increase in jobs in 7% of businesses. An overall job loss of approximately six (6) positions was anticipated. This generally assumes that median openings are provided to allow cross turning movements especially for south bound traffic.

This compares to a large anticipated decrease in employment under a bypass proposal, with a stated loss of 135 jobs from 61% of responding businesses. No businesses are anticipating an increase in employment under the bypass scenario.

3.7.3 General attitudes

Respondents were asked to outline the positive and negative aspects of each highway upgrade concept from a business as well as the broader Karuah community perspective. These attitudes are summarised in **Table 3.12**.

It should be noted that the order of listing does not indicate any order of priority, nor does the number of comments reflect overall attitude of the business community. In fact, a number of businesses prefaced their comments on the basis that the nature and degree of impact (both positive and negative) will be dependant on the detailed designed and construction of each of the options.

Table 3.12: Summary of Attitudes

HIGHWAY UPGRADE	
Impact on Business	
Negative	**Positive**
Upgrade would: ❑ have no or minimal negatives on business; ❑ result in loss of trade to varying degrees, but most businesses would survive; ❑ restrict access to individual business; ❑ result in loss of parking; ❑ require land resumption; and ❑ increase noise pollution. Closed median strip would: ❑ restrict vehicular access to business; ❑ limit passing trade to one direction only; and ❑ restrict pedestrian access across road, particularly for towns aging population.	Upgrade would: ❑ have less impact than bypass; ❑ have no or minimal positives for businesses; ❑ retain passing trade required for businesses to survive; ❑ increase business activity over time and therefore employment; ❑ result in increased turnover for some businesses resulting in additional development; ❑ decrease impact of noise due to improved road surface; and ❑ improve traffic flow allowing more time for travellers to stop.
Impact on Karuah	
Negative	**Positive**
Upgrade would: have no or minimal negatives on business; ❑ split Karuah town in two; ❑ restrict business access to rear lane and Franklin Street; ❑ restrict parking and result in increased congestion; ❑ decrease employment; ❑ decrease home values along highway; ❑ restrict access if only closed median is provided; and ❑ create security problems if underpasses provided.	Upgrade would: ❑ allow Karuah to continue to grow; ❑ minimise impact on businesses; ❑ maintain existing businesses and employment; ❑ increase overall trade and employment; ❑ need to provide cross highway access by means of underpasses; ❑ allow more time for travellers to stop and enjoy town; ❑ help promote the town by bringing people to Karuah; ❑ ensure movement through town and increase local security; and ❑ assist the case for relocation of the school off the highway.

BYPASS	
Impact on Business	
Negative	**Positive**
Bypass would: ❑ result in the closure of numerous businesses; ❑ decrease trade due to the lack of passing traffic; ❑ decrease business incomes; ❑ decrease property prices; ❑ decrease local employment; ❑ decrease good will and therefore saleability of business; ❑ result in loss of existing business investment; ❑ increase business reliance on local residents; and ❑ result in loss of other services in Karuah (eg Newspaper, Newspaper agencies, NRMA services, Pharmacy).	Bypass would: ❑ attract more people from Newcastle to buy holiday houses/weekenders; and ❑ allow main street/town to be done up and attract more tourists and permanent residents.
Impact on Karuah	
Negative	**Positive**
Bypass would: ❑ decrease employment and income; ❑ increase crime due to lost income; ❑ decrease property prices; ❑ stop Karuah being used as a 'Rest Revive Survive Centre; ❑ kill Karuah, as the town is unlikely to attract tourists off Bypass due to the lack of attractions; ❑ cause businesses to close; ❑ cause loss of jobs and life savings; ❑ decrease numbers of visitors to Karuah and result in the downgrading all services and businesses; ❑ increase travel for local residents to employment; ❑ decrease local expenditure in Karuah; ❑ cause Karuah to become a Ghost Town; and ❑ decrease local services for elderly population.	Bypass would: ❑ provide cleaner air; ❑ reduce semitrailers through town; ❑ create peaceful village; ❑ improve parking; ❑ make Karuah a better place to live; ❑ make Karuah much quieter; ❑ cause Karuah to change from a highway town to a low cost retirement town; ❑ allow main street and town to be done up and made more attractive to tourists and permanent residents; and ❑ remove the traffic hold-ups in main street on the few days a year they occur.

3.8 General Discussion

The consultant team undertook a number of discussions with business owners and managers while collecting the completed survey forms. In addition to the above information the following observations were made by individual respondents:

Reaction to survey and investigations

- all participants were courteous and friendly towards the Study Team, and willing to discuss issues affecting both their own business and possible implications for the wider community;
- consultants need to provide projected traffic flows (ie what will the highway traffic be like in 5, 10, 15 years time); and
- this study is putting the lives of the local community on hold.

General Strategies for Pacific Highway Improvements

- 'Rest, Revive Survive' strategy is important. However, people don't rest by choice. However, small towns or slow points on major highways help to enforce rest /breaks on drivers;
- RTA should be concentrating on upgrading sections of highways between towns and leave the bypass of towns to the last. Towns should be used to relieve journeys (ie 'Rest, Revive Survive' centres);
- accidents don't happen in towns. They happen on the open road; and
- traffic flows better if there is only one lane. Example quoted was closure of overtaking lanes south of Karuah during peak traffic periods.

Reaction to Bypass Option

- a bypass of Karuah is seen by many people to be a foregone conclusions and the RTA is seen to have made its up mind up;
- the town should still be visible from any bypass, if constructed, to ensure travellers are aware of the facilities it provides;
- a bypass of Karuah should include a highway service centre, with local businesses being given first priority to operate such facilities. This would minimise the impact on employment loss associated with a bypass; and
- Karuah is to be sewered in the near future. Some people believe this will be jeopardised by the highway bypass. Other see this as bolstering the future development of the town.

Reaction to Highway Upgrade Option

- there is some uncertainty as to how a highway upgrade through town would work (eg. median breaks, road width, etc) and to where a bypass is located. There are different perceived effects if a bypass is closer to town than further afield;

- upgrade needs to be either upgrade through town on a complete bypass not through the backyards of houses/businesses. Franklin Street is not an option. Koori community will not give up land easily;

- an upgrade through Karuah should minimise the impact on access to individual business as well as cross town access. Provisions of vehicular underpasses and or pedestrian overbridges should be considered for the few times a year when such access is not possible. Such underpasses could be provided at the river bank or in the vicinity of Mustons Road. No reference was made to the use of traffic lights;

- one option for the upgrade of the highway through town involves the RTA buying one or other side of street and widen the highway but still providing access to remaining businesses;

- Highway upgrade will result in a change to the town but it will not be an end to the town;

- there is no point upgrading the highway through town if in ten years or so, Karuah is to be or needs to be bypassed anyway; and

- 80km/hr is too fast for a Highway upgrade through town. 60km/hr is satisfactory but 40km should be considered.

Business Characteristics

- trade catchments for local businesses vary. In addition to Karuah, local businesses serve Tea Gardens, Hawks Nest, North Arm Cove, Swan Bay. The bypass will encourage people from these towns to travel direct to Raymond Terrace;

- grocery shops generally act as convenience stores only. The majority of food shopping is done in Woolworths at Raymond Terrace. A large supermarket is proposed for Hawks Nest. This will reduce the catchment for grocery stores in Karuah; and

- Karuah has developed because the highway and the cheap price of land.

3.9 Highway Upgrade Options

As a result of discussions with businesses, five broad options can be defined. However the detailed location and design of these options where not generally discussed and it is recognised that detailed development of options would occur through the community reference group and further investigations by the study team. The options raised were:

- **Do nothing** - retain the existing road with maintenance and improvement to road surface only;

- **Highway upgrade through Karuah** - This option would result in a similar highway to that through Heather Brae/Motto Farm (south of Raymond Terrace). It was recognised by some businesses that this may involve the purchase and demolition of properties one side of the road to provide sufficient space for the highway upgrade;

- **One-way Bypass** - This Option would involved use of the existing highway for south bound traffic. A north bound lane would be constructed roughly along the alignment of Franklin Street. Links between the two lanes would be provided at the northern and southern ends of the town centre, possible at Bundabah Street and Mustons Road. A second bridge would be provided over the river adjoining that existing;

- A **full bypass of Karuah** being located between the town centre and the residential area to the north. The township would then be visible from the bypass and local access would be provided by means of overpasses or underpasses; and

- **A full bypass of Karuah located in further land.**

In either of the two full bypass options the location of a highway service centre was seen to be important to retain local employment. Existing local franchisees should be given first chance to operate these facilities.

4 CONCLUSIONS

The business survey presented a useful opportunity for the consultant team to meet individually with owners and managers of businesses to discuss the impacts of both the existing highway and the proposed upgrade. A good response was received from traders with contact successfully being made with 34 of the 37 known business in Karuah (excluding oyster farmers). A high level of interest in the proposed Community Reference Group was noted, although most people spoken to are still cynical of outcomes and the RTA's motives.

The survey and associated discussions have indicated a **very high level of dependence on the existing highway** by the business community for trade and jobs. Apart from timber milling and oyster farming, most of the 260 local jobs are highway dependant, either directly or indirectly. The survey indicated that an estimated 135 jobs would be lost from 63% of local businesses if a bypass was introduced.

An **upgrade of the highway** through Karuah would have an impact on the local businesses particularly if access was restricted or removed. However, provided such access was retained, a significant impact by way of loss of trade or jobs is not anticipated.

A **bypass of Karuah** will have a major adverse affect on local business prospects and severe loss of local employment prospects. However, development of a conventional highway service centre near Karuah could substantially offset local job loss although may not do much for loss of local business opportunities.

Issues of amenity and future development have not been generally considered in this report and will require further consideration after the development of options.

PURDON ASSOCIATES
August 1997

ATTACHMENT A:

SURVEY FORM

CONFIDENTIAL

LOCAL BUSINESS SURVEY

Please complete this questionnaire for discussion with Purdon Associates in Karuah commencing Monday 19 May 1997.

Name of Business .....

Address .....

Q1. Please briefly describe your *TYPE OF BUSINESS.* *(Please tick)*

Restaurant/cafe/take-away ..... ☐
Food ..... ☐
Hardware ..... ☐
Newsagent ..... ☐
Club ..... ☐
Petrol station ..... ☐
Motor vehicle retailing ..... ☐
Hairdresser ..... ☐
Tourist accommodation ..... ☐
Other business *(please specify)* ..... ☐

.....

Q2. How many *EMPLOYEES* does the business have, *including* yourself?
(Please write in numbers)
Full-time employees .....

Part-time or casual employees .....

Q3. Where do you *LIVE*? *(Please tick)*

In Karuah ..... ☐
Karuah local area ..... ☐
Elsewhere ..... ☐

Q4. Where do your *EMPLOYEES LIVE*? *(Please write in number for each area)*

In Karuah .....
Karuah local area .....
Elsewhere .....

Q5. How long have you been *RUNNING THE BUSINESS*? *(Please tick)*

Less than 1 year ..... ☐
1 - 3 years ..... ☐
3 - 6 years ..... ☐
6 - 10 years ..... ☐
More than 10 years ..... ☐

Q6. Do you own the *BUSINESS PROPERTY* or is it leased? *(Please tick)*

Property owned ..... ☐
Property leased ..... *(See Q6a)* ☐

*If you **lease** the property,*
Q6a. How long until the lease is due for renewal?

Less than 12 months ..... ☐
1 - 3 years ..... ☐
3 - 5 years ..... ☐
Over 5 years ..... ☐

Q7. Please estimate what percentage of your *BUSINESS SUPPLIES* come from.....
(Please write in percentages)

Karuah..... %

Newcastle and Hunter region..... %

Sydney area..... %

Elsewhere..... %

TOTAL ..... 100 %

Q8. During the last 2 financial years, what *PERCENTAGE OF YOUR ANNUAL TURNOVER* (approximately) was received from each of the following market sectors?

	1995/96	1996/97
Trade from local residents	..... %	.....%
Hunter Region trade - excluding Karuah	..... %	.....%
Passing or highway trade	..... %	.....%
Indirect highway trade (ie. supply of goods to businesses that rely on highway trade)	..... %	.....%
Holiday makers/seasonal trade at Karuah	..... %	.....%
Sales to other NSW (not from highway)	..... %	.....%
Interstate/overseas sales	..... %	.....%
TOTAL	100 %	100%

Q9. For the last 2 financial years please estimate the following *FINANCIAL DATA* for your Karuah business.....

	1995/96	1996/97
Gross annual turnover	$.....	$.....
Wages and salary bill	$.....	$.....

Q10. How much *CAPITAL INVESTMENT* have you made in this business over the last 5 years? **$**.....

Q11. Why did you *CHOOSE KARUAH* to set up business? *(Please tick all that apply)*

High volume of passing trade..... ☐
Cheap land/premises available ..... ☐
Available business opportunity ..... ☐
Raw materials available..... ☐
Lifestyle..... ☐
Other (please specify)..... ☐

Q12. Does your business have a *HIGHWAY FRONTAGE*? *(Please tick)*

Yes ☐
No ☐

Q13. If the *highway was upgraded* through town, with a closed median strip and 80km speed limit what would be the *EFFECT ON YOUR BUSINESS*? *(Please choose one)*

No effect ☐
Business would close ☐
Small decrease in trade ☐
Large decrease in trade ☐
Small increase in trade ☐
Large increase in trade ☐

Please answer Q13a

Q13a. Please estimate the *PERCENTAGE CHANGE IN TRADE.*

10% or less ☐
11 - 20% ☐
21 - 30% ☐
31 - 40% ☐
41 - 50% ☐
More than 50% ☐

Q14. If the *highway was upgraded*, what CHANGE *IN THE NUMBER OF EMPLOYEES* in your business would you anticipate?

No change ☐
Decrease ☐ **How many?** .....
Increase ☐ **How many?** .....

Q15. If a *bypass* is built, what do you think would be the *EFFECT ON YOUR BUSINESS*? *(Please choose one)*

No effect ☐
Business would close ☐
Small decrease in trade ☐
Large decrease in trade ☐
Small increase in trade ☐
Large increase in trade ☐

Please answer Q15a

Q15a. Please estimate the *PERCENTAGE CHANGE IN TRADE.*

10% or less ☐
11 - 20% ☐
21 - 30% ☐
31 - 40% ☐
41 - 50% ☐
More than 50% ☐

Q16. If a *bypass* is built, what *CHANGE IN THE NUMBER OF EMPLOYEES* in your business would you anticipate?

No change..... ☐
Decrease ..... ☐ **How many?** .....
Increase ..... ☐ **How many?** .....

Q17. If a *bypass* is built, what would you consider to be the.....
***NEGATIVE EFFECTS* on your business?**.....

.....

.....

***NEGATIVE EFFECTS* on Karuah?** .....

.....

.....

Q18. If the *highway was upgraded*, what would you consider to be the.....
***NEGATIVE EFFECTS* on your business?**.....

.....

.....

***NEGATIVE EFFECTS* on Karuah?** .....

.....

.....

Q19. If a *bypass* is built, what would you consider to be the.....
***POSITIVE EFFECTS o*n your business?** .....

.....

.....

***POSITIVE EFFECTS* on Karuah?**.....

.....

.....

Q20. If the *highway was upgraded*, what would you consider to be the.....
***POSITIVE EFFECTS o*n your business?** .....

.....

.....

***POSITIVE EFFECTS o*n Karuah?**.....

.....

.....

THANK YOU FOR YOUR CO-OPERATION
PLEASE NOTE THAT ALL SURVEY RESULTS FROM INDIVIDUALS WILL BE TREATED IN CONFIDENCE & FORMS DESTROYED WITHOUT COPIES MADE

ATTACHMENT D:
KARUAH BUSINESS SURVEY 1998

PACIFIC HIGHWAY UPGRADE

KARUAH BUSINESS SURVEY 1998

Report to

ROADS AND TRAFFIC AUTHORITY OF NSW

Prepared by

PURDON ASSOCIATES PTY LTD

3/9 McKay Street Turner ACT 2612

Tel: (06) 257 1511 Fax: (06) 248 8347

16 February 1999

ACKNOWLEDGMENTS

The Study Team for this project comprised personnel from **Purdon Associates** including Robert Purdon, Brenton Dickins, Patty Shaw, Emma Darley and Susan Elekessy.

We wish to acknowledge our appreciation for the co-operation and assistance provided by business owners and managers in Karuah.

Results of the study and conclusions drawn therefrom, as documented in this report, represent the views of the Study Team and do not necessarily reflect those of the Roads and Traffic Authority of NSW.

PURDON ASSOCIATES

February 1999

DISCLAIMER

Any representation, statement, opinion or advice expressed or implied in this publication is made in good faith but on the basis that Purdon Associates, its agents and employees are not liable to any person for any damage or loss whatsoever which has occurred or may occur, in relation to that person taking (or not taking) action, in respect of any representation, statement or advice referred to above.

CONTENTS

ACKNOWLEDGMENTS I

CONTENTS II

1 PURPOSE 1

2 METHODOLOGY 3

2.1 Methodology 3

2.2 Response Rates 4

2.3 Oyster farming 4

3 MAIN FINDINGS 5

3.1 Business Type and Ownership 5

3.2 Employee Characteristics 7

3.3 Business Characteristics 10

3.4 Reliance on Highway 12

3.5 Capital Investment 16

3.6 Anticipated Impact of Bypass 19

3.7 General Discussion 31

4 CONCLUSIONS 32

TABLES

Table 3.1: Principal Business Type 6
Table 3.2: Employment Numbers 7
Table 3.3: Residential Address of Managers and Employees 9
Table 3.4: Business Characteristics 10
Table 3.5: Reasons for Choosing Karuah 12
Table 3.6: Highway Reliance Definitions 12
Table 3.7: Reliance on Highway by Business Type 14
Table 3.8: Reliance on Highway for Employment 15
Table 3.9: Capital Investment 17
Table 3.10: Attitudes to Highway Upgrade 20
Table 3.11: Business Response to Bypass 24
Table 3.12: Design Response 26
Table 3.13 : Town Response to Bypass 30

FIGURES

Figure 3.1: Residential Address of Managers and Employees 9
Figure 3.2: Reasons for Choosing Karuah 11
Figure 3.3: Business Reliance on Highway 13
Figure 3.4: Highway reliance by Nature of Employment (1998) 16
Figure 3.5: Highway Reliance by Gender (1998) 16
Figure 3.6: Capital Investment Distribution 18
Figure 3.7: Impact on Trade 19
Figure 3.8: Extent of Anticipated Decrease in Trade 22
Figure 3.9: Impact on Employment (1997-98) 23
Figure 3.10: Business Response 24
Figure 3.11: Design Response 26
Figure 3.12: Karuah Bypass Access Preferences 27

ATTACHMENTS

Attachment A 33

1 PURPOSE

The Roads and Traffic Authority of NSW (RTA) is proposing a bypass of the Pacific Highway in the vicinity of the Karuah township, north of Newcastle and Raymond Terrace. A route selection study undertaken in 1997 identified six route options. Of these options, the Horse Island Option was recommended as the preferred alignment (**Figure 1**). The Minister for Roads accepted this recommendation in mid 1998, subject to further investigation of this option through the preparation of an Environmental Impact Statement (EIS).

As part of the above investigation processes, Purdon Associates have been engaged to investigate the nature of Karuah's economy and the impacts of the proposed highway upgrade. This investigation has included two surveys of the business community, one during the route selection phase (May 1997) and the second as part of the preparation of the EIS for the preferred route (December 1998).

This report documents the findings of the second Karuah Business Survey and, where appropriate, compares these with the findings of the first survey. Issues relating to the other highway upgrade options were addressed in the report dated August 1997 and have not been reconsidered here.

The purpose of the surveys was to:

- consult directly with local traders on their attitudes to the proposed highway upgrade;
- obtain data as a basis for defining the local business profile for the study area; and
- provide a basis for assessing the impact of the proposed highway upgrade options on the local business community.

This report does not provide detailed consideration of social impact and amenity factors associated with the proposed highway bypass apart from reporting on the comments made by respondents during the Survey.

This report also needs to be viewed in the context of broader research on the *Economic Impacts of By Pass Roads on Country Towns*. This research, undertaken by Parolin and Garner (1997) for the RTA, indicated that the actual impact of bypass roads on local businesses was smaller than had been predicted. The broad findings included:

- the reduction in employment attributable to the opening of bypass roads is smaller than predicted;
- redundancies primarily affect casual and part-time employment;
- largest number of job losses and reduction in gross annual turnover occurs in businesses directly serving highway traffic;

- businesses can make compensatory adjustments to their operations in response to the bypass (eg increased advertising or diversification of product lines);
- despite a decline in gross annual turnover, indirect wholesale businesses impacts have not resulted in reduced employment levels; and
- highway service centres, in the vicinity of existing settlements, help mitigate the overall extent of job losses predicted to result from bypass roads.

Although experiencing short-term economic decline, bypassed towns have generally recaptured a large proportion of this highway trade. This ability to recapture trade has resulted from improved environmental conditions created by the removal of highway traffic from town centres.

2 METHODOLOGY

2.1 Methodology

The methodology adopted for the 1998 business survey was as follows:

- a written survey form was forwarded to all known businesses in the study area in the week commencing 7 December 1998. The survey (refer **Attachment A**) included questions covering issues addressed in the initial survey along with issues directly relevant to the anticipated impact of the Horse Island Bypass Option. The survey also explored ways in which the businesses, RTA and the community might mitigate any impacts;
- the mailing list for the survey was defined by responses to the 1997 business survey. This listing was checked for currency through a review of the current local telephone directory;
- businesses were advised that only aggregated survey results would be published as part of this report and that the privacy of individual business outlets would be maintained. Confidentiality was guaranteed with no information on individual companies to be published or given to RTA without written authorisation.
- two consultants from Purdon Associates visited Karuah in the week commencing 14 December 1998 to collect the survey forms from businesses and make direct contact with business owners/operators.
- analysis of survey results.

The results of the survey are presented in **Section 3** with conclusions drawn in **Section 4**.

Surveys were initially sent to 40 businesses in the study area, excluding oyster farmers (refer **Section 2.3**). During the consultant teams visit to Karuah:

- one business surveyed in 1997 was identified as no longer being in operation;
- one business formally located in Karuah had transferred its operations to Raymond Terrace and was unable to be contacted for discussions. This business was not considered to be highway related and was not identified in the 1997 survey. It has therefore been excluded from the analysis of the 1998 survey; and
- one other known business was unable to be contacted, but is not considered to be highway-related.

Surveys were unable to be collected from eleven businesses during the consultant visit to Karuah. These businesses were requested to send or fax the completed forms to the consultant team. Five surveys were received by this means.

2.2 Response Rates

In total, 34 surveys were received and analysed resulting in a response rate of approximately 89% (34 out of 38). One of the responses was only received in part. Despite efforts, the remainder of the survey could not be followed up. Of the remaining businesses, only one declined outright to participate in the survey process.

This compares to a response rate to the 1997 survey of 92% (34 out of 37). The difference in total business numbers is due to:

- closure of one business;
- establishment of another; and
- subdivision of management of another business into two.

It should be noted that slight variations in composition of businesses responding to the surveys can produce substantial changes in the results because of the small size of the total number of businesses in Karuah.

2.3 Oyster farming

Discussions have also been held with NSW Fisheries regarding the local oyster industry. It is believed that, although the construction aspects of the highway upgrade may temporarily affect this industry, business operations are unlikely to be affected by any gain or loss of trade as a result of the highway bypass, and will continue to provide employment in the local area. Environmental management will be required to minimise any such construction impacts on these businesses and will be addressed in the EIS.

3 MAIN FINDINGS

The following discussion summarises the findings of the 1998 Karuah Business Survey.

3.1 Business Type and Ownership

The range and number of businesses has not changed significantly since the first business survey. In the intervening period, one business closed and another was established.

The businesses have been analysed on the basis of their principal activity (refer **Table 3.1**), although it should be noted that a number of these businesses include a mix of activities (e.g. service station / restaurant or newsagent/food/post office).

The principal types of business surveyed in Karuah include:

- 1. ***Petrol stations and motor vehicle repairs***. This category include six businesses comprised of four service stations and two motor vehicle repair workshops. One of the service stations primarily targeted at trucks. While both motor repair businesses target the local market and highway trade, one of these also acts as the local NRMA agent.
- The bulk of petrol and other motor products are sold by three main outlets and are heavily dependent on passing trade. Although there appears to have been an increase in the total number of businesses in this category since the 1997 survey, this increase has resulted from a change in management structures of one business. As a result, two of the above businesses were classified as one in 1997.
- One of the service stations has not responded to the 1998 survey. During contact, this operator expressed concern about the future of his business and felt that completion of the survey fulfilled no useful purpose.
- 2. ***Food stores***. In 1998, this category includes four outlets predominantly aimed at highway service trade, tourists and the local convenience market. A further business had closed in the period since the 1997 business survey. The majority of Karuah residents appear to do weekly shopping in Raymond Terrace or Newcastle.
- 3. ***Restaurants/cafes/takeaways***. Karuah has four stand alone outlets in this group, with businesses in other categories (e.g. service stations, clubs and hotels) also providing eat-in facilities. Of these, one provided a partial response to the survey. This information has been included where available.
- 4. ***Tourist accommodation***. Karuah has two motels, and two caravan parks. One of these businesses declined to respond to the 1998 survey, on the basis that 'it was a waste of his time' and fulfilled no useful purpose.

5. ***Clubs and Hotel.*** Karuah has two clubs and a hotel. All three businesses responded to the 1998 survey. The Hotel sublets its bistro as does the Golf Club and shop. As a result, these have been included as separate businesses.

6. ***Other businesses*** located in Karuah include personal services, bulky goods (e.g. hardware, outdoor products and furniture repairs), recreational facilities, concrete water tanks construction, and oyster farming. NSW Fisheries has estimated that there are approximately twenty oyster farmers in the vicinity of Karuah, based on the number of licensed sheds.

Table 3.1: Principal Business Type

Business Type	1997		1998		Comment on Difference
	No.	%	No.	%	
Petrol Station/Motor Vehicle Repairs	5	15%	5	15%	No response from 1 in '98
Food	5	15%	4	12%	1 business closed
Restaurant/cafe/takeaway	4	12%	4	12%	Part response from 1 in
Tourist Accommodation	4	12%	3	9%	1 declined to respond
Club/Hotel	3	9%	3	9%	
Industrial/Timber mill	2	6%	2	6%	
Hardware/Power Products	2	6%	2	6%	
Newsagent/Post Office Agency	1	3%	1	3%	
Chemist	1	3%	1	3%	
Furniture/Upholsters	1	3%	1	3%	
Hairdressers	1	3%	1	3%	
Golf Shop	1	3%	1	3%	
Boarding Kennels	1	3%	1	3%	
Medical Centre	1	3%	1	3%	
Boat Hire	1	3%	1	3%	
Newspaper	1	3%	0	0%	No response in 1998
Liquor Supplier	0	0%	1	3%	No response in 1997
Gifts	0	0%	1	3%	New
Professional Services	0	0%	1	3%	Not contactable in 97
Total	34	100%	32	100%	

Source: Purdon Survey, May 1997 & December 1998

Although not specifically surveyed in December 1998, it was noted that a number of the existing business had changed ownership or management structures. Of the 34 businesses surveyed:

- four business are under new ownership (two of which were tourist accommodation facilities); and
- one owner/operator in 1997 has become absentee owner and/or landlord.

3.2 Employee Characteristics

The businesses surveyed employed a total of 227 people including the owners and/or managers. Of these, the majority (57% or 129) were employed on a part-time or casual basis, while 43% (98) are in full-time employment (refer **Table 3.2**). It is also noted that the majority (60% or 137) of those employed were female.

Although there appears to be been a decline of 13% in employment in Karuah between the two surveys, it should be noted that:

- three businesses not responding to the survey in 1998 indicated in their response to the 1997 survey a total employment of approximate 26 full and part-time positions; and
- three additional businesses included in the 1998 survey only indicated a total employment of four positions.

In addition, NSW Fisheries estimate that the oyster industry in Karuah employs between 30-40 people. Due to the seasonal and family nature of such businesses it is not possible to more accurately define employment in this industry within the scope of the current exercise.

The inclusion of these additional jobs increases total employment in Karuah in late 1998 to between 280-290 positions.

Table 3.2: Employment Numbers

	1997 Survey		1998 Survey				1996 Census	
			Male	Female		Total		
	No.	%	No.	No.	No.	%	No.	%
Full Time	111	42%	61	37	98	43%	279	64%
Part-time/casual	151	58%	29	100	129	57%	149	34%
Not Stated							6	1%
Total	262	100%	90	137	227	100%	434	100%
			40%	60%	100%			

Source: Purdon Survey, May 1997 & December 1998

ABS 1996 Census of Population and Housing - Basic Community Profiles (CD 1111108, 1111107 & 1092009).

Note: Gender of Employment was not sought in 1997.

This survey data compares with a total employed workforce resident in Karuah and surrounding areas, as identified in the 1996 Census of population and housing, of approximately 434 people. It is believed that a significant portion of this employment is located outside the study area. The discrepancy between these data sources reflects the following:

- lapse in time between the Census and business surveys;
- differing emphasis. The 1998 business survey was focused on place of employment while the 1996 Census is based on the place of residence;
- absence of oyster farmers from the business surveys; and
- marginal differences in the areas covered by the survey and census. The survey focused on all businesses within the urban and immediately adjoining areas, on both sides of the river. It included the businesses west of the township out to and including the golf course. The census covers a larger rural area surrounding the Karuah township on both sides of the Karuah River. Whilst including the small settlement of Swan Bay, it excludes all settlements south east of the Pacific highway but east of the River.

The 1998 survey also indicated that the majority of owners/managers and employees resided in Karuah on the surrounding local area. These classifications represent 90% (204) of the total surveyed employed (refer **Table 3.3** and **Figure 3.1**) and is a marginal increase on the 1997 results (83% or 217).

Although overall local residency of managers and employees has increased since the 1997 survey, the level of owners or managers resident in Karuah or adjoining area appears to have fallen from 80% (27) to 58% (18) in 1998 (refer **Figure 3.1**). However, it should be noted that a number of the owners/managers of businesses not responding to the 1998 survey had indicated in 1997 that they were resident in Karuah.

Figure 3.1: Residential Address of Managers and Employees

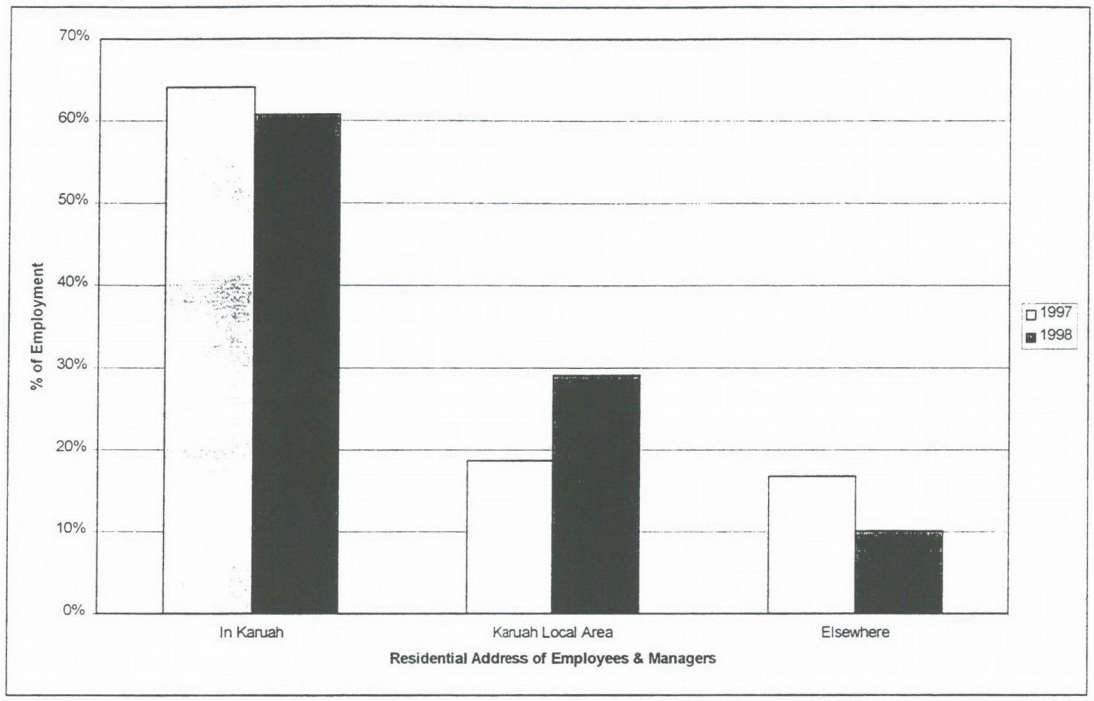


Table 3.3: Residential Address of Managers and Employees

	1997 Survey		1998 Survey	
	No.	%	No.	%
Residential Location of Manager				
In Karuah	27	79%	20	59%
Karuah Local Area	1	3%	8	24%
Elsewhere	5	15%	5	15%
Not Stated/Applicable	1	3%	1	3%
Sub Total	34	1	34	100%
Residential Location of Employees				
In Karuah	141	62%	118	61%
Karuah Local Area	48	21%	58	30%
Elsewhere	39	17%	18	9%
Sub Total	228	100%	194	100%
Residential Location of Managers & Employees				
In Karuah	168	64%	138	61%
Karuah Local Area	49	19%	66	29%
Elsewhere	44	17%	23	10%
Not Stated/Applicable	1	0%	1	0%
Total	262	100%	227	100%

Source: Purdon Survey, May 1997 & December 1998

3.3 Business Characteristics

3.3.1 General

Of the businesses surveyed in 1998, the majority (54%) had operated for less than six years while 30% for less than three years. About one-third of business have operated for 10 years or more (refer **Table 3.4**).

The majority of businesses also have existing highway frontage (88%), and own their own premises (59%) (refer **Table 3.4**). Of the 41% of businesses that lease their premises, about two-thirds have less than 5 years remaining on their existing lease. This time period coincides with the anticipated timing of the proposed highway upgrade (i.e. 2004).

These patterns generally reflect the results obtained from the 1997 Business Survey.

Table 3.4: Business Characteristics

Characteristic	1997		1998	
	No.	%	No.	%
Length of Running Business				
Less than 1 year	4	12%	4	12%
1-3 years	10	29%	6	18%
3-6 years	10	29%	8	24%
6-10 years	2	6%	5	15%
More than 10 years	8	24%	11	32%
Total	34	100%	34	100%
Tenure of Business Property				
Owned	19	56%	20	59%
Leased	15	44%	14	41%
Total	34	100%	34	100%
Length of Lease Remaining				
Less than 1 year	1	7%	3	21%
1-3 years	3	20%	2	14%
3-5 years	6	40%	4	29%
Over 5 years	5	33%	5	36%
Total	15	100%	14	100%
Highway Frontage				
Yes	29	85%	30	88%
No	5	15%	4	12%
Total	34	100%	34	100%

Source: Purdon Survey, May 1997 & December 1998

3.3.2 Business Location Decisions

The principal factors affecting the choice of Karuah as a location for businesses in 1998 were (refer **Figure 3.2** and **Table 3.5**):

- available business opportunity (65% of all businesses responding);
- high volumes of passing traffic (53%);
- lifestyle (12%); and
- availability of raw materials, cheap land/premises available and centrality to markets (each 6%).

Although not specifically differentiated within the survey, available business opportunity includes both the purchase of existing businesses and identified gaps within the Karuah market. These generally reflect the priority of responses received from the 1997 survey.

Figure 3.2: Reasons for Choosing Karuah

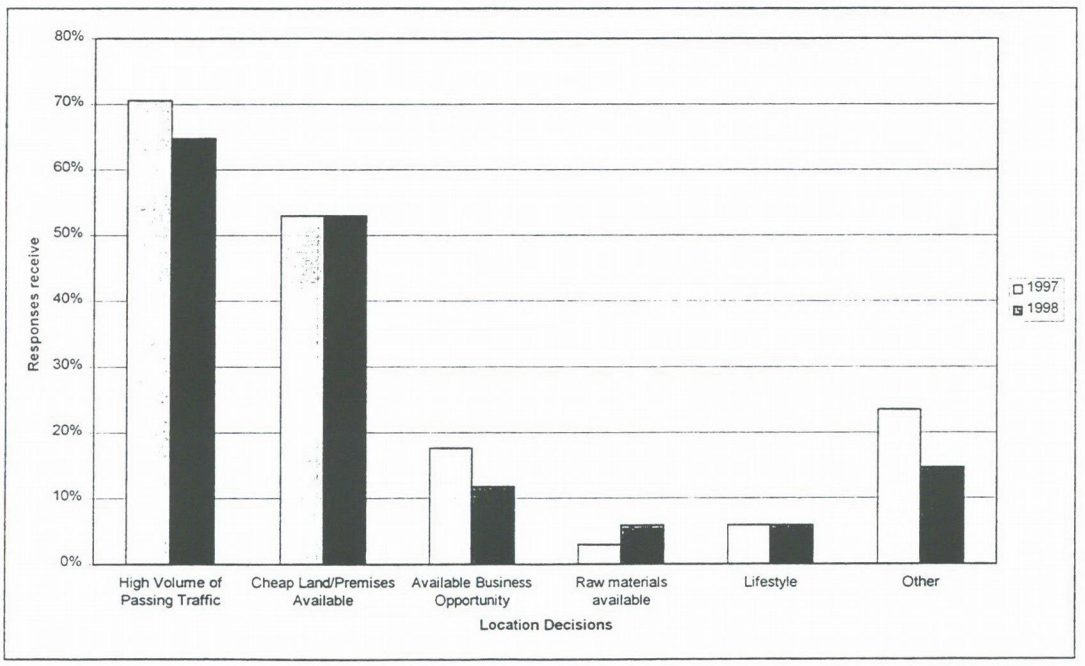


Table 3.5: Reasons for Choosing Karuah

Reason	1997 Survey		1998 Survey	
	No.	%	No.	%
Available Business Opportunity	24	71%	22	65%
High Volume of Passing Traffic	18	53%	18	53%
Lifestyle	6	18%	4	12%
Raw materials available	3	9%	2	6%
Cheap Land/Premises Available	2	6%	2	6%
Central to Market	1	3%	2	6%
Family Reasons	1	3%	1	3%
Tourism potential	1	3%	1	3%
Local Demand for products/services	1	3%	1	3%
Other	1	3%	0	0%
Location	1	3%	0	0%
Total Businesses Responding	34		34	

Source: Purdon Survey, May 1997 & December 1998

Note: Multiple responses were possible to this question hence total exceeding 100%

3.4 Reliance on Highway

Karuah's reliance on trade generated by traffic using the Pacific Highway can be assessed through a number of issues unrelated to the current bypass proposal. Comparison has been drawn between the amount of trade individual businesses received from highway traffic (including related businesses) and business type and total employment. Each business was requested to indicate their principal market by percentage of trade derived. The principal markets provided were 'Highway traffic', 'Local residents', 'Business serving highway traffic' and 'Other (please specify)'. On the basis of the responses to this question, four broad reliance categories were defined (refer **Table 3.6**).

Table 3.6: Highway Reliance Definitions

Nature of Highway Reliance	% of trade/turnover derived from highway traffic or business serving highway traffic
➢ Total reliance	81% to 100%
➢ Substantial reliance	51% to 80%
➢ Partial reliance	21% to 50%
➢ No reliance	0% to 20%

3.4.1 Business Type

Of the 34 businesses in Karuah responding to the survey, nine (29%) are consider to be 'totally reliant' on the highway traffic for their trade. This is due to their direct servicing of highway traffic or their servicing of businesses that provide facilities for highway traffic (refer **Figure 3.3**), and represents about twice as many establishments in 1997. The increase appears to be largely due to changes in business ownership creating new highway oriented business and/or changes in perception of existing business owners associated with the impending bypass.

The principal nature of these facilities includes petrol station/motor vehicle repairs, tourist accommodation and takeaway foods. However a number of other facilities including Club/hotel, food stores and boarding kennels also assessed a high level of reliance on the highway (refer **Table 3.7**). The discussion with the boarding kennels indicated that the majority of their business was from people dropping pets of on their way north on holidays.

This increase in 'totally reliant' activities is reflected in a decrease in the number of businesses which were classified as 'substantially', 'partially' or 'not reliant' on the highway for trade (refer **Figure 3.3**).

The largest group of businesses (41%) were noted as 'not reliant' on the highway for their trade.

Of the four non-responding businesses in 1998, two could be included within the 'totally reliant' category, based on their responses to the 1997 Survey. As a result approximately 40% of all business in Karuah (16 out of 38) can be considered to be either total or substantially reliant on the Pacific Highway for the majority of their trade.

Figure 3.3: Business Reliance on Highway

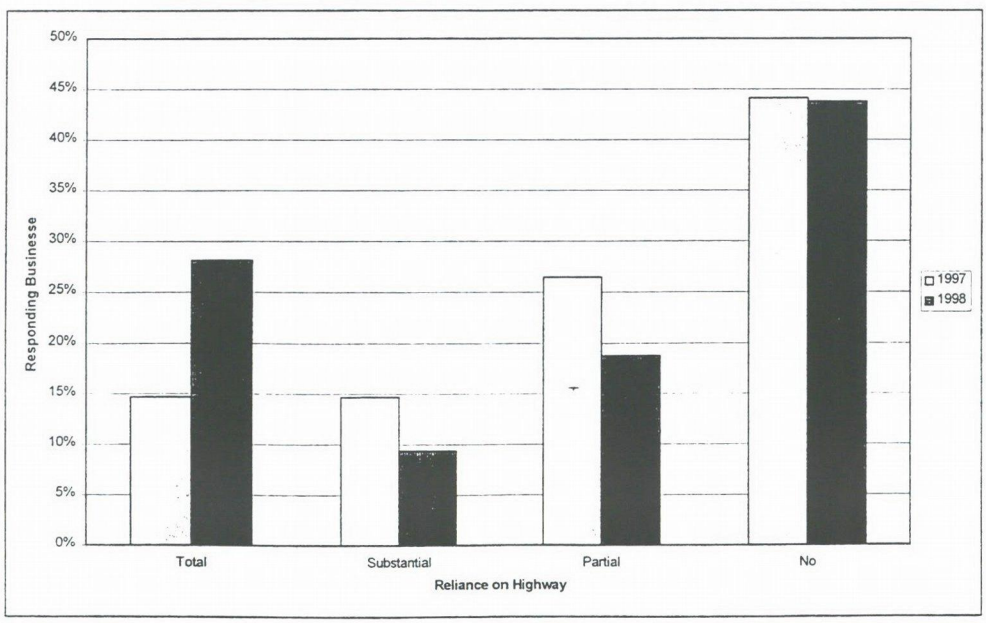


Table 3.7: Reliance on Highway by Business Type

Principal Business Type	Businesses Reliance on Highway (1998)				
	Total Reliance	Substantial Reliance	Partial Reliance	No Reliance	Total Businesses
	No.	No.	No.	No.	No.
Petrol Station/Motor Vehicle Repairs	2		1	2	5
Food	1	2	1		4
Tourist Accommodation	2			1	3
Club/Hotel	1		1	1	3
Restaurant/cafe/takeaway	3	1			4
Industrial/Timber mill				2	2
Hardware/Power Products				2	2
Newsagent/Post Office Agency			1		1
Chemist				1	1
Furniture/Upholsters		1			1
Hairdressers				1	1
Golf Shop				1	1
Boarding Kennels	1				1
Medical Centre				1	1
Boat Hire				1	1
Liquor Supplier			1		1
Gifts			1		1
Professional Services				1	1
Total – 1998 - (No.)	10	4	6	14	34
Total – 1998 - (%)	29%	12%	18%	41%	100%
Total – 1997 - (No.)	5	5	9	15	34
Total – 1997 - (%)	15%	15%	26%	44%	100%

Source: Purdon Survey, May 1997 & December 1998

3.4.2 Total Employment

About 60% of total employment in Karuah is created by businesses that are either 'totally' or 'substantially' dependent on the highway (refer **Table 3.8**). This has increased marginally since the 1997 survey when 53% of jobs were in these businesses.

Table 3.8: Reliance on Highway for Employment

Reliance on Highway	1997 Total		1998 Nature of Employment					
			Full-time		Part-time		Total	
	No.	%	No.	%	No.	%	No.	%
Totally	103	39%	32	33%	87	67%	119	52%
Substantially	37	14%	10	10%	8	6%	18	8%
Partially	28	11%	19	19%	15	12%	34	15%
No Reliance	94	36%	37	38%	19	15%	56	25%
Total	262	100%	98	100%	129	100%	227	100%
			Gender					
			Male		Female		Total	
			No.	%	No.	%	No.	%
Totally			23	26%	96	70%	119	51%
Substantially			8	9%	10	7%	18	8%
Partially			19	21%	15	11%	34	15%
No Reliance			40	44%	16	12%	56	25%
Total			90	100%	137	100%	227	100%

Source: Purdon Survey, May 1997 & December 1998

Businesses with 'total' and 'substantial reliance' on the highway also dominate the part-time employment sector with 73% of positions, as well as female employment (77% of female jobs) (refer **Figures 3.4 and 3.5**).

Those businesses with only 'partial' or 'no reliance' on the highway generally provide full-time employment (57% of full-time positions) for men (65% of male jobs) (refer **Figures 3.4 and 3.5**).

Figure 3.4: Highway reliance by Nature of Employment (1998)

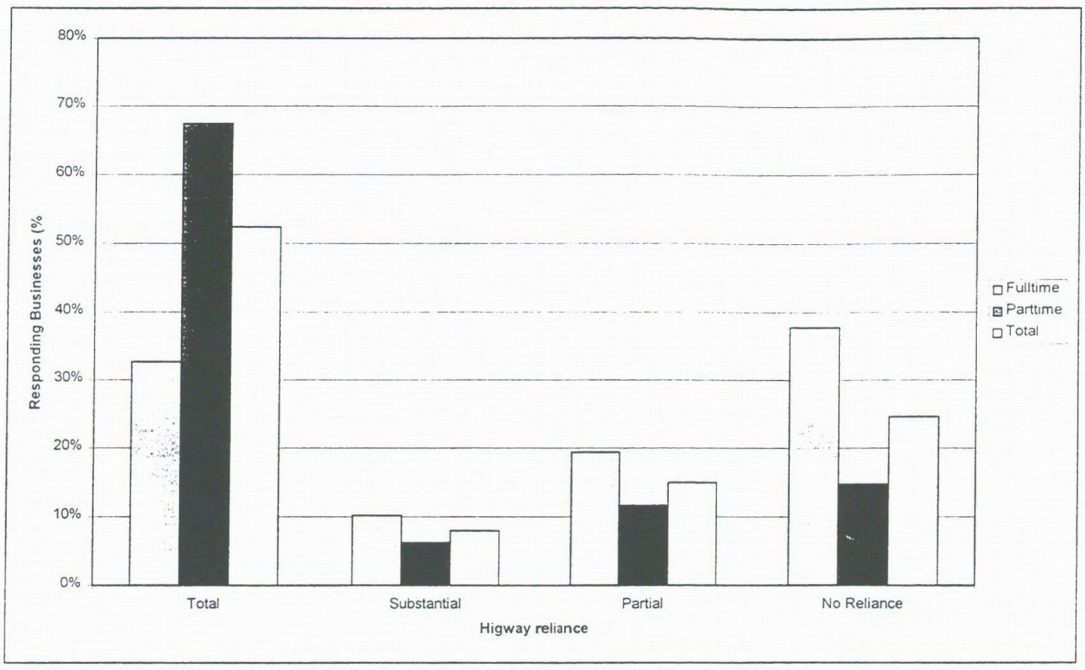
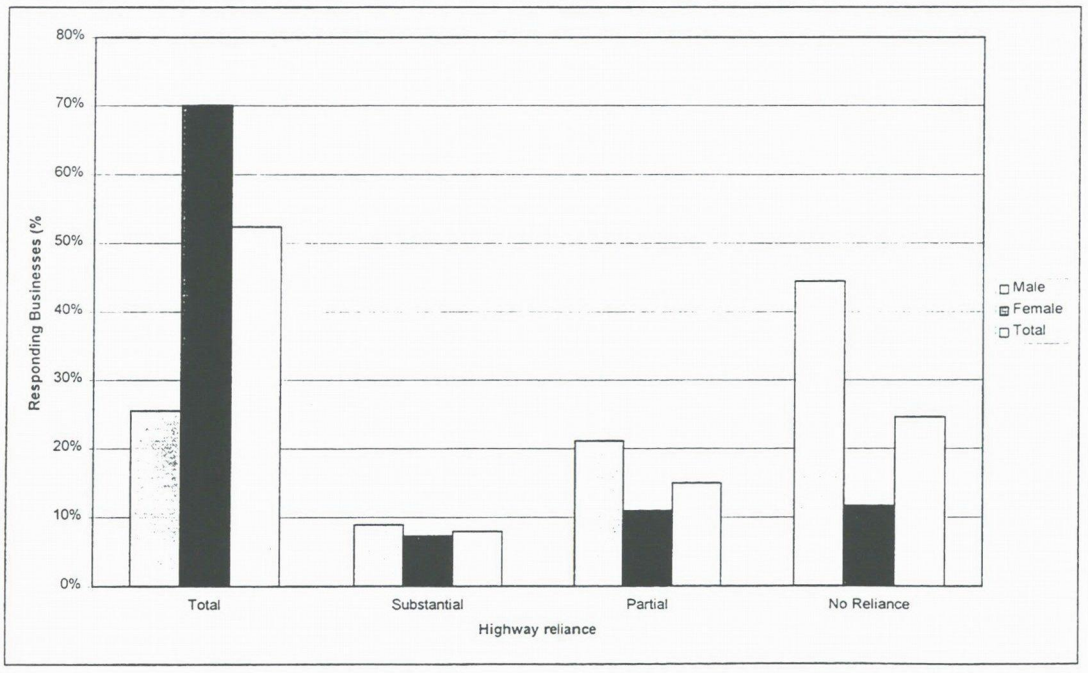


Figure 3.5: Highway Reliance by Gender (1998)



3.5 Capital Investment

Businesses were requested to provide data on capital investment made in the business over the past five years and an estimation of capital investment proposed for the next five years. A summary of the results is shown in **Table 3.9** and **Figure 3.6**.

Concerns regarding confidentiality and the anticipated impact of the bypass busin resulted in a lower response rate for these questions than for the remainder of the survey. Of the total establishments surveyed, 62% (21 out of 34) responded to the question on capital investment for last five years and only 38% (13 out of 34) for next five years.

Attempts have been made to obtain comparable data from the Australian Bureau of Statistics. However due to differing catchment boundaries and collection techniques, any comparisons drawn are rendered meaningless and have not been made.

Over the past five years, the 21 responding businesses estimated a total capital investment of approximately $8.1 million, with an average of $384,700 per business. Of these, three businesses (14%) made capital investments in excess of $1million (refer **Figure 3.6**). One of these establishments is considered to be totally highway reliant.

All other businesses (86% or 18) had made capital investments of less than $500,000 (refer **Figure 3.6**), with:

- 48% (10 out of 21) making investments of less than $50,000; and
- 10% (2 out of 21 making no investment in the five year period.

These figures represent a 30% reduction in estimated capital investment since the 1997 survey. This decrease is possibly due to:

- timing of the surveys (i.e. some capital investment was made 6 years ago); or
- lack of responses from key businesses.

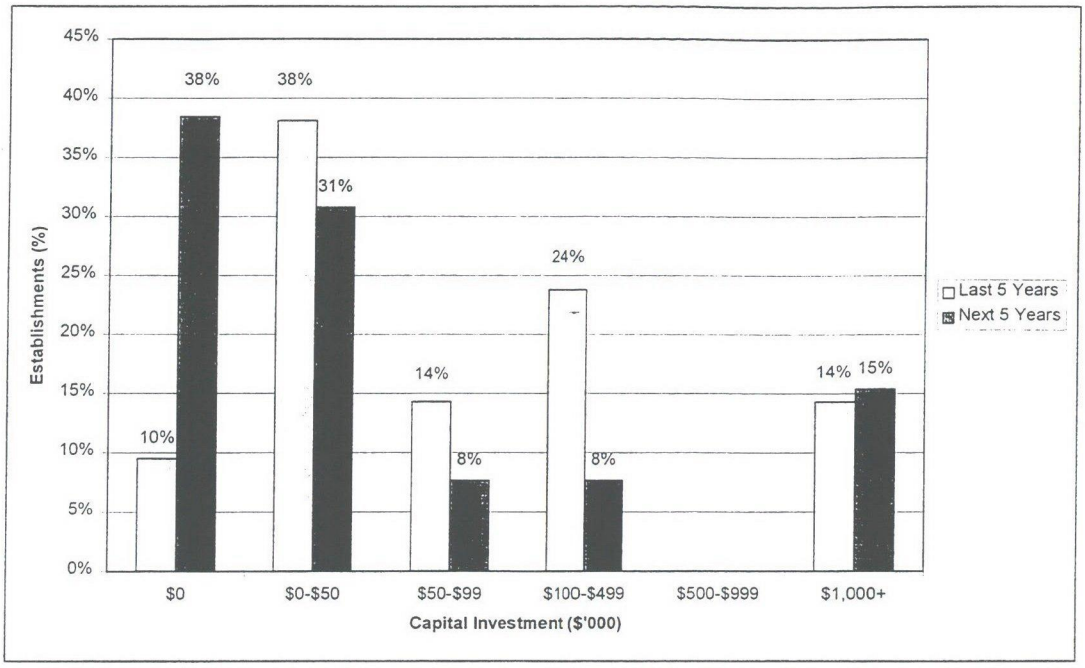
Table 3.9: Capital Investment

	1997	1998	
		Last 5 Years	Next 5 Years
Total	$11,755,000	$8,032,000	$1,418,000 *(1)*
Average	$534,300	$384,700	$118,200 *(1)*
Establishments			
Responding	22	21	13
Not Stated	12	13	21
Total	34	34	34

Source: Purdon Survey, May 1997 & December 1998

Note: (1) Excludes estimated capital investment by one business of $10 million.

Figure 3.6: Capital Investment Distribution



Source: Purdon Survey, December 1998

In terms of future business investment prospects, eight business indicated anticipated capital investment over the next five years totalling approximately $11.4 million. However of this, $11.3 million or 99% was expected by three businesses and $10 million or 88% was proposed by one business alone. The latter investment included some land development which was indirectly related to the highway bypass, reflecting changing role for Karuah as a commuter town in the lower Hunter Region. The remaining five businesses were expecting to spend between $30,000 and $60,000 over the next five years (refer **Figure 3.6**).

The exclusion of the business proposing land development results in a capital investment for remaining businesses of $1.4 million or an average of $118,200.

Comments made on survey forms and in discussions with traders indicated that the lower level of future capital investment is at least in part due to the uncertainty being created by the bypass.

3.6 Anticipated Impact of Bypass

The anticipated impact of the Horse Island Bypass on Karuah was also assessed through the survey. Business owners/managers were requested to provide a quantitative estimate of the impact on trade and employment of the bypass proposal. In addition, business owners were requested to consider:

- their business response to the bypass;
- elements of design which could minimise the impact of the bypass; and
- the town's response to the bypass.

The quantitative results are discussed below and summarised in **Table 3.10**.

3.6.1 Impact on Trade

Thirty four businesses responded to the questions on the impact of the bypass on trade. A total of 24% of respondents indicated that the bypass would have no effect on trade. This was higher
than in the 1997 survey when 16% of respondents indicated that the bypass would have no effect on them (refer **Table 3.10** and **Figure 3.7**).

Figure 3.7: Impact on Trade

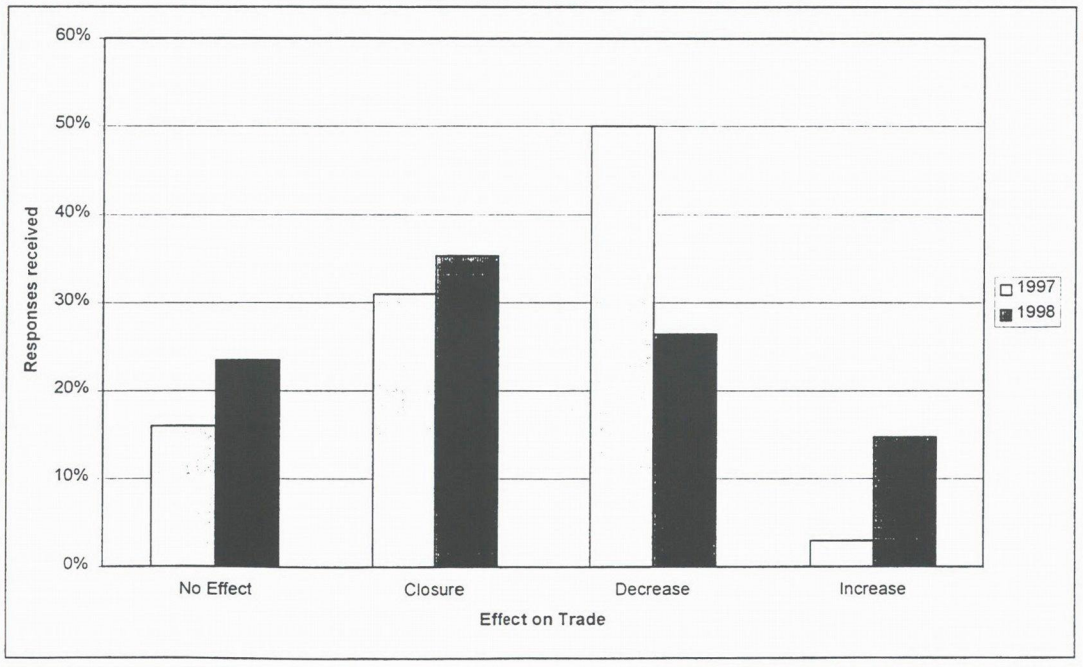


Table 3.10: Attitudes to Highway Upgrade

	1997				1998			
Effect on Business	**No.**	**%**			**No.**	**%**		
No Effect	5	16%			8	24%		
Closure	10	31%			12	35%		
Decrease	16	50%			9	26%		
Increase	1	3%			5	15%		
Total Responses	32	100%			34	100%		
Not Stated	2				0			
Total Establishments	34				34			
Size of Change	**Decrease**		**Increase**		**Decrease**		**Increase**	
10% or less	4	25%	1	100%	1	13%	2	67%
11-20%	1	6%			1	13%		
21-30%	2	13%			3	38%		
31-40%	1	6%			1	13%	1	33%
41-50%	2	13%			1	13%		
50-99%	6	38%			1	13%		
Total Responses	16	100%	1	100%	8	100%	3	100%
Not Stated					1		2	
Change in Employees								
No change	12	39%			15	45%		
Decrease	19	61%			16	48%		
Increase					2	6%		
Total Responses	31	100%			33	100%		
Not Stated	3				1			
Change in Number of Employees								
Decrease	-135				-133			
Increase					2			
Total	-135				-131			
Residential Location of Employment Changes					**Decrease**		**Increase**	
Karuah					120	90%	2	100%
Elsewhere					13	10%	0	0%
Total					133	100%	2	100%

Source: Purdon Survey, May 1997 & December 1998



3.6.1.1 Business Closure

The level of anticipated business closures was marginally higher in the 1998 survey than in 1997, with 35% (12) of responding businesses anticipating closure as a result of the bypass. This compares with 29% or 10 businesses in 1997.

These closures were expected as a result of the loss of passing traffic and reduced access to Karuah. Local business currently provides some services to areas such as Hawks Nest, Tea Gardens and North Arm Cove. Several businesses felt that residents from these areas would also bypass the town for facilities in Raymond Terrace.

Of those businesses in the 1997 survey that anticipated closure, only three had improved their impression of the bypass proposal in 1998. These three were still expecting a decrease in trade.

Concern was also expressed that closure of some non-highway related businesses would also occur as an indirect result of the Karuah bypass. Such closures were anticipated by business on the basis that the closure of highway related businesses would force residents to shift away from Karuah in search of work. The resulting loss in population would cause a decrease in trade for remaining business and result in some closures.

Fewer businesses anticipated a decrease in trade in the 1998 survey (26%) than in the 1997 survey (50%). This is particularly offset against a slightly higher level of business closures in 1998 to 1997.

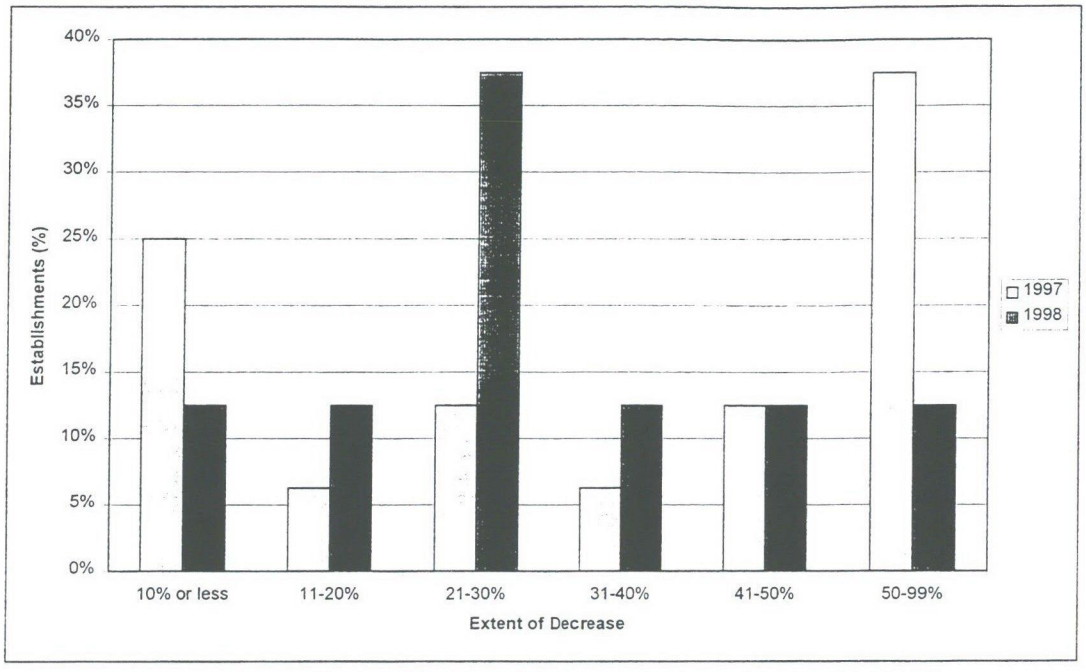
3.6.1.2 Decrease in Trade

Of the nine business anticipating a decrease in trade but not closure in 1998, eight estimated the level of decrease in trade:

- only one (13%) felt that this decrease would be greater than 50%; while
- six or 77% felt that this decrease would be greater than 20%.

Although the level of closure has marginally increased, these results indicate that for remaining businesses the anticipated decrease in trade is in fact less than that estimated in 1997 (refer **Figure 3.8**).

Figure 3.8: Extent of Anticipated Decrease in Trade



3.6.1.3 Increase in Trade

Five (15%) businesses anticipated an increase in trade. This is an increase on the results of the 1997 survey where only one (3%) business indicated such a result. Of these businesses three had either anticipated closure or at least a decrease in trade in their response to the 1997 survey.

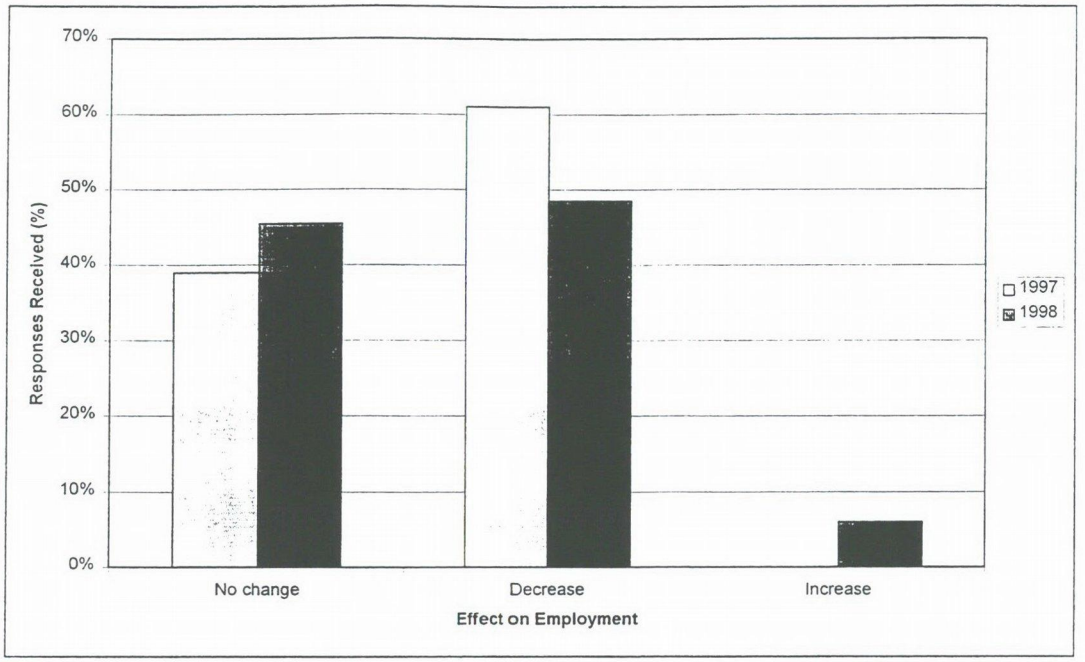
3.6.2 Impact on Employment

Survey responses indicated that businesses are anticipating a significant decline in employment as a result of the loss in trade caused by the bypass. Of the thirty four responses, 48% (16) of responding businesses indicated a partial or total lost of employment. This is slightly down on the response to the 1997 survey (61% or 19 businesses) (refer **Table 3.10** and **Figure 3.9**). Only two businesses indicated an increase in employment, with only one quantifying the increase.

Overall it is expected that employment will decline by approximately 130 positions, which represents a decline in Karuah's employment base of 58%. This is comparable with the 1997 survey results. The majority of those employees (90%) expected to lose their positions were also residents of Karuah in 1998.

It should also be noted that of the four businesses not responding to the 1998 survey, two had indicated in 1997 that the bypass would result in a significant decline in trade, possibly resulting in business closure. Based on these results, it is estimated that a further 14-20 positions may be lost from these facilities as a result of the bypass.

Figure 3.9: Impact on Employment (1997-98)



3.6.3 Business Response to Bypass

In addition to assessing the impact of the bypass on the business community, the survey endeavoured to assess the initiatives being proposed by businesses to minimise the impact of the bypass. The responses received are summarised in **Figure 3.10** and **Table 3.11** and can be broken into three broad categories:

- no effect on business and therefore no response;
- differing approaches to business operation, including more promotion and advertising or diversification of products and/or services; and
- sale or closure of business.

Figure 3.10: Business Response

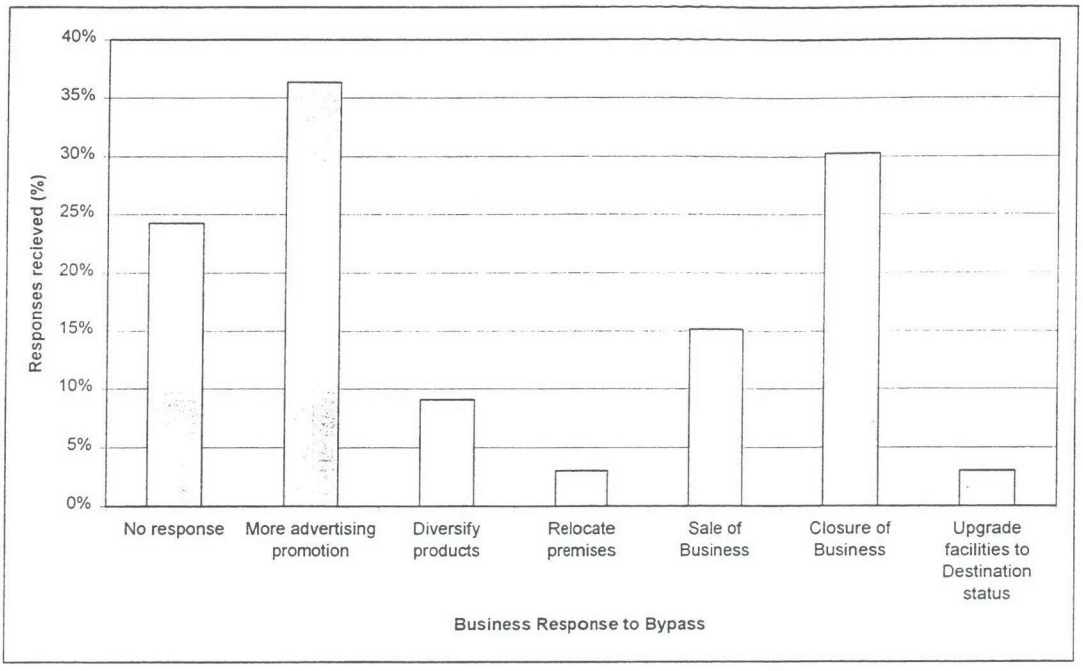


Table 3.11: Business Response to Bypass

	No.	%
No Response	8	24%
More advertising promotion	12	36%
Diversify products	3	9%
Relocate premises	1	3%
Sale of Business	5	15%
Closure of Business	10	30%
Upgrade facilities to Destination status	1	3%
No. of Businesses Responding	33	

Source: Purdon Survey December 1998
Note: Multiple responses were possible to this question hence sum of percentages exceeds 100%
One business provided only a partial response to the survey and was therefore excluded from this issue.

Businesses could provide multiple responses to this question. As a result, while some suggested that they might undertake promotion and advertising in the short-term, business closure was also identified.

Eight businesses (24% of 33 responding businesses) indicated that no additional action w be taken. These businesses were predominantly not reliant on the highway for trade.

The principal response to be taken by businesses was an increase in advertising and promotion (36% of responding businesses). This action was done on the basis of improving tourism to Karuah or ensuring that residents in adjoining settlements (e.g. North Arm Cove) continued to be aware of the facilities on offer in Karuah. The businesses proposing this action were evenly reliant on the highway for trade. Six of the businesses where either 'totally' or 'partially reliant' on the highway for trade, while the remaining six were considered to be 'partially' or 'not reliant'.

The sale or closure was identified by 15% and 30% of responding businesses respectively. Of those responding in this manner 60% of both sale (3 out of 5) and closure (6 out of 10) were businesses which were either totally or substantially reliant on the highway. One of the businesses indicated that bankruptcy may also occur as a result of the loss of trade, but that would be dependent on the timing of the bypass. The greater the delay in its construction and opening the less the likelihood of bankruptcy.

3.6.4 Design Response to Bypass

The Karuah Township has evolved into a highway service centre over the last 40 years and, as indicated above, relies heavily on the highway for its survival. Although having some amenity benefits, the removal of highway traffic is likely to have a major detrimental economic impact on the town. The improved amenity issues, which are not likely to be considered significant by businesses are beyond the scope of this Business Survey Report.

Unlike some other bypassed towns such as Goulburn and Mittagong, which have an economy partly or predominantly independent of the highway, special provisions in the design of the bypass were identified by Karuah business to assist its adjustment to a decreased highway service role. Ways which this could be achieved were explored through the questionnaire. The responses are summarised in **Figure 3.11** and **Table 3.12** and discussed in the following sections.

Figure 3.11: Design Response

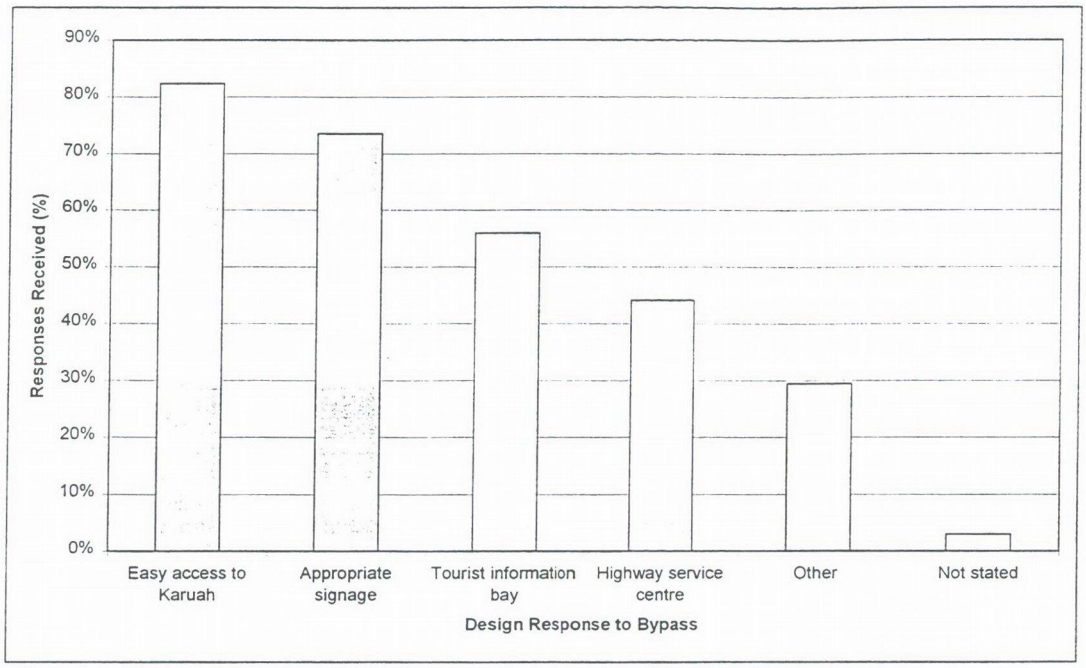


Table 3.12: Design Response

	No.	%
Easy access to Karuah	28	82%
Appropriate signage	25	74%
Tourist information bay	19	56%
Highway service centre	15	44%
Other	10	29%
Not stated	1	3%
No. of businesses responding	33	

Source: Purdon Survey December 1998

Note: Multiple responses were possible to this question hence percentages exceeding 100%

One business provided only a partial response to the survey and was therefore excluded from this issue.

3.6.4.1 Easy Access to Town

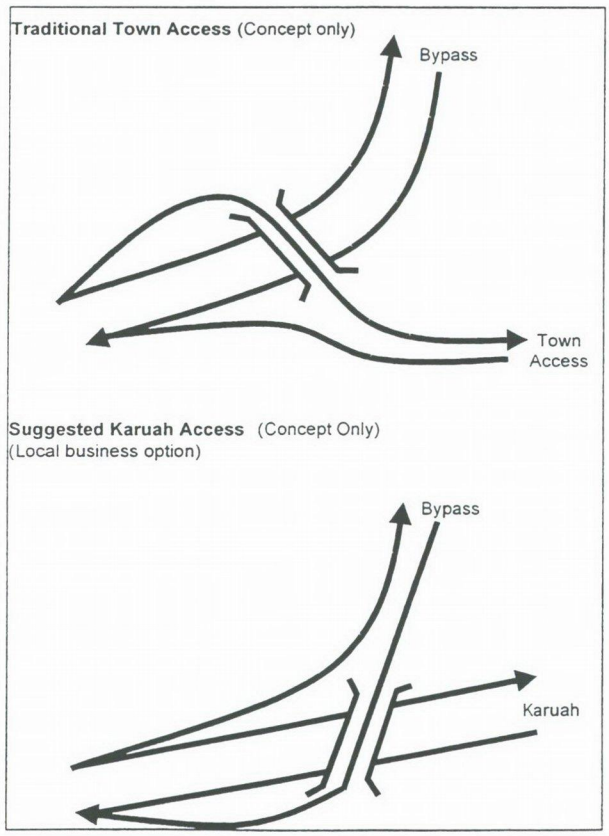
Easy access to town was recognised as the most important design issue with 82% (28) of businesses responding to this issue. Such access would maximise the town's opportunity to retain at least some of its highway service function.

The provision of T-intersections or roundabouts was seen generally as too cumbersom highway users and would therefore discourage highway traffic entering Karuah. Over and underpasses were seen as the preferred option.

One suggestion was that such overpasses or underpasses should be designed in a way that emphasises access to Karuah and that bypassing traffic should make a conscious decision to use the bypass. **Figure 3.12** shows the way in which this could be achieved. The advantages of such a proposal include:

- Karuah township continuing to act as a highway service centre and coach stop;
- ability of heavy traffic to bypass the township if so desired;
- motorists being encouraged to 'stop, revive and survive'; and
- use of a slightly different intersection treatment to stimulate drivers and help combat driver boredom and fatigue.

Figure 3.12: Karuah Bypass Access Preferences



3.6.4.2 Appropriate Signage

The provision of appropriate signage near the access points to Karuah and along the bypass was recognised as being important by 74% (or 25) of responding businesses.

Traditional highway signage solely indicating the town's name is seen as being an insufficient response to the town being bypassed. Discussions with business operators indicated that signage on the bypass needs to indicate:

- Karuah's proximity to the bypass.

  Such signs need to indicate that travellers will not lose significant time by travelling via Karuah. Therefore it was suggested that the signs should indicate that 'Karuah is only "X minutes" off the highway'. Comparative distances on the signs may also be of use (i.e. via bypass "X kilometres", via Karuah "Y kilometres"); and

- Karuah's attractions.

  Such signs should not only contain the international symbols for 'Petrol, Food, Accommodation' but also specific features (e.g. golf club, RSL, riverside park, boat hire, water access and boat ramp).

3.6.4.3 Tourist Information Bay

Of the responding businesses, 56% (19) supported some form of Tourist Information Bay, although little comment was received in discussion on the type or location of such a facility.

3.6.4.4 Highway Service Centre

The provision of a highway service centre on the Pacific Highway in the vicinity of Karuah received a mixed response. Of the 33 responding businesses, 15 or 44% indicated that a highway service centre should be part of the design for the bypass. Through discussion, this option appears to have been raised on the basis of the replacement of jobs lost in the town and the need to retain local employment. The suggested location was on the Raymond Terrace side of Karuah.

However, concern was also expressed that development of such a facility would further exacerbate the impact felt by other businesses in town, as even less traffic would need to enter Karuah. Ease of access to the town was seen as an encouragement to drivers and coaches to stop in the town rather than at a service centre.

It was also recognised that coach drivers are required to stop every five hours for at least half an hour. It is understood that the majority of coaches travel via the coastal Pacific Highway as opposed to the F3 Expressway in order to provide passenger services to these areas. As a result Karuah is a five hour trip from Sydney and is a convenient place to break the trip. It was believed that despite road improvements, this would continue to be the case, as facilities at Bulahdelah will be outside this time limit. Provision of easy access to Karuah will allow the town to continue to fulfil its coach stop role.

3.6.4.5 Other Responses

Other responses included:

- preference for no bypass or alternative routes (5 responses); and
- preparation of a 'Stop, Revive Survive' strategy for the Town (6 responses).

3.6.5 Town Response to Bypass

Space was provided on the survey form for businesses to comment on an appropriate response by the town to the bypass issue.

Of the responses received, 50% (16 responses) provided one or more suggestions on how the town needs to respond to the bypass. These suggestions are summarised in **Table 3.13** and included:

- re-focussing of the town away from the highway and onto the river and Port Stephens. Such re-focussing may include improved river access and river-focussed tourist developments. In addition, the future peace and tranquillity of the town was seen as an attribute to be promoted;
- co-ordinated promotion and advertising of the town's feature and facilities;
- facilitation of development in Karuah, including development of tourist attractions and facilities (e.g. proposed Koori Cultural Centre and Wetlands Centre), additional residential area and retail facilities (possibly including a supermarket);
- beautify Tarean Street and making it responsive to resident and visitor needs rather than highway traffic; and
- co-ordination of annual event and festivals (e.g. fishing competitions or bridge to bridge boat races).

The responses also recognised the need for Karuah to be more creative in looking towards its future and for the community to be educated in the way it can respond to proposed changes.

Table 3.13 : Town Response to Bypass

		No.	%
Town Development			
Focus on River/Improve Foreshores		9	31%
Promotion Advertising		7	24%
Tourist Attraction/s		5	17%
Town needs to combine to face issue		3	10%
Beautify Main Street		3	10%
Town Manager to ensure improvements		1	3%
Community educated on Change		1	3%
Annual events/ festivals		1	3%
More Creativity towards Towns Future		1	3%
Residential Development		1	3%
Sponsor supermarket Development		1	3%
	Subtotal	16	55%
Negative			
Nothing can be done		9	31%
No comment		**6**	**21%**
Total Responses		29	

Source: Purdon Survey December 1998

Note: Multiple responses were possible to this question hence percentages exceeding 100%

A Strategic Management Plan for Karuah is currently being prepared by part of the local community, and incorporates strategies and actions towards the following issues:

- Business and Tourism;
- Karuah Wetland Walking Trail;
- Foreshore/ Cycleway/ Recreational Development;
- Koori Development; and
- Main street Beautification.

While recognising that such initiatives are important to the future of the town, it is beyon scope of this report to review and comment on the effectiveness of the initiatives proposed. However, the consultant team observed that there appears to be little support from the business community for these initiatives. One business operator commented that although the initiatives were creative they were not grounded in reality and would be unlikely to mitigate against the impacts of the bypass on the business community. Nine responses (28%) felt that there was nothing that could be done by the town in response to the bypass. Comments like "Let the town die gracefully" or "Town cannot be saved" were prevalent in these responses.

3.7 General Discussion

The consultant team undertook a number of discussions with business owners and managers while collecting the completed survey forms. In addition to the above information, individual respondents made the following observations:

3.7.1.1 Reaction to survey and investigations

All participants were courteous and friendly towards the Study Team. However the team felt that the majority of business owners were resigned to the bypass and very negative about their business future and that of the town.

3.7.1.2 General Strategies for Pacific Highway Improvements

Similar to the first business survey, business owners questioned the reasons for upgrading the highway.

Although it was recognised that the safety of the travelling public was the principal concern, the provision of duplicated high speed road as a means of resolving this was questioned. Such roads were viewed as being 'easy driving' which can lead to driver boredom and fatigue. The need to encourage drivers to stop and rest or to provide mental stimulus to drivers by varying road design and signage was recognised by several businesses.

3.7.1.3 Flow-on Effects

Concerned was also expressed about the flow on effects of business closures. These effects could further reduce employment opportunities and service provision in Karuah.

In cases where one partner loses a job, due to business reduction or closure and are unable to find employment in surrounding areas (e.g. Raymond Terrace), it was believed that families may shift from Karuah, further reducing the market size. This has implications for service provision (e.g. schools) as well as business suppliers.

4 CONCLUSIONS

The 1998 business survey presented a useful opportunity for the consultant team to meet individually with owners and managers of businesses to discuss the impacts of the proposed Horse Island Bypass option. In addition it allowed the consultant team to review the findings of the 1997 survey.

A good response was received from traders with contact successfully being made with 34 of the 38 known businesses in Karuah (excluding oyster farmers). However, the consultant team observed that the business community was generally resigned to the bypass proposal and negative towards both their own business future and that of the town.

The survey and associated discussions have indicated a very high level of dependence on the existing highway by the business community for trade and jobs. Apart from timber milling and oyster farming, most of the 300 local jobs are highway dependent, either directly or indirectly. The survey indicated that an estimated 130 jobs could be lost as a result of a Karuah bypass, unless action was taken to minimise its impact.

A bypass of Karuah will have a major adverse effect on local business prospects and severe loss of local employment prospects. Flow-on effects may further increase this employment loss.

Although the development of a highway service centre near Karuah could substantially offset local job loss and was generally supported during the 1997 survey, concerns have now been raised about the impact of such a centre on remaining businesses in Karuah. Retention of a high level of highway access to Karuah, use of the existing facilities and promotion of their highway service role now seems to be preferred.

There is also a need for the Karuah community to refocus and to define a future for itself in light of the bypass proposal. Some of this work is currently being undertaken. However from comments made by business operators, it appears to have little support from the local business community.

PURDON ASSOCIATES

February 1999

Attachment A

Survey Form

KARUAH LOCAL BUSINESS SURVEY

Please complete this questionnaire for discussion with Purdon Associates in Karuah commencing Monday 14 December 1998

1. Name of Business.....

2. Street Address .....

3. **Please briefly describe your TYPE OF BUSINESS.** (*Please tick)*

Restaurant/café/take-away ..... ☐
Food ..... ☐
Hardware..... ☐
Newsagent..... ☐
Club..... ☐
Petrol station ..... ☐
Motor vehicle retailing ..... ☐
Hairdresser ..... ☐
Tourist accommodation ..... ☐
Other business (please specify) ..... ☐
.....

4. How many EMPLOYEES does the business have, *including* yourself?

(Please write in numbers)

Full-time employees	male ..... ☐	female..... ☐
Part-time or casual employees	male ..... ☐	female..... ☐

5. Where does the business owner LIVE? *(please tick)*

In Karuah ..... ☐
Karuah local area ..... ☐
Elsewhere ..... ☐

6. Where do your EMPLOYEES LIVE? *(please write in number for each area)*

In Karuah ..... ☐
Karuah local area ..... ☐
Elsewhere ..... ☐

7. **How long have you been RUNNING THE BUSINESS?** *(please tick)*

Less than 1 year ..... ☐
1 – 3 years..... ☐
3 – 6 years..... ☐
6 – 10 years..... ☐
More than 10 years ..... ☐

8. **Why did you CHOOSE KARUAH to set up business?** *(please tick all that apply)*

High volume of passing trade..... ☐
Cheap land/premises available ..... ☐
Available business opportunity ..... ☐
Raw materials available..... ☐
Lifestyle..... ☐
Other (please specify) ..... ☐

9. Do you own the BUSINESS PROPERTY or is it leased? *(please tick)*

Property owned ..... ☐
Property leased .....(see Q10) ☐

COPYRIGHT

If you lease the property,

10. How long until the lease is due for renewal? (*please tick*)

Less than 1 year ..... ☐
1 – 3 years ..... ☐
3 – 6 years ..... ☐
6 – 10 years ..... ☐
More than 10 years ..... ☐

11. How much CAPITAL INVESTMENT has been made in your business:

Over the last five (5) years? $.....
Expected over the next 5 years? $.....

12. Does your business currently have a HIGHWAY FRONTAGE? (*please tick*)

Yes ..... ☐
No ..... ☐

13. When the Horse Island bypass is built, what do you think will be the EFFECT ON YOUR BUSINESS? (*please choose one*)

No effect ..... ☐
Business would close ..... ☐
Decrease in trade (please estimate %) ..... ☐
Increase in trade (please estimate %) ..... ☐
Large increase in trade ..... ☐

14. How many jobs in your business will be affected by the bypass? (*specify number)*

jobs lost ..... ☐
jobs gained ..... ☐
no change ..... ☐

15. Where do the people live whose jobs will be affected? (*please tick*)

Lost: Karuah township ..... ☐
elsewhere ..... ☐
Gained: Karuah ..... ☐
elsewhere ..... ☐

16. What steps will you take in YOUR BUSINESS in response to the highway bypass?

None ..... ☐
More advertising/promotion ..... ☐
Other (please specify) ..... ☐

17. What steps can the TOWN take in response to the bypass? (*please specify*)

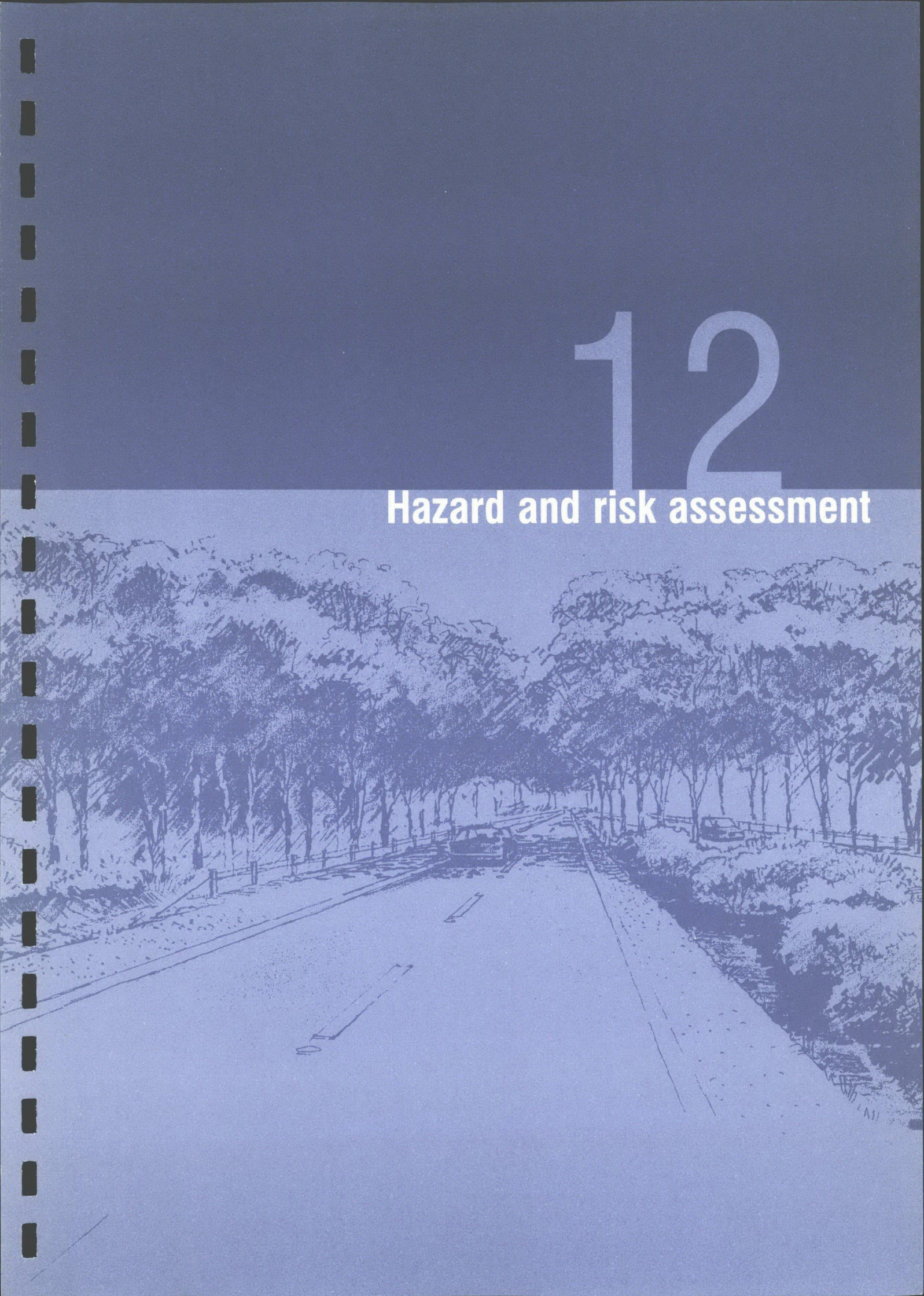
.....
.....

THANK YOU FOR YOUR CO-OPERATION
PLEASE NOTE THAT ALL SURVEY RESULTS FROM INDIVIDUALS WILL BE TREATED IN CONFIDENCE AND FORMS DESTROYED WITHOUT COPIES MADE

COPYRIGHT

12

Hazard and risk assessment



Karuah Bypass

HAZARDS AND RISKS ASSESSMENT

For

Roads and Traffic Authority

New South Wales

By

Evans & Peck Management

July 1999

DATE :	19 July 1999
JOB No. :	98131
REVISION :	Draft 3
PREPARED BY :	Chris Lock
CHECKED/APPROVED BY :	Peter Gemell

DOCUMENT REVISION RECORD				
Title:	**Karuah HAZARDS & RISKS Assessment Draft 2**			
Job No:	98131			
Rev	**Description**	**Prepared by:**	**Checked / Approved by:**	**Date:**
DRAFT	Draft	Chris Lock	Peter Gemell	18/10/99
Qest Draft	Changes for Qest to consider	Chris Lock	Peter Gemell	21/01/99
DRAFT 2	Final EPM Draft	Chris Lock	Peter Gemell	26/3/99
DRAFT 3	Final	Chris Lock	Peter Gemell	19/7/99

HAZARDS AND RISKS
CONSTRUCTION CONSIDERATIONS ASSESSMENT

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 4

1.1. INTRODUCTION 4
1.2. HAZARDS DURING CONSTRUCTION 4
1.3. HAZARDS AFTER CONSTRUCTION 5
1.4. ENVIRONMENTAL RISKS 6

2. BACKGROUND 7

2.1. PROJECT OVERVIEW 7
2.2. PROJECT BACKGROUND & ISSUES 7
2.3. WORK BRIEF 8
2.4. HAZARDS AND RISKS ASSESSMENT 8

3. HAZARDS DURING CONSTRUCTION 10

3.1. TERMS 10
3.2. POTENTIAL DANGEROUS GOODS 10
3.3. POTENTIAL HAZARDOUS SUBSTANCES 11
3.4. HAZARDOUS INCIDENTS DURING CONSTRUCTION 11
3.5. DANGEROUS GOODS HANDLING PROCEDURES DURING CONSTRUCTION 13
3.6. RISKS TO THE PUBLIC DUE TO ALTERNATIVE CONSTRUCTION METHODS 13

4. HAZARDS AFTER CONSTRUCTION 16

4.1. INTRODUCTION 16
4.2. APPROACH 16
4.3. TRANSPORT HAZARDS 17
4.4. KEY PARAMETERS USED IN THE STUDY 20
4.5. FREQUENCY ANALYSIS 23
4.6. SCENARIO DEVELOPMENT 24
4.7. CONSEQUENCE ANALYSIS 34
4.8. FINDINGS 36
4.9. REFERENCES 39
4.10. APPENDICES 40

5. ENVIRONMENTAL RISKS 41

5.1. ENVIRONMENTAL CHARACTERISTICS OF THE KARUAH AREA 41
5.2. DESIGN FEATURES OF THE PROPOSED HIGHWAY UPGRADING 41
5.3. VOLUME AND NATURE OF DANGEROUS GOODS 41
5.4. DANGEROUS OR HAZARDOUS EVENTS OR INCIDENTS 42
5.5. QUALITATIVE ASSESSMENT OF THE ENVIRONMENTAL RISK LEVELS FOR THE UPGRADE COMPARED WITH THE EXISTING HIGHWAY 43
5.6. MITIGATION MEASURES 43

1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

This report is in relation to the proposed upgrade of Pacific Highway for a length of 9.8km passing to the north of the township of Karuah. The upgrade commences 5km to the south and rejoins the existing highway 4km to the north of the township. Karuah Township has an estimated population of about 1,000 residents with a district population of 1,200 to 1,500 residents. There are about 30 businesses in the town employing about 260 staff.

The present objective is to develop a functional and socially acceptable concept design for a bypass of the town to the west (north) of the existing Pacific Highway. A major part of the exercise is the management of community involvement and consultation, resulting in route selection and detailed concept design work. The present work will culminate in the preparation and exhibition of an Environmental Impact Statement (EIS) and a number of other important assessments and management plans.

Ove Arup and Partners appointed Evans & Peck Management in November 1998 to undertake an Operations Hazards and Risks assessment.

The objective of the assessment is to examine the risks of accidents involving hazardous goods during and after construction.

1.2. HAZARDS DURING CONSTRUCTION

1.2.1. Hazardous Incidents During Construction

Hazard identification is the first and most important step in any hazard analysis. It involves the identification of all possible conditions that could lead to a hazardous incident.

A hazard study "HAZOP" adopting a group brainstorming approach, using a series of "what if" questions has been used.

The assessment contains the results of the brainstorming, in the form of a word diagram.

1.2.2. Dangerous Goods Handling Procedures During Construction

Construction sites are work areas where numerous hazardous substances, such as dusts (including asbestos and synthetic mineral fibres), cleaning agents, cement, paint, lacquers and timber preserving agents, can be found. Dangerous goods, such as explosives, gases, flammable liquids and solids, oxidising and poisonous substances are also to be found.

The report considers that the Contractor ought to be required to undertake formalised hazard identification and risk analysis techniques on dangerous goods to be brought on to the site.

The Contractor ought to also be required to have in place a formal process of actions and responsibilities in regard to hazardous substances – suggestions are included within the report.

1.2.3. Risks To The Public Due To Alternative Construction Methods

The currently proposed alignment for the Karuah Upgrade is through generally uninhabited areas. The bypass connects with the existing Pacific Highway at each end, but is otherwise isolated from the public.

The only interface of construction activities with the public will therefore be at either end of the project (at its junction with the existing Pacific Highway), or with general construction traffic in the locality of the site. The public risk must also be managed in the area of the Karuah River – both when working in the river and when working overhead.

The alternative methods vary in such a minor way that there is very little difference in the risk to the public in different methods of construction.

1.3. HAZARDS AFTER CONSTRUCTION

Evans & Peck Management commissioned QEST Consulting to carry out a quantitative study of the risks to the public and surrounding area associated with transportation of LPG, Petroleum and Chlorine for the proposed upgrade of the Pacific Highway at Karuah.

The approach used in the analysis has been to complete the following process:

- Establish the hazards associated with the three goods being transported.
- Determine the on-road and off-road population densities along the route for future populations (year 2014).
- Determine the frequency of transport movements for petrol, LPG and chlorine for future transport movements.
- Establish the frequency of which incidents are predicted to occur.
- Determine the probability that a particular outcome from an incident will occur
- Define the potential consequences of any of these outcomes.

The risk analysis reached the following conclusions:

- By inspection, the proposed upgrade will significantly reduce the risk to people in Karuah as the population exposed is greatly reduced and the likelihood of an accident is also reduced.
- The risks to the public resulting from the proposed upgrade are tolerable when compared to risk criteria for industrial sites and open areas. Risk criterion for public areas may generally be considered to be more stringent than those presented for industrial developments.
- The major finding from this analysis is that the planned transport of LPG contributes only a small proportion (4 %) of the total societal risk attributed to

petrol, LPG and chlorine transport. This is primarily as a result of the low frequency of LPG events.

- The dominant transport related risk (73 %) arises from the carriage of Petrol which gives rise to a risk of pool fires. The major contribution from petrol transit is essentially because:
  - there are greater numbers of petrol tankers than LPG tankers or chlorine trucks, therefore the accident probability is greater for petrol tankers than LPG tankers or chlorine trucks;
  - the probability of ignition is greater for petrol tankers than for LPG tankers or chlorine trucks;
  - in the event of an accident, the likelihood of loss of containment is considered to be greater in the case of petrol tankers than for LPG tankers or chlorine trucks.
- Although petrol dominated the risk, the risk of carrying chlorine was also significant at 23%. This was mainly due to the nature of chlorine releases evaporating and forming a cloud and the low concentrations in which it affects humans.
- The combined Rate of Death *(RoD)* for all three goods is 2.17 E-2 (equivalent to one fatality every 46 years).

1.4. ENVIRONMENTAL RISKS

The report considers that construction of the upgrade will result in substantially lower overall levels of hazard and risk to property and environmental assets. This reduction will occur because of:

- the much smaller population living within 250 metres of the upgrade compared to the existing Highway which passes through the centre of Karuah (population approximately 1,900 people and close to shops, major service stations and community facilities such as the Karuah Public School, and the Karuah RSL Club. All of these facilities generate 'side friction' to the Highway, which increases the potential for both major and minor accidents.
- the higher standard of road design on the upgrade which will reduce existing hazardous situations for traffic, for example, having to stop at the traffic signals in the centre of Karuah and the substandard curve on the eastern approach to the relatively narrow bridge over the Karuah River.
- the smaller length of roadway passing close to or parallel to SEPP 14 wetlands - approximately 1.5 km of the existing Highway runs immediately north of SEPP 14 wetland to the east of Karuah.

The report finally comments upon mitigation measures proposed.

2. BACKGROUND

2.1. PROJECT OVERVIEW

The site of the project centres on Pacific Highway (State Highway 10, SH10) at Karuah. The study area extends from approximately 3 km South of Karuah to 4 km North of Karuah (48.3 km to 57.9 km North of Newcastle).

The present objective is to develop a functional and socially acceptable concept design for on upgrade of the Pacific Highway at through Karuah. A major part of the exercise is the management of community involvement and consultation, resulting in route selection and detailed concept design work. The present work will culminate in the preparation and exhibition of an Environmental Impact Statement (EIS) and a number of other important assessments and management plans.

2.2. PROJECT BACKGROUND & ISSUES

The Pacific Highway has an unacceptably poor history of road crashes and a programme has been developed to upgrade the highway. It is planned to achieve a four lane divided road, including town bypasses within ten years (Government commitment). The main aim in upgrading the Pacific Highway is the reduction of motor vehicle incidents through the separation of traffic by a divided road. Combined with this are the associated benefits of:

- better level of service through increased capacity and controlled access conditions;
- separation of through and local traffic in some areas; and
- opportunity to provide increased flood immunity.

Existing land use and classification suggest that a number of issues are likely to arise in respect of the upgrade of the Pacific Highway at Karuah Bypass. They include:

- The social and economic impact on Karuah;
- The effect on SEPP 14 wetlands;
- The impact on oyster leases;
- The effect on Aboriginal heritage and/or on the Aboriginal Community;
- The curtailing of open water views at certain locations;
- The effect on river traffic;
- Land use consideration is, eg future sewerage treatment works;
- Noise during construction and operations;
- Pollution control and water quality safeguards; and
- Potential Acid Sulphate soils.

2.3. WORK BRIEF

The Roads and Traffic Authority (Newcastle) (RTA) appointed Ove Arup and Partners in March 1997 to provide project management services for, amongst other items, concept design and EIS preparation. The objectives of the brief to Ove Arup were:

- To achieve broad community and local community involvement;
- To collect and analyse data sufficient for an EIS, including a BCR;
- Prepare a draft concept design for an upgrade or bypass and associated access arrangements;
- Draft an EIS, carry out public consultation and obtain EIS responses;
- Produce a revised concept design reflecting public consultation;
- Produce an Environmental Management Plan; and
- Carry out a Risk Management and Economic Assessment of the proposal.

2.4. HAZARDS AND RISKS ASSESSMENT

Ove Arup and Partners appointed Evans & Peck Management in November 1998 to undertake an Operations Hazards and Risks assessment.

The objective of the assessment is to examine the risks of accidents involving hazardous goods during and after construction.

The assessment has been divided into three sections:

Hazards during Construction

The assessment is to be a qualitative review, considering:

- Dangerous goods to be used during construction;
- Identification and assessment of hazardous incidents during construction;
- Dangerous goods handling procedures during construction; and
- Risks to the public due to different methods of construction.

Hazards after Construction

The assessment is to be both qualitative and quantitative and is to address the hazards from transport of dangerous goods on the upgrade after construction, including:

- Event tree analysis;
- Consequence analysis; and
- A demonstration as to whether or not the effects of an incident on the new road would be likely to have a significant impact on the surrounding area, including centres of population.

Environmental risks

The assessment is to be a review of environmental risks associated with transport of dangerous goods, including:

- Identification of types of chemicals which may spill into the environment;
- Identification of credible spill scenarios;
- Determination of broad frequency and severity of spill events;
- Identification of sensitive receptors along the route; and
- A qualitative assessment of the environmental risk levels for the bypass compared with the existing highway.

The outcome of the review is to be a Hazards and Risks Report.

3. HAZARDS DURING CONSTRUCTION

3.1. TERMS

3.1.1. Hazards Analysis

The objective of hazard analysis is to develop a comprehensive understanding of the hazards and risks associated with dangerous goods used in the construction of the upgrade and of the adequacy of safeguards.

3.1.2. Hazard

A hazard is any thing or situation with a potential for causing damage to people, property or the environment.

3.1.3. Hazardous Incident

A hazardous incident is an event that initiates a thing or situation to potentially cause damage to people, property or the environment.

3.1.4. Dangerous Goods

Dangerous Goods are as defined by the Dangerous Goods Act, 1975 and the Dangerous Goods Regulations, 1978.

3.2. POTENTIAL DANGEROUS GOODS

Regardless of the construction methods to be adopted, it is probable that the following dangerous goods will be used during construction:

- explosives;
- distillate fuel;
- petrol;
- oils, grease, lubricants;
- additives;
- gases (oxygen, acetylene);
- bitumen.

3.3. POTENTIAL HAZARDOUS SUBSTANCES

Regardless of the construction methods to be adopted, it is probable that the following hazardous substances will be used during construction:

- all dangerous goods listed above;
- cement;
- fly ash;
- paints;
- epoxies;
- solvents, thinners.

3.4. HAZARDOUS INCIDENTS DURING CONSTRUCTION

Hazard identification is the first and most important step in any hazard analysis. It involves the identification of all possible conditions that could lead to a hazardous incident.

As this assessment is qualitative only, analytical hazard identification methods (such as Fault Tree Analysis and Event Tree Analysis) have not been adopted. Rather, a hazard study "HAZOP" adopting a group brainstorming approach, using a series of "what if" questions has been used.

The assessment is related to dangerous goods only, therefore rather than the more usual function or operational area analysis, a "dangerous goods type" assessment was made.

Members of the HAZOP team were:

Peter Gemell
Chris Lock, and
Rob Stevenson.

The following hazard identification table records the outcome of the HAZOP:

Dangerous Goods	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Explosives (in store)	Lightning strike Radio interference External collision Static electricity Aging / degradation Fire from other areas	Explosion Fire Escalation to other areas	Safe, isolated and secure storage facility Lightning conductors Isolated storage of detonators Adequate binding Minimum on-site storage
Distillate fuel, petrol, bitumen	Lightning strike External collision Static electricity Fire from other areas Accidental spillage Striking by moving vehicle	Explosion Fire Escalation to other areas	Safe and secure storage facility Lightning conductors Minimum on-site storage Fire extinguishers, hoses etc. Staff training
Oils, greases, lubricants, additives, paints, epoxies, solvents, thinners	Accidental spillage Fire from other areas Aging / degradation	Explosion Fire Spillage	Safe and secure storage facility Minimum on-site storage Use of MDS system Staff training
Gases (oxygen, acetylene)	Fire from other areas Heat (overheating) Vapour loss (puncture, valve leakage)	Fire Explosion	Safe and secure storage facility Minimum on-site storage Staff training
Cement, fly ash	Dust leakage	Airborne contamination Inhalation	Safe and secure storage facility Minimum on-site storage Staff training Use of MDS system

3.5. DANGEROUS GOODS HANDLING PROCEDURES DURING CONSTRUCTION

Construction sites are work areas where numerous hazardous substances, such as dusts (including asbestos and synthetic mineral fibres), cleaning agents, cement, paint, lacquers and timber preserving agents, can be found. Dangerous goods, such as explosives, gases, flammable liquids and solids, oxidising and poisonous substances are also to be found.

The RTA will require that the Contractor awarded the contract for the construction of the Karuah Upgrade comply with all legislative and standards requirements for the safe handling of hazardous substances and dangerous goods.

The Contractor will be required to undertake formalised hazard identification and risk analysis techniques on dangerous goods to be brought on to the site.

Only hazardous substances will be permitted where a Material Safety Data Sheet (MSDS) is available from the relevant supplier.

The Contractor will also be required to have in place a formal process of actions and responsibilities in regard to hazardous substances; these may, by way of example, include procedures for:

- the appropriate training of employees in the storage, handling, use and safe disposal of hazardous substances;
- ensuring hazardous substances are safely stored;
- ensuring quantities of hazardous substances are kept to a minimum, and that only compatible substances are stored in close proximity to each other;
- emergency containment in the event of a spill and the notification of the relevant authorities;
- the protection of personnel in the event of an emergency and in the clean up operation after the emergency; and
- the maintenance of appropriate records (Hazardous Substance Storage Register and Explosives Magazine Register).

3.6. RISKS TO THE PUBLIC DUE TO ALTERNATIVE CONSTRUCTION METHODS

The currently proposed alignment for the Karuah Upgrade is through generally uninhabited areas. The upgrade connects with the existing Pacific Highway at each end, but is otherwise isolated from the public.

The successful Contractor will be required to comply with all legislation to ensure that the work site remains safe and secure from public intrusion. It is generally the practice of Contractors to construct the permanent fencing as soon as site clearance has been completed, thereby ensuring a safe site.

The main interface of construction activities with the general public will therefore be at either end of the project (at its junction with the existing Pacific Highway), or with general construction traffic in the locality of the site. There will be further specific construction interfaces with farmers/landowners along the route of the project and river users in the locality of the proposed new bridge.

There will also be interfaces at locations where the new upgrade intersects with existing local roads.

It is likely that the successful Contractor awarded the construction of the Karuah Upgrade will adopt the following methodology:

ACTIVITY	EQUIPMENT / METHOD
Site clearance	Heavy cutting equipment, mulching, topsoil storage
Earthmoving	Heavy earthmoving equipment, explosives, trucks, compaction equipment
Drainage	Excavation equipment, pipe jointing, concreting equipment
Pavement	Crushing plant, compaction equipment, concrete batch plant and laying equipment, asphalt batch plant and laying equipment
Bridge	Barges, concrete batch plant and over water delivery and placing system, pre-cast concrete yard, girder erection equipment (possibly cranes)
Other items	Site offices and ablutions

It is considered highly unlikely that alternative construction methods are available for site clearance, bulk excavation and select material pavements – nor are there likely to be any developments in this area in the foreseeable future. This will lead to the delivery of heavy plant by road to and from the site, together with the delivery of fuels and lubricants.

The structure of the road pavement may be in concrete or asphalt. In either case, production plants will be needed on or close to the project. Both processes require the use of crushed aggregate, although asphalt additionally requires the use of bitumen. Neither option is considered to be a higher risk relative to the other. The raw materials will be required to be delivered to the site (if an onsite plant is used) or to the plant (if an offsite plant is used). In the former case, the product (concrete or asphalt) is delivered around the site, whereas in the latter case the product has first to be delivered to the site. There is very little difference in either of these methods as far as the public is concerned.

The major bridge structure over the Karuah River may enable some innovation from the successful Contractor, but well within the limits of current custom and practice. The bridge will require foundations within the river itself, these will be of concrete.

The superstructure of the bridge may be of concrete or steel. A concrete structure may be built of pre-cast beams either cast on site in a specialist yard or off the site in a specialist supplier's yard. In the former case, concrete batching on or just off the site may be required, but this is also probably necessary for other parts of the bridge superstructure and road pavement. Steel beams may be fabricated off site.

The superstructure may be erected in-situ or by the incrementally launched method. In either case, work over water is required.

In all of the foregoing, the public risk must be managed in the area of the Karuah River – both when working in the river and when working overhead. Public risk

must also be managed in the areas of the new interchanges with the existing Pacific Highway.

Conclusion:

The alternative methods vary in such a minor way that there is very little difference in the risk to the public in different methods of construction.

4. HAZARDS AFTER CONSTRUCTION

4.1. INTRODUCTION

QEST Consulting have been commissioned to carry out a quantitative study of the risks to the public and surrounding area, associated with transportation of LPG, Petroleum and Chlorine for the proposed upgrade of the Pacific Highway at Karuah.

4.1.1. Objectives

The objectives of this study are to calculate the societal risk along the proposed 9.4km route of the Pacific Highway Karuah Upgrade as a result of transporting:

- LPG
- Petroleum
- Chlorine

4.1.2. Study Area Description

The study area centres on the township of Karuah, which is currently located astride the Pacific Highway some 50km north of Newcastle and largely on the western side of the Karuah River. The study area includes both the built-up township area as well as surrounding cleared rural and forested lands. A substantial part of Karuah's immediate hinterland comprises either State Forest or protected wetlands of state significance, with little agriculture development in the district.

Karuah township has an estimated population of about 1,000 residents with a district population of 1,200 to 1,500 residents. There are about 30 businesses in the town employing about 260 staff. Economic activity in and around Karuah includes highway services (accommodation, petrol, and fast food), oyster farming, timber milling, building contractors, education and community services.

The proposed upgrade is approximately 9.8km long and involves the construction of a dual carriage bypass to the north of the township. The bypass deviates from the existing Pacific Highway approximately 5km south of Karuah and reconnects with the highway approximately 4km north of the township.

4.2. APPROACH

This analysis required the following process:

- Establish the hazards associated with the three goods being transported.
- Determine the on-road and off-road population densities along the route for future populations.
- Determine the frequency of transport movements for petrol, LPG and chlorine for future transport movements.
- Establish the frequency of which incidents are predicted to occur.

- Determine the probability that a particular outcome from an incident will occur
- Define the potential consequences of any of these outcomes.
- Each incident presents a number of potential outcomes. The likelihood of each particular outcome occurring is established. At this stage of the analysis the consequences and effect zones for each of the potential outcomes is defined.
- Finally the probability of each event occurring and the potential consequences of that event are overlaid on the route. This is achieved by building a mathematical model of the route that incorporates the data obtained during the above steps. The computer model combines the frequencies and consequences of each event to establish the risk attributable to each substance being transported. This is done for future (year 2014) transport and population densities.

4.3. TRANSPORT HAZARDS

In Australia, few serious transport incidents involving dangerous goods have occurred and only small numbers of people have been affected. However, there have been incidents elsewhere which demonstrate that serious accidents with multiple fatalities can and do occur. Some major incidents, which are relevant to the LPG and petrol analysis in the present study, are given inTable 4.1. The table is an extract from information provided in the UK ACDS report on, Major Hazard Aspects of the Transport of Dangerous Substances [1].

4.3.1. Hazards from the Transport of LPG by Road

LPG (Liquid Petroleum Gas) is a collective name for the hydrocarbons butane and propane and mixtures of these gases, which are vaporous at ambient temperature and atmospheric pressure. LPG is heavier than air and after being released, will sink to ground level and collect in hollows unless spread by the wind. LPG is conveyed throughout New South Wales in pressure vessels mounted on the chassis of a truck or trailer as a liquid under pressure. If it is allowed to escape it will form a heavier than air gas approximately 240 to 270 times its compressed volume.

Release of LPG from the pressurised vessel during transport may result from a variety of reasons:

- Malfunctioning equipment:
- Failure of the pressure vessel
- Failure of pipework
- Failure of valves
- Overfilling of the vessel
- Puncture of pipework or vessel

- Vehicle fire leading to rupture.

When mixed with air, LPG vapour is flammable. The concentration at which LPG ignites is dependent on the component concentrations (ie, butane and propane). The lower limit for pure butane is 1.8 %vol and the upper limit is 8.4 %vol. Similarly for propane the lower limit is 2.2 %vol and the upper limit is 9.5 %vol [10].

The potential outcomes of such releases of LPG include jet fire, vapour cloud explosion (VCE), flash fire and BLEVE (Boiling Liquid Expanding Vapour Explosion). Each of these outcomes is described in detail in Section 8 of this report.

4.3.2. Hazards from the Transport of Petrol by Road

Petrol is a mixture of hydrocarbons, propane (C_3H_8) being the lightest component. Under normal conditions petrol is a liquid and is stored and transported as such. If it escapes, a pool of liquid forms and the various components vaporise. Release of petrol from the tanker during transport may result from similar reasons highlighted above:

When mixed with air, petrol vapour is flammable. To ignite the vapour the concentration must lie within certain limits. The lower limit is 1.4 %vol and the upper limit 7.4 %vol [10].

The exposure hazard for a toxic vapour cloud from a petrol spill has not been analysed as the spilled liquid will not vaporise to form a toxic gas cloud in open conditions.

4.3.3. Hazards from the Transport of Chlorine by Road

Chlorine is normally stored and transported as a liquid. If a release occurs, some of the chlorine will flash off, the remainder forming a pool of liquid and the various components continue to vaporise. Chlorine liquid is transported by trucks in 920 kg tanks, 68kg or 32 kg cylinders. The trucks can carry up to a maximum of 15 tanks on semi trailers or 6 on smaller rigid trucks. Cylinders are transported in 12 berth cradles generally on rigid trucks. Loads vary depending on customer demands, however for this analysis a typical load of 6 tanks on a rigid truck has been assumed.

Chlorine gas is heavier than air and can have fatal consequences if exposed to concentrations of 40-60 ppm for lengthy periods of time [21].

Table 4.1 Selected Major Hazard Accidents Involving Petrol and LPG [1]

Date	Location	Area	Substance	Quantity (tonnes)		Consequences		
				Available	Released	Nature of Accident		Fatalities
25/7/62	New Berlin, NY, USA	Urban	Propane	13	13	Failure of Tank following Jack-knife and collision	Release of contents resulted in fire	10
23/10/70	Hull, UK	Urban	Propane	2	0.1	Control Valve an dome sheared off in collision with subway roof	Cloud and flash fire	2
4/1/78	Nr Hatfield, UK	Rural	Petrol	19	19	Multiple crash and tank rupture	Fire	0
16/7/78	Nr Tula, Mexico	Rural	Butane	4-23	4-23	Vehicle crashed and overturned resulting in rupture	Explosion	10-15
7/4/82	Oakland, Calif, USA	Urban	Petrol	24	24	Petrol tanker collision with car in tunnel	Explosion and fire	7
13/6/84	Salmon Arm, BC, Canada	Rural	Propane	-	-	Tanker collision with vehicle and fell down embankment	Gas release and explosion	1
1/11/85	Padaval, India	Rural	Petrol	-	-	Vehicle into ditch and tank ruptured	Explosion and fire	>43
21/3/86	Calcutta, India	Urban	Petrol	-	-	Tanker collision with crowded bus	Explosion and fire	2
7/7/87	Herborn, Germany	Urban	Petrol	25	25	Tanker crashed into shop following brake failure	Explosions and fires over large area	4
23/12/88	Memphis, Tenn., USA	Urban	Propane	26	26	Tanker skidded	Explosion and fireball	9

4.4. KEY PARAMETERS USED IN THE STUDY

This study has required a wide range of data to be gathered to enable a representative analysis to be performed. The following sections detail the route details used in the analysis, the numbers of movements of dangerous goods and the details of populations both on and off the route which are all key components in the analysis.

4.4.1. Route

The proposed section of highway extends from approximately 5km west of Karuah to approximately 4km east of the township, having a total length of 9.8km.

The planned bypass route has been divided into 0.5km equal sections. There are 19 sections in total. Population densities, both on and off the road, encountered along the route have been addressed, refer to Section 7.4.3.

4.4.2. Movements

The following assumptions concerning the number of movements and the quantities of material have been made. It is assumed that movements of LPG, petrol and chlorine take place 7 days a week. All movements are assumed to be fully loaded and travelling along the new route.

The number of vehicle movements along the Karuah Upgrade in the year 2014 is estimated to be 18363 per day of these 2864 are heavy goods vehicles [6]. During the daytime period (6am and 6pm) eighty percent of the daily traffic volume is present on the road. The relative proportions of dangerous goods carried by all heavy vehicles in New South Wales are shown in Table 4.3. It is assumed that the percentages are valid for traffic flows greater than the current New South Wales figures.

Table 4.3 Dangerous Goods Vehicle Type as Percentage of All Heavy Vehicles in NSW [3]

Vehicle Type	% of Total Heavy Vehicles
Petrol	0.75
LPG	0.1
Chlorine	0.1
Poisons	0.1
Other Dangerous Goods	0.1
Total	1.15

The annual daily average of petrol, LPG and chlorine vehicle movements for 2014 are presented in Table 4.5 below.

Table 4.5 Range and Number of Petrol, LPG and Chlorine Vehicle Movements Forecast per day in 2014 [4]

Dangerous Goods	Year 2014 per day
Petrol	22
LPG	3
Chlorine	3

It is assumed that the number of movements per week of, petrol, LPG and chlorine remains constant throughout the year. The average quantity carried by an LPG tanker at any time along the route is 42,000 litres LPG. The average quantity carried by a petrol tanker at any time along the route is 40,000 litres. The average quantity carried by a chlorine truck is 6 tanks (6,000 litres).

4.4.3. Population

Two population types have been defined in the study: the on-road population (people in vehicles), and the off road population (residents) either side of the transport route.

On-road populations have been estimated from traffic flow rates and assumptions about the average number of people per car. The upgrade traffic flow rate is assumed to be constant along the proposed route, and for each route section they have been represented as an average evenly spaced population continually present on the road. It has been assumed that the average number of occupants in a vehicle is two. For the on-road population a population density of 14 people / 500m during the day and 3 people / 500m at night has been calculated. Estimated traffic volumes have been provided by Ove Arup [6].

The off-road population densities have also been provided by Ove Arup [5]. The population has been distributed evenly within each zone to establish populations exposed to potential effects.

Table 4.7 Off Road Populations Used in Analysis [5][6]

Ave house pop % time spent at home
2.5 0.5

No. of houses	Population Off Road per section	Day	Night	Comments / landowner
4	10.0	5.0	10.0	Mr TNO'Keefe land owner
1	2.5	1.3	2.5	MJ Vann Der Zalm Mountainous Industries, R Pickford owns land
	0.0	0.0	0.0	R Pickford owns land
	0.0	0.0	0.0	R Pickford owns land
	0.0	0.0	0.0	
	0.0	0.0	0.0	
1	2.5	1.3	2.5	RJ & KP Skelton
	0.0	0.0	0.0	Bridge crosses river
	0.0	0.0	0.0	
	0.0	0.0	0.0	GA & DG Hill
2	5.0	2.5	5.0	DA & LN Powell, MH & CP Garrett
	0.0	0.0	0.0	Karuah Nature Reserve (assume uninhabited)
	0.0	0.0	0.0	Karuah Nature Reserve (assume uninhabitated)
	0.0	0.0	0.0	Karuah Nature Reserve (assume uninhabitated)
	0.0	0.0	0.0	Hunter Water Corporation (proposed site unmanned)
	0.0	0.0	0.0	Hunter Water Corporation (proposed site unmanned)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	Sydstone P/L, Pinmark Pty Ltd

Ave house pop % time spent at home
2.5 0.5

No. of houses	Population Off Road per section	Day	Night	Comments / landowner
4	10.0	5.0	10.0	Mr TN O'Keefe land owner
1	2.5	1.3	2.5	MJ Vann Der Zalm Mountainous Industries, R Pickford owns land
	0.0	0.0	0.0	R Pickford owns land
	0.0	0.0	0.0	R Pickford owns land
	0.0	0.0	0.0	
	0.0	0.0	0.0	
1	2.5	1.3	2.5	RJ & KP Skelton
	0.0	0.0	0.0	Bridge crosses river
	0.0	0.0	0.0	
	0.0	0.0	0.0	GA & DG Hill
2	5.0	2.5	5.0	DA & LN Powell, MH & CP Garrett
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	Hunter Water Corporation (proposed site unmanned)
	0.0	0.0	0.0	Hunter Water Corporation (proposed site unmanned)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	State Forests (assume uninhabitated)
	0.0	0.0	0.0	Sydstone P/L, Pinmark Pty Ltd

4.5. FREQUENCY ANALYSIS

Two fatal incidents involving heavy goods vehicles were recorded in Karuah district during the 5 years from 1993 – 1997 [8]. These local fatality accidents recorded are as follows:

- On 18 May 1994 at 7.30pm, near Mustons Road in Karuah, a pedestrian walking along the road with the traffic was killed when struck by a semi trailer.
- On 9 July 1994 at 5.10pm, near Reedy Creek west of Karuah, the driver of a station wagon was killed when his vehicle collided with a semi-trailer travelling in the opposing direction.

This historical information has not been used as the proposed bypass will make this data invalid. The NSW state average accident rates have been used to establish accident frequencies. This is a conservative approach which is likely to overstate the likelihood of accidents on the new bypass (a two lane divided road), given that the State accident rates are gathered from a variety of road standards

The average accident rates used were 21.9 accidents per 100 million vehicle-kms (2.19×10^{-7} /km) and a heavy vehicle accident rate of 21% of this (4.6×10^{-8}/km).

In order to establish frequency of spills from petrol, LPG and chlorine the accident frequency is adapted to include the percentage of each type of vehicle travelling on the road.

Table 4.9 Karuah Upgrade Heavy Goods Vehicle Traffic and Accident Frequency

	Dangerous Goods %	Dangerous Goods (Total)	Dangerous Goods (Day)	Dangerous Goods (Night)	KM/yr (Day)	KM/yr (Night)	Accidents / 9.4km (Day)	Accidents / 9.4km (Night)
Petrol	0.75%	22	14	8	47013	26685	2.16E-03	1.23E-03
Chlorine	0.10%	3	2	1	6268	3558	2.88E-04	1.64E-04
LPG	0.10%	3	2	1	6268	3558	2.88E-04	1.64E-04

This correlates with UK and Victorian data that spill frequencies of 5.6×10^{-8}/km and 5.2×10^{-8}/km respectively. For the purpose of this assessment, the accident frequency is assumed to equate to the release frequency.

4.6. SCENARIO DEVELOPMENT

This section describes the analysis of the initiating events for which frequencies have been calculated in the previous section. The analysis concludes with the description and frequency of the possible outcomes which are then analysed for their potential consequences.

Event tree analysis is a technique used for describing and analysing situations in which an initiating event may lead to a number of different outcomes. It can be used when the outcomes depend on both human and system responses. Quantification of each branch of the event tree enable the probabilities of the final outcomes to be established. The event trees are presented as Appendix I.

4.6.1. LPG

The possible consequences of an LPG release event are dependent on the release mechanism, ie continuous or instantaneous, and whether or when ignition occurs. The potential outcomes of an LPG release are no ignition, jet fire, vapour cloud explosion (VCE), flash fire and BLEVE (Boiling Liquid Expanding Vapour Explosion). As each of the above outcomes lead to significantly different consequences it is therefore important to analyse the likelihood of each such events. This is accomplished through the use of event trees.

Table 4.11 Generic Event Tree for Releases of LPG

1	2	3	4	5	6	7	8	9
Annual Frequency	Release <100kg	Hole size	Ignition	Vapour Cloud Explosion	Flame Impingement	Event Outcome Frequency	Outcome	Description
F1	P1 Yes					F2	_OK	LPG_Rel_<100kg_OK
		P2 Hole 25mm	P4 Yes		P12 Yes	F3	_BLEVE	LPG_Rel_25mm_Imp_BLEVE
					P12 1-P12 No	F4	_OK	LPG_Rel_25mm_OK
			1-P4 No			F5	_No Ign	LPG_Rel_25mm_No Ign
			P5 Immediate		P12 Yes	F6	_BLEVE	LPG_Rel_100mm_Imp_BLEVE
					P12 1-P12 No	F7	_JetFr	LPG_Rel_100mm_NotImp_JetFr
				P11		F8	_HaVCE	LPG_Rel_100mm_HaVCE
			P6 Delayed	P11 Yes		F9	_HaFlshFr	LPG_Rel_100mm_HaFlshFr
				P11 1-P11 No		F10	_FullVCE	LPG_Rel_100mm_FullVCE
	1-P1 No	P3 Hole 100mm	P7 Further Delayed	P11 Yes		F11	_FullFlshFr	LPG_Rel_100mm_FullFlshFr
				P11 1-P11 No		F12	_No Ign	LPG_Rel_100mm_No Ign
			1-P5-P6-P7 None			F13	_FIREBALL	LPG_Rel_Rup_FIREBALL
			P8 Immediate			F14	_HaVCE	LPG_Rel_Rup_HaVCE
				P11		F15	_HaFlshFr	LPG_Rel_Rup_HaFlshFr
			P9 Delayed	P11 Yes		F16	_FullVCE	LPG_Rel_Rup_FullVCE
				P11 1-P11 No		F17	_FullFlshFr	LPG_Rel_Rup_FullFlshFr
		1-P2-P3 Rupture	P10 Further Delayed	P11 Yes		F18	_No Ign	LPG_Rel_Rup_No Ign
				P11 1-P11 No				
			1-P8-P9-P10 None					

4.6.1.1. LPG Release Case Probabilities

It has previously been calculated that the annual frequency of LPG accidents for the Karuah Upgrade route is 4.6 x 10^{-8} spills per loaded tanker kilometre or 4.5x10^{-4} per year.

The probability of a quantity of LPG escaping is determined in two stages. The first stage is to determine the probability of releases larger than 100 kg, which are considered significant and a potential hazard to the population. A probability of 0.95 (P1) has been used for a small leak (< 100 kg) occurring. This figure is based on a study into LPG risks for the Dutch Ministry of Housing, Physical Planning and the Environment which used comprehensive data from a number of sources [12].

This residual frequency (F1 x (1-P1)) is further divided into different representative events. Significant releases from LPG vessels are represented with three release cases. These three release cases have been defined as two hole sizes and a rupture of the vessel. The probability of each of the three release cases corresponds with those used in [12] and are considered as 0.9 (P2) for a hole size of 25 mm, 0.07 (P3) for a hole size of 100 mm and 0.03 (1-P2-P3) for rupture of the vessel. Each case is also defined by a release rate. Table 4.13 below gives the three cases together with the mass release rate used for the consequence calculations, together with the probability of each case.

Table 4.13 Release Cases for LPG Transport

Release Case	Release	Release Rate	Probability
Hole size 25 mm	Continuous	2 kg/s	0.045 = (1-P1) x (P2)
Hole size 100 mm	Continuous	36 kg/s	0.0035 = (1-P1) x (P3)
Rupture of the vessel	Instantaneous	22,600 kg	0.0015 = (1-P1) x (1-P2-P3)

LPG Ignition Probabilities

Table 7.15 presents the different ignition probabilities used for the different cases. The total weighted probability of ignition for all the above cases comes to 0.176, which is comparable to Victorian historical data. The probabilities of ignition are sourced from data used by TNO, [12].

Table 4.15 Probabilities of Ignition

Release Case	Probability of Failure Case	Total Probability of Ignition	Event Probability of Ignition
Hole size 25 mm	0.9 (P2)	0.15 (P4)	0.135 (P2)(P4)
Hole size 100 mm	0.07 (P3)	0.2 (P5+P6+P7)	0.014 (P3) (P5+P6+P7)

Rupture of the vessel	0.03 (1-P2-P3)	0.9 (P8+P9+P10)	0.027 (1-P2-P3) (P8+P9+P10)

The ignition probabilities are further split between an immediate ignition resulting in a jet fire or fireball, a delayed ignition probability resulting in a half-developed flammable cloud and a further delayed ignition probability resulting in a fully developed flammable cloud. The probability splits used in the event tree are summarised in Table 4.17.

Table 4.17 Ignition Probability Splits

Release Case	Immediate	Delayed	Further Delayed	Total
Result	Jet Fire or fireball	Half developed flammable cloud	Fully developed flammable cloud	
Hole size 25 mm	0.15 (P4)	-	-	0.15
Hole size 100 mm	0.1(P5)	0.05 (P6)	0.05 (P8)	0.2
Vessel Rupture	0.4 (P8)	0.25 (P7)	0.25 (P9)	0.9

The small hole size (25 mm) represents leaks of 2 kg/s, if ignited, such events would form a jet fire. The probabilities of immediate, delayed and further delayed ignition used for the 100 mm hole and rupture case are again comparable to those used in [12].

The quantified event tree for the bypass is shown in Table 4.19 Appendix I contains event trees for the upgrade.

Table 4.19 Event Tree for Releases of LPG

1 Annual_Frequency	2 Release <100kg	3 Hole size	4 Ignition	5 Vapour Cloud Explosion	6 Flame Impingement	7 Event Outcome Frequency	8 Outcome	9 Description
	0.95 Yes					4.3 E-04	_OK	LPG_Rel_<100kg_OK
					0.1 Yes	2.0 E-07	_BLEVE	LPG_Rel_25mm_Imp_BLEVE
			0.1 Immediate		0.9 No	1.8 E-06	_OK	LPG_Rel_25mm_OK
		0.9 Hole 25mm		0.05 Yes		1.0 E-07	_HaVCE	LPG_Rel_25mm_HaVCE
			0.1 Delayed	0.95 No		1.9 E-06	_HaFlshFr	LPG_Rel_25mm_HaFlshFr
			0.8 None			1.6 E-05	_No Ign	LPG_Rel_25mm_No Ign
					0.1 Yes	1.6 E-08	_BLEVE	LPG_Rel_100mm_Imp_BLEVE
4.50 E-4			0.1 Immediate		0.9 No	1.4 E-07	_JetFr	LPG_Rel_100mm_NotImp_JetFr
				0.05 Yes		3.9 E-09	_HaVCE	LPG_Rel_100mm_HaVCE
			0.05 Delayed	0.95 No		7.5 E-08	_HaFlshFr	LPG_Rel_100mm_HaFlshFr
	0.05 No	0.07 Hole 100mm		0.05 Yes		3.9 E-09	_FullVCE	LPG_Rel_100mm_FullVCE
			0.05 Further Delayed	0.95 No		7.5 E-08	_FullFlshFr	LPG_Rel_100mm_FullFlshFr
			0.8 None			1.3 E-06	_No Ign	LPG_Rel_100mm_No Ign
			0.4 Immediate			2.7 E-07	_FIREBALL	LPG_Rel_Rup_FIREBALL
				0.05 Yes		8.4 E-09	_HaVCE	LPG_Rel_Rup_HaVCE
			0.25 Delayed	0.95 No		1.6 E-07	_HaFlshFr	LPG_Rel_Rup_HaFlshFr
		0.03 Rupture		0.05 Yes		8.4 E-09	_FullVCE	LPG_Rel_Rup_FullVCE
			0.25 Further Delayed	0.95 No		1.6 E-07	_FullFlshFr	LPG_Rel_Rup_FullFlshFr
			0.1 None			6.8 E-08	_No Ign	LPG_Rel_Rup_No Ign
					Check Sum	4.50 E-04		

4.6.1.3. Flame Impingement

A hazard may develop from jet fire fed by a 2kg/s release if the flame was able to impinge on the vessel. This may eventually result in a Boiling Liquid Expanding Vapour Explosion (BLEVE).

The probability of escalation of the jet fire case to result in BLEVE of the vessel is estimated based on:

1. Proximity of release to inventory/probability of impingement,
2. Duration of the release,
3. Consideration of the mechanism, i.e. jet fire

A jet fire release, by its nature, is in close proximity to the vessel. However in many cases the flame will not be impinging directly on the vessel.

Historically, it is reported by Martinsen & Cavin (1981) [13] that four BLEVE incidents involving fixed LPG storage vessels occurred within 10 to 25 minutes of

fire start. Other observations by Wall (1979) [14] indicate time to BLEVE of 8 to 30 minutes. A total fire engulfment test on a 70 te capacity LPG vessel recorded a time to BLEVE of 24 minutes (Charles *et al*, 1974) [15]. Some recent tests have shown much shorter times to BLEVE of about 5 minutes. These times were all for storage vessels, however, there is no significant difference which can be postulated for LPG transport vessels. Heat-up calculations performed on carbon steel vessels with no allowance for waterspray protection effects (Blything & Reeves, 1988) [16], using a failure temperature of 500°C give times to BLEVE from an impinging jet fire of about 5 minutes. The continuous release rates used in this analysis will sustain a jet fire for longer than 5 minutes.

There are no mitigation measures considered possible within five minutes, such as cooling the vessel with water.

A probability of 0.1 (P12) for a jet fire escalating to a BLEVE has been used in the analysis based on the judgement of the analyst.

4.6.1.4. Immediately Ignited Release from 100 mm Hole

This scenario is similar to the previous case of a release from a 25 mm hole. The first outcome considered is a jet fire fed by a flow rate of 36 kg/s. This event may also escalate to fail the vessel and result in a BLEVE. A probability of escalation to BLEVE (0.1) is used.

4.6.2. Petrol

In this analysis petrol releases are modelled as a range of spill sizes with different probabilities of ignition resulting in a pool fire. This is consistent with the approach of ACDS [17]. Consequences other than pool fires can be postulated, e.g. explosions due to the ignition of a confined amount of vapour. However, it is considered that such events, with limited amounts of vapour, would not lead to greater impact distances than large pool fires, which may have sudden ignition flame heights up to 50 m. Here again scenario development is through the use of event trees. An unquantified event tree for Petrol releases is given in Figure 7.3.

It has previously been calculated that the frequency of petrol leaks for the Karuah Bypass is 4.6×10^{-8} spills per loaded tanker kilometre or 3.4×10^{-3} per year.

4.6.2.1. Petrol Release Case Probabilities

The probability of a quantity of petrol escaping is also determined in two stages. The first stage is to determine the probability of releases, which are not considered to present a potential hazard to the population. A probability of 0.5 (P1) has been used for a small leak occurring, which does not develop to a significant event. This figure is based on a study into the risks from the transport of petrol for the Dutch Ministry of Housing, Physical Planning and the Environment [12]. The probability of a small leak occurring is lower than the equivalent LPG

probability as a petrol tanker wall is much thinner than an LPG pressure vessel.

This residual frequency (F1 x (1-P1)) is further divided into different representative events. Significant releases from petrol tankers ware represented with five cases. These five release cases have been defined as two hole sizes and three different ruptures of the tanker. Petrol tankers are normally divided into 5 compartments of equal size. The petrol tanker capacity used for this analysis is 42,000 litres. It is postulated that no event would involve more than 3 compartments (as it was the case with the 1995 Melbourne incident). The maximum spillage is therefore 25,200 litres. Three cases have been assumed in the case of an instantaneous release. Each case assumes a different number of compartments. Table 4.21 identifies the release cases considered. The probabilities used for petrol releases are consistent with [12].

Table 4.21 Release Cases for Petrol Transport

Release Case	Release	Release Rate/ Total Release	Probability
Hole size 25 mm	Continuous	2.3 kg/s	0.125 = P2 x (1-P1)
Hole size 75 mm	Continuous	25 kg/s	0.125 = P3 x (1-P1)
Release of 1 compartment	Instantaneous	8,400 litres	0.2375 = (1-P1) x (1-P2-P3) x P4
Release of 2 compartments	Instantaneous	16,800 litres	0.01125 = (1-P1) x (1-P2-P3) x P5
Release of 3 compartments	Instantaneous	25,200 litres	0.00125 = (1-P1) x (1-P2-P3) x (1-P4-P5)

In the case of the 25mm hole it is assumed that people in the vicinity of the leak can easily move away before the pool, and possibly a pool fire establishes itself.

Reference [12] does not consider that the numbers of compartments ruptured may vary. Reference [13] considers the probabilities for one, two and three compartments rupturing are 0.5, 0.25 and 0.25 respectively. However, it is the analyst's judgement that this is unduly pessimistic and that there should be significantly lower probabilities of rupture for larger numbers of compartments. It is therefore assumed for the case of an instantaneous release that in 95% (P4) of occasions this involves only one compartment, that in 4.5% (P5) of cases two compartment's contents are spilled and that in the remaining case three compartment's contents are spilled 0.5% (1-P4-P5).

Table 4.23 Generic Event Tree for Releases of Petrol

1	2	3	4	5	6	7	8
Annual Frequency	Very Small Release	Hole size	Tank numbers	Ignition	Event Outcome Frequency	Outcome	Description
	P1				F2	_OK	Pet_Rel_Small_OK
	Yes						
		P2			F3	_OK	Pet_Rel_25mm_OK
		Hole 25mm					
				P6	F4	_Poolfire	Pet_Rel_75mm_Poolfire
F1		P3		Yes			
		Hole 75mm		1-P6	F5	_OK	Pet_Rel_75mm_OK
	1-P1			No			
	No			P6	F6	_Poolfire	Pet_Rel_Rupture_Poolfire_8.4
			P4	Yes			
			One	1-P6	F7	_OK	Pet_Rel_Rupture_OK
				No			
				P6	F8	_Poolfire	Pet_Rel_Rupture_Poolfire_16.8
		1-P2-P3	P5	Yes			
		Rupture	Two	1-P6	F9	_OK	Pet_Rel_Rupture_OK
				No			
				P6	F10	_Poolfire	Pet_Rel_Rupture_Poolfire_25.2
			1-P4-P5	Yes			
			Three	1-P6	F11	_OK	Pet_Rel_Rupture_OK
				No			

4.6.2.2. Petrol Ignition Probabilities

This probability of ignition is considered applicable for all releases of petrol. The same ignition probability is used for the different cases. Though the ignition probability is quite high it is considered reasonable as it is based on historical data.

Table 4.25 gives an overview of the probabilities used in the event tree for petrol releases.

Table 4.25 Overview of Probabilities Used in Petrol Release Event Tree

Branch	Probability Tag	Probability Used
Very Small Release	P1	0.5
Hole Size 25 mm	P2	0.25
Hole Size 75 mm	P3	0.25
Rupture 1 Tank Compartment	P4	0.95
Rupture 2 Tank Compartments	P5	0.045
Rupture 3 Tank Compartments	P6	0.005

The quantified event tree for the full route is shown in Figure 4.6-1. Appendix I contains event trees for the route.

Figure 4.6-1 Event Tree for Releases of Petrol

1	2	3	4	5	6	7	8
Annual Frequency	Very Small Release	Hole size	Tank numbers	Ignition	Event Outcome Frequency	Outcome	Description
3.40 E-3	0.5 Yes				1.7 E-03	_OK	Pet_Rel_Small_OK
		0.25 Hole 25mm		0.4 Yes	1.7 E-04	_Poolfire	Pet_Rel_25mm_Poolfire
				0.6 No	2.6 E-04	_No Ign	Pet_Rel_25mm_No Ign
		0.25 Hole 75mm		0.4 Yes	1.7 E-04	_Poolfire	Pet_Rel_75mm_Poolfire
				0.6 No	2.6 E-04	_No Ign	Pet_Rel_75mm_No Ign
	0.5 No	0.5 Rupture	0.95 One	0.4 Yes	3.2 E-04	_Poolfire	Pet_Rel_Rupture_Poolfire_8.4
				0.6 No	4.8 E-04	_No Ign	Pet_Rel_Rupture1_No Ign
			0.045 Two	0.4 Yes	1.5 E-05	_Poolfire	Pet_Rel_Rupture_Poolfire_16.8
				0.6 No	2.3 E-05	_No Ign	Pet_Rel_Rupture2_No Ign
			0.005 Three	0.4 Yes	1.7 E-06	_Poolfire	Pet_Rel_Rupture_Poolfire_25.2
				0.6 No	2.6 E-06	_No Ign	Pet_Rel_Rupture3_No Ign
				Check Sum	3.40 E-03		

4.6.3. Chlorine

In this analysis chlorine releases are modelled as a range of leak sizes resulting in a release of toxic gas. Chlorine is transported as a liquid, however if instantaneously released to the atmosphere (eg drum rupture) it will rapidly flash-off about 25% of the liquid, with the remainder forming a liquid pool and will then continue to evaporate as it picks up heat from its surroundings. Here again scenario development is through the use of event trees. An unquantified event tree for Chlorine releases is given on Table 4.27.

It has previously been calculated that the frequency of chlorine leaks for the Karuah Upgrade is 4.6×10^{-8} spills per loaded tanker kilometre or 4.5×10^{-4} per year.

4.6.3.1. Chlorine Release Case Probabilities

The probability of a quantity of chlorine escaping is determined in two simple stages. The first stage determines in the event of an accident whether there will be a release. However, an assumption associated with the accident frequency is that all accidents will result in a spill. Therefore the probability of a release is 1. The second stage is to determine the probabilities for small and medium leaks and drum ruptures. A probability of 0.45 (P2) has been used for a small leak occurring, which does not develop to a significant event. The probability of a small leak occurring is lower than the equivalent LPG or petrol tanker probability as a chlorine drum wall is much thinner than, for example, an LPG pressure vessel. A probability of 0.45 (P3) has also been used for a medium leak occurring (75mm hole size).

Significant releases have been defined as three different ruptures of the drums. Chlorine tankers are normally divided into 6 drums of equal size. For this analysis, it is assumed that no event would involve more than three drums. The maximum release is therefore 3,000L.

The three cases which have been assumed in the event of an instantaneous release are identified in Table 4.27.

Table 4.27 Release Cases for Chlorine Transport

Release Case	Release	Release Rate/ Total Release	Probability
Hole size 25 mm	Continuous	250 kg/s	0.45 = P2 x (1-P1)
Hole size 75 mm	Continuous	2200 kg/s	0.45 = P3 x (1-P1)
Rupture of 1 compartment	Instantaneous	1,000 litres	0.095 = P1 x (1-P2-P3) x P4
Rupture of 2 compartments	Instantaneous	2,000 litres	0.0045 = P1 x (1-P2-P3) x P5
Rupture of 3 compartments	Instantaneous	3,000 litres	0.0005 = P1 x (1-P2-P3) x (1-P4-P5)

The probabilities for one, two and three compartments rupturing are 0.95, 0.045 and 0.005 respectively. It is therefore assumed for the case of an instantaneous release that in 95% (P4) of occasions this involves only one compartment, that in 4.5% (P5) of cases two compartment's contents are spilled and that in the remaining case three compartment's contents are spilled 0.5% (P6).

The quantified event tree for the full route is shown in Figure 4.6-1. Appendix I contains event trees for the route.

Figure 4.6-2 Generic Event Tree for Releases of Chlorine

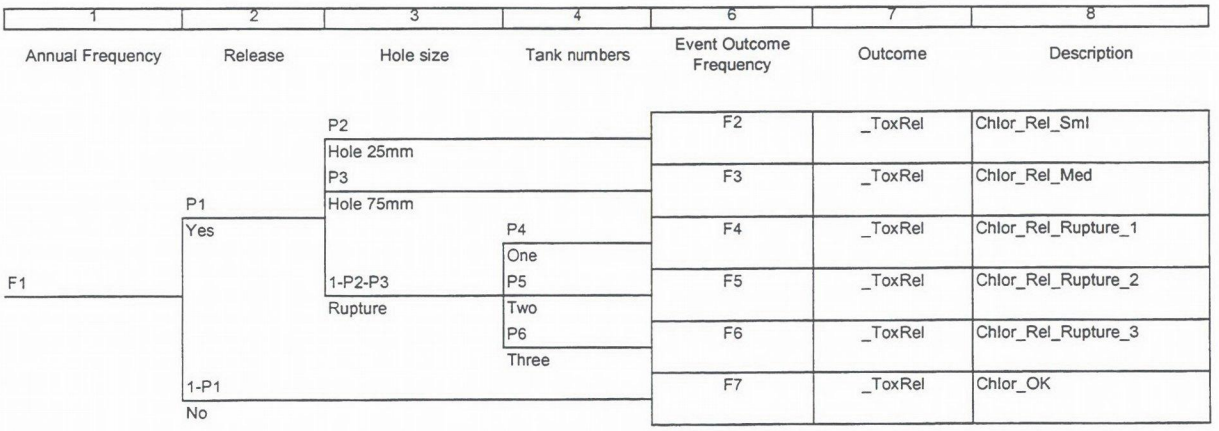
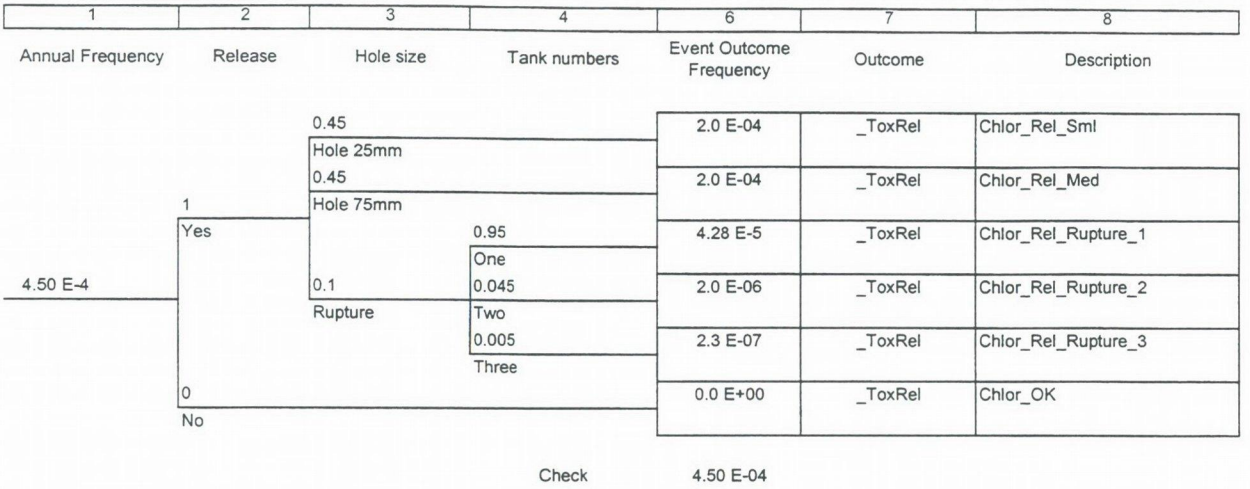


Figure 4.6-3 Event Tree for Releases of Chlorine



4.7. CONSEQUENCE ANALYSIS

This section of the report summarises the approach taken to model the impact of releases on people. The outcomes following a release have been evaluated using event tree analysis. This provides a definition of each scenario for which the consequence analysis is performed.

4.7.1. Hazard Effect Zones

The impacts on people from fireballs, jet fires, pool fires and flash fires are:

i.) Effects within the flame area,

ii.) Effects outside the flame area from thermal radiation exposure.

Within Flame Area: LPG fireballs, and flammable vapour clouds cause death by encompassing persons in a burning mass of fuel. It is likely that any person encompassed by a burning mass of fuel would die. It is therefore assumed that the probability of death for a person trapped within the flame area is 100 per cent.

Thermal radiation exposure: LPG fireballs and burning pools of hydrocarbons will emit high levels of heat flux which could pose a threat to life beyond the boundary of either the fireball hemisphere or the pool. The relationship between thermal dose and consequences of radiation is taken from Fire Safety Guidelines Department of Planning Sydney [19]. The potential for fatality at 23 KW/m^2 is deemed to be 100 per cent for long exposure times and 10 per cent for instantaneous exposure. Other fatality rates have been conservatively assumed based on radiation levels quoted and an assumed exposure time of 25 seconds. The radiation levels and their thermal effects are shown in Table 4.29.

Table 4.29 Radiation Fatality Rates for given levels

Heat Radiation KW/m^2	Fatality Probability %
9	3
16	50
23	90

Fatality contours were calculated for probabilities given in the above table. That means that if the event were to occur persons at the distance specified by the contour have a certain probability of being fatally injured from the effects of the event. On average, it is assumed that the fatality rate between two contours is the geometric mean of the fatality rate at the two contours.

A more detailed description of the consequences of petrol and LPG incidents that are to be modelled is given below. Following the description of each hazard a summary of the methods used in estimating the consequence zones and their output is given.

4.7.2. Fireball/BLEVE

A fireball is caused by the sudden release of a large quantity of flammable vapour and liquid (such as a rupture of LPG vessel), which is ignited immediately and can burn as an unsteady turbulent diffusion flame. The vapour concentration in the bulk of the fuel/air mixture will be above the upper flammable limit. Burning then occurs at the edges and this will entrain more air thus allowing more combustion to take place. The fuel mass moves upwards and the diameter increases with the accelerating burning to produce an expanding fireball.

A BLEVE (Boiling Liquid Expanding Vapour Explosion) can occur when a pressure vessel containing liquid is exposed to fire causing the vessel to fail. The classic BLEVE mechanism is as follows. The vessel is usually a sphere or a cylinder, containing liquefied flammable gas under pressure. The heating causes the liquid in the tank to boil and the vapour pressure rises until the relief valve lifts. If the heating is only to the liquid phase and the relief valve is correctly sized and operates successfully, all the liquid may boil out of the tank without rupture occurring.

The heating also causes the temperature of the shell to rise. Once this reaches about 550°C, the tensile strength of the steel may be reduced to half that at ambient temperature. At first, the steel may be cooled by natural convection of the liquid on the inside, but as the liquid level falls, due to venting, the fire may impinge on the vapour space, which is not cooled in this way. The flow from the relief valve may also burn and add to the heating of the vessel. The higher internal pressure combined with the weaker shell may result in failure of the wall.

The BLEVE/fireball model uses empirical correlations derived from experimental data to calculate the size, duration and radiation intensity of the fireball.

4.7.3. Jet Fire

A significant hazard arising from prolonged pressurised ignited LPG releases is that of a jet fire. The vapour will form a turbulent momentum jet which will disperse, but, if ignited will form a jet fire with a flame envelope equal to the distance to its lower flammable limit concentration and elliptical hazard zones corresponding to different levels of radiation. People are at risk both from the flame front and from the thermal radiation emitted.

Throughout this analysis it is assumed that all LPG releases result in a jet fire if they are immediately ignited. This is because liquid petroleum gas stored at 8 bar will flash to a large vapour fraction when released to 1 bar.

The consequences of the Jet fire cases were modelled using the "TRC radiation model for gas flares" as described in (Chamberlain, G.A., 1987) [20]. The wind speed is assumed not to have a significant effect.

4.8. FINDINGS

4.8.1. Measures of Risk

By combining the frequencies and consequences established in the previous sections a picture of the societal risk associated with Petrol, LPG and Chlorine can be formed. The societal risk is presented in two forms, total rate of death (*RoD*) and the societal risk represented by *FN* pairs. The *RoD* is the predicted number of fatalities per year from hazardous events for a particular population. For each hazardous event outcome the frequency of occurrence and the number of fatalities are calculated; the product of these is the rate of death for that outcome. Societal risk may also be presented in the form of an *FN* curve, showing the frequency *F* with which accidents incurring *N* or more fatalities are expected to occur.

In order to estimate the number of fatalities for each hazardous outcome, the risk summation process mathematically overlays the population distribution and the effect zones calculated in the consequence analysis.

4.8.2. Results of Analysis

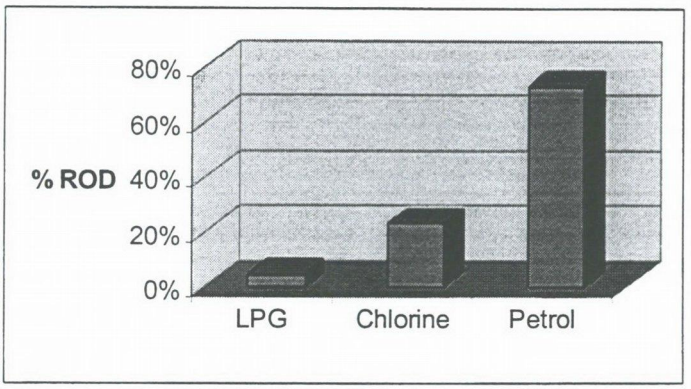
The comparative risks results for future (2014) transport operations are shown in Table 4.31 and Figure 4.8-1 (Rate of Death - *RoD*) and in Figure 4.8-2 (*FN* curves). The combined *RoD* for all three goods is 2.17 E-2 (equivalent to one fatality every 46 years).

Table 4.31 Rates of Death (*RoD*) - Future (2014) Transport Operations

Hazard	*RoD*	%*RoD* of Total	Fatality per *X* years
Petrol	1.58 E-2	73.0	63 yrs

LPG	9.38 E-4	4.0	1066 yrs
Chlorine	5.01 E-3	23.0	200 yrs
Total	2.17 E-2	100.0	46 yrs

Figure 4.8-1 Percentage Rates of Death (*RoD*) – Future (2014) Transport Operations



The major finding from this analysis is that the planned transport of LPG contributes only a small proportion (4 %) of the societal risk attributed to petrol, LPG and chlorine transport. This is primarily as a result of the low frequency of LPG events by comparison to the petrol.

The dominant risk arises from the carriage of Petrol (73 %). The major contribution from petrol transit is essentially because:

- there are greater numbers of petrol tankers than LPG tankers or chlorine trucks, therefore the accident frequency is greater for petrol tankers than LPG tankers or chlorine trucks;
- the probability of ignition is greater for petrol tankers than for LPG tankers or chlorine trucks;
- in the event of an accident, the likelihood of loss of containment is considered to be greater in the case of petrol tankers than for LPG tankers or chlorine trucks.

Although petrol dominated the risk, the risk of carrying chlorine was also significant at 23%. This was mainly due to the nature of chlorine releases evaporating and forming a cloud and the low concentrations in which it affects humans.

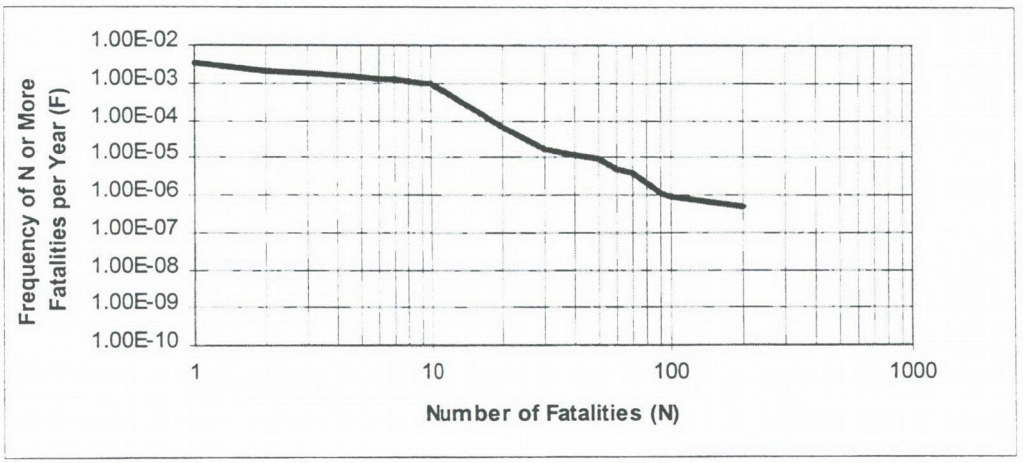
It should be noted that in the case of petrol fires, although they present the highest frequency of fatalities, the analysis indicates the impact is limited to one person per event. While clearly the potential for more than one fatality does exist as a result of a petrol tanker incident, the method used in the analysis, i.e., distributing the on-road population evenly over each route section, has restricted the number of people

in the potentially affected area. This has been the common approach used throughout the analysis and does not effect the comparative or proportional results.

As a result, this analysis has demonstrated that the effects of an incident on the new Karuah Upgrade are only likely to have a significant impact on the surrounding population in the event of a large petrol fire. However, the risks to the public resulting from an incident on the proposed Upgrade are tolerable when compared to risk criteria for industrial sites and open spaces. Risk criterion for public areas may generally be considered stricter than those presented for industrial developments.

By inspection, the proposed upgrade will reduce the risk to people in Karuah as the population exposed is greatly reduced (Section 7.4.3) and the likelihood of an accident is also reduced.

Figure 4.8-2 F-N Curve for Future (2014) Transport Operations



The individual fatality risk levels shown are for active open space areas/sporting complexes ($1x10^{-5}$) and industrial sites ($5x10^{-5}$). These criteria are set out in the Risk Criteria for Land Use Safety Planning [22].

4.9. REFERENCES

[1] ACDS – Major Hazard Aspects of the Transport of Dangerous Substances.

[2] Annual and Seasonal Wind roses for Williamtown 1985, Holmes Air Sciences.

[3] Pacific Highway Ulmarra Bypass Environmental Impact Statement, Connell Wagner.

[4] Traffic Assessment Report, Concept Design – ARUP Karuah Bypass

[5] Population information provided is an extract from the Pacific Highway Upgrade at Karuah Overview of Social effects, Extract Australian Bureau of Statistics, 1996 Census

[6] Extract from Karuah Pacific Highway Upgrade estimation of AADT and heavy vehicle proportions at Karuah, Reference Project file fax from Lara Sossi (16/12/98), Ove Arup job file no. 9809.

[7] Not Used

[8] Accident Statistics from the Pacific Highway Upgrade Traffic Assessment Report, Reference Project file fax from Lara Sossi (2/12/98), Ove Arup job file no. 9809.

[9] Not Used

[10] G. Weiss, Editor, Hazardous Chemicals Data Book, 1986 Noyes Data Corporation

[11] Not Used

[12] LPG - A Study: A Comparative Analysis of the Risks Inherent in the Storage, Transhipment, Transport and Use of LPG and Motor Spirit. Part 10 - Main Report on LPG, Dutch Ministry of Housing, Physical Planning and the Environment, TNO Division of Technology for Society, May 1983

[13] Martinsen W.E. and Cavin W.D., LPG Land Transportation and Storage Safety, ATC, USA, Report No DOE/EV/06070-T5, September 1981

[14] Wall W.L., The BLEVE - Part 2, Fire Command, June 1979

[15] Charles, Anderson, Townsend, Zook, Cowgill, The Effect of a Fire Environment on a Rail Tank Car filled with LPG, US Department of Transportation, September 1974

[16] Blything K.W. and Reeves A.B., An initial prediction of the BLEVE frequency of a 100 te Butane Storage Vessel, UKAEA SRD/HSE/R488, August 1988

[17] Health and Safety Commission, Advisory Committee on Dangerous Substances, (1991). Major Hazard Aspects of the Transport of Dangerous Substances, HSC, HMSO.

[18] Not Used

[19] Fire Safety Guidelines, Department of Planning, Sydney.

[20] Chamberlain G.A., Development in Design Methods for Predicting Thermal Radiation from Flares, Chem Eng. Res. Dev. 65, July 1987

[21] Cox, Lees & Ang, Institute of Chemical Engineers 1990, Classification of Hazardous Locations.

4.10. APPENDICES

Annual Frequency of LPG Releases Along the Full Route

Release of LPG Along Full Route

1	2	3	4	5	6	7	8	9
Annual_Frequency	Release <100kg	Hole size	Ignition	Vapour Cloud Explosion	Flame Impingement	Event Outcome Frequency	Outcome	Description
4.50 E-4	0.95 Yes					4.3 E-04	_OK	LPG_Rel_<100kg_OK
		0.9 Hole 25mm	0.1 Immediate		0.1 Yes	2.0 E-07	_BLEVE	LPG_Rel_25mm_Imp_BLEVE
					0.9 No	1.8 E-06	_OK	LPG_Rel_25mm_OK
				0.05 Yes		1.0 E-07	_HaVCE	LPG_Rel_25mm_HaVCE
			0.1 Delayed	0.95 No		1.9 E-06	_HaFlshFr	LPG_Rel_25mm_HaFlshFr
			0.8 None			1.6 E-05	_No Ign	LPG_Rel_25mm_No Ign
					0.1 Yes	1.6 E-08	_BLEVE	LPG_Rel_100mm_Imp_BLEVE
			0.1 Immediate		0.9 No	1.4 E-07	_JetFr	LPG_Rel_100mm_NotImp_JetFr
				0.05 Yes		3.9 E-09	_HaVCE	LPG_Rel_100mm_HaVCE
			0.05 Delayed	0.95 No		7.5 E-08	_HaFlshFr	LPG_Rel_100mm_HaFlshFr
	0.05 No	0.07 Hole 100mm		0.05 Yes		3.9 E-09	_FullVCE	LPG_Rel_100mm_FullVCE
			0.05 Further Delayed	0.95 No		7.5 E-08	_FullFlshFr	LPG_Rel_100mm_FullFlshFr
			0.8 None			1.3 E-06	_No Ign	LPG_Rel_100mm_No Ign
			0.4 Immediate			2.7 E-07	_FIREBALL	LPG_Rel_Rup_FIREBALL
				0.05 Yes		8.4 E-09	_HaVCE	LPG_Rel_Rup_HaVCE
			0.25 Delayed	0.95 No		1.6 E-07	_HaFlshFr	LPG_Rel_Rup_HaFlshFr
		0.03 Rupture		0.05 Yes		8.4 E-09	_FullVCE	LPG_Rel_Rup_FullVCE
			0.25 Further Delayed	0.95 No		1.6 E-07	_FullFlshFr	LPG_Rel_Rup_FullFlshFr
			0.1 None			6.8 E-08	_No Ign	LPG_Rel_Rup_No Ign
					Check Sum	4.50 E-04		

Annual Frequency of LPG Releases Along the Full Route

Case: **Release of LPG Along Full Route - Weeknight**

1	2	3	4	5	6	7	8	9
Annual_Frequency	Release <100kg	Hole size	Ignition	Vapour Cloud Explosion	Flame Impingement	Event Outcome Frequency	Outcome	Description
1.60 E-4	0.95 Yes					1.5 E-04	_OK	LPG_Rel_<100kg_OK
		0.9 Hole 25mm	0.1 Immediate		0.1 Yes	7.2 E-08	_BLEVE	LPG_Rel_25mm_Imp_BLEVE
					0.9 No	6.5 E-07	_OK	LPG_Rel_25mm_OK
				0.05 Yes		3.6 E-08	_HaVCE	LPG_Rel_25mm_HaVCE
			0.1 Delayed	0.95 No		6.8 E-07	_HaFlshFr	LPG_Rel_25mm_HaFlshFr
			0.8 None			5.8 E-06	_No Ign	LPG_Rel_25mm_No Ign
			0.1 Immediate		0.1 Yes	5.6 E-09	_BLEVE	LPG_Rel_100mm_Imp_BLEVE
					0.9 No	5.0 E-08	_JetFr	LPG_Rel_100mm_NotImp_JetFr
				0.05 Yes		1.4 E-09	_HaVCE	LPG_Rel_100mm_HaVCE
			0.05 Delayed	0.95 No		2.7 E-08	_HaFlshFr	LPG_Rel_100mm_HaFlshFr
	0.05 No	0.07 Hole 100mm		0.05 Yes		1.4 E-09	_FullVCE	LPG_Rel_100mm_FullVCE
			0.05 Further Delayed	0.95 No		2.7 E-08	_FullFlshFr	LPG_Rel_100mm_FullFlshFr
			0.8 None			4.5 E-07	_No Ign	LPG_Rel_100mm_No Ign
			0.4 Immediate			9.6 E-08	_FIREBALL	LPG_Rel_Rup_FIREBALL
				0.05 Yes		3.0 E-09	_HaVCE	LPG_Rel_Rup_HaVCE
			0.25 Delayed	0.95 No		5.7 E-08	_HaFlshFr	LPG_Rel_Rup_HaFlshFr
		0.03 Rupture		0.05 Yes		3.0 E-09	_FullVCE	LPG_Rel_Rup_FullVCE
			0.25 Further Delayed	0.95 No		5.7 E-08	_FullFlshFr	LPG_Rel_Rup_FullFlshFr
			0.1 None			2.4 E-08	_No Ign	LPG_Rel_Rup_No Ign
					Check Sum	1.60 E-04		

Annual Frequency of LPG Releases Along the Full Route

Case: **Release of LPG Along Full Route - Weekday**

1	2	3	4	5	6	7	8	9
Annual_Frequency	Release <100kg	Hole size	Ignition	Vapour Cloud Explosion	Flame Impingement	Event Outcome Frequency	Outcome	Description
	0.95 Yes					2.8 E-04	_OK	LPG_Rel_<100kg_OK
			0.1 Immediate		0.1 Yes	1.3 E-07	_BLEVE	LPG_Rel_25mm_Imp_BLEVE
					0.9 No	1.2 E-06	_OK	LPG_Rel_25mm_OK
		0.9 Hole 25mm	0.1 Delayed	0.05 Yes		6.5 E-08	_HaVCE	LPG_Rel_25mm_HaVCE
				0.95 No		1.2 E-06	_HaFlshFr	LPG_Rel_25mm_HaFlshFr
			0.8 None			1.0 E-05	_No Ign	LPG_Rel_25mm_No Ign
			0.1 Immediate		0.1 Yes	1.0 E-08	_BLEVE	LPG_Rel_100mm_Imp_BLEVE
2.90 E-4					0.9 No	9.1 E-08	_JetFr	LPG_Rel_100mm_NotImp_JetFr
				0.05 Yes		2.5 E-09	_HaVCE	LPG_Rel_100mm_HaVCE
			0.05 Delayed	0.95 No		4.8 E-08	_HaFlshFr	LPG_Rel_100mm_HaFlshFr
	0.05 No	0.07 Hole 100mm		0.05 Yes		2.5 E-09	_FullVCE	LPG_Rel_100mm_FullVCE
			0.05 Further Delayed	0.95 No		4.8 E-08	_FullFlshFr	LPG_Rel_100mm_FullFlshFr
			0.8 None			8.1 E-07	_No Ign	LPG_Rel_100mm_No Ign
			0.4 Immediate			1.7 E-07	_FIREBALL	LPG_Rel_Rup_FIREBALL
				0.05 Yes		5.4 E-09	_HaVCE	LPG_Rel_Rup_HaVCE
			0.25 Delayed	0.95 No		1.0 E-07	_HaFlshFr	LPG_Rel_Rup_HaFlshFr
		0.03 Rupture		0.05 Yes		5.4 E-09	_FullVCE	LPG_Rel_Rup_FullVCE
			0.25 Further Delayed	0.95 No		1.0 E-07	_FullFlshFr	LPG_Rel_Rup_FullFlshFr
			0.1 None			4.4 E-08	_No Ign	LPG_Rel_Rup_No Ign
					Check Sum	2.90 E-04		

	Day	Night	
Annual Frequency of LPG Releases for full route	2.90E-04	1.60E-04	4.50E-04

5. ENVIRONMENTAL RISKS

Risks to the surrounding environment from the operation of the upgrading of the Pacific Highway at Karuah would relate principally to the transport of dangerous goods along the highway and the potential for incidents causing spillage of such materials and release into the environment, particularly areas of environmental significance.

5.1. ENVIRONMENTAL CHARACTERISTICS OF THE KARUAH AREA

Virtually all of the area through which the upgraded Pacific Highway at Karuah will pass drains, directly or indirectly, into the Karuah River, which is one of the major tributaries of Port Stephens. The Karuah River is used for oyster production and for recreational fishing. Extensive areas of wetlands of state significance (SEPP 14 wetlands) are located on both sides of the Karuah River, generally south of the proposed route. To the west of the Karuah River, the Highway will pass through mainly forested land (including an area recently gazetted as the Karuah Nature Reserve) and just south of Wallaroo Swamp. East of the River, the highway will pass through generally cleared land used mainly for cattle grazing - this land drains into SEPP 14 wetlands east of the river or south of the existing Pacific Highway near Branch Lane. Only very few houses are located with 250 m of the entire length of the proposed route.

5.2. DESIGN FEATURES OF THE PROPOSED HIGHWAY UPGRADING

A key feature of the proposed Highway upgrading is a major bridge (approximately 600m long) proposed across the Karuah River in the vicinity of Horse Island. A number of smaller bridges are proposed elsewhere along the route. Two multi-directional interchanges are proposed at either end of this section of Highway upgrading to provide access to Karuah. No other interchanges or access points to and from this section of the Highway are proposed.

Drainage design and the location of settlement ponds for runoff from the road pavement have had regard to the sensitive environment through which this section of the Highway passes. These design measures are intended to ensure that no runoff which exceeds water quality guidelines will enter the designated wetlands or directly into the Karuah River.

5.3. VOLUME AND NATURE OF DANGEROUS GOODS

5.3.1. Estimated volume of traffic transporting dangerous goods

The average daily traffic volume for this section of the Pacific Highway in 2007 is forecast to be approximately 16,400 vehicles per day. Heavy vehicles are estimated to account for up to 20 per cent of the total traffic. Data from other sections of the Pacific Highway suggests that vehicles transporting 'dangerous goods' are likely to comprise approximately 1.15 per cent of total estimated traffic volume.

5.3.2. Definition of dangerous goods

In broad terms, dangerous goods are goods that potentially could cause a dangerous or hazardous event or incident. The Australian Dangerous Goods Code (6th edition) identifies dangerous goods by name and class, and also specifies the packaging, labelling, compatibility and emergency provisions for each dangerous good. The operation of carriers transporting dangerous goods in New South Wales is regulated by the provisions of the Road and Rail Transport (Dangerous Goods) Act 1997. This Act and Regulations provide for licencing of carriers and specifies offences and penalties.

5.4. DANGEROUS OR HAZARDOUS EVENTS OR INCIDENTS

A dangerous or hazardous event or incident is an unplanned, adverse or emergency situation that could potentially harm the environment or place public health at risk involving toxic releases, explosions or fires. The potential for such an incident to occur along the upgraded section of the Pacific Highway is considered to be very low due to the combination of:

- the very small estimated volume (1.15 per cent) of traffic transporting dangerous goods – petrol generally accounts for up to 70 per cent of dangerous goods transported and is represented in approximately half the accidents involving dangerous goods. Of these accidents, approximately 10 per cent result in a fire.
- the high standard of divided road to be provided with specific safety features including high standard horizontal and vertical alignments, a continuous breakdown lane on both carriageways, and interchanges with grade separation for major traffic flows.
- the stringent controls imposed on the transport of dangerous goods

However, the environmental characteristics of the area through which this section of the Pacific Highway passes are such that if there was a spill of certain types of dangerous goods that was not contained, there potentially could be serious environmental consequences. The principal 'spill scenario' that could occur along this section of the Pacific Highway is a rupture to a vessel carrying dangerous goods. Table 5.1 indicates the potential environmental consequences of 'worst case' situations involving spills of fuels such as liquid petroleum gas (LPG) or petroleum or chemicals such as ammonium nitrate or chlorine.

Table 5.1 Potential environmental consequences of worst case spill scenarios

DANGEROUS GOODS		POTENTIAL ENVIRONMENTAL CONSEQUENCES
Fuels	Petroleum	Fire resulting from incineration of spilt petrol could damage to vegetated/forested areas or land used for grazing purposes. Leakage of petrol into wetlands could contaminate these areas and certain aquatic species and damage destroy sensitive plants.
	Liquid petroleum gas (LPG)	If the LPG evaporates prior to reaching waterways or other sensitive environments, little or no adverse environmental consequences. Ignition could cause a fireball which could cause generally localised damage limited to actual vehicle, but potential for wildfire damage to areas beyond road reserve.
Chemicals	Ammonium nitrate	Potential explosion could damage nearby flora and fauna.
	Chlorine	Toxic gas cloud could affect small numbers of nearby residents or native fauna.
Poisons (various)		Death or injury to native fauna if poisons infiltrate into habitat areas.

5.5. QUALITATIVE ASSESSMENT OF THE ENVIRONMENTAL RISK LEVELS FOR THE UPGRADE COMPARED WITH THE EXISTING HIGHWAY

The construction of the Karuah upgrade will result in substantially lower overall levels of hazard and risk to property and environmental assets. This reduction will occur because of:

- the much smaller population living within 250 metres of the bypass compared to the existing Highway which passes through the centre of Karuah (population approximately 1000 people) and close to shops, major service stations and community facilities such as the Karuah Public School, and the Karuah RSL Club. All of these facilities generate 'side friction' to the Highway which increases the potential for both major and minor accidents.
- the higher standard of road design on the bypass which will reduce existing hazardous situations for traffic, for example, having to stop at the traffic signals in the centre of Karuah and the substandard curve on the eastern approach to the relatively narrow bridge over the Karuah River.
- the smaller length of roadway passing close to or parallel to SEPP 14 wetlands - approximately 1.5 km of the existing Highway runs immediately north of SEPP 14 wetland to the east of Karuah. By comparison the upgrade will cross (on bridge) approximately 350m of SEPP 14 wetlands.

5.6. MITIGATION MEASURES

Measures to mitigate spillages of dangerous goods and associated incidents include both in-built passive road design measures, design measures incorporated in the vessels containing dangerous goods, and active emergency response procedures.

Sufficient sedimentation and accidental spill basins will be provided along this section of the Highway to ensure that a minimum of 20 cubic metres of a toxic spill can be contained (as specified in RTA Road Design Guidelines). The spilt material will remain in the basin until pumped out and removed to an approved disposal and/or treatment point. All basins will be designed to accommodate 90% of a five-day rainfall event and will thus have a larger capacity than that required for management of toxic spills.

The NSW Fire Service has the overall responsibility for the site coordination where fire or chemical incidents occur. The Service's functions include containment and suppression of any chemical fire, spillage or other incident. The EPA's Chemical Responses Manual specifies procedures for a co-ordinated response to dangerous goods incidents by all relevant authorities. The RTA also has a standing operational emergency procedures plan (reference) for its roads that would be implemented. This plan refers to and complements emergency response plans and manuals developed by the other authorities.