Moorland to Herons Creek EIS

Working Paper No. 6
Aquatic Ecology

Pacific Highway Upgrade, Moorland to Herons Creek

Aquatic Ecology Investigations – EIS Phase

June 2004

Report Prepared for:

Ove Arup & Partners
Level 10, 201 Kent Street
Sydney, NSW, 2000

Report Prepared by:

The Ecology Lab Pty Ltd
4 Green Street
Brookvale, NSW, 2100
Phone: (02) 9907 4440

Report Number – 030001/B
Report Status – FINAL, 10/06/2004

Table of Contents

SUMMARY

The Roads and Traffic Authority (RTA) is proposing to upgrade a 22.2 km section of the Pacific Highway between Moorland and Herons Creek on the mid north coast of New South Wales. The section of highway upgrade would cross 6 perennial waterways comprising moderate to major fish habitat plus a number of intermittent channels/creek lines. The proposal includes the construction of bridges and culverts immediately to the west or east of the existing crossing.

The Ecology Lab was engaged by Ove Arup & Partners to investigate issues relating to fish and aquatic habitats along this section of highway. The study was done in two stages. Stage 1 reported on opportunities and constraints related to aquatic habitats and fish at potential and existing highway crossings within the study area to aid in selecting a route that reduced adverse impacts on aquatic habitats. Six perennial waterways comprising moderate to major fish habitat were identified in the study area. These waterways were considered medium to high priorities in terms of the need for additional ecological studies during the EIS and consideration of the most appropriate (i.e. ecological benign) waterway crossing. This report covers Stage 2 – the aquatic investigations for the Environmental Impact Statement (EIS). The specific aims of this stage were:

- To complete the Eight-Part Test for black cod,
- To collect data (fish, mobile invertebrates and water quality) and make visual observations of aquatic habitats,
- Using these data, undertake an assessment of impacts,
- Identify measures at the planning, construction and follow-up stages that may ameliorate the identified impacts.

Sampling for aquatic biota (fish and mobile invertebrates), water quality and habitat assessment were done in November 2001 using a combination of qualitative and quantitative techniques. Commercial and recreational fishing activities were described from published accounts for the area, and discussions held with a local representative for commercial fishers.

Eight-Part Test for Black Cod

From discussions held with commercial fishers, it was concluded black cod occur in the Camden Haven River (above Watson Taylors Lake) and may potentially occur within the area that would be affected by the proposed highway upgrade. To minimise effects on this species, appropriate measures would include:

- protection of the species be incorporated into a Construction Environmental Management Plan for the project, including the minimal removal of habitat (i.e. large woody debris),
- the development of Soil and Water Management Plan that identifies best-practice engineering principles and procedures for minimising erosion and sediment inputs, and
- a practical program for monitoring water quality in the Camden Haven River when bridge piling/drilling activities are done in the river – See Section 4.2.1

A Species Impact Statement for black cod is not recommended given that the above precautions are incorporated into the Construction Environmental Management Plan.

Fish and Mobile Invertebrate Surveys

In estuarine habitats, the assemblage of fish and mobile invertebrates in the study area were found to be relatively diverse comprising 20 species of fish and 3 species of mobile invertebrates. The greatest number of species and individuals were recorded at the existing crossing in the Camden Haven River compared to positions further upstream and the existing crossing of the Stewarts River. The reasons for this are unclear but may be that some combination of factors operate jointly to produce the patterns observed. These factors may include physiological preferences of individual species, biological factors, disturbance in surrounding catchment, water quality and chance.

In freshwater habitats, 7 species were recorded whilst electrofishing, including one introduced species, *Gambusia holbrooki*. No species currently listed on the threatened species schedules of the *Fisheries Management Act 1994* were recorded during our survey.

Aquatic Habitats

There are few mangroves within the study area that would be disturbed (removed, trimmed or effected by shading) by the proposal. Although details of the area of foreshore disturbance are not yet finalised, on the basis of the concept design for the proposal, we would anticipate a small number (no more than 15 trees, shrubs and saplings) of these plants would require removal or trimming.

There is bed of seagrass (*Zostera capricorni* - about 100 m^2) in shallow habitat (less than 1 m) along the western shoreline of the Camden Haven River, about 200 m downstream of the existing crossing lies. The works in the Camden Haven River would be confined mostly to an immediate corridor upstream of the existing bridge (and possibly around the site of the old bridge piles if removed under this proposal). As the proposal would not encroach on this habitat, there would be no direct effect of seagrass removal from this proposal

Preliminary observations of the aquatic habitat at the Camden Haven River suggests some snag habitat may need to be removed during the site preparation. These structures may provide habitat for black cod and other biota in the area. If removal of these structures is required to accommodate the bridge construction, NSW Fisheries have recommended the relocation and retention of these snags to areas adjacent to the works to reduce handling.

Water Quality

The monitoring of water quality during construction is recommended, focusing on levels of turbidity and pH. Although results at the time of sampling indicated that there was no evidence of water quality conditions attributable to run-off from acid sulphate soils, the presence of acid sulphate soil run-off can be ephemeral, and difficult to detect. Given the likelihood of acid sulphate soils occurring in the study area, monitoring should focus on pH levels in the context of background levels in similar habitats elsewhere in the system. Further, given the potential presence of black cod near the area of disturbance it is recommended that a comprehensive program to monitor levels of turbidity be developed as part of Construction Environmental Management Plan.

Fish Passage

Where major and moderate fish habitat was identified in this study (i.e. Stewarts River, Stony Creek, Camden Haven River and Herons Creek), it is understood bridge crossings would be erected as part of the proposed upgrade. Where feasible, single span bridges are the preferred option for streams narrower than 30 m. The wetted width of the Stewarts River, Stony Creek and Herons Creek (during low flow as was observed during the sampling program) are narrower than 30 m. If single span bridges are not achievable at

these waterways, then NSW Fisheries guidelines require that bridge piers are positioned in the riverbed so as to avoid the low flow section of these waterways.

If the bridge crossing over the Camden Haven River is to match the dimensions of the existing bridge, then 5 pylons are required in the river. To minimise impacts on fish passage, excavation and pile driving works should be carried out over the shortest possible timeframe. Given that the instream works would most likely be done from a barge and thus not done simultaneously across the entire width of the river at any one point in time, this would help confine any limited noise and/or vibration exerted on the aquatic environment to a small section of river. As such, these works in the Camden Haven River should not impede fish moving up- or downstream of the construction area.

A box culvert design would be employed in Walkers Creek and Passionfruit Gully. It is recommended that box culvert cells be set into the creek bed to allow an optimum water depth of 0.2 -0.5 m within a culvert under base flow condition. This recommendation is consistent with NSW Fisheries requirements for culvert crossings in ephemeral streams Given the intermittent nature of both waterways, this recommendation should be factored into the design of the culvert.

Mitigation of Impacts

To minimise impact on fish passage and maintain connectivity between habitats in waterways crossed by the upgrade, NSW Fisheries Policies and Guidelines for waterway crossings have been used in designing "fish friendly" waterway crossings.

During construction in and surrounding waterways, care should be taken to minimise water quality impacts. Erosion and sedimentation control measures to be used during construction may include silt fences/curtains and a detailed array of erosion and sediment controls and sedimentation basins designed in accordance with the "Blue Book" developed by the Department of Housing (1998) and NSW RTA's Road Design Manual (1993).

Where work in watercourses is required (e.g. installing culverts) these works should be carried out in the shortest possible timeframe. During the operational phase, it is recommended that the efficiency of retained operational basins be assessed after rainfall events of various magnitudes.

Commercial and Recreational Fishing

About 10 commercial fishing operators mesh net, crab trap and prawn haul in the Camden Haven River above and below the existing highway corridor. Commercial fishing occurs year-round in the Camden Haven River depending on the time of fish recruitment in the estuary (K. Poole, pers. comm, 2003). With the strict mitigative measures (as outlined in Section 5.0) to be in place to minimise sedimentation effects and impacts on fish passage, the works in and surrounding Camden Haven River are likely to have minimal effect (in terms of habitat removal or effects on fish passage) on commercial fishing in the Camden Haven system. Bridge construction works may take up to 2 years. To avoid disruption of commercial fishing operations vessels should be allowed to navigate up- and downstream through the construction corridor in order to access areas regularly fished in the Camden Haven River. If possible, bridge construction works should be done in sections across the Camden Haven River to allow for continual passage of fishing vessels.

Discussions with local fisheries officer suggests recreational fishing in the Camden Haven system is focused in the lower reaches around the population centres of Laurieton and North Haven, although prized recreational species including Australian bass and mulloway do inhabit the Camden Haven River and are targeted by recreational anglers at times of the year (depending on tide, flood conditions, lunar cycle) near the existing highway crossing.

Given the implementation of mitigative measures to be developed and implemented under the project's Construction Environmental Management Plan, the construction of a bridge across the Camden Haven River is likely to have minimal effect on species of recreational importance that may occur nearby, and be targeted by, recreational anglers

Oyster leases are located in the lower parts of the Camden Haven system (in or downstream of Watson Taylors and Queens Lakes), in excess of 7 km downstream of where works would be carried out on the study waterways. Although sessile animals like oysters are adapted to natural periods of turbid water where they will cease to feed, any potential sedimentation effects that the project may have would be addressed as part of the project's Construction Environmental Management Plan and site species Erosion and Sedimentation Control Plans. Thus, we would anticipate that the proposal would have no direct or indirect impacts on oyster farming in the estuary.

1.0 INTRODUCTION

1.1 Background

The Roads and Traffic Authority (RTA) proposes to upgrade a 22.2 km section of the Pacific Highway between Moorland and Herons Creek on the mid north coast of New South Wales. The study area extends from Camp Obadiah, Johns River to the existing dual carriageway at Bobs Creek Road just north of Herons Creek. The Highway upgrade would provide a dual carriageway with two lanes in each direction, and would include Highway improvements at the townships of Johns River and Kew.

The Ecology Lab was engaged by Ove Arup & Partners to investigate issues relating to fish and aquatic habitats along this section of highway. Stage 1 of this study reported on opportunities and constraints related to aquatic habitats and fish at potential and existing highway crossings within the study area to aid in selecting a route that reduced potential adverse impacts on aquatic habitats. Six perennial waterways comprising moderate to major fish habitat were identified in the study area. These waterways were considered medium to high priorities in terms of the need for additional ecological studies during the EIS phase and consideration of the most appropriate (i.e. ecologically benign) waterway crossing. A number of intermittent channels/creek lines were also inspected, graded (according to NSW Fisheries Policy and Guidelines 1999) and aquatic habitats were described (The Ecology Lab 2001). Although these waterways were graded Class 3-4 ("minimal to no fish habitat"), the culvert design used in these waterways is required to comply with NSW Fisheries Policies and Guidelines (The Ecology Lab 2001, NSW Fisheries 1999a) (Table 1).

During Stage 1, the review of literature found it was unlikely that any scheduled species, currently listed under Threatened Species Legislation administered by NSW Fisheries would occur in, or encroach the study area and as such be directly affected by the proposal. We noted that this finding would be later reviewed and, subsequently, a request was made by NSW Fisheries that an Eight-Part Test done for black cod based on anecdotal records supplied by commercial fishers.

This report covers Stage 2, aquatic investigations for the Environmental Impact Statement (EIS), of an on-going process aimed at reducing and appropriately mitigating the potential adverse impacts of the proposed highway upgrade on aquatic habitats and biota. The final route chosen crosses all 6 perennial waterways of the study area within close proximity of the existing highway.

1.2 Aims of this Study

The specific aims of the sampling during the EIS phase were:

- To complete the Eight-Part Test for black cod,
- To collect data (fish, mobile invertebrates and water quality) and make visual observations of aquatic habitats,
- Using these data, undertake an assessment of impacts,
- Identify measures at the planning, construction and follow-up stages that may ameliorate the identified impacts.

2.0 STUDY METHODS

2.1 Review of Existing Information

Prior to sampling done for the EIS, The Ecology Lab was supplied with the document *"Display of Upgrade Options"* by Ove Arup and Partners, which comprised a series of aerial photographs of the study area with an overlay of route options. These maps were used to pin point the location where new bridges or culverts would be erected across waterways in the study area and allow us to design a sampling program for the EIS phase of investigations. In addition, we used Lorne, Coopernook and Byabarra 1:25,000 topographic maps (Central Mapping Authority of NSW) to identify points of access to sampling sites in waterways.

2.2 Statutory Requirements

With reference to aquatic flora and fauna, the following statutory requirements are relevant to the proposal:

- *NSW Fisheries Management Act* (*FM Act*) 1994
- *NSW Threatened Species Conservation Act (TSC Act)* 1995

2.2.1 Fisheries Management Act 1994

2.2.2.1 Threatened Species and Key Threatening Processes

The *Fisheries Management Act 1994* was amended in 1997 by the inclusion of provisions (listed in the *Fisheries Management Amendment Act 1997*) to declare and list threatened species of fish and marine vegetation, endangered populations and ecological communities and key threatening processes. One of the major features of the new legislation is the integration of threatened aquatic species into the development control processes under the Environmental Planning and Assessment Act 1979 (EP&A Act).

The EP&A Act sets out the factors to be considered in preliminarily assessing whether there is likely to be a significant effect on threatened species arising from a development. Eight factors are considered and the assessment process is referred to as the 8-part test. The test is a series of questions, the answers to which assist in determining whether a planned action would significantly affect threatened species, populations, ecological communities or their habitats. If the test indicates that the activity is likely to significantly affect threatened species, then the Determining Authority for the project must seek the concurrence of the Director of NSW Fisheries. In essence, the primary role of NSW Fisheries in such a situation is to provide the Director's Requirements for a detailed assessment of impacts on the threatened species. The assessment is referred to as a Species Impact Statement.

On completion of Stage 1 and prior to the commencement of Stage 2, there were amendments to the threatened schedules under the *Fisheries Management Act* 1994. Of relevance to this proposal, was the listing of three key threatening processes:

- the degradation of riparian vegetation along waterways which includes the removal or modification of native species (note estuarine and marine waters are excluded from this listing),
- removal of large woody debris from waterways,

These issues are to be considered in relation to mitigating impacts during the planning construction phase of the proposal and are discussed in more detail in Section 4.4.

2.2.2.2 Licences and Permits

Under Section 199 of the *Fisheries Management Act* 1994, it is an offence to dredge or reclaim land in any waters in NSW without a permit from NSW Fisheries. Guidelines for dredging and reclamation are set out in the NSW Fisheries Policy and Guidelines Document (NSW Fisheries 1999). Under the Act, such activities may include:

- construction of temporary waterway crossings,
- creek diversion,
- geotechnical investigations,
- excavating or reclaiming the bed of waterways.

Under Section 205 of the *FM Act* 1994, any harm to marine vegetation (including seagrass, macroalgae and mangroves) requires a permit from NSW Fisheries. Under the Act, harm to vegetation may include cutting, removing, trimming or otherwise injuring marine vegetation.

2.2.2 Threatened Species Conservation Act 1995

The threatened species legislation administered by the National Parks and Wildlife Service (NP&WS) under the TSC Act 1995 and that administered by NSW Fisheries under amendments of the FM Act 1994, are essentially identical in application. NSW Fisheries deals with "fish' and 'marine vegetation' and NPWS deals with all other flora and fauna. With reference to the proposal, there are two issues relevant to the proposal:

- Predation by *Gambusia holbrooki* (Mosquito Fish) as a Key Threatening Process, and,
- The listing of Coastal Saltmarsh in the North Coast Bioregion as an Endangered Ecological Community.

These issues are to be considered in relation to mitigating impacts during the planning and construction phase of the proposal and are discussed in more detail in Section 4.4

2.3 Commercial and Recreational Fishing

Fishing activities were described from published accounts for the area, discussions with local Fisheries Officers (Mr Julian Brown and Mr Marty Manson) and the local representative for commercial fishers (Mr Kim Poole), and from observations made during our field trip.

2.4 Sampling Sites and Methods

2.4.1 Descriptions of Aquatic Habitats

General habitat descriptions (as outlined in NSW Fisheries 1999a and 1999b) were made at each site prior to sampling for biota. Features noted in each waterway included:

- condition of the vegetation in the riparian zone,
- type of waterway substratum,
- presence of fish habitat including snags,
- bank undercuts and macrophytes, and
- presence of any barriers to fish passage into and beyond the site.

The existing crossing structures at these waterways were also recorded. Sites were photographed to assist in their description and their position recorded using a Garmen 12 channel GPS.

2.4.2 Grading of Waterways

During Stage 1, The Ecology Lab graded waterways (where access was granted by landowners) in the study area according to NSW Fisheries Guidelines (1999). Subsequent to this inspection, NSW Fisheries inspected and graded some of these waterways. A comparison of grades given to each waterway by The Ecology Lab and NSW Fisheries are presented in Table 2a.

2.4.3 Fish and Mobile Invertebrates

Sampling for aquatic biota (fish and mobile invertebrates), water quality and habitat assessment were done from 6 to 8 and 13 to 15 November 2001. A list of waterways sampled is provided in Table 2b.

2.4.3.1 Estuarine Habitats

The existing crossings of the in Stewarts and Camden Haven River and a proposed crossing of an un-named tributary of the Camden Haven River were sampled for fish and mobile crustaceans. These three 'locations' were chosen because new crossings were likely or under consideration for the waterways. At each location, there were three sites (positions) sampled – the existing or proposed crossing and sites approximately 200-300 m up- and downstream (Figure 1).

Gill nets were used to target large mobile species whilst sedentary and juvenile fish were sampled with bait traps. Three replicate gill nets were set obliquely to the shoreline. The gill nets consisted of nylon mono-filament and were 60 m long, 1.5m deep and contained 100 mm and 25 mm mesh panels. Nets were set for approximately 3 – 3.5 hours, depending on the time that it took to clear each net of fish. As each gill net was retrieved, fish were removed, identified and released where possible. The lengths of the caudal fork (LCF, mm) (i.e. length from tip of snout to fork in caudal fin) of species of economic importance were also measured. Photographic records were kept of species that were not identified in the field.

Bait traps were deployed along the shoreline. At each position, 10 traps were deployed randomly amongst snags and vegetation and on bare substratum. The traps were 350 mm long, 200 mm wide with an entrance that tapered in to 45 mm, with 3 mm mesh size throughout. The traps were baited with 70 ml of a mixture of chicken pellets and sardines and allowed to fish for 1.5 h. Fish caught were collected, identified and released. Exotic species were not returned to the water.

2.4.3.2 Freshwater Habitats

Back-pack electrofishing was used to sample fish and mobile invertebrates in the freshwater reaches of Herons, Stony and Walkers Creeks and Passionfruit Gully. In addition, the Stewarts River upstream of the weir at Bulley's Rd Bridge was sampled. Although this reach of the Stewarts River was about 1 km upstream of the highway corridor, it was sampled to give some indication of those species within the catchment likely to be moving between estuarine and freshwater habitat.

In general, sampling was confined to reaches of waterway either side of the existing Pacific Highway (i.e. within the existing highway corridor) due to access reasons. Because the channel was dry in many sections (due to the dry weather conditions in the months preceding our survey), pools were chosen at random and sampled qualitatively. The aim was to provide a snap-shot of species likely to occur in these waterways.

The back-pack electrofisher was operated in shallow pools and around the edges of the deeper pools. At each site, two-2 minute shots were done. Fish were collected in a small scoop net, identified, measured and released, where possible. Exotic species were not released back into the waterways.

2.4.4 Water Quality

Measurements of water quality (*in situ* physico-chemical variables) were taken at each site where sampling for biota was done (Figure 1). Surface measures were taken at each site, and where there was sufficient water depth, a bottom reading was also taken. At each site, 2 replicate readings 5 – 10 m apart were taken of the following water quality variables using a Yeo-Kal 611 probe:

- oxidation-reduction potential,
- pH,
- dissolved oxygen,
- turbidity,
- temperature,
- conductivity, and
- salinity.

The probe was lowered below the surface to a depth of 10 – 20cm (surface sample) and approximately 1.5m (bottom sample) and switched on for a one-minute adjustment period before any measurements were recorded. Where applicable, the results were compared to ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems.

2.5 Data Analysis

Spatial differences in the assemblage of fish and invertebrates were compared using multivariate procedures and the program PRIMER (Plymouth Routines in Multivariate Ecological Research software 1996, Clarke 1993). These analyses consider the entire assemblage of animals sampled, that is what species were present and how may of each were present. Similarities between samples were calculated and ranked to form a triangular matrix of association. The relative distances between paired samples are proportional to relative similarity between samples (Clarke, 1993). The matrix was calculated by the Bray-Curtis similarity measure (Bray and Curtis, 1957) which was then used to construct two-dimensional MDS (multi-dimensional scaling) plots (see examples in Figure 4). In the scatter plot, the samples are positioned in the two dimensional space according to their ranked similarity with other samples. Samples grouped close together are more similar to each other than samples that are widely separated on the plot. Such plots display the relationship between samples in fewer dimensions (in this case, two), than the original data matrix. This technique of reducing high-dimensional data to fewer dimensions is subject to constraints inherent in the data matrix. The measure of how well the data have been reduced to two dimensions is indicated by a "stress" value (Kruskal and Wish, 1978), where values between 0 and 0.1 provide accurate information, values between 0.1 and 0.2 are adequate, but values above 0.2 should be interpreted with caution (Clarke, 1993), as the latter may not provide an adequate representation of the relationship among samples. Note that "stress" is a statistical term and has no relationship with environmental stress. Since the plots are determined on arbitrary ordinations, reflections, locations and scales (Clarke, 1993), the axes of the plot were not labelled.

The statistical significance of any apparent groupings identified in MDS plots were determined using the a two-way, nested ANOSIM (Analysis of Similarities) permutation test (Clarke and Green, 1988). Similarity analyses (SIMPER) were used to determine the relative contribution that a particular species or taxa made to the dissimilarity among sites (Clarke, 1993).

Univariate analyses consider only one variable at a time (such as number of species present, or number of a particular species sampled), and identify differences in that variable at the various locations and sites sampled. Analysis of variance (ANOVA) was used to identify differences among locations and between sites in the mean abundance of selected taxa and taxon richness and total abundance of fish. The two factors in the statistical model were:

- Location, which was random and orthogonal and was represented by three locations; and
- Site, which was a random factor nested within location and was represented by three levels: upstream, crossing and downstream (Figure 2).

Prior to analysis, homogeneity of variances was tested using Cochrans C test (Underwood 1997) and heterogenous variances were appropriately transformed. Where significant effects were detected by ANOVA, Student Newman Kuels (SNK) Tests were used to identify differences among significant treatment means (Underwood 1997). Separate ANOVAs were done for total number of taxa and individuals, numbers of economic individuals and total number individuals of the most common taxa.

3.0 RESULTS

3.1 Descriptions of Aquatic Habitats and Waterway Grades

The Ecology Lab (2001) lists those waterways of the study area that were inspected and classified according to NSW Fisheries Policy and Guidelines (1999) during Stage 1. These waterways were prioritised in terms of further investigations (i.e. sampling to fulfil EIS requirements) and consideration of the most effective (i.e. ecologically benign) waterway crossing. Those waterways selected for further investigation as part of EIS investigations are listed in Table 2b. Descriptions of the habitat at each site are also provided in Table 2a.

Information from NSW Fisheries regarding their classification of some of the waterways in the study area was received after the site inspection by The Ecology Lab during Stage 1 (Table 2a). Some of the grades assigned by NSW Fisheries differ slightly from those made by The Ecology Lab (e.g. Herons Creek) which may be due to several reasons . If environmental conditions at the times of inspection differed (e.g. changes in amount of base flow) a different interpretation could result. Additionally, the presence of a defined waterway channel may be interpreted slightly differently by different observers on different days. However, gradings of a single waterway made at the same location do not differ by more than one class. Differences between waterway gradings by NSW Fisheries, if available, and those determined by TEL are considered in the discussion of each waterway in The Ecology Lab (2001).

3.2 Threatened Species

The threatened species schedules of the *FM Act* 1994, current as of 10 June 2004 are summarised in Table 3. The searches of literature and the Australian Museum database during the constraints and opportunities mapping exercise suggested it was unlikely any threatened species occurred in or encroached upon the study area. However, subsequent discussion with a representative of local commercial fishers reported that black cod (*Epinephalus daemelii*), on this list of scheduled species, have been caught in the Camden Haven River system as far upstream as Rossglen (i.e. to the existing Pacific Highway crossing over the Camden Haven River). It is understood commercial fishers have made only anecdotal reports of capturing black cod in mud crab traps and have not placed an official record with NSW Fisheries. When sampling for the EIS, no black cod were caught which could verify these records, although sampling was only done on one occasion using gill nets and small baited traps; large traps such as the mud crab traps used by commercial fishers were not used. Despite the uncertainty about their occurrence, an eight-part test for black cod has been completed based on the verbal reports of its occurrence in the Camden Haven River, near Rossglen. Note that this test also assumes that the identification of the species is correct – as far as we know, no specimens from the area have been sent to the Australian Museum or NSW Fisheries for identification.

In completing the eight-part test, we took a precautionary approach given the major knowledge gaps in the ecology of the threatened species and we considered the planning and design of the project. Hence we assumed worst-case scenarios, such as disturbance to acid sulphate soils, localised rainfall events during construction, and human error during construction. We also considered the construction methodology and mitigation of impacts planned for the construction of bridges.

Eight-part test for Black Cod *(Epinephalus daemelii)*

(i) *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.*

Black cod (family Serranidae), are listed as vulnerable on the threatened species schedules of the Fisheries Management Act 1994. They occur along the east coast of Australia from southern Queensland to Kangaroo Island (South Australia), and are found at Lord Howe Island, Norfolk Island, Kermadec Island and the North Island of New Zealand. Along the NSW coast, they are regularly sighted on shallow coastal and estuarine rocky reefs. Adults are territorial, usually adopting a cave as a core territory. The life cycle of the species reportedly revolves around rocky reefs and possible rock pools with pelagic dispersal of eggs and larvae (Pollard 1999; Pogonoski 2000). Apart from occupying natural reefs and artificial breakwalls at the mouths of estuaries, there is no reference in the literature that acknowledges black cod to use estuaries beyond the rocky reef habitat usually found at the mouths of estuaries to complete their life cycle. Under this proposal, the proposed bridge duplication across the Camden Haven River is about 16.5 km upstream from the entrance to the Camden Haven River Inlet.

Search of the Australian Museum database for threatened species records in the Camden Haven River system, along with a review of studies done previously in the catchment (e.g. The Ecology Lab 1993) did not return a record for black cod. (Note the closet record for black cod was from Diamond Head – southern end of Dunbogan Beach, where there are three records for the species). Anecdotal information acquired from commercial fishers suggests, however, they are caught in the Camden Haven estuary as far upstream as Rossglen. There is no confirmation as to whether the species is correctly identified as black cod. Importantly, if these anecdotal records are correct for black cod, the precautionary principle is applied and the local population is considered viable (unless the contrary can be conclusively demonstrated through analysis of records and references) (NSW Fisheries 1999c).

Despite limited understanding about the life cycle of black cod (Pollard 1999), there are aspects of the proposal that may disrupt the life cycle of black cod, particularly the potential for increased erosion and turbidity and contaminants associated with the disturbance of acid sulphate soils. As part of the further investigations done for this proposal, a Soil and Water Management Plan would be prepared for the project which details measures to reduce sediment inputs during bridge construction over the Camden Haven River. The investigative processes would need to identify:

- Problematic sediments,
- Necessary best-practice engineering principles and procedures for minimising sediment inputs, drawing on experience gained from other RTA projects,
- Necessary best-practice compliance principles and procedures that ensure environmental goals are achieved which would detail the frequency and thoroughness of environmental audits/inspections and design for monitoring during construction.

Under the proposal a multi-span bridge would be erected in the Camden Haven River, immediately to the west of the existing bridge. The bridge footings for such a bridge at this location would typically comprise approximately 8 circular piles driven into the river bed from a floating barge. These piles would be capped at the surface with reinforced concrete. On completion of the works, the footprint of each capped bridge pile group would be approximately 30 m^2. Best practice for minimising sediment dispersion would be to deploy

sediment curtains around the site of excavation or other methods acceptable to NSW Fisheries.

Provided the proposed mitigative measures are carried out, we conclude that the proposal would not disrupt the life cycle of the species to the extent that the local population would be placed at risk of extinction.

(ii) *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.*

To date, there are no threatened populations of black cod listed on the Schedules of the *FM* Act 1994. Thus, the proposal would not affect a threatened population as currently listed.

(iii) *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.*

All records for black cod in the study area are anecdotal, hence this river could not be confidently classed as 'known habitat'. If it is 'known habitat', then the potential exists for the modification of an area under a worst-case scenario (e.g. sediment input, removal of snag habitat from the littoral zone and disturbance to acid sulphate soils). These potential problems would be addressed in the Construction Environmental Management Plan for the project but can be greatly reduced with mitigative processes identified in part (i).

(iv) *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.*

Anecdotal evidence suggests black cod are relatively abundant throughout Watson Taylors and Queens Lakes and that the existing Pacific Highway crossing at Rossglen is at about the upstream limit where black cod are taken by commercial anglers in the Camden Haven River. As such, the proposed crossing at the Camden Haven River is considered unlikely to isolate up- and downstream habitat for black cod.

(v) *Whether critical habitat would be affected*.

No areas of critical habitat in relation to black cod have yet been listed on the Threatened Species Schedules of the *FM* Act 1994.

(vi) *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*.

Black cod are completely protected from fishing in NSW, which is the main threat to this species. This species occurs in a number of protected areas, including Bushrangers Bay (Illawarra), Middle Harbour Aquatic Reserve (Sydney), Fly Point and Halifax Park (Pt Stephens), Shiprock Aquatic Reserve (Pt Hacking), Cook Island Aquatic Reserve (Tweed Heads), Julian Rocks Aquatic Reserve (Byron Bay), Jervis Bay Marine Park, Solitary Islands Marine Park and Lord Howe Island. Therefore, we conclude that there is adequate provision within conservation areas.

(vii) *Whether the action proposed is of a class of action that is recognised as a threatening process*.

The proposal may be classed as a threatening process if it involves the removal of large woody debris (i.e. snags) from those waterways during the erection of bridge crossings. In Camden Haven, if the new bridge was to match the dimensions of the existing crossing, some snags that were scattered along the shorelines may need to be removed for the duration of works. A few snags are present near the proposed bridge piles near the northern bank of the river, and one large tree is reported in the middle of the river. NSW

Fisheries have recommended the relocation of snags to areas of the river adjacent to the construction and for these snags to remain in this position on completion of works as this would reduce handling.

(viii) *Whether any threatened species or ecological community is at the limit of its known distribution.*

The study area is not at the limit of distribution of black cod within Australia, although Rossglen may be the limit of black cod within the Camden Haven River system.

Conclusion: The eight part test suggests that

1) black cod may potentially occur within the river reach that would be disturbed by the proposed highway upgrade,

2) protection of the species should be incorporated into the Construction Environmental Management Plan for the project, including:

- the minimal removal of habitat (i.e. large woody debris),
- the development of a Soil and Water Management Plan that identifies best-practice engineering principles and procedures for minimising erosion and sediment inputs, and
- a program for monitoring water quality prior to and during construction.

Additional information on the timing and frequency of occurrence of black cod capture by commercial fishers would assist in the finalisation the Construction Environmental Management Plan. While targeted sampling for black cod would not be supported due to its protected status (Greg Davey, NSW Fisheries, pers. com November 2002), further information may be sought from commercial fishers using mud crab traps in the area. Discussions between The Ecology Lab and Mr Kim Poole (commercial fishing representative), indicated that commercial fishers may be willing to participate in a program to monitor black cod in the Camden Haven system (in consultation with NSW Fisheries). The recommended methodology would include the development (in liaison with NSW Fisheries) and issue of easy-to-use logbooks to enable information such as location, number of fish, length and approximate weight, etc. to be recorded. This information could then be stored in a central database at NSW Fisheries for analysis and feedback to management during the course of construction.

A Species Impact Statement for black cod is not recommended given that the above precautions to be incorporated into the Construction Environmental Management Plan.

3.3 Commercial and Recreational Fishing

3.3.1 Commercial Fishing

Published fisheries production data for NSW estuaries are available for the years 1993-1999 (NSW Fisheries 2000a, 2000b). Examination of these data revealed that commercial fishing for finfish was relatively stable in NSW for the period 1993/94-1998/99 (Table 4a), and that Camden Haven estuary ranked 10th in the state in terms of value of finfish landed, estimated to be worth $673,000 in the 1998/99 financial year, the most recent period for which data are available.

Commercial fishing in the estuary is done mainly by gill netting (for fish), pocket netting and hauling (prawns) and trapping (crabs and eels). Commercially, important species of

fish include sea mullet (*Mugil cephalus*), luderick (*Girella tricupidata*), dusky flathead (*Platycephalus fuscus*), bream (*Acanthopagrus australis*), sand whiting (*Sillago ciliata*) and eels (*Anguilla reinhardti*). Prawn species include school prawns (*Metapenaeus macleayi*) and, to a lesser extent, eastern king prawns (*Penaeus plebejus*). Crabs targeted include mud crabs (*Scylla serrata*) and blue swimmer crabs (*Portunus pelagicus*).

Commercial fishing in the Camden Haven River occurs from the weir at Kendall downstream to Watson Taylors Lake, between the lake and Stingray Creek and in the reach from Stingray Creek to the entrance at North Haven. Fishing activities in the Camden Haven River in the vicinity of the existing highway crossing include trapping (for mud crab along the riverbanks), mesh netting (for mullet) and hauling (for prawns).

Commercial fishing in the Stewarts River and Herons Creek occurs downstream of the existing highway corridor. Fishing closures prevent access to reaches of river where construction would occur under the road upgrade proposal. Prawn hauling occurs in the Stewarts River up to the confluence with Passionfruit Gully (i.e. about 500 m downstream of the existing highway crossing) whilst mesh netting for mullet is the main form of commercial fishing in Herons Creek, but is confined to the lower reaches of the creek near Queen's Lake due to narrowing of the watercourse.

There are about 16 endorsed fishers in the Camden Haven estuary at present after recent buy-outs by the NSW state government, however, this number of fishers is likely to increase over the coming years as fishers are bought out in the Manning and Macleay River estuaries and compensated by being granted permission to fish in the Camden Haven system (K. Poole pers. comm. 2003).

There are over 50 oyster leases within the Camden Haven estuary, most of which are concentrated in the lower reaches of the Camden Haven River, Stingray Creek and around the southern shoreline of Queens Lake (Figure 3b). Oyster cultivation in the Camden Haven estuary was worth $601,735 in the 1999/2000 fiscal year or about 2% of the states total Sydney Rock oyster production (Table 4b). Like finfish production, examination of oyster production data for the period 1994/95 – 1999/00 suggest that the production of oysters is relatively stable.

3.3.2 Recreational Fishing

Discussions with NSW Fisheries Office at Taree suggests that recreational fishing in the Camden Haven estuary is very popular all year round. 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. Like the commercial sector, fishing is popular throughout the estuary, but tends to be focussed in the lower reaches of the Camden Haven River (e.g. Breakwall at the entrance to the river and Stingray Creek) where good fishing spots are easily accessible. Fish taken include typical estuarine species such as bream, flathead, luderick, whiting and mulloway. Fishing is also popular along the western boundaries of Watson Taylors Lake, where shallow water provides for prawning and crabbing. Fishing also occurs in the Camden Haven River, above Watson Taylors Lake, but is restricted mostly to boat access. With respect to recreational fishing in the study area, deep holes around the existing highway crossing in the Camden Haven River are reported to be good fishing for mulloway at certain times of the year (M. Manson, pers. comm). Australian bass (*Macquaria novemaculata*) (predominantly freshwater species and are not targeted by commercial anglers) have also been reported to occur with estuary perch (*Macquaria colonorum*) in the Camden Haven River after flood events, as far downstream as Watson Taylors Lake (Horrobin 1996). Both these species are prized recreational species.

3.4 Fish and Mobile Invertebrate Surveys

3.4.1 General Findings

3.4.1.1 Bait Traps

Mean abundance (± standard error, SE) of fish and mobile invertebrates caught via bait traps at the three study locations (Figure 1) are shown in Table 5a. A total of 2945 individuals, comprising 12 species of fish and 2 species of invertebrates were caught bait trapping at the three locations. Of these species, 4 species of fish and 1 species of invertebrate were of economic importance, accounting for 44 % of the total abundance, flat tail mullet contributed to more than 73 % of the fish caught. Flat tail mullet (*Liza argentea*) and yellowfin bream (*Acanthopagrus australis*) were the most abundant species of economic importance. Overall, Flat tail mullet and Port Jackson perchlet (*Ambassis jacksoniensis*) were the most abundant species, each accounting for 28 and 27 % of the total number of individuals, respectively. None of the species caught were introduced or listed under the threatened species schedules of the *Fisheries Management Act* 1994.

Location 2 (the existing highway at Camden Haven) had the highest number of species (13), species of economic importance (5) and individuals (1363) of all the locations. This location had more than 1.5 times the number of individuals as the location on the Camden Haven River about 7 km further upstream, and nearly twice the number of individuals as the crossing at the Stewarts River (Figure 1). The reasons for this are unclear but may be that some combination of factors that jointly operate to produce the patterns observed. These factors may include physiological preferences of individual species, biological factors, disturbance in surrounding catchment, water quality and chance.

3.4.1.2 Gill Nets

Mean abundance (± standard error, SE) of fish and mobile invertebrates caught in gill nets at Locations 1-3 (Figure 1) are shown in Table 5b. A total of 59 individuals, comprising 10 species of fish and 1 species of invertebrate were recorded from gill nets at the three locations. Of these species, 7 species of fish and 1 species of invertebrate were of economic importance, and accounted for about 81% of the total abundance. Sea mullet (*Mugil cephalus*) and Luderick (*Girella tricuspidata*) were the most abundant species, and accounted for 31% and 25% of the total abundance, respectively. Both species are of economic importance. None of the species recorded is protected or listed on the threatened species schedules of the *FM Ac*t 1994.

Locations 1-3 had similar numbers of individuals (23, 20 and 16, respectively) although Locations 1 and 2 (the two locations sampled on the Camden Haven River) had more than three times as many species as Location 3 (Stewarts River) (Table 5b). Again, the reasons for this are unclear.

3.4.2 Analysis of Assemblages

3.4.2.1 Bait Traps

The two-dimensional MDS plot of the assemblages of fish and mobile invertebrates among locations and sites showed no clear separations between samples (Figure 4). Note the stress value of 0.15 indicates only a fair representation of the relationship between samples. A

two-way nested ANOSIM detected a significant difference among locations (Global R =0.506, $p<0.05$) and sites within locations (Global R = 0.079, $p<0.05$) (Table 6a), although it was not possible to use pairwise tests to confidently determine which locations differed, due to the limited number of permutations.

Empire gudgeon, Ramsey's perchlet, Pacific blue-eye and flat-tail mullet regularly contributed high proportions of the dissimilarity between locations (SIMPER analysis, Table 7). Locations 1 and 3 were the most similar whilst Location 2 was of equal dissimilarity to Locations 1 and 3. These patterns were largely attributable to the smaller abundances of Port Jackson perchlet and flat tail mullet, and greater abundance of empire gudgeon at Locations 1 and 3 than at Location 2. It may be that some combination of water quality, physiological preferences of individuals species, biological factors, differences in available fish habitat and chance jointly operate to produce the patterns observed.

3.4.2.2 Gill Nets

The MDS plot of the assemblages of fish and mobile invertebrates among locations and sites showed no clear separations between samples (Figure 5), nor did ANOSIM reveal any significant differences in assemblages among sites and locations (Table 6b).

3.4.3 Analysis of Populations

3.4.3.1 Bait traps

Populations of abundant species, including 1 species of economic importance were analysed using ANOVA (Table 8). In terms of species of economic importance, there were significantly more flat tail mullet at the existing crossing than there were at other locations. Of the abundant non-commercial species, both empire gudgeon and carid shrimp showed significant differences among locations. Empire gudgeon were more abundant at Location 3 than at all other locations, whereas there were significantly fewer carid shrimp at Location 1 than at the other locations (Figure 6). Again, the reasons for these differences are unclear, but may reflect habitat preferences of these two species.

3.4.3.2 Gill nets

ANOVA revealed no significant difference in the total number of species, individuals, number of economic individuals or populations of abundant species among locations and sites within locations (Table 9).

3.4.4 General Findings – Electrofishing

A total of 7 species of fish and 1 species of macroinvertebrate were caught from the Stewarts River, Passionfruit Gully, Stony Creek, Walkers Creek and Herons Creek whilst electrofishing (Table 10). These species included long and short finned eel (*Anguilla reinhardtii* and *Anguilla australis*), striped gudgeon (*Gobiomorphus australis*), empire gudgeon (*Hypseleotris compressa*), firetail gudgeon (*Hypseleotris galii*), mosquito fish (*Gambusia holbrooki*), common jollytail (*Galaxias maculatus*) and mohawk shrimp (*Atya striolata*). Both *Anguilla* spp. are of economic importance. Striped and empire gudgeon were recorded in all waterways whilst sampling yielded a single common jollytail in Passionfruit Gully. No threatened species were recorded whilst electrofishing. One introduced species - Mosquito fish was recorded in two waterways (Stony Creek and Passionfruit Gully).

3.5 Water Quality – Comparisons with ANZECC Guidelines

Variables measured in this study which are applicable to ANZECC Guidelines (2000) for estuarine and freshwater lowland rivers are listed in Table 10. Due to large diurnal fluctuations in dissolved oxygen, it is suggested that one-off measurements alone are of limited value. 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.

Levels of dissolved oxygen recorded at each site and depth failed to comply with ANZECC Guidelines, although some values were only marginally below these guidelines. When dissolved oxygen concentrations were compared at surface and bottom, there appeared to be some stratification occurring at Location 1, but not where there are existing crossings at Locations 2 and 3 (Table 11, Figure 6b). These results must be treated cautiously because sampling has only been done at one point in time.

Given that the levels of pH recorded were within the normal range for estuarine and freshwaters, 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. To detect acid sulphate soil run-off, 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.

Levels recorded for turbidity at the majority of sites sampled complied with ANZECC guidelines (Table 11). Turbidity readings slightly above guidelines were recorded at mouth of the Camden Haven River at the edge of Watson Taylors Lake, probably reflecting localised turbulence at the point where fresher river water enters the lake.

4.0 ASSESSMENT OF IMPACTS

4.1 Description of Proposal

There are 6 perennial (Class 1-3) waterways in the study area. Under the proposal, the final route would cross the Stewarts River, Stony Creek, the Camden Haven River and Herons Creek via single or multi-span bridges, and Passionfruit Gully and Walkers Creek via box culverts. Further, there are a number of ephemeral unnamed waterways/drains (Class 3-4) in the study area and under the proposal, these would be crossed via box or pipe culverts. NSW RTA have indicated that a low flow cell (or similar structure) is likely to be incorporated into the culvert configuration at Walkers Creek and Passionfruit Gully to assist fish passage during periods of reduced run-off and low water levels in these watercourses.

The new crossings would be built immediately to the east or west of the existing highway except for the bypass section around Kew where a new carriageway and waterways crossings would be constructed. Water quality basins would be constructed near the Stewarts River, Stony Creek and Herons Creek and possibly at the Camden Haven River. These structures are designed to catch and treat surface run-off during the operation of the carriageway (Ove Arup 2002).

A multi-span bridge would be erected in the Camden Haven River, immediately to the west (i.e. upstream) of the existing bridge. The bridge footings for each pier for such a bridge at this location would typically comprise approximately 8 circular piles driven into the river bed from a floating barge. These piles would be capped at the surface with reinforced concrete. On completion of the works, the footprint of the pile cap at each bridge pier would be approximately 30 m^2. Sediment containment devices would be implemented as part of standard RTA practice under site specific erosion and sedimentation control plans and the Soil and Water Management Plan.

As part of the duplication of the bridge over the Camden Haven River, RTA proposes to remove the two disused lift span piers located immediately downstream of the current bridge, and to remove rubble on the river bed associated with the lift span pier (bearing seat beam and possibly deck diaphragm) and the remaining seven trestle piers of the superseded bridge. NSW Fisheries supports the removal of the disused bridge piers and rubble as per the NSW Fisheries Policy and Guidelines for bridges (NSW Fisheries 1999). NSW Fisheries is of the opinion that the bridge piles do not represent prime black cod habitat, and as such their removal would have no impact on loss of habitat for black cod. They advised that the removal of the pier pilings and rubble would need to be carefully managed, with demolition details needing to be outlined in the EIS (Greg Davey, NSW Fisheries pers. comm. November 2002).

The upgraded highway would traverse the floodplains of the Stewart River and the Camden Haven River. These floodplains have been identified as areas likely to contain soils with acid sulphate material in their immediate surface layers (Department of Land and Water Conservation, undated). As part of the on-going design and planning for this proposal, the EIS would outline decisions made to avoid disturbance of acid sulphate soils, and from this develop a Acid Sulphate Soil Management Plan (ASSMP). Prior to any disturbance of the sediments at the risk area (i.e. near waterways and wetlands), further sampling and testing would be done to quantify the risk of disturbing acid sulphate soils (J. O'Donnell, NSW RTA pers. comm 2002). The ASSMP would draw on recent NSW RTA experience from other sections of the Pacific Highway Upgrade in developing ways to treat and contain run-off from acid sulphate soils. Previous construction in acid sulphate soils has shown that

isolation of excavations with potential ASS, bunding, lining runoff drains with limestone material that has potential to increase the pH of run-off water can be effectively used to mitigate the potential impacts of run-off from acid sulphate soils.

To the north of the Camden Haven River, the new carriageway would remain within the existing road reserve as far north as the commencement of the Kew bypass, north of the crossing of the Stewarts River. The upgrade would not encroach upon SEPP 14 (No. 544 c) wetland, nor is it likely to impinge on an unprotected wetland which is of similar floral characteristics west of the existing highway. Given the proximity of these habitats to the highway reserve, however, there is the potential for effects from runoff from earthworks during construction. Specific details regarding the location of stockpiles, sedimentation basins, etc. would be included in the Soil and Water Management Plan for the Proposal.

4.2. Potential Effects of the Proposal on Aquatic Habitats and Biota

A number of construction and operational activities can potentially result in adverse impacts on freshwater and estuarine biota: These can be grouped as follows:

- Those causing sediment and contaminant inputs to waterways, including disturbance of stream beds,
- Those causing physical alteration or removal of aquatic habitat, and
- Those causing blockage to fish passage.

4.2.1 Sediment and Contaminant Inputs into Waterways

The construction of roads can potentially impact on the water quality, sediment quality and biota of waterways by introducing sediment and contaminants (e.g. Krein and Schorer 2000, Perdikaki and Mason, 1999, McNeill and Olley 1998, Ellis *et al.* 1997, Maltby *et al.* 1995a, 1995b, Boxall *et al* 1995, 1997, Lund *et al.* 1991, Richardson 1985). The proposal to upgrade the Pacific Highway between Moorland and Herons Creek would incorporate techniques successfully used elsewhere on the Pacific Highway to control the introduction of sediment and contaminants into adjacent waterbodies [Moorland to Herons Creek Soil and Water Controls, RTA 2003 (John O'Donnell via email to Ray Dallen dated 31 March 2003). Full details of the proposed soil and erosion protection measures are described in the section on Water Quality, Erosion and Sedimentation Control in the Preliminary Engineering Design Report (Arup, 2003). The proposed measures have been developed in consultation with RTA and are based on the "Blue Book" (Department of Housing 1998), RTA's Road Design Guide (1993) and as advised by RTA and other relevant agencies. The construction contractor would be required to produce a Construction Environmental Management Plan that would include a Soil and Water Management Plan detailing mitigation measures for the project. As the work proceeds, location specific Erosion and Sedimentation Control Plans (ESCPs) would be prepared and implemented by the contractor. Techniques to prevent and/or manage the introduction of soil and contaminants into waterways may include:

- Retention of as much grassed or vegetated cover during clearing as possible to avoid erosion of soil,
- Diversion of clean runoff around construction sites,
- Bunding of stored chemicals and contained machinery wash-down areas for chemicals stored near waterbodies,

- Use of stabilised temporary and permanent diversion banks and drains to reduce water volume and reduce speed of runoff water from construction and operation sites,
- Diversion of road runoff away from environmentally sensitive areas such as SEPP 14 wetlands
- Use of sediment fences, vegetation barriers, rock barriers
- Early installation and minimised construction time for appropriately designed sediment retention ponds,
- Quick installation of culverts,
- Environmentally friendly installation of scour protection for creek banks, river banks and low flow channels
- Revegetation and stabilisation of construction areas as soon as practical after construction
- Regular inspection and maintenance of erosion, sediment and pollution control devices

Sampling done for the present study suggests the waterways of the study area support a relatively diverse assemblage of fish and mobile invertebrates. Sensitive aquatic habitats also exist in the study area. Approximately 200 m downstream from the existing highway crossing of the Camden Haven River was a patch (about 80-100 m^2) of seagrass (*Zostera capricorni*). This was the only substantial patch of seagrass habitat observed in Camden Haven River between the existing Pacific Highway and its confluence with Watson Taylors Lake, about 5 km downstream. Hence this habitat may play an important role on a local scale and needs to be considered in the overall project assessment. SEPP 544c is a protected wetland habitat located to the east of the existing highway and to the north of the Camden Haven River. The highway upgrade proposal is not expected to directly affect this wetland habitat as it does not encroach upon this habitat. Furthermore, the likelihood of introducing contaminants from the construction and operation of the proposal to this habitat would be reduced greatly by the treatment of road runoff (possibly through measures listed above) before it enters the wetland or drainage lines which flow into the wetland.

The Camden Haven River is the largest waterway in the study area and is in excess of 100 m wide at the proposed crossing point. A duplicated crossing would require several pile groups driven into the riverbed to support the structure. If the new bridge is to mirror the existing crossing, then 5 piers, placed about 30 m apart would be required. A high standard of soil control measures would be employed in the river to trap suspended sediments disturbed during excavation and driving of bridge piles. Although details of the measures to reduce sediment inputs have not been finalised, current best practice would indicate the use of silt curtain around each new pile driven into the riverbed or other options as discussed with NSW Fisheries, whilst silt fences would be deployed around excavated areas on land.

The positioning of those bridge piles closest to the river bank would have the potential to alter the pattern of flow under the highway corridor causing scouring to the banks and bed of the river, which in turn could alter the distribution of biota on the scale of metres around the piers. Based on observations of the existing bridge it appears that scouring to the riverbank caused by the positioning of the existing bridge piles is no greater than the natural scouring that occurs through natural processes up- and downstream. However, NSW

Fisheries recommend the retention of riparian vegetation via the cut stump method to mitigate potential bank scouring.

The wetted width of the Stewarts River, Stony Creek and Herons Creek (during times of low flow as was observed during the sampling program) was narrower than 30 m. If single span bridges are not achievable at these waterways, then NSW Fisheries guidelines recommend the use of bridge piers which should be set into the riverbed to avoid the low flow section of these waterways. Further, it is recommended that the bridge abutments/piles used at all waterways be set back as far as is possible from the rivers edge and high bank. This would reduce the potential for scouring to riverbanks during flood events.

Culverts would be the likely crossing structures used in Passionfruit Gully and Walkers Creek. It is recommended that installation of these structures be done in the shortest possible timeframe to reduce the risk of soil erosion from disturbed creek beds due to heavy rainfall or flood events.

In summary, at each waterway the incidence of worst-case sediment inputs can be greatly reduced by:

- Identifying problematic soil materials (particularly acid sulphate and highly erodable clay based soils),
- Identifying best practice principles for minimising sediment inputs, drawing on past and recent experience from other RTA projects, and
- Identifying necessary best-practice compliance principles and procedures to ensure environmental-protection goals are met.

An issue raised during local community consultation for the 'Healthy Rivers Commission on Coastal Lakes' was that of disturbance to acid sulphate soils and their effects on aquatic habitats in the Camden Haven River area (Fletcher and Gerrand 2000). Although our water quality data indicated that at the time of sampling there was no evidence of water quality conditions attributable to run-off from acid sulphate soils, the presence of acid sulphate soil run-off can be ephemeral and difficult to detect. Note the Department of Land and Water Conservation, through the Waterwatch Program, keeps records for water quality data from 21 catchments statewide. In the Camden Haven system, there are sites on two freshwater tributaries (Batar Creek and Black Creek which flow into the Camden Haven River about 4 and 13 km upstream of the existing crossing) for which there data are available, although it would appear that no data has been collected after May 2001. Because the data are collected from freshwater habitats, they are not suitable to serve as baseline data against which to compare potential changes in water quality in the estuarine reaches of Camden Haven River during construction. The map of acid sulphate soils produced by DLWC indicates the likelihood that these soils occur near the crossings of most of the waterways in the study area (see Figure 1 in The Ecology Lab 2001, source - DLWC undated). Investigative processes would need to identify problematic soils. Appropriate erosion control measures should be planned to avoid water quality problems in surrounding waterbodies in the event acid sulphate leachate drains from the site. Soil excavated from areas of catchment surrounding the waterways may also contain iron pyrite. Where possible, soils that contain iron pyrite should not be stockpiled near waterways or wetland habitats. If this is not possible, any stockpiled ASS material should be bunded to control potential run-off into surrounding aquatic habitat or reused below groundwater level or contained in fill after appropriate treatment to neutralise.

Erosion and sedimentation prevention measures including the use of sediment basins are designed in accordance with the "Blue Book" developed by the Department of Housing

(1998). Based on recent experience on other RTA projects, sediment basins which are set close to the waterway maximise the capture of site run-off and minimise the area of cleared land. During both construction and operational phases of the project, there is the potential for fuel/oil spills to cause contaminant inputs into waterbodies. Likewise, exudates from recently-heated bitumen may contain complex mixtures of toxic materials. Some of these basins (particularly those near Class 1 and 2 waterways) would be important during the operation of the road to collect hazardous spills and wash water.

4.2.2 Physical Alteration or Removal of Aquatic Habitat

Where new crossings would be erected, bands of vegetation generally extend for several metres away from the waters edge. Although not strictly 'aquatic' vegetation, these trees and shrubs helped consolidate the riverbank habitat. Under the proposal, some of the riparian vegetation would invariably be disturbed during site preparation (either removed entirely or trimmed). Where bridges are installed across the Class 1 and some Class 2 waterways, it is recommended that the bridge abutments are set back from the high bank. This would limit the area of vegetation to be cleared. In a waterway like the Camden Haven River, where boat launching and mooring facilities are to be most likely required, additional vegetation from the riparian zone may need to be removed. If 'riparian' vegetation needs to be removed from the banks of rivers and creeks, NSW Fisheries preference is for the "Cut Stump" method of removal to maintain natural scour protection. We recommend that once the works are complete, replanting of trees/shrubs occurs along the section of shoreline cleared of vegetation for boat launching/mooring facilities.

An interesting feature at most of the existing waterway crossings was the area of 'bare earth' under and adjacent to each of the carriageways. To maintain natural scour protection during the operation of the project, it is recommended that a revegetation program at each new crossings be initiated once all construction is complete to maintain natural scour protection.

There were few mangroves scattered along the foreshore of the Camden Haven River immediately upstream (i.e. to the west) of the existing crossing that may lie in the path of the proposed bridge alignment. Although details of the 'area of foreshore disturbance ' are not yet known, we would anticipate a small number (no more than 15 trees, shrubs and saplings)of these plants would require removal or trimming. Further, there is the potential for indirect effects (i.e. from shade cast by the bridge) on mangrove habitat that lies adjacent to the crossings, however, the indirect impact on mangrove habitat would be considered small and acceptable.

Immediately upstream of the existing highway crossing of the Camden Haven River, there were a number of snags (mostly toppled Casuarinas) scattered along the shoreline of the river. Woody debris can act as refuge of fish and other biota. When baited traps are deployed by commercial fishers amongst this habitat, they regularly report the capture of fish and crabs. The proximity of new bridge pylons to the shoreline (particularly the northern bank) may require the removal of snags during site preparation. Although snags scattered around the shoreline of the road corridor were few in number (relative to reaches of the river up- and downstream), these objects may be act as habitat for biota on a local scale. As such, it is recommended that the removal of snags be kept to a minimum. The snags that are removed could be stockpiled for the duration of construction and on completion of works, be returned to near their pre-construction positions.

4.2.3 Removal of Old Bridge Piles and Rubble in the Camden Haven River

A reconnaissance dive around the old bridge piles (Gray Diving Services on behalf of ARUP, October 2001) reported on the condition of the two partially demolished piers located in the river immediately downstream of the current bridge and mounds of debris remaining after the removal of the seven other trestle piers. The two piers now each consist of four approximately equal segments, with the pile cap located at 0.7 m below bed level for the northernmost pier (pier 6) and at one metre below bed level for pier 5. Reinforced concrete rubble surrounds the two piers and the remaining seven pile trestle piers of the old bridge. The debris mounds peak at 1 metre above the riverbed and taper into the surrounding silt riverbed over areas typically 4 m x 2 m. Beyond the debris piles, the riverbed is comprised of river gravel overlain by soft silt (Gray Diving Services, 2001).

The options for removing the disused piers and pier rubble have considered the disturbance the operation would cause, and methods to mitigate these impacts. The main potential environmental effect would be the increase in turbidity caused by disturbing the layer of silt which overlies the debris piles and surrounds the remains of the pier structures. A second potential impact would be the further disturbance to the river bed caused by dropping cut sections of the pier columns on the river bed. The preferred method for removal of disused piers and rubble would be developed according to the principles outlined in the Preliminary Engineering Design Report, but would allow for:

- consideration of practicality,
- provision of effective silt control wherever possible, taking into account the difficulty of the task,
- preparation of a Work Method Statement for this issue,
- liaison with NSW Fisheries and EPA in regard to best practice and review of the Work Method Statement,
- optimum timing of the works,
- water quality monitoring,

4.2.4 Fish Passage

Species of fish caught in waterways of the study area need to move between habitats for a variety of reasons, including the search for food and shelter, dispersal into available habitat and most importantly for reproduction. Barriers to fish passage from the erection of waterway crossings can occur temporarily (i.e. during construction from the erection access pads) and over the long term where inappropriate structures are used. (Note a permit would be required from NSW Fisheries under S219 of the *FM Act* 1994 to block fish passage). Where major and moderate fish habitat was identified in this study (i.e. Stewarts River, Stony Creek, Camden Haven River and Herons Creek), bridge crossings would allow the passage of fish between upstream and downstream habitats. Where feasible, single span bridges are the preferred option on Class 1 streams narrower than 30 m to avoid in-stream structures that may affect fish passage.

The wetted width of the Stewarts River, Stony Creek and Herons Creek (during low flow as was observed during the sampling program) are narrower than 30 m. If single spans are not achievable at these waterways, then NSW Fisheries Policy and Guidelines require that the bridge piers are set into the riverbed so as to avoid the low flow section of these waterways. It is understood that the existing bridges at Stony and Herons Creeks would be replaced with new bridges in similar positions as part of the upgrade (Ove Arup 2002). Because the

existing crossing at Stony Creek includes a concrete base (which sits about 40 cm above the existing creek bed level) the replacement of this bridge would improve connectivity between up- and downstream habitat particularly during period of low creek discharge

If the bridge crossing over the Camden Haven River is to match the dimensions of the existing bridge, then 5 pylons are required in the river. Excavation of the riverbed and bridge piling is likely to be done from a barge in sections across the river. Driving of bridge piles into the riverbed would be done for short periods during daylight hours. Given that work in the river would not be done simultaneously at once across the river, it is likely that any limited noise or vibration that may be exerted on the river would be confined to a small area of the river. As such, these works in the Camden Haven River should not impede fish moving up- and downstream of the construction area.

Walkers Creek and Passionfruit Gully are, Class 2 and Class 3 waterways respectively, crossed by the existing highway via box culverts. NSW Fisheries requests that new or replacement culvert designs aim to retain natural geomorphological features of streams including stream width, streambed composition, stream slope and stream flow. The latter three factors can be achieved by ensuring that the invert of the culvert cells are appropriately located to cater for low, medium and high flow and accumulation of natural sediments with culvert cells (NSW Fisheries, 12 April 2002). Eels and gudgeons were collected in sampling done in Walkers Creek upstream of the existing culvert in this study, suggesting that some fish can negotiate the existing box culverts under the low to medium flow regime observed during our sampling. Our once-only sampling, however, does not allow us to assess the efficacy of the culvert under different flow conditions. An interesting feature in both Passionfruit Gully and Walkers Creek was the build-up of aquatic plants and sediment within the waterway, particularly on the upstream side at these crossings. The culvert at Passionfruit Gully consists of 3 cells, each 2.4 m wide, seated about level or above the existing creek bed. The Walkers Creek culvert is similar, but is comprised of 2 cells only. While our capture of fish above the culvert at Walkers Creek suggests that the existing structure is sufficient to allow fish passage, the build-up of plants and sediment suggests that the depth and the number of cells at this waterway may hamper fish passage under other flow conditions than those observed during our field studies. NSW Fisheries recommends box cells be set into the creek bed to allow an optimum water depth of 0.2 -0.5 m within a culvert under base flow condition (NSW Fisheries, 12 April 2002). Given the intermittent nature of both waterways, this recommendation should be factored into the design of the new culverts, and may require rehabilitation if the existing culverts are to be retained as part of the proposal.

4.3 Threatened Species and Ecological Communities

4.3.1 Fisheries Management Act 1994

The eight part test suggests that black cod may occur within the area that would be disturbed by the proposed highway upgrade, but the identity of the species needs to be verified. Targeted sampling for this protected species is not supported by NSW Fisheries, but assistance may be given by commercial fishers who could photograph individuals caught in mud crab traps. Second, there are aspects of the proposal that may disrupt the life cycle of individuals that occur in the vicinity of the proposal. Therefore, protection of the species should be incorporated into the Construction Environmental Management Plan for the project, including the minimal removal of habitat (i.e. large woody debris), the development of Soil and Water Management Plan that identifies best-practice engineering

principles and procedures for minimising sediment inputs and a comprehensive program for monitoring water quality tailored around the period of construction in the Camden Haven River. A Species Impact Statement for black cod is not recommended given that the above measures are incorporated into the Construction Environmental Management Plan.

4.3.2 Threatened Species Conservation Act 1995

Coastal saltmarsh was confined in the study area to a protected (SEPP 544c) and unprotected wetland to the north of Camden Haven River. As discussed in Section 4.2.1, the upgrade would not encroach upon either wetland causing direct loss of saltmarsh habitat. Moreover, the likelihood of introducing contaminants from the construction and operation of the proposal to this habitat would be reduced greatly by the treatment of road runoff (possibly thought measures listed in Section 4.2.1) before it enters the wetland or creeks draining into the wetland.

4.4 Key Threatening Processes

4.4.1 *Fisheries Management Act* 1994

4.4.4.1 Removal of Large Woody Debris

Large woody debris consists of large masses of trees and shrubs that have fallen or that have been washed into rivers and streams, and are commonly removed from rivers for reasons such as navigation (Fisheries Scientific Committee, Undated). Snags (large woody debris) may need removing during site preparation for construction of waterway crossings. We recommend that woody debris collected from the waterways be stockpiled during construction and returned to near their pre-disturbance positions on completion of works.

4.4.4.2 Degradation of Native Riparian Vegetation

Riparian vegetation refers to the vegetation fringing waterways and can be defined as any vegetation on land which adjoins, directly influences, or is influenced by a body of water. Degradation of riparian vegetation includes the removal or modification of native species (Fisheries Scientific Committee, FSC, undated).

Under the proposal, limited removal of native riparian vegetation at most waterways would be required for the erection of crossings (for the crossing itself or access for people and machinery to construct the crossing). In most cases, the removal would be confined to a narrow corridor adjacent to the existing crossing. Notwithstanding this, areas adjacent to waterways that are cleared of riparian vegetation to allow access for people and machinery should be revegetated on completion of the construction works.

4.4.2 Threatened Species Conservation Act 1995

Predation by *Gambusia holbrooki* (Mosquito Fish)

The NSW Scientific Committee were of the opinion that predation by *Gambusia holbrooki* (mosquito fish) is a serious threat to the survival of several threatened native frog species, which brought about its listing under the *TSC Act* 1995.

The following information on the biology and ecology of mosquito fish is taken from the draft threat abatement prepared by the NSW National Parks and Wildlife Service. Mosquito fish are an introduced species of freshwater fish that usually prefer slow moving and/or still water, and can tolerate a wide range of habitats including turbid, silty reaches of rivers, swamps, lakes (including salt lakes in coastal dunes), billabongs and farm ponds. Habitat with dense surface vegetation appears less attractive as it obstructs access to surface water where mosquito fish forages. Lloyd (1984) suggested that disturbed habitats (e.g. cleared river banks and river bed alterations) were particularly susceptible to invasion by mosquito fish due to these areas having relatively abundant sources of food, and usually a paucity of other fish species because of harsh physical conditions. Mosquito fish tolerate a range of water quality conditions including acidic pH and low dissolved oxygen. Arthington *et al*. (1990) argued that the ability of mosquito fish to tolerate low dissolved oxygen concentration enabled them to survive in still, oxygen deprived, waterbodies.

Activities during the project's construction phase that remove habitat (instream and riparian vegetation) and affect water quality may provide conditions suitable for the proliferation and/or spread of mosquito fish. Mosquito fish were recorded in Stony Creek and Passionfruit Gully, but only in relatively small numbers. As part of the planning phase, site specific Erosion and Sedimentation Control Plans would be prepared and implemented at each waterway. These plans, which are designed to ensure water quality impacts are minimised, would serve to reduce the likelihood of population increase by mosquito fish.

4.5 Commercial and Recreational Fishing

With the strict mitigative measures (as outlined in Section 5.0) to be in place to minimise sedimentation effects and impacts on fish passage, the works in and surrounding the Camden Haven River are likely to have minimal effect (in terms of habitat removal or effects on fish passage) on commercial fishing in the Camden Haven system. To minimise potential disruptions to commercial fishing operations, construction of the bridge duplication should be planned to allow a navigable path through construction corridor at all times to allow vessels access to areas regularly fished in the Camden Haven River.

Like commercial fishing, with strict mitigative measures developed and implemented under the project's Construction Environmental Management Plan the construction of a bridge across the Camden Haven River is likely to have minimal effect on species of recreational importance that may occur near, and be targeted by, recreational anglers

Oyster leases are located in the lower parts of the Camden Haven system (in or downstream of Watson Taylors and Queens Lake), in excess of 7 km downstream of where works would be done in the study waterways. Although sessile animals like oysters are adapted to natural periods of turbid water when they will cease to feed, any potential sedimentation effects that the project may have would be addressed as part of the project's Construction Environmental Management Plan and site species Erosion and Sedimentation control Plans. Thus, we would anticipate that the proposal would have no direct or indirect impacts on oyster farming in the estuary

5.0 MITIGATION OF IMPACTS

Mitigation of impacts of road construction and operation over waterways would be included in a detailed Construction Environmental Management Plan and Operational Environmental Management Plan for the project. A summary of mitigative measures to assist during the planning and construction phases of the project to protect aquatic habitats and biota is presented in Table 12. Issues and considerations for protection to aquatic habitat in the study area include:

5.1 Design Phase

- To minimise impact on fish passage and maintain connectivity between habitats in waterways crossed by the upgrade, NSW Fisheries Policies and Guidelines for waterway crossings would be used in designing "fish friendly" waterway crossings.
- Where feasible, single span bridges are the preferred option on Class 1 (and some Class 2) streams narrower than 30 m. If single span are not achievable at the Stewarts River, Stony Creek and Herons Creek waterways, then NSW Fisheries require that the bridge piers are set into the riverbed so as to avoid the low flow section of these waterways. Where possible, the bridge abutments should be situated back from the high bank to maintain natural scour protection.
- Culvert design should allow for fish passage. Culverts should be set into the creek bed and match the cross sectional width of the creek bed. It is recommended by NSW Fisheries that the box cells be set into the creek bed to allow an optimum water depth of 0.2-0.5 m within a culvert under base flow condition. Current practice is for culverts to be installed as quickly as practicable to ensure transverse drainage is in place during the early stage of construction [see Moorland to Herons Creek Soil and Water Controls, RTA 2003].

5.2 Construction Phase

- Erosion and sedimentation control measures used during construction including the use of silt fences/curtains and sedimentation basins are designed in accordance with the "Blue Book" (Department of Housing 1998) and RTA's Road Design Guide to achieve best practice erosion control and mitigation.
- As part of the Construction (EMP) for the project, and Acid Sulphate Management Plan would be prepared in acid sulphate soil risk areas, with further sampling and testing to be done of the sediments at risk area prior to any disturbance.
- If riparian vegetation needs to be removed during site preparation, NSW Fisheries prefer the "Cut Stump" method of removal to maintain natural scour protection.
- Current practice is for sediment basins to be set as close as possible to the waterway, maximising the capture of site run-off and minimising the area of cleared land. For works done in waterways, basic RTA practice is to surround the works with silt fences.

- If excavated/dredge material comprises acid sulphate material, it should be stockpiled away from waterways and wetlands. If this is not possible the stockpiled material should be bunded or contained to control potential run-off into surrounding habitat.
- Where work in watercourses is required (e.g. installing culverts) these works should be carried out during under the shortest possible timeframe and in as dry a condition as possible.
- NSW Fisheries prefer snags to be relocated to areas of the river adjacent to the construction and for these snags to remain in this position on completion as this would reduce handling.

5.3 Operational Phase

- The roadway would incorporate control measures to treat run-off from the carriageway before entering sensitive environments such as nearby wetlands and waterways.

6.0 RECOMMENDATION FOR MONITORING

Monitoring prior to and during construction should be undertaken for water quality in the Camden Haven River and in other waterways where disturbance to the creek bed or near the creek line would occur. Note the Department of Land and Water Conservation keeps water quality records from two freshwater tributaries which flow into the Camden Haven River about 4 and 13 km upstream of the existing crossing. It would appear that no data have been collected after May 2001, and the data are from the freshwater, not estuarine portions of the catchment. These data are not suitable to serve as baseline data or to include in a monitoring program that aims to identify potential changes in water quality in any of the waterways where construction would occur.

Monitoring should focus on levels of dissolved oxygen, turbidity and pH in the context of background levels in similar habitats elsewhere in the system. Given the likelihood that acid sulphate soils occur in the area and the potential for disturbance to these soils during construction, it is recommended that the potential for run-off from acid sulphate soils into the surrounding waterbody be investigated further. The design for such investigations should provide for sampling water immediately after the first flush of rain.

7.0 ACKNOWLEDGEMENTS

This report was written by Paul Godfrey and Karen Judd and reviewed and edited by Dr Peggy O'Donnell. Fish and mobile invertebrate samples were identified by Charmaine Bennett. Karen Judd did the statistical analyses and assisted Paul Godfrey with the Tables and Figures. Paul Godfrey, Tim Cooper and Scott Burgess did the field work.

8.0 REFERENCES

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

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

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

Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Trial Bay to Crowdy Head. Environment Protection Authority. Chatswood. NSW

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

Department of Land and Water Conservation (undated). GIS layer of Acid Sulphate Soils for the study area. Provided by Ove Arup and Partners.

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

Fletcher. B. and Gerrand. D (2000). Submission to the 'Independent Inquiry into Coastal Lakes, Healthy Rivers Commission'. Prepared by B. Fletcher, Wharf Road, Johns River.

Grey Diving Services (2001). Underwater Investigation of Proposed Bridge Location over Camden Haven River. Report to AURP, 25 October 2001.

Horrobin, P. (1996). A Guide to Inland Angling Waters of New South Wales. Australian Fishing Network, Victoria.

House, M. A., Ellis, J. B., Herricks, E. E., Hvitvedjacobsen, T., Seager, J., Lijklema, L., Aalderink, H. and Clifforde, I. T. (1993). Urban drainage - impacts on receiving water quality. *Water Science and Technology* **27**, pp. 117-158.

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

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

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

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

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

NSW Fisheries (1999a). Policy and Guidelines for Bridges, Causeways, Culverts and Similar Structures, 1999. Eds. S. Fairfull and S. Carter. NSW Fisheries, Sydney, 19 pp. The Ecology Lab (1996).

NSW Fisheries (1999b). *Policy and Guidelines: Aquatic Habitat Management and Fish Conservation:* (1999 Update). Smith, A. and Pollard, D. A. (eds.) NSW Fisheries, Port Stephens Research Centre.

NSW Fisheries (1999c). Threatened Species Management. Threatened Species Assessment under the EP&A Act: The '8 Part Test' of Significance. NSW Fisheries, Office of Conservation. Port Stephens, NSW

NSW Fisheries (2000a). New South Wales Commercial Fisheries Statistics 1993/94 to 1997/98. Fisheries Research Centre Cronulla, NSW Australia 2230.

NSW Fisheries (2000b). New South Wales Commercial Fisheries Statistics 1998/99. Fisheries Research Centre Cronulla, NSW Australia 2230.

NSW Fisheries (undated) 1999-2000 Oyster Production Data from Oyster Farms in New South Wales.

NSW Fisheries (undated). 1995/96 Oyster Production Data from Oyster Farms in New South Wales.

NSW Fisheries (undated). 1996-97 Oyster Production Data from Oyster Farms in New South Wales.

NSW Fisheries (undated). 1994/95 Oyster Production Data from Oyster Farms in New South Wales.

Perdikaki, K. and Mason, C. F. (1999). Impact of road run-off on receiving streams in Eastern England. *Water Research* **33**, pp. 1627-1633.

Pogonoski, J. (2000). Threatened Fish Profile. Black Rockcod *Epinephelus daemelii*.

Pollard. D (1999) Black Cod. Species Notes. Marine Parks News. The Newsletter of the Marine Parks Authority. Summer 1999/Autumn 2000. Volume 2 Issue No. 1.

Richardson, B.A. (1985) The impact of forest road construction on the benthic invertebrate and fish fauna of a coastal stream in southern NSW. Aust. Soc. Linmnol. Bull. 10, 65-68.

The Ecology Lab (2001). Pacific Highway Upgrade, Moorland to Herons Creek. Route Selection – Aquatic Ecology. Report No. 030001/A. Report Prepared for Ove Arup & Partners

Underwood, A. J. (1997). Experiments in Ecology, Their Logical Design and Interpretation Using Analysis of Variance. Cambridge University Press, UK, 504 pp.