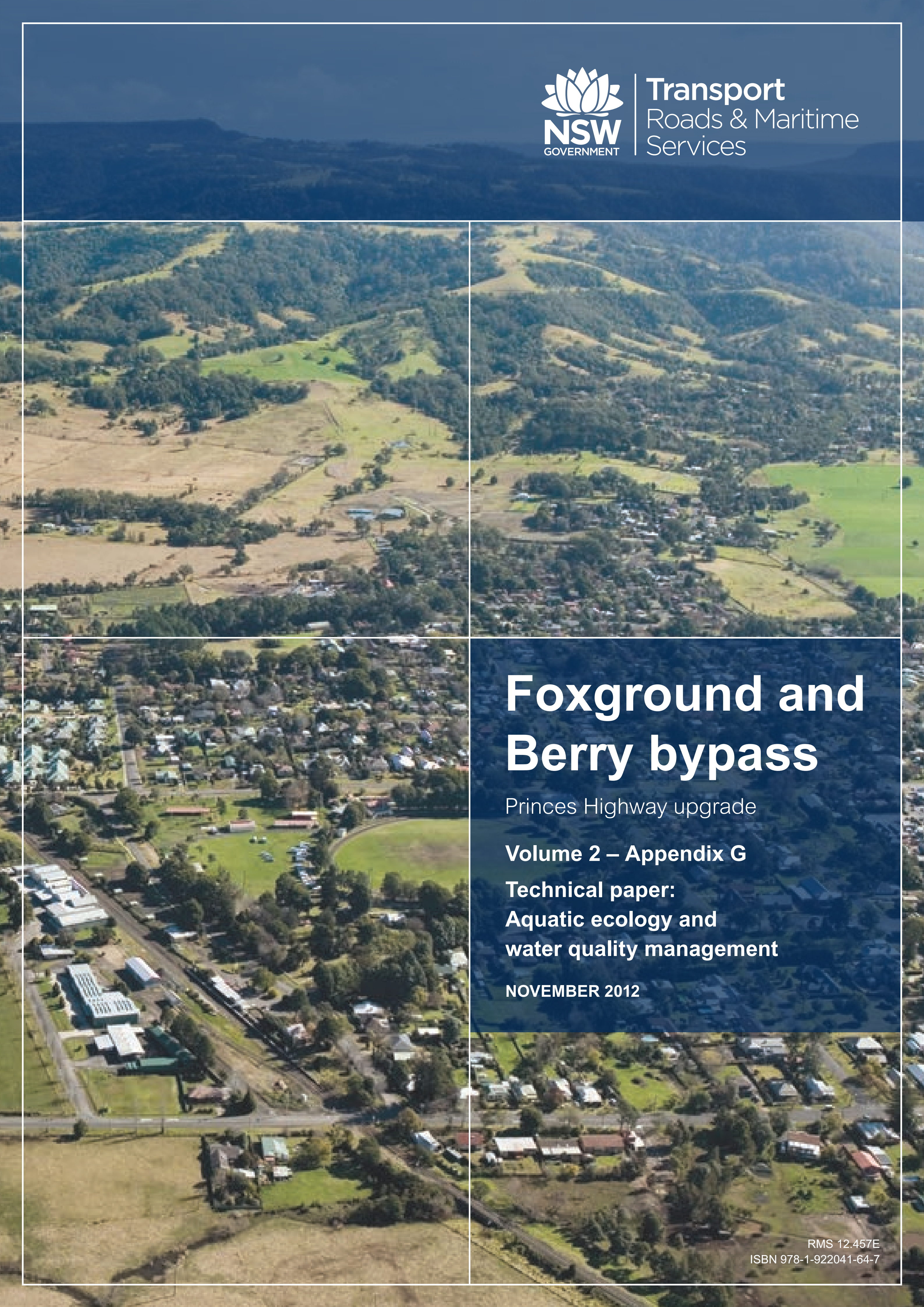

NSW GOVERNMENT | Transport Roads & Maritime Services

Foxground and Berry bypass

Princes Highway upgrade

Volume 2 – Appendix G

Technical paper: Aquatic ecology and water quality management

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Foxground and Berry bypass

Prepared for

Roads and Maritime Services

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Executive summary

Cardno Ecology Lab Pty Ltd was commissioned by AECOM on behalf of the Roads and Maritime Services of NSW (RMS) to carry out an aquatic ecology and water quality management assessment for the Foxground and Berry bypass project (the project).

RMS is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The aim of the assessment is to identify issues of conservation significance associated with the project. The specific objectives are to:

- Update existing information on aquatic habitat, biota and water quality within the region of the project (study area), including threatened species, populations, ecological communities and key threatening processes.
- Describe the nature, extent and condition of aquatic habitats and biotic communities and associated waterways within the study area based on field assessments.
- Assess the potential impacts of the project on aquatic ecology and water quality in the study area.
- Make recommendations to mitigate or offset potential impacts.

Aquatic ecology and water quality

The majority of the project is contained within the Broughton Creek catchment. Broughton Creek is the dominant watercourse within this catchment and originates in the Cambewarra Range. South of the Princes Highway alignment the creek flows in a south-westerly direction towards Berry. To the north and north-west of Berry are the smaller Broughton Mill Creek and Bundewallah Creek catchments. A smaller section of the project is located in the Crooked River catchment. This section of the project does not cross any significant waterways.

Freshwater habitat within the study area ranged from relatively healthy to significantly degraded. Riparian vegetation was generally absent on the smaller waterways, banks were unconsolidated, eroded and channels often colonised by pasture grasses and/or annual weeds. The larger waterways, particularly Broughton Creek, Broughton Mill Creek and Bundewallah Creek retain large sections of relatively complete riparian vegetation, support frequent alternation of riffles and pools sequences and considerable instream habitat (eg macrophytes, submerged woody debris, rocks and deep holes). Water quality in the catchment is typical of aquatic ecosystems that have been disturbed by agricultural practices. Downstream of the study area, in the low-lying floodplain, the tributaries of Broughton Creek have been highly modified by flood mitigation works.

AusRivAS (Australian River Assessment System) assessments found the aquatic macroinvertebrate assemblages within the Broughton Creek were generally moderately impaired, reflecting the effects of diffuse agricultural pollution and/or local habitat degradation, although the assemblages from pool edge habitat at Broughton Mill Creek and Bundewallah Creek were equivalent to reference condition. Macroinvertebrate assemblages were often dominated by pollution-tolerant taxa and usually had a greater proportion of pollution-tolerant taxa than at equivalent reference sites.

Assessment of impacts and recommendations

The potential environmental issues relating to the proposed highway upgrade primarily included:

- Mobilisation of sediment into waterways.
- Mobilisation of pollutants into aquatic habitat.
- Disturbance of acid sulfate soils.
- Establishment of invasive species within the study area.
- Degradation of riparian vegetation.
- Removal of large woody debris.
- Changes to the natural flow regime.
- Obstructions to fish passage.
- Presence of threatened and protected populations, species and endangered ecological communities.

An inventory of freshwater fish identified a total of 36 species as potentially being present within the region. Of these, three are introduced and two are listed as threatened. Macquarie Perch (*Macquaria australasica*) is listed as Vulnerable under the *Fisheries Management Act 1994* (FM Act) and Endangered under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). Australian Grayling is listed as Vulnerable under the EPBC Act. No listed threatened or protected species were observed in freshwater habitat within the study area.

Eight species of freshwater fish were recorded during the field surveys with the greatest diversity occurring in Broughton Creek. Broughton Creek was assessed as providing ‘major’ fish habitat (Class 1 Waterway) and Bundewallah and Broughton Mill Creek as providing ‘moderate’ fish habitat (Class 2 Waterway) (Fairfull and Witheridge 2003). The remaining watercourses in the study area are ephemeral and degraded and were assessed as providing ‘minimal’ to ‘unlikely’ fish habitat (Class 3 – 4 Waterways).

Provided the recommended mitigation measures are implemented it is unlikely that the works and structures associated with the construction and operation of the project would have long-term impacts on other threatened or protected species or the wider aquatic ecology of the area. The majority of potential impacts on aquatic ecology and water quality associated with the construction and design of the project could be avoided, minimised or mitigated.

Potential impacts from mobilised sediment would be minimised by an erosion and sediment control plan that implements standard sediment control measures. Similarly, potential contamination of waterways with polluted runoff from the highway or accidental spills would be mitigated by channelling and treating runoff in a system of sediment basins and/or vegetated swales.

Specific guidelines for the design and construction of waterway crossings to maintain fish passage have been developed by the NSW Government. An assessment of minimum recommended crossing requirements for each waterway that would be crossed by the project has been provided as input to the concept design.

Mitigation

It is recommended that several measures be implemented to avoid, minimise or mitigate potential issues arising from the project in regard to both its design and operation.

Design

It is recommended that the project design aim to minimise stormwater and disturbed surface runoff entering adjacent waterways by diverting and/or containing it in sediment basins/vegetated swales. Earthworks are recommended to be designed to minimise the risk of mobilising acid sulfate soils.

The project design would require the removal of 10 hectares of riparian habitat (within the project corridor, ancillary infrastructure and temporary crossing footprint) which would be compensated for within an offset.

Impacts on the natural surface and groundwater flow regime of the study area would be minimised through the redirection of groundwater seepage into aquatic habitats via longitudinal drainage systems. It is recommended that bridge structures be designed to have minimal impact on the natural flow regime and to provide immunity from 100 and 50 year ARI flood events respectively. It is recommended that no bridge piers or abutments be positioned within the section of waterway channel (wetted width) that carries median flows. Therefore, bridges are the recommended structures for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. It is recommended that bridge piers be placed outside the main channel where possible to avoid formation of turbulence and bed erosion, and abutments placed away from the bank. Due to their size and classification as fish habitat, culverts are considered adequate crossings for the remaining waterways.

It is recommended that the design of the channel created to divert flows from Town Creek into Bundewallah Creek aim to mimic a natural creek line, mimicking as far a practical natural (non-linear) alignment, creek beds and bank form. Bank design should be optimised to allow planting and maintenance of native riparian floral communities.

Construction

Erosion and sediment controls, such as bunding, silt fences/curtains, sediment basins and vegetated swales are recommended to mitigate potential impacts to aquatic ecology during the construction phase of the project.

It is recommended that runoff from disturbed areas, stockpiles and dust suppression/washdown facilities be diverted into sediment basins and erosion controls, and that clean water be diverted around disturbed areas. Areas of exposed earthworks are recommended to be re-vegetated and remediated as soon as possible with erosion controls and sediment traps remaining in place until vegetation cover has been established. It is recommended that project works and ancillary infrastructure not take place within 50 metres of Category 1 (Environmental Corridor) riparian habitat.

The outline of a surface water quality monitoring program consistent with (Australian and New Zealand Environment Conservation Council (ANZECC) guidelines has been prepared (Appendix F) and its incorporation into the erosion and sediment control plan is recommended. The measures that are recommended to mitigate erosion and sedimentation would also address potential contamination and pollution issues. It is additionally recommended that any hazardous substances be properly handled, stored, transported and disposed of.

To avoid spreading the invasive aquatic Alligator Weed observed within the study area it is recommended that large woody debris displaced during construction be relocated within the same reach.

Residual impacts on aquatic ecology and water quality that cannot be adequately mitigated and fail to 'maintain or improve' biodiversity include:

- Loss of 10 hectares of riparian habitat within the project corridor, comprised of 2.9 hectares Riverbank forest directly impacted and 7.1 hectares indirectly impacted, including ancillary sites and temporary creek crossing footprints. The area directly impacted includes a small area of riparian habitat that would be degraded as a result of the diversion of flow from Town Creek north of the upgrade, across pasture land and directed into Bundewallah Creek via a constructed creek channel.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Slight changes to hydrology due to placement of a pier structures within the waterway at Bundewallah Creek.
- Potential reduced longitudinal connectivity at temporary creek crossings and temporary construction pads during low flows.
- Changes to hydrology at Town Creek, Bundewallah Creek and Broughton Creek from the diversion of Town Creek and installation of transverse road drainage structures.

The Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) have a policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat (Smith and Pollard 1999). Compensation for the unavoidable loss of riparian habitat for the project is addressed in a Biodiversity Offset Strategy detailed in the *Foxground and Berry bypass Terrestrial Flora and Fauna Technical Paper* (Biosis 2012) which was prepared for this environmental assessment and is provided at Appendix F of the environmental assessment.

Due to the potential lag in the response of aquatic macroinvertebrates to disturbances it is recommended that aquatic ecological monitoring be carried out in conjunction with surface water quality monitoring to assess the effectiveness of the construction erosion and sediment control plan and potential operational impacts on aquatic macroinvertebrates. Outlines for surface water quality monitoring and ecological monitoring programs are presented in Appendices F and G of this report.

Should the recommended mitigation measures and Biodiversity Offset Strategy be implemented as outlined, then the project should result in no net/residual/long-term impacts on aquatic ecology and water quality.

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1 Introduction

1.1 Background and objectives

The Roads and Maritime Services (RMS) is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) highway with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The general features of the project are:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Road, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent stockpiling site for general road maintenance.

The project and the key features of the project are shown **Figure 1.1**.

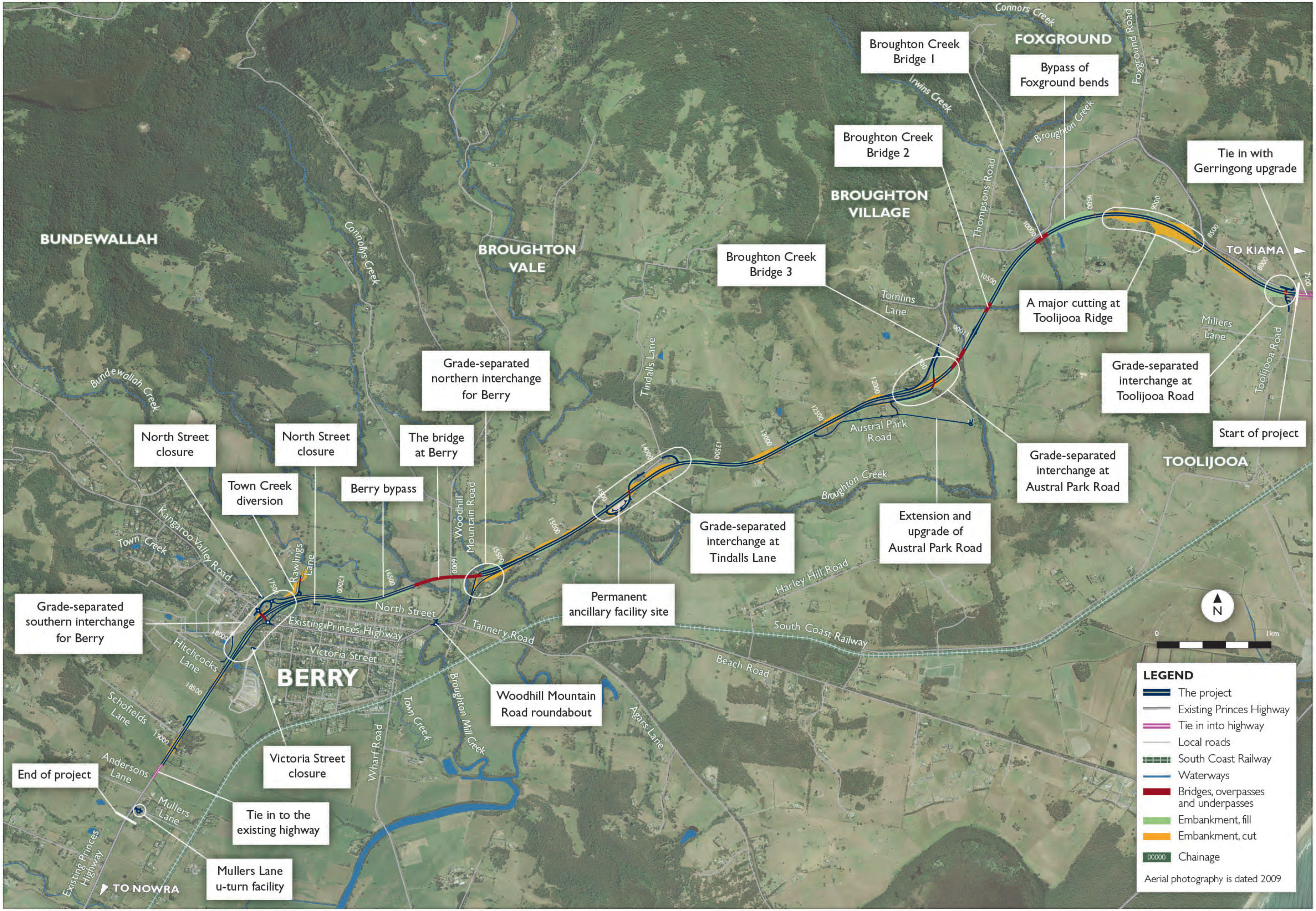

Figure 1-1: Foxground and Berry bypass project area

This technical paper presents an assessment of the potential environmental impacts of the project on aquatic ecology and water quality in the context of an environmental assessment as required under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1.1 Objectives of the aquatic ecology and water quality assessment

The objectives of this assessment are to provide a description of the aquatic habitats, biota and water quality within the study area (the footprint of the project and 50 metre buffer), with the aim of assessing constraints and opportunities associated with the project. This report provides information that would assist the selection of the most appropriate design structures and construction methodology. The specific objectives of this assessment study are:

- Update existing information on aquatic habitat, biota and water quality within the study area, including threatened species, populations, ecological communities and listed key threatening processes.
- Describe the nature, extent and condition of aquatic habitats and biotic communities and associated waterways within the study area based on field assessments.
- Assess the potential impacts of the project on aquatic ecology and water quality in the study area.
- Make recommendations to mitigate or offset potential impacts.

1.2 Agency consultation

In relation to aquatic ecology and water quality, this document addresses the relevant Director-General's requirements (DGRs) as indicated in **Table 1.1** below.

Table 1.1: DGRs for aquatic ecology and water quality

Director-General's requirements	Relevant section in this document
An **assessment of the key issues,** including an assessment of the worst case and representative impact for each issue for all aspects of the project (including the proposed locations of and/or options for the ancillary facilities) with the following aspects addressed for each key issue (where relevant):	Summarised in Executive Summary Section 4
• Describe the existing environment.	Section 3
• Assess the potential impacts of the proposal at both construction and operation stages, in accordance with relevant policies and guidelines. Both direct and indirect impacts must be considered including potential interactions with the existing Princes Highway (as relevant).	Section 4
• Identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/or in developing management/mitigation measures.	Section 1.4 Section 3.3 Section 4.3 Section 4.3 Section 5.1
• Describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the project and the residual impacts.	Section 5.1

Director-General's requirements	Relevant section in this document
Flora and fauna – including but not limited to:	
• An assessment of all project components on flora and fauna and their habitat (both terrestrial and aquatic as relevant) consistent with the Draft Guidelines for Threatened Species Assessment (DEC 2005).	Section 4
• Specific consideration of impacts to threatened species, populations, ecological communities and/or critical habitat listed under both State and Commonwealth legislation that have been recorded on the site and surrounding land.	Section 3.3 Section 4.2 Section 4.3
• Details on the existing site conditions (both terrestrial and aquatic) and quantity and likelihood of disturbance (including quantifying the worst case extent of impact on the basis of vegetation type and total native vegetation disturbed).	Section 4
• As relevant, consideration of weed infestation and edge effects; habitat fragmentation, impacts to wildlife and riparian corridors; impacts to groundwater-dependent communities, riparian and aquatic habitat (including impacts on SEPP 14 wetlands and fish passage).	Section 4
• Provide details of how flora and fauna impacts would be managed during construction and operation for all project components, including adaptive management and maintenance protocols and monitoring programs.	Section 5.1 Appendix F Appendix G
• Demonstrate actions to be undertaken to avoid, mitigate or offset impacts associated with the project (all components) consistent with the principles of "improve or maintain". Sufficient details must be provided to demonstrate the availability of viable and achievable options to offset the impacts of the project, where offset measures are proposed to address residual impacts.	Section 5 Appendix F
Surface and ground water - including but not limited to:	
• Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase.	Section 5 Appendix F
• Identify potential risks of the project on groundwater resources including: impacts to groundwater quality and implications for groundwater-dependent ecological communities.	Section 4.1.4
• Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	Section 5 Appendix G

1.3 Project description

1.3.1 The study area

The project is located west of Gerringong, and extends from the junction of Toolijooa Road and the Princes Highway for around 11.6 kilometres to the junction of Schofields Lane and the Princes Highway, south of Berry. The project lies partly within the Kiama local government area (LGA) and partly within the Shoalhaven LGA.

The project largely follows the existing Princes Highway corridor, deviating away in two locations, once across Toolijooa Ridge and the Broughton Creek floodplain and a second deviation with a northern bypass of Berry.

In addition to crossings of minor waterways and ephemeral drainage lines along its length, the project crosses Broughton Creek three times as it traverses the floodplain, with the northern-most crossing occurring adjacent to the existing Princes Highway bridge crossing. The project also includes a substantial crossing of Broughton Mill Creek and Bundewallah Creek as part of the bypass around Berry via a bridge around 600 metres long. The bridge at Berry would extend over Broughton Mill Creek and Woodhill Mountain Road, and then run along the north side of Bundewallah Creek for around 300 metres before crossing the creek (downstream of the confluence of Bundewallah and Connollys creeks).

Potential environmental impacts associated with the project can extend to areas beyond the immediate footprint of the project corridor. The area considered in the aquatic ecology and water quality management assessment therefore includes aquatic habitat and biota upstream and downstream of the project (**Figure 1.1**). The project crosses sections of both the Crooked River and Broughton Creek catchments. The Crooked River catchment includes the estuarine Crooked River Lagoon. The upper Broughton Creek catchment includes the smaller sub-catchments of Bundewallah Creek and Broughton Mill Creek. The estuarine reach of Broughton Creek and the Shoalhaven/Crookhaven estuary are located downstream of the project.

1.3.2 Concept design

Project design and engineering considerations relevant to aquatic ecology and water quality include:

- Bridge structures over three crossings of Broughton Creek and one substantial bridge structure (around 600 metres long) spanning Broughton Mill Creek, Woodhill Mountain Road and Bundewallah Creek (the bridge at Berry).
- Five temporary creek crossings and possible temporary construction pads in the vicinity of the proposed bridge structures (above) during the construction phase.
- Placement of bridge pier structures within the waterway at Bundewallah Creek.
- Provision of drainage structures (such as culverts and bridges) within the road embankment for flood mitigation during flow events. Transverse drainage structures would be sized to control flow and manage downstream flooding in some instances.
- The diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.
- Drainage and retention basin/swale systems to control and discharge drainage from cuttings and embankments.
- Widening of the existing highway corridor.
- Earthworks include cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep as the project traverses Toolijooa Ridge.

- Construction of an embankment linking two bridge structures crossing Broughton Creek (Crossing L and Crossing M).
- Appropriate batter slopes and engineering treatment to mitigate potential instability on steep side slopes of ridges with deep colluvial soils.
- Possible ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Ancillary infrastructure constructed near or over existing waterways such as stockpiles, drilling/blasting compound and crushing plant, temporary traffic facilities (temporary creek crossings) and diversion networks, site compounds and offices, vehicle washdown facilities and vehicle/plant storage. Examples include:
  - RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane.
  - Bridge compound and stockpile associated with the proposed Broughton Creek Bridge 1 (Crossing K).
  - Bridge satellite compound near Town Creek.
  - Permanent ancillary facility at the site of the existing quarry/stockpile adjacent to the Princes Highway two kilometres north-east of Berry.
  - Temporary creek crossings near each proposed bridge structure.
- Clearing of limited riparian vegetation to provide temporary creek crossings.

1.3.3 Limitations of assessment

Field surveys of aquatic habitat, biota and water quality were undertaken by Cardno Ecology Lab from 15 April 2009 to 17 April 2009, with subsequent inspection of potential sites for temporary creek crossings on 28 June 2011. Water quality parameters recorded, species sampled or observed are likely to be representative of the range of conditions and species that could be recorded using the methodology employed, but should be considered "snapshot" in nature rather than representing seasonal changes in aquatic assemblage that may occur. Surveys were undertaken following a period of locally significant rainfall which was not considered to have significantly affected the number or type of species recorded.

1.4 Policy context and legislative framework

With reference to aquatic flora and fauna and aquatic habitat, the following statutory requirements and policy are relevant to the project.

1.4.1 *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Under the EPBC Act, administered by the Commonwealth via the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), actions that are likely to have a significant impact on a matter of national environmental significance (MNES) are subject to a referral, assessment and approval process. MNES relevant to the project include threatened aquatic species, populations and ecological communities listed under the EPBC Act. Listed migratory species; cetaceans; marine species and Ramsar areas of national significance are protected under this Act.

1.4.2 *Environmental Planning and Assessment Act 1979* (EP&A Act)

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) provide the statutory planning framework for environmental assessment of the project. The Minister for Planning has declared by Order that the project is "*major infrastructure*" and as such will be assessed under Part 3A of the EP&A Act. The provisions of Part 3A detail the approval process for major infrastructure and other significant projects, with the Minister for Planning as the approval authority for the project.

Aquatic threatened species assessment was carried out according to NSW Office of Environment and Heritage (OEH) and Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) (DEC/DPI 2005). The guidelines identify important factors and/or heads of consideration that must be considered by proponents when assessing impacts on threatened species, populations, or ecological communities for projects assessed under Part 3A of the EP&A Act.

Section 75R (2) of the EP&A Act states that State Environmental Planning Policies (SEPPs) apply to:

(a) *The declaration of a project as a project to which this Part applies or as a critical infrastructure project; and*

(b) *The carrying out of a project, but (in the case of a critical infrastructure project) only to the extent that provisions of such a policy expressly provide that they apply to and in respect of the particular project.*

The following SEPPs are relevant to the project:

- ***State Environmental Planning Policy No. 14 – coastal wetlands***

  SEPP 14 provides protection for wetlands identified as significant coastal wetlands and gazetted for protection.

- ***State Environmental Planning Policy No. 71 – coastal protection***

  SEPP 71 applies to land defined as the coastal zone by maps held by local council and identifies a number of issues to be considered by a consent authority before issuing development consent.

Section 75R (3) of the EP&A Act states that:

> *"environmental planning instruments (other than State environmental planning policies) do not apply to or in respect of an approved project".*

As the project has been declared to be a project to which Part 3A applies, local environmental plans do not apply to the project. The Minister may, but need not, consider these plans in the determination of the project. The following Local Environmental Plans *(*LEPs) apply to the land in the project location;

- *Shoalhaven LEP 1985.*
- *Kiama LEP 1996.*
- *Draft Kiama LEP 2010.*

As discussed above the Director-General of the NSW Department of Planning and Infrastructure (DP&I) has issued DGRs for the project. The points relevant to the aquatic ecology and water quality assessment are detailed in **Table 1.1**.

1.4.3 *Water Management Act 2000* (WM Act)

Works within 40 metres of a lake, river or estuary require a controlled activity approval under this Act. However as '*major infrastructure'* under Part 3A of the EP&A Act, controlled activity approval is not required. Requirements under the WM Act are addressed by DP&I in the issuing of DGRs.

1.4.4 *Protection of the Environment Operations Act 1997* and *Protection of the Environment Operations Amendment Act 2005*

It is offence to pollute the environment under the *Protection of the Environment Operations Act 1997*. An environmental protection licence is required for scheduled activities.

1.4.5 *Threatened Species Conservation Act 1995* (TSC Act)

The TSC Act lists threatened species, populations and endangered ecological communities (EECs) under Schedules 1 and 2 of the TSC Act, that are priorities for conservation within NSW. Schedule 3 of the TSC Act lists key threatening processes for species, populations and ecological communities within NSW. The TSC Act is predominantly concerned with terrestrial biota but does include some aquatic groups; such as aquatic plants, aquatic reptiles, aquatic mammals and aquatic EECs.

This aquatic ecology and water quality management assessment considered potential impacts to aquatic biota listed under the TSC Act that are known or considered likely to occur within the study area. A licence under Section 91 is required if it is determined that a threatened species, population or ecological community is likely to be harmed.

NSW OEH (formerly DECCW), a division of the NSW Department of Premier and Cabinet (DPC), is responsible for administering the TSC Act. In 2010, the then DECCW released the South Coast Regional Conservation Plan (RCP) (DECCW 2010) to guide natural heritage conservation on lands on the south coast excluding national parks and State forests. The RCP identifies areas of high conservation value and provides strategic direction to planning so that future development can occur without jeopardising regional goals of 'improving or maintaining' biodiversity. The project has been assessed to ensure it is consistent with the objectives of the South Coast RCP.

Riparian habitat of each waterway within the study area was classified according to criteria developed by the then NSW Department of Infrastructure, Planning and Natural Resources *Riparian Corridor Management Study* in the Wollongong LGA (DIPNR 2004). DIPNR has subsequently become part of DP&I and OEH.

1.4.6 *Fisheries Management Act 1994* (FM Act) and *Fisheries Management Amendment Act 1997* (FMA Act)

The FM Act and its regulations are administered by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS; formerly Industry and Investment NSW and also referred to in this document as DPI) and are relevant to aquatic habitat and fauna that have the potential to be affected by the project. The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW Waters. This aquatic ecology and water quality management assessment considers potential impacts to all species, populations and EECs listed under the FM Act that are known or considered likely to occur within the study area.

The following sections of the FM Act have relevance but are exempt under a Part 3A approval:

- Section 199 – permit required for any dredging or reclamation works.
- Section 219 – permit required for any obstructions to fish passage.

Other relevant sections include:

- Section 37 (Miscellaneous collection) – permit required to harm more fish or invertebrates than is currently allowed by restrictions on daily limits.

The classification of waterways in the study area was carried out according to 'NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The assessment of impacts assumed that any waterway crossing would be designed and built to comply with these guidelines and policies.

2 Methods

2.1 Review of existing information

Existing information on aquatic habitats and their associated biota within the study area was obtained by searching Cardno Ecology Lab's extensive specialist library and undertaking searches for relevant literature using the internet.

Relevant threatened species, populations and EECs that do, or may, occur within the study area were identified by reviewing published distributions and current listings on databases maintained by DSEWPaC, DTIRIS and OEH. Results from a previous search of NSW Government database BioNet made on 7 September 2007 during the aquatic ecology and water quality management assessment stage were also used (note: BioNet database is no longer operational). DSEWPaC, DTIRIS and OEH database searches were current as at 22 June 2011. The following search tools were used:

- The *DSEWPaC Protected Matters Search Tool*: used to determine relevant MNES, listed Marine Species and Migratory Marine Species under the schedules of the EBPC Act pertaining to the project. The primary search area was defined as the section of the Crooked River catchment traversed by the project and Broughton Creek catchment downstream to its confluence with Shoalhaven River (about 16 kilometres downstream of Berry). A second expanded search included the ecologically significant but distant downstream aquatic habitat of the Shoalhaven/Crookhaven estuary.
- The DTIRIS *Threatened and Protected Species Record Viewer* used to search for records of relevant threatened and protected species listed by Schedules 4, 4A and 5 of the FM Act as occurring in the Kiama and Shoalhaven LGAs and the broader Southern Rivers Catchment Management Authority (CMA) area.
- *The OEH Geographic Region Search tool and NSW Atlas of Wildlife database*: used to determine whether relevant threatened species, populations or aquatic EECs listed under the TSC Act were present. The Illawarra and Jervis sub-regions of the broader Southern Rivers Catchment Management Authority (CMA) area were selected as the search region for the OEH Geographic Region Search and the Kiama and Shoalhaven LGAs were selected as the search region for the *Atlas of Wildlife database*.
- Water Quality Data from The Ecology Lab (1999, 2007).

Searches were done for the presence of significant or critical aquatic habitat such as SEPP 14 and Ramsar wetlands.

2.2 Field sampling methodology

Field investigations of aquatic habitat, biota and water quality were undertaken by Cardno Ecology Lab from 15 April 2009 to 17 April 2009. Additional field investigations to identify four potential sites for temporary creek crossings were done on 28 June 2011 (Crossing K, L, M and T on **Figure 2.1**).

At each site a general habitat description, a Riparian, Channel and Environmental inventory (RCE, NSW Environment Protection Authority (EPA) and Chessman *et al.* 1997) and fish habitat assessment was made. Where appropriate, recordings were made of water quality, macrophyte, macroinvertebrate and fish assemblages and existing waterway crossings. Sampling at each site depended on the nature of the waterway, with factors such as stream width, depth, flow rate and likelihood of target groups occurring in that area.

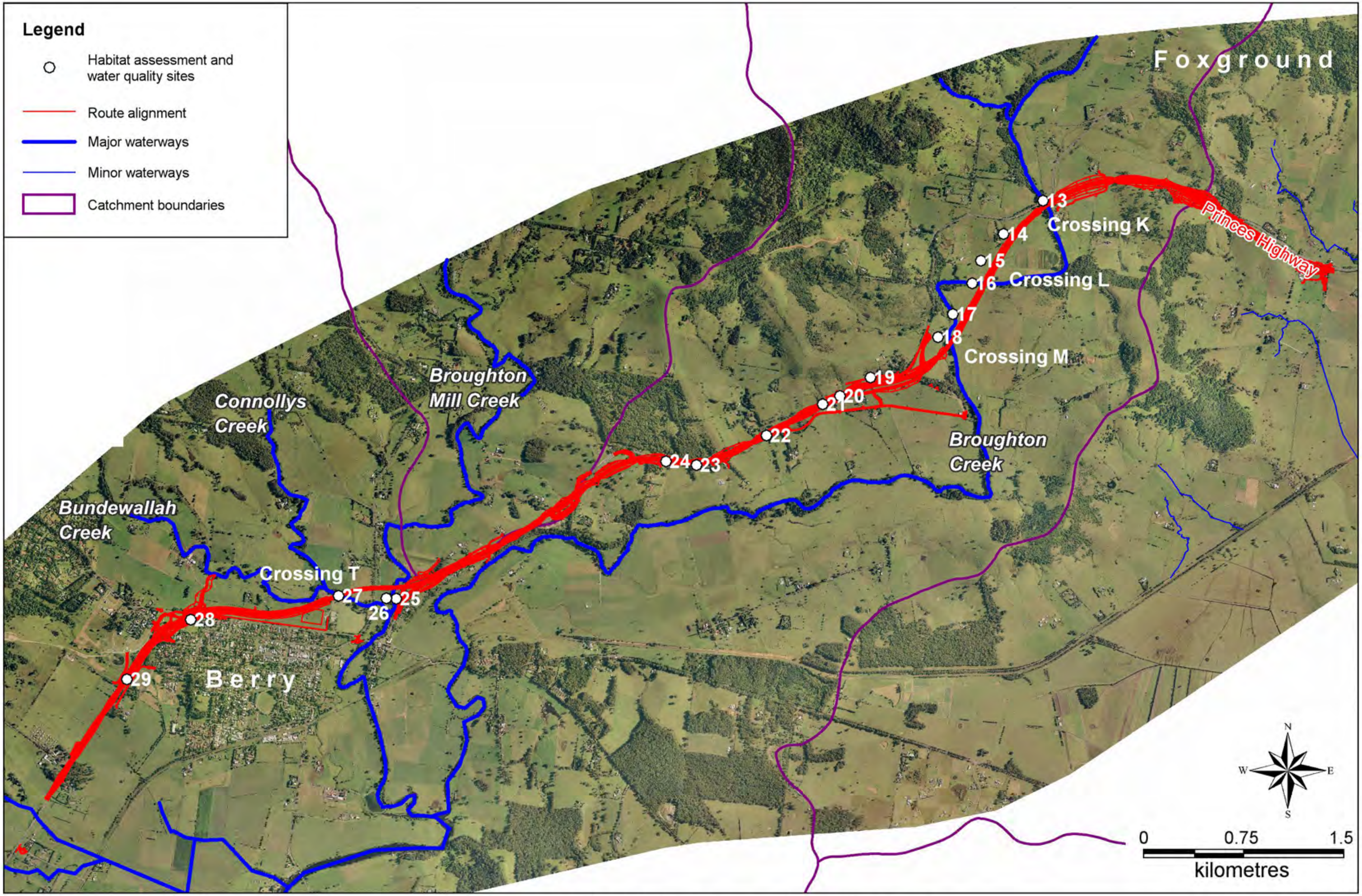

Figure 2.1: Foxground to Berry project area indicating major waterways and sites for habitat assessment and water quality

2.2.1 Site selection

Aquatic ecology and water quality management assessment sites were selected where waterways intersected with the project alignment and/or where aquatic habitat was present that could potentially support threatened species. The aquatic habitat at each site ranged from moderate sized rivers to ephemeral waterways that only flow in high rainfall events. In total, 17 sites were selected along the project (**Figure 2.1**).

RMS identified the need for five temporary creek crossings, for construction purposes, which would be required near the site of each permanent creek crossing by a proposed bridge structure. These include the three crossings of Broughton Creek by Bridge 1, Bridge 2 and Bridge 3 (Crossings K, L and M respectively in the *Foxground and Berry bypass Concept Design report* (RMS 2012)) and the crossings of Broughton Mill Creek and Bundewallah Creek by Bridge 4 (Crossing T in the Concept Design report (RMS 2012)) (**Figure 2.1**). RMS identified the location of the temporary creek crossing at Bridge 1 (Crossing K) as immediately downstream of the proposed bridge site but asked Cardno Ecology Lab and Biosis (terrestrial ecology consultants) to identify suitable locations for the remaining four temporary crossings. Constraints on the location of temporary crossings identified by RMS were:

- Sites may be upstream or downstream of the proposed bridge structures.
- Sites should be dependent on space, environmental issues (eg mature riparian vegetation) and bank shape (shallow low banks preferred).
- Sites should require minimal bank works.
- Sites should be located within RMS owned land.

Cardno Ecology Lab and Biosis Research selected four sites within RMS' identified constraints that would result in the least possible impacts on aquatic and terrestrial ecology and water quality for Crossings L, M and T. The location of the temporary creek crossing at Bridge 1 (Crossing K) was identified by RMS.

2.2.2 Habitat characteristics

Habitats were characterised using three classification schemes.

RCE classification

At each site, a standardised description of adjacent land and condition of riverbanks, channel and bed was recorded using the RCE. RCE is used to scale and quantify the environmental state of particular locations for use in management decisions. The RCE score for each site is calculated by summing the scores for each descriptor noted (Appendix A). The highest score (52) would be assigned to a stream with little or no obvious physical disruption. The lowest score (13) would be assigned to a heavily channelled stream without any riparian vegetation.

This methodology was developed by Peterson (1992) and modified for Australian conditions by Chessman *et al.* (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4. Habitat descriptors included:

- Geomorphological characteristics of the waterways.
- Types of land use along the waterway (eg industries associated with the river, recreational uses).
- Riparian vegetation and instream vegetation (eg presence/absence, native or exotic, condition).
- Substratum type (eg rock, sand, gravel, alluvial substrata).

Riparian corridor management classification

Riparian habitat of each waterway was classified according to criteria developed by NSW DIPNR *Riparian Corridor Management Study (RCMS) in the Wollongong Local Government Area* (DIPNR 2004). The aim of an RCMS is to develop a strategic context or long-term vision for how a region's waterways are valued and anticipated to function in the future. RCMS moves away from a simple riparian classification based purely on stream order, as all key aspects of a streams' function and context are considered. The classifications are therefore informed by existing habitat values and also potential value if rehabilitated. In this system, watercourses are assigned to one of three categories, each with different protection requirements and minimum core riparian zone (CRZ) widths. In order of importance, these categories are:

- *Category 1* – Environmental Corridor: The objective is to provide biodiversity linkages by maintaining connectivity for the movement of aquatic species along the riparian corridor and between key destinations (eg bottom and top of catchment or adjacent wetlands). The CRZ is 100 metres (two metre x 40 metre fully vegetated, two metre x 10 metre buffer).
- *Category 2* – Aquatic Habitat: The objective is to provide basic habitat and preserve or emulate as much as possible a naturally functioning stream (not necessarily linking key destinations). The width of the riparian corridor must be sufficient to provide long-term robust habitat and refuge for native fauna. The CRZ is 60 metres (two metre x 20 metre fully vegetated, two metre x 10 metre buffer).
- *Category 3* – Bank Stability and Water Quality: The objectives are to prevent accelerated rates of soil erosion and enhance water quality. This category may have limited habitat value but contributes to the overall basic health of a catchment. Although an open watercourse emulating some natural stream function is the preferred option, it is recognised for example, that the practicality and economics of developing urban land may make this difficult. It is this category of watercourse where alternative solutions to deliver the category objectives can be considered. The CRZ is 20 metres (two metre x 10 metre, no buffer).

Note: DIPNR's (2004) holistic riparian classification system considers hydrology, geomorphology, aquatic ecology and terrestrial ecology. The aquatic ecology and water quality management assessment has applied RCMS categories to waterways within the study area on the basis of water quality and aquatic ecological structure and function. Terrestrial ecology is outside the scope of the aquatic ecology and water quality management assessment and therefore assessment and discussion of riparian corridors within the study area from the perspective of terrestrial ecology (linking nodes of vegetation) is contained within the *Terrestrial Flora and Fauna assessment* (Biosis 2012) located at Appendix F of the environmental assessment.

Fish habitat classification

The waterway at each site was classified for fish habitat. The classification of fish habitat in the study area's waterways was done according to *NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation* (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The criteria for the fish habitat classifications are reproduced in Appendix B. The assessment of impacts assumed that any waterway crossing would be designed and built to comply with these guidelines and policies.

General observations were also recorded, including water characteristics such as flow rates and colour, the presence of spawning areas (eg gravel beds, riparian vegetation, snags), refugia (eg deep pools) and presence of natural or artificial barriers to fish passage both upstream and downstream (eg weirs, dams, waterfalls and causeways) and the type of existing waterway crossing if present.

2.2.3 Water quality

Water quality was measured at each site (refer **Figure 2.1**) using a Yeo-Kal 611 probe. Physical-chemical properties measured included: electrical conductivity (ms/cm and µs/cm); salinity (ppt); temperature (^{0}C); turbidity (ntu); dissolved oxygen (mg/L and per cent saturation); pH; and ORP (oxidation reduction potential: mV). Alkalinity (mg $CaCO_3$/L) was measured *in situ* using hand-held titration cells from CHEMetrics.

Two replicate measures of each variable were taken from just below the water surface at each site, except for alkalinity, where only one replicate measure was taken.

2.2.4 Macrophytes

The presence of instream macrophyte taxa was recorded. The survey was done at an appropriate time to reveal a comprehensive range of macrophyte species present.

2.2.5 Macroinvertebrates

Macroinvertebrates in the pool edge and riffle habitats of three sites were sampled during the autumn period (defined as the 15 March to 15 June) in accordance with the Rapid Assessment Method (RAM) based on AusRivAS (Turak *et al*. 2004). The three sampled sites were located in Broughton Creek (site 13), Broughton Mill Creek (site 25) and Bundewallah Creek (site 27) (**Figure 2.1**). One edge sample and one riffle sample were collected from each site. Pool edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al.* 2004). Riffle habitat is an area of broken water with rapid current that generally has some cobble or boulder substratum.

Under AusRivAS protocol, the size of sites for macroinvertebrate sampling is determined as a distance ten times the mode channel width or a minimum of 100 metres in length. Samples were collected over a total length of 10 metres of edge or 10 metres of riffle habitat, usually in one to two metre sections, ensuring that all significant sub-habitats within each site were sampled (Turak *et al*. 2004). The chemical and physical variables required for running the AusRivAS predictive model were also recorded from each site.

Dip nets with a mesh size of 250 µm were used to collect invertebrates. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect suspended invertebrates and surface dwelling animals. Each AusRivAS sample was rinsed in the net with local water to minimise fine particles and placed into a white sorting tray. Animals were removed from the tray using forceps and pipettes. Trained staff removed animals for a minimum period of thirty minutes. Thereafter, removals were performed in ten minute periods to a total of one hour, at which time removals would cease if no new taxa were found in a ten minute period. The animals collected were placed inside a labelled jar containing 70 per cent ethanol and taken to the laboratory. Finally, debris remaining in the tray after processing was returned to the creek in the locality where the sample was originally collected.

2.2.6 Fish

Electrofishing was used in appropriate habitats at four sites to sample fish and large mobile macroinvertebrates. These techniques are non-destructive, and all but introduced pest species such as the mosquito fish (*Gambusia holbrooki*), were returned unharmed to the water. The sampled sites were Broughton Creek (site 13), unnamed watercourse (site 22), Broughton Mill Creek (site 25) and Bundewallah Creek (site 27) (**Figure 2.1**). Sampling for fish was not possible at many of the waterways that cross the project as they were either dry or did not contain enough standing water.

Electrofishing is a commonly used, non-destructive technique for sampling fish in freshwater habitats such as creeks, drainage ditches and streams. The technique involves discharging an electric pulse into the water which stuns fish, allowing them to be easily netted, counted, identified and released. Electrofishing was done in riffles, shallow pools and beneath overhanging banks and vegetation. One staff member used the electrofisher, whilst a second handled a dip net and was primarily responsible for the capture of stunned fish. Captured fish were placed into a fish box, filled with stream water, which was handled by a third person on the bank. The third person acted as a safety officer for the other two.

The entire length of each site was electrofished and duration of fishing recorded. The amount of fishable habitat varied among sites and therefore time fished varied. Fishing power (amps) was standardised across sites by adjusting voltage output according to the electrical conductivity of the water. All fish caught were identified in the field and released as quickly as practicably possible.

Surveys of fish were undertaken once during autumn (April 2009) and revealed the fish present at the time at each site. This survey provides no information on potential variation in fish populations through time; rather it presents an appropriate ‘snapshot’ of fish communities. Electrofishing was preferred to sampling with baited fish traps, as the latter can be relatively ineffective if certain taxa or individuals are not feeding.

2.3 Data analysis

2.3.1 Water quality

The results of water quality analysis collected *in situ* during site inspections by Cardno Ecology Lab were used to assess water quality within the study area in terms of the health of aquatic ecosystems by comparison with the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines for low-land rivers in south-eastern Australia.

As water quality data was collected only once, it is a ‘snapshot’ in nature, and does not provide information on possible variations through time. The data is supported by data collected from previous studies (AWT 1999, The Ecology Lab 1999, 2007).

2.3.2 Macroinvertebrate AusRivAS models

The AusRivAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at undisturbed, reference sites. Observed freshwater macroinvertebrate assemblages (ie those collected in the field) are compared to macroinvertebrate assemblages expected from reference (undisturbed) waterways of the same type, to provide a basis to assess the health of the stream. The data from this study was analysed using the NSW model for pool edge habitats sampled in autumn. The AusRivAS predictive model generates the following indices:

- OE50Taxa – This is the number of macroinvertebrate families with a greater than 50 per cent predicted probability of occurrence that were actually observed (ie collected) at a site expressed as a ratio of the number of macroinvertebrate families with a greater than 50 per cent probability of occurrence expected to occur at pristine sites with similar physical and chemical characteristics. OE50 taxa values range from zero to slightly greater than one and provide a measure of the impairment of macroinvertebrate assemblages at each site. Values close to zero indicate an impoverished assemblage while values close to one indicate that the condition of the assemblage is similar to that of the reference streams.
- Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. AusRivAS Autumn bands are graded as follows (E = Edge and R = Riffle):
  - **Band X** = Richer invertebrate assemblage than reference condition (OE50 > 1. 17 (E) 1. 13 (R)).
  - **Band A** = Equivalent to reference condition (OE50 upper limit = 1. 17(E) 1. 13 (R)).
  - **Band B** = Sites below reference condition (ie significantly impaired) (OE50 upper limit = 0. 81 (E) 0. 86 (R)).
  - **Band C** = Sites well below reference condition (ie severely impaired) (OE50 upper limit = 0. 46 (E) 0. 6 (R)).
  - **Band D** = Impoverished (OE50 upper limit = 0. 11 (E) 0. 34 (R)).

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between one and 10 to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index.

The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

- SIGNAL > 6 = Healthy habitat.
- SIGNAL 5 – 6 = Mild pollution.
- SIGNAL 4 – 5 = Moderate pollution.
- SIGNAL < 4 = Severe pollution.

Two SIGNAL scores produced by the AusRivAS predictive model were also examined:

- O0Signal index - observed SIGNAL score for taxa that have a probability of occurrence greater than zero per cent. This is calculated by averaging the SIGNAL grades for all the taxa observed and is equivalent to the SIGNAL score developed by Chessman (1995).
- OE0Signal index - the ratio of the observed to expected SIGNAL score per site for taxa that have a probability of occurrence of more than zero per cent.

3 Results

3.1 Existing information

3.1.1 Description of study area and aquatic habitats

The study area is contained within the Southern Region catchment. The project originates in the Illawarra sub-region of the Southern Region catchment and extends south into the Shoalhaven sub-region.

Physical setting

The study area is bordered to the north and west by the foothills of the Illawarra escarpment and ranges. The junction of Toolijooa Road and the Princes Highway lies near the base of a spur coming off the ridge that connects Toolijooa Hill to Currys Mountain. Whilst this section of the project lies within the upper Crooked River catchment the proposed alignment does not intersect any significant or even ephemeral waterways as it ascends the spur, cutting through the Toolijooa Ridge and crossing into the adjacent Broughton Creek catchment. The project corridor crosses Broughton Creek on three occasions before ascending into the foothills of the Illawarra Range that run parallel to the north. The project traverses these foothills before descending into Berry on the spur used by the existing highway alignment. It bypasses the township of Berry on its northern side, crossing Broughton Mill Creek and Bundewallah Creek in the process (**Figure 2.1**).

Crooked River and Broughton Creek both originate in the ranges to the west as a number of secondary streams. The Crooked River flows in a south-easterly direction into a coastal floodplain before discharging into the ocean via the estuarine Crooked River Lagoon. Broughton Creek flows in a south-west direction, bordered by the lower slopes of the Illawarra Range on its north and a ridge linking a series of hills to the south. At Berry it is joined by Broughton Mill Creek at the entrance of a coastal floodplain and eventually discharges into the lower Shoalhaven River. The Crooked River and Broughton Creek catchments are separated by the ridge that extends from Currys Mountain to Toolijooa Hill, Moeyan Hill and eventually Coolangatta Mountain.

Crooked River catchment

The creeks and streams that form the Crooked River originate at Currys Mountain and flow south-east. Just downstream of the crossing of the Princes Highway, the Crooked River turns south-west and flows across the floodplain traversing a small section of the study area, and is joined by tributaries that originated on the south side of Currys Mountain in Willow Vale and the saddle between Toolijooa Hill and the Cambewarra Range. The Crooked River floodplain includes the low-lying areas to the south-west of Gerringong, generally between Toolijooa Road or the Princes Highway and the railway line. There have been substantial drainage works in the area to improve its use for agriculture. Crooked River then broadens substantially for its final 2.5 kilometres where it becomes an estuary and enters the ocean at the northern end of Seven Mile Beach adjacent to Black Head and Gerroa.

There are other small watercourses that flow east from Toolijooa Hill and Harley Hill and become a series of modified channels (eg those found in Foys Swamp) and eventually drain into the Crooked River lagoon via Blue Angel Creek. A few ephemeral creeks also drain south-west into Crooked River from the elevated landforms on the coast that link Gerroa and Gerringong.

Two small freshwater wetlands occur within the Crooked River catchment (Chafer, 1997). The 5.5 hectare Willow Vale wetlands occur to the west of the Princes Highway and the three hectare Gerringong Wetlands forms a small series of pondages east of the Princes Highway (Chafer 1997).

Broughton Creek catchment

The Broughton Creek catchment lies adjacent to the Crooked River catchment. Broughton Creek is the dominant watercourse in this catchment and originates just below the Illawarra Plateau at around 500 metres AHD (Australian height datum) (see **Figure 3.1**). The upper reach flows in a southerly direction and is joined by a number of tributaries migrating south-east off the Illawarra Range. After crossing the existing Princes Highway corridor it meanders in a southerly direction before heading west towards Berry. The Broughton Creek valley is bordered to the north by the lower slopes of the Illawarra Ranges and to the south by a moderate ridge originating at Currys Mountain. This southern ridge includes Toolijooa Hill, Harley Hill, Moeyan Hill and after a final saddle continues to Coolangatta Mountain, located to the west of Shoalhaven Heads. The Broughton Creek Catchment upstream of Berry is about 30 square kilometres.

To the north and north-west of Berry are the Broughton Mill Creek and Bundewallah Creek catchments, respectively (see **Figure 3.1**). Broughton Mill Creek originates underneath the Illawarra Plateau as a number of secondary streams. It flows south through Broughton Vale and crosses the existing Princes Highway near the Woodhill Mountain Road intersection on the eastern edge of Berry, about two kilometres upstream of its confluence with Broughton Creek. Bundewallah Creek originates to the north-west of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Connollys Creek enters Bundewallah Creek 600 metres upstream of the point Bundewallah Creek joins Broughton Mill Creek. Bundewallah Creek and Connollys Creek have catchments of around 1500 hectares and 630 hectares respectively (RTA 2008). Broughton Mill Creek has a catchment of around 2000 hectares immediately upstream of the confluence with Bundewallah Creek (RTA, 2008).

Town Creek is a small ephemeral watercourse that passes directly through the Berry township. It has a catchment of 70 hectares upstream of Berry. Town Creek crosses the undeveloped section of North Street, on the north-west edge of Berry, before traversing the town between Princess Street and Queen Street and exiting via Prince Alfred Street. Town Creek flows south east before joining Broughton Mill Creek near its confluence with Broughton Creek.

After being joined by Broughton Mill Creek to the north-west of Moeyan Hill, the Broughton Creek channel widens considerably and enters a coastal floodplain. At this point Broughton Creek is estuarine and has a permanent saline influence. It flows in a southerly direction across the floodplain and is joined by a number of creeks flowing south-east off the Cambewarra Range south of Berry, such as Jaspers Creek, Flying Fox Creek and Tandingulla Creek. Broughton Creek eventually discharges into the lower reach of Shoalhaven River to the north of Numbaa Island, around five kilometres west of Shoalhaven Heads.

Geology

The geology of the area is characterised by the Gerringong Volcanics and the Berry Formation, which together form the Permian Shoalhaven Group. The Gerringong Volcanics are younger and typically found along the ridgelines of Mount Pleasant, Toolijooa Hill and Harley Hill, whereas the sandstone, siltstone and shales of the Berry Formation are more common south-east of the Crooked River (RTA, 2008). The lowland floodplains are overlain by recent fluvial and estuarine sediments. Estuarine soil deposits occur in the vicinity of the Broughton Creek floodplain.

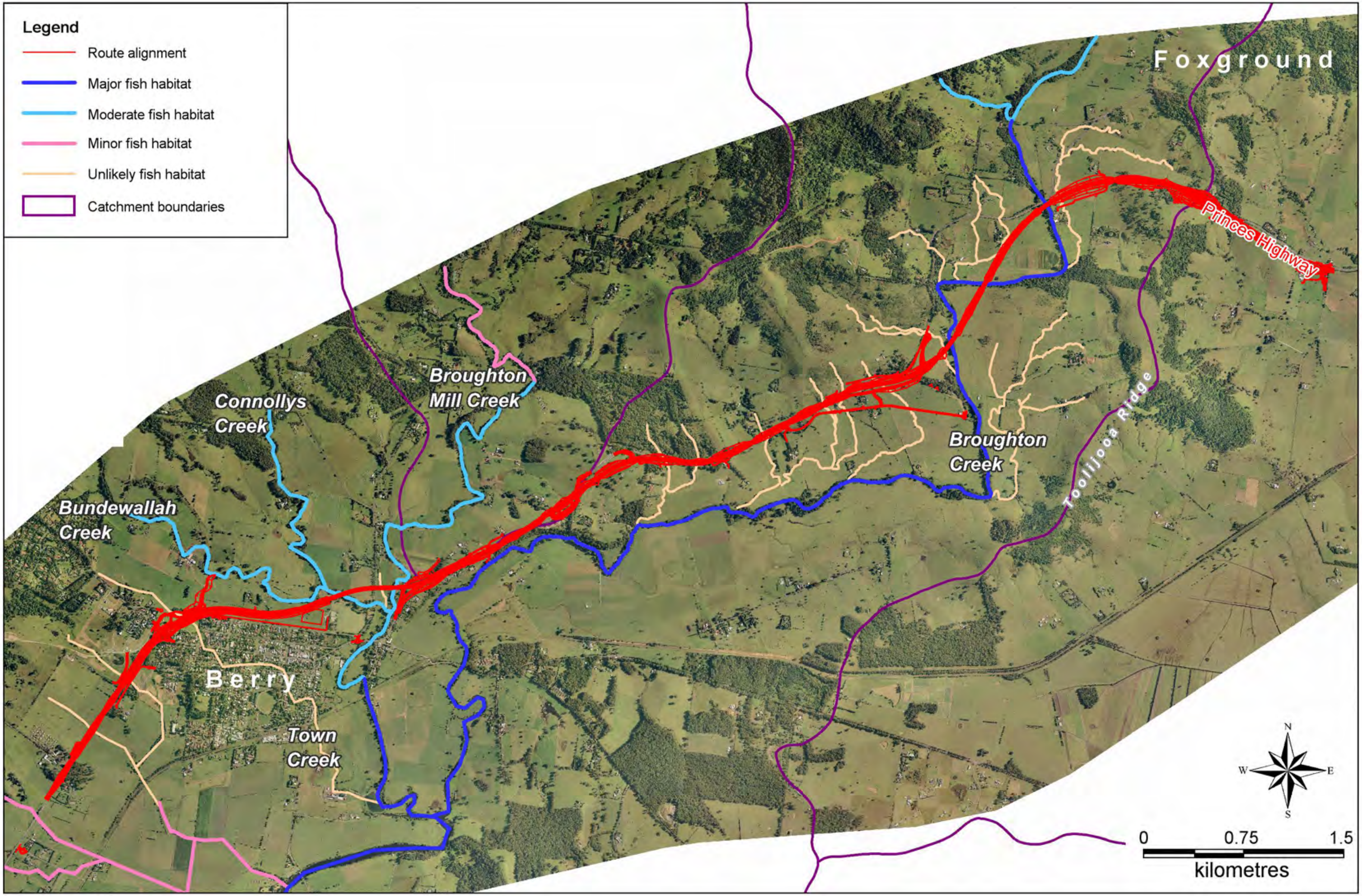

Figure 3.1: Watercourses and physical setting within the study area

The project generally passes over geological conditions mapped by the then Department of Land and Water Conservation (DLWC, 1997) as having no known occurrence of acid sulfate soils (ASS), with only one area of low ASS risk occurring at depths greater than four metres close to a section of the project south of Berry (refer to Figure 8-1 of the environmental assessment which shows ASS in the project area). Areas of no known occurrence generally correspond with landforms above 10 metres AHD and are based on an assessment of the geomorphic processes occurring there.

Following further consideration of the known geological information for the project area, an additional area of low risk of potential acid sulfate soils (PASS) being encountered has been identified. This corresponds with areas with alluvial floodplain soils at the Broughton Creek floodplain, and to a lesser extent at the bypass of Berry (refer to Figure 8–2 of the environmental assessment which shows additional areas of PASS soil risk).

Land use

Pasture and rural settlement are defining features of land use within the study area. The largest agricultural influence has historically come from the dairy industry although there has been a more recent shift to crop farms and vineyards (RTA 2008).

Agricultural activities have created the general pattern of vegetation clearance observed today. Much of the region’s woodland and riparian vegetation has been removed, and where it does occur it is often dominated by introduced species such as coral trees, willow, camphor laurel, privet and lantana. Broughton Creek does support sections of relatively intact riparian vegetation in its upper reaches. More ephemeral creek lines have often been cleared entirely and colonised by pasture grasses. In the low-lying floodplain, waterways have been highly modified to improve the drainage of arable lands.

The project corridor passes along the northern edge of the Berry township. The Berry town centre has a small distinct urban zone and is surrounded by low density residential areas. Outside of Berry, the residential development is predominantly isolated rural dwellings.

Groundwater

“Based on the available borehole data and geological mapping, it can be assumed that the study area is characterised by relatively shallow unconfined groundwater which would be expected to closely mimic the natural topography. Due to undulating terrain, a number of sub-basins would be expected, superimposed on the regional system. This unconfined groundwater profile may include some areas of perched water table. Several boreholes indicate possibly confining layers below the unconfined aquifers comprising clays or hard sandstones (p 46, RTA, 2010).”

“Below this are several different confined or semi-confined water bearing layers, mainly within fractured shales and sandstones within areas of the Berry formation, and within fractured tuff and basalt in areas characterised by Gerringong Volcanics. These deeper aquifers are accessed by the majority of licensed bores within the study area generally at depths ranging between 15 metres and up to 50 metres below ground level (p 46, RTA 2010).”

“Areas of shallow groundwater generally coincide with the occurrence of soft soils. However, shallow groundwater was also identified further upstream in the Broughton Creek floodplain and in the area immediately north of Berry, where a number of watercourses converge. In these areas, groundwater levels are typically between 0.37 metres and 2.5 metres below ground level (p 46, RTA 2010).”

Water quality

There are numerous water quality issues facing watercourses within the Shoalhaven area due to past and present land use practices. These include: elevated nutrient levels, heavy metal contamination, suspended sediment resulting from erosion of soils, low dissolved oxygen, bacterial pollution and drainage of ASS (EPA, 1997).

Previous studies have found water quality within the study area to be typical of aquatic ecosystems that have been disturbed by agricultural practices (The Ecology Lab 1999, 2007). The long-term agricultural land use in the area has resulted in pollution of surface waters that exceeds levels considered to be required for the sustainability of ecosystem integrity. This is corroborated by other studies that have used aquatic macroinvertebrate communities as indicators of disturbance (The Ecology Lab, 1999).

Levels of phosphorus within the Crooked River and Broughton Creek catchments frequently exceeded ANZECC threshold values for the protection of aquatic ecosystems (AWT 1999, The Ecology Lab 1999, 2007). The likely source of these nutrients is fertilizer applied to improve grazing pastures and livestock manure. The effects of cattle access to the creeks is also evident as numbers of faecal coliform bacteria in surface water samples often exceeded guidelines for recreational use of water (AWT, 1999).

Crooked River, Broughton Creek and Broughton Mill Creek have previously been found to be within ANZECC aquatic ecosystem threshold limits for a range of organochlorine pesticides, oxides of nitrogen and trace elements, although all exceeded ANZECC guidelines for chloride. Crooked River also exceeded ANZECC guidelines for copper and recorded concentrations of oil and grease, and suspended solids, that were much higher than samples taken from sites within the Broughton Creek catchment (The Ecology Lab, 2007).

Previous studies within Crooked River and Broughton Creek catchments have found that water quality was generally within the ANZECC threshold limits for pH and conductivity, and to a lesser extent, turbidity (The Ecology Lab, 1999; 2007). Sampling carried out in 2007 during a period of low rainfall found that sites within Crooked River and Broughton Creek catchments were frequently below ANZECC lower limits for dissolved oxygen (The Ecology Lab, 2007). Low dissolved oxygen values can be caused by low flow conditions and/or high in-stream organic loads. An earlier study had also recorded low dissolved oxygen levels from sites within the Crooked River (The Ecology Lab, 1999).

Aquatic habitats

Crooked River catchment

Previous assessments have found that freshwater habitat within the Crooked River catchment was degraded. Riparian vegetation is either absent or composed of exotic species and banks are often unconsolidated, eroded and trampled by livestock. Channel substratum is often dominated by loose accumulations of soft-sediments and substantial macrophyte and/or algal growth observed in the channel ‘wetted-width’.

Freshwater sites within Crooked River catchment have previously been assessed as providing minimal fish habitat (Class 3 Waterways, after Fairfull and Witheridge 2003) and occasionally as moderate fish habitat (Class 2 Waterway) on some sections of the Crooked River (The Ecology Lab, 2007). The more ephemeral creek lines in the area, such as those that flow off Toolijooa Hill, have been considered unlikely to provide fish habitat (Class 4 Waterways), as they only flow during larger events, have poorly defined channels with few standing pools and are often colonised by pasture grasses (The Ecology Lab, 2007).

The Willow Vale and Gerringong wetlands within the Crooked River catchment are both highly degraded. The majority of standing water within Willow Vale wetlands is contained within farm dams or open pondages without riparian vegetation. The Gerringong wetlands are predominantly creek swamp habitat on a degraded watercourse that passes through the outskirts of Gerringong.

The Crooked River estuarine lagoon is located downstream of the project. It is usually open to the sea and the lower part of the estuary is predominantly marine. Tidal flushing is vigorous although it declines in the upper reaches due to siltation (The Ecology Lab, 1999). Occasionally, however, the entrance can be blocked by a low sandbar (Chafer, 1997). The lagoon contains mangrove (0.008 square kilometres of *Avicennia marina*), saltmarsh (0.017 square kilometres) and seagrass (0.046 square kilometres of *Zostera capricorni*) habitat (Williams *et al*., 2006). All these habitats are protected under DTIRIS's *'Fish Habitat Protection Plan No. 1* (2005). Most of the banks are vegetated with a thin riparian strip of native species (eg *Eucalyptus* sp. and *Casuarina* sp.) and considerable amounts of sandflat and mudflat habitat are present.

Broughton Creek catchment

The reach of Broughton Creek upstream of Berry is surrounded by cleared agricultural land although there are significant sections with relatively intact native riparian vegetation (dominated by river oak (*Casuarina cunninghamiana* subsp. *Cunninghamiana* and *Eucalyptus* spp.), significant riffle-pool sequences and instream fish habitat (snags, rocks and deep holes). Closer to Berry riparian vegetation becomes sparse and there is greater access of livestock to the creek. The channel also becomes wider and there are longer, deep pool sections with cleared steep banks. Previous surveys have found Broughton Creek to provide major fish habitat (Class 1 waterway) and it has recorded relatively high RCE scores (The Ecology Lab 2007). The ephemeral tributaries of upper Broughton Creek have been considered unlikely to provide fish habitat (Class 4 Waterways), as they only flow during larger events, have poorly defined channels with few standing pools and are often colonised by pasture grasses (The Ecology Lab 2007).

Habitat within the Broughton Mill Creek and Bundewallah Creek catchments are relatively degraded (The Ecology Lab, 2007). Riparian vegetation is sparse or dominated by river oak and mixed exotic species and banks are often unconsolidated and eroded. Assessments completed during a prolonged dry period in Bundewallah Creek and Connollys Creek found minimal fish habitat (Class 3 waterway), whereas the sections of Broughton Mill Creek just above and below the Bundewallah Creek confluence were considered to provide moderate fish habitat (Class 2 waterway). This watercourse had a sequence of pools and riffles, with some large snags and deeper holes. The larger proportion of the Town Creek catchment is urbanised and unlikely to provide fish habitat (Class 4 Waterway), and reaches of the creek to the north and south of the urbanised reaches have poorly defined channels with few standing pools and are often colonised by pasture grasses.

The Agars Lane Bridge crossing of Broughton Creek marks the downstream extent of freshwater habitat. Further downstream the channel becomes considerably wider (up to 50 metres) and is estuarine. It meanders through the Broughton floodplain which has been cleared for agricultural use and the riparian vegetation is thin and sparse. There have been historical flood mitigation works in this area and a number of tributaries of Broughton Creek have been straightened and contain tidal gates. The estuarine reach of Broughton Creek has been previously classed as major fish habitat (Class 1 waterway) (The Ecology Lab 2007).

Aquatic habitats adjacent to, or downstream of the study area

There is considerable wetland habitat within the region, beyond the study area.

The SEPP 14 listed Coomonderry Swamp lies behind Seven Mile Beach National Park on the eastern side of the ridge that separates the Broughton Creek valley and floodplain from the coast. Coomonderry Swamp is a 670 hectare semi-permanent freshwater swamp fed by surface and groundwater from the eastern slopes of Harley Hill, Moeyan Hill and Coolangatta Mountain (NSW National Parks and Wildlife Service (NPWS) 1998). The maximum water depth is around one metre and the swamp is dominated by sedges and aquatic herbs. At the swamp edge extensive reed beds and sedgelands merge into thickets of *Casuarina*, paperbark (*Melaleuca* spp.), tea tree (*Leptospermum* spp.) and swamp mahogany (*Eucalyptus robusta*). The swamp feeds water to an aquifer in the sand dunes to the east and also flows out via a narrow drainage channel dug from the southern end to the Shoalhaven River. The drainage of Coomonderry Swamp would be unaffected by works associated with project.

In the estuarine reach of Broughton Creek, downstream of the study area there is a relatively continuous mangrove community (grey mangrove, *Avicennia marina*) (NSW Fisheries, 2004).

The Shoalhaven/Crookhaven estuary is located downstream of the Broughton Creek and Shoalhaven River confluence. It supports a number of significant estuarine wetlands, many of which are SEPP 14 listed, including the Comerong Island Nature Reserve. The eastern side of Comerong Island consists of a marine sand barrier on which dunes have formed. The northern part of this sand barrier is a sandpit across the Shoalhaven River entrance which is only intermittently open during flooding. The estuary entrance at Crookhaven Heads five kilometres to the south is permanently open. The remainder of Comerong Island and the other islands within the estuary have built up on river silt behind the sand barrier. The islands are joined by mudflats at low tide. The Shoalhaven and Crookhaven estuaries support 4.24 square kilometres of seagrass beds (*Z. capricorni* and *Halophila ovalis*), 4.18 square kilometres of mangroves (grey mangrove, *A. marina* and river mangrove, *Aegiceras corniculatum*) and 2.06 square kilometres of saltmarsh habitat (West *et al*., 1985; NSW Fisheries, 2004; Umwelt, 2005).

Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are ecosystems that have their species composition and natural ecological processes determined by groundwater (DLWC 2002). A GDE may either be entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water. GDEs include base flow in streams, wetlands, terrestrial vegetation and aquifer and cave ecosystems (DLWC 2002).

Shallow alluvial groundwater systems have been identified upstream in the Broughton Creek floodplain and in the area immediately north of Berry, where Broughton Mill Creek, Bundewallah Creek and Connollys Creek converge (RTA, 2010). In these areas, groundwater levels are typically between 0.37 metres and 2.5 metres below ground level. Shallow alluvial groundwater systems are often in direct connection with surface water bodies, such as coastal waterways. These systems can be quickly recharged and water levels restored when droughts break (DLWC, 2002). The groundwater system in the study area is likely to support surface base flows, hyporheic ecosystems and terrestrial vegetation such as riparian forests. The hyporheic zone is a fluctuating region where water exchanges between the surface and groundwater and is an important habitat for many aquatic invertebrates and a refuge during droughts and floods.

Shallow groundwater can support riparian forest either permanently or seasonally. The groundwater needs to be sufficiently high to sustain the vegetation therefore the sections of riparian habitat most dependent on groundwater within the study area probably occur in areas where the water table is closest to the surface. However, the relationship between groundwater and persistence of riparian habitat in the study area is not known. Groundwater can also be important for the persistence of aquatic macrophytes stands during periods of no flow, such as cumbungi (*Typha orientalis*), whose roots and rhizomes penetrate beneath creek beds.

Groundwater contributions to base flow typically emerge as springs or diffuse flow from saturated sediments. It can be an important component of instream flow and critical to the health and persistence of shallow aquatic habitat, such as riffles, which support its own particular aquatic assemblages and were common within the major waterways of the study area. It can also be important to the persistence of discontinuous pools during droughts which function as refugia for aquatic biota unable to utilise the hyporheic zone. The importance of groundwater to baseflow of waterways within the study area is not known. There are no known significant springs in the study area.

Coomonderry Swamp is a well-known GDE within the region, but its groundwater inflows originate from outside the study area catchment to the east of Harley Hill, Moeyan Hill and Coolangatta Mountain and therefore would be unaffected by works associated with the project.

Aquatic biota

Macrophytes

Previous surveys of creeks within the Crooked River and Broughton Creek catchments recorded cumbungi (*Typha* sp.), spikerush (*Isolepis prolifera*), starwort (*Aster* sp.), duckweed (*Lemna* sp.), water ribbons (*Triglochin procerum*), arum lilies (*Zantedeschia aethopica*), tall spikerush (*Eleocharis sphacelata*), river clubrush (*Schoenoplectus validus*), unidentified rush (*Cyperus* sp.), common reed (*Phragmites australis*), knotweed (*Persicaria* sp.), water plantain (*Alisma plantago-aquatica*), watermilfoil (*Myriophyllum* sp.), watercress (*Nasturtium officinale*) and blunt pondweed (*Potamogeton ochreatus*) (The Ecology Lab, 1999; 2007).

<u>Macroinvertebrates</u>

A study of aquatic macroinvertebrates from slow-flowing 'pool edge' freshwater habitat in the Crooked River and adjacent Ooaree Creek catchments recorded 41 taxa (The Ecology Lab, 1999). Consistent with results for water quality the most common macroinvertebrates collected from pool habitat were midge fly larvae (family Chironomidae), which are tolerant to pollution or degraded habitat. Other relatively abundant taxa included the families; Leptophlebiidae, Hydroptilidae, Physidae, Tricladidae, Baetidae, Tasimiidae and the sub-family Orthocladiinae (The Ecology Lab, 1999).

The estuarine Crooked River lagoon benthos is dominated by the polychaete families Nephtyidae and the Orbiniidae. The lagoon's benthic macroinvertebrate assemblage is structured by its high proportion of sandy sediments, which reflect its predominantly 'open' nature (The Ecology Lab, 1999). A previous survey on benthic assemblages of the lower Shoalhaven River (downstream of the confluence with Broughton Creek) found the community dominated by the polychaete families of Nephtyidae and Oweniidae and the bivalve, *Arthritica helmsi* (The Ecology Lab, 1995). Other taxa included phoronid worms, nemerteans and crustaceans (such as amphipods, mysids and the ghost shrimp, *Calllianassa arenosa*).

Fish

A literature and database search was conducted to obtain an inventory of freshwater fish fauna for the region of the study area (**Table 3.1**). Sources included Australian Museum and DTIRIS (fisheries) collections, published distributions of freshwater fish, other surveys and a historical recreation of fish communities in the Shoalhaven River. Given the relatively small size of the project corridor there have been few formal fish surveys conducted in the study area (exceptions include the surveys documented in; The Ecology Lab, 1999; 2007). The results of other surveys conducted within nearby and equivalent reaches of the Shoalhaven River system (ie of similar elevation, morphology and habitat to the study area) were also incorporated into **Table 3.1**, for example; the surveys documented in; Faragher, 1999; Gehrke *et al*. (2001) and Harris and Gehrke (1997).

Thirty six fish species were identified as potentially existing or have historically existed within the region of the project. Of these, 33 are native species and three are exotic species. Two native species in **Table 3.1** are listed as threatened. The FM Act lists the Macquarie perch (*Macquaria australasica*) as a vulnerable species and Australian grayling (*Prototroctes maraena*) as a protected species. The Macquarie perch and the Australian grayling are listed under the EPBC Act as endangered and vulnerable respectively. The Australian grayling has been recorded by Australian Museum from Broughton Mill Creek, to the south-east of Berry and from the lower section of Jaspers Creek, just upstream of its confluence with Broughton Creek.

It is probable that not all 36 species identified in **Table 3.1** occur within the study area. The estimate was obtained by including surveys from a wider area, including the larger Shoalhaven River system, which has historically provided considerable fish habitat at altitudes ranging from sea level to over 500 metres AHD. The Broughton Creek catchment supports an estuarine floodplain and freshwater reach, but the catchment is still relatively small and most of the higher altitude streams are ephemeral and are unlikely to provide fish habitat. It is possible that some species, particularly the larger and more sensitive, may not be present.

Moreover, not all sources were in agreement on the composition of the regional freshwater fish assemblage. Gehrke *et al*. (2001) did not consider it likely that the mountain galaxid (*Galaxias olidus*) historically occupied sites at elevations lower than 130 metres AHD yet Allen (2003) describe the species as occupying watercourses from 1800 metres AHD to sea level. Similarly, the Macquarie perch is generally thought to inhabit higher freshwater reaches than those commonly found in the study area (NSW DPI 2005), particularly in the presence of Australian bass (*Macquaria novemaculeata*), but Gehrke *et al*., (2001) claim that Macquarie perch was historically present (prior to the construction of the Tallowa dam) in reaches of the Shoalhaven River as low as 30 metres ASL. Equivalent low elevation habitat exists, albeit smaller and more degraded, within the study area.

Table 3.1 Species of freshwater fish that have been recorded in the region of the proposed Foxground and Berry bypass or whose published distribution includes the study area

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al.* (2001)	McDowall (1996)	Allen *et al.* (2003)
Mordaciidae	*Mordacia mordax*	Shortheaded Lamprey							s, h	d	d
Anguillidae	*Anguilla australis*	Shortfinned Eel			s				s, h	d	d
Anguillidae	*Anguilla reinhardtii*	Longfinned Eel	s[1]	s	s		s[2,3]	s	s, h	d	d
Clupeidae	*Potamalosa richmondia*	Freshwater Herring					s[3]	s	s, h	d	d
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias							h	d	d
Galaxiidae	*Galaxias maculatus*	Common Jollytail	s[1]		s		s[2,3]		s, h	d	d
Galaxiidae	*Galaxias olidus*	Mountain Galaxias									d
Retropinnidae	*Retropinna semoni*	Australian Smelt	s[1]	s		s	s[2,3]	s	s, h	d	d
Prototroctidae	*Prototroctes maraena*	Australian Grayling**, ***				s	s[3]		h	d	d
Cyprinidae	*Carassius auratus*	Goldfish #						s	s, h	d	d
Cyprinidae	*Cyprinus carpio*	Common Carp #					s[3]	s	s	d	d
Poeciliidae	*Gambusia holbrooki*	Mosquito Fish #	s[1]	s	s			s		d	d
Atherinidae	*Atherinosoma microstoma*	Small-mouthed Hardyhead								d	d

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al.* (2001)	McDowall (1996)	Allen *et al.* (2003)
Psuedomugilidae	*Psuedomugil signifer*	Pacific Blue-eye		s					h	d	d
Scorpaenidae	*Notesthes robusta*	Bullrout	s[1]				s[3]	s	s, h	d	d
Chanidae	*Ambassis marianus*	Estuary Perchlet		s						d	d
Percichthyidae	*Macquaria australasica*	Macquarie Perch*, **, ***							h		
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	s[1]				s[1,3]	s	s, h	d	d
Percichthyidae	*Macquaria colonorum*	Estuary Perch							s, h	d	d
Sparidae	*Acanthopagrus australis*	Yellowfin Bream								d	d
Mugilidae	*Myxus elongatus*	Sand Mullet						s		d	
Mugilidae	*Myxus petardi*	Freshwater Mullet					s[3]	s	s, h		
Mugilidae	*Mugil cephalus*	Sea Mullet		s			s[3]	s	s, h	d	d
Mugilidae	*Aldrichetta forsteri*	Yellow-eyed Mullet								d	d
Mugilidae	*Liza argentea*	Flat-tail Mullet								d	
Gobiidae	*Philypnodon grandiceps*	Flathead Gudgeon	s[1]	s			s[2]	s	s, h	d	d
Gobiidae	*Philypnodon* sp.	Dwarf Flathead Gudgeon						s	s, h	d	d

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al*. (2001)	McDowall (1996)	Allen *et al*. (2003)
Gobiidae	*Gobiomorphus coxii*	Cox's Gudgeon			s		s[2,3]	s	s, h	d	d
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon	s[1]	s	s		s[2,3]	s	s, h	d	d
Gobiidae	*Hypseleotris compressa*	Empire Gudgeon		s	s			s	s, h	d	d
Gobiidae	*Hypseleotris galii*	Firetailed Gudgeon								d	d
Gobiidae	*Psuedogobius* sp. 9	Blue Spot Goby								d	d
Gobiidae	*Redigobius macrostoma*	Large Mouth Goby								d	d
Gobiidae	*Acentrogobius bifrenatus*	Bridled Goby								d	
Gobiidae	*Afurcagobius tamarensis*	Tamar River Goby								d	d
Gobiidae	*Mugilogobius platynotus*	Flat-backed Goby									d

** = vulnerable species (NSW FM Act), ** = vulnerable species (EBPC Act), *** = endangered species (EPBC Act), # = alien species, s = sampled, h = historically recreation, d = published distribution includes proposed route for the project*

[a] Cardno Ecology Lab field survey –4 - 17 April 2009 was done in Ooaree Creek, Crooked River and Broughton Creek catchments. [1] = fish sampled in the region of the project.

[b] The BioNet search area (decimal degrees) was defined as North -34.733 East 150.772 South -34.779 West 150.682

[c]Faragher's survey (1999) included sites: at Broughton Mill Creek = [1]; a downstream freshwater reach of Broughton Creek = [2]; on the Shoalhaven River below Tallowa Dam = [3]

The Ecology Lab (1999) surveys were done in freshwater reaches of the Ooaree Creek and Crooker River catchments. The Ecology Lab (2007) surveys were done in Ooaree Creek, Crooked River and Broughton Creek catchments.

Source: Field data recorded by Cardno Ecology Lab (15/04/2009 - 17\04\2009) and The Ecology Lab (29/01/2007 – 01/02/2007) and literature review (McDowall 1996, Harris and Gehrke 1997, Faragher 1999, The Ecology Lab 1999, Gehrke et al. 2001, Allen et al 2003)

A previous survey of waterways intersecting the project recorded nine species of freshwater and estuarine fish (The Ecology Lab, 2007). Four species were recorded within freshwater habitat from the Broughton Creek catchment: Longfinned Eel (*Anguilla reinhardtii*), Flathead Gudgeon (*Philypnodon grandiceps*), Striped Gudgeon (*Gobiomorphus australis*) and Empire Gudgeon (*Hypseleotris compressa*). In addition to flathead gudgeon, another five species were recorded at the upper tidal limit in the Broughton channel: Australian Smelt (*Retropinna semoni*), Pacific Blue-eye (*Psuedomugil signifer*), Estuary Perchlet (*Ambassis marianus*), Sea Mullet (*Mugil cephalus*) and the introduced Mosquito Fish (*Gambusia holbrooki*) (The Ecology Lab, 2007).

There are a large number of fish species that utilise estuarine waters in this region at some time during their life history. The estuaries found downstream of the project in Crooked River lagoon and Shoalhaven/Crookhaven system are considered to be major fish habitat (Class 1 Waterways). A survey of Crooked River lagoon recorded fish from 20 families, representing 29 species (**Table 3.2**; The Ecology Lab, 1999). Of these, 13 species were of commercial interest. Crooked River lagoon was characterised by Luderick (*Girella tricuspidata*), Flat-tail Mullet (*Liza argentea*), Sea Mullet (*Mugil cephalus*), Tarwhine (*Rhabdosargus sarba*), Sand Whiting (*Sillago ciliata*), Yellow-finned Leatherjacket (*Meuschenia trachylepsis*), Swan River Goby (*Pseudogobius olorum*), Blue Groper (*Achoerodus viridis*) and Eastern King Prawn. Many of the most abundant species were found associated with seagrass habitat.

The Shoalhaven/Crookhaven estuary supports a significant fish assemblage. The estuary supports commercial fishing in the NSW Estuary General Fishery which utilises a variety of gears to target fish such as luderick, whiting (Sillaginidae), mullet (Mugilidae), flathead (Platycephalidae), bream (Sparidae) and crab species. A number of threatened and protected species either occur or suitable habitat for them may occur in the region of the estuary (**Table 3.3**).

Table 3.2: The means and standard errors (SE) for numbers of fish and mobile invertebrates caught using seine nets over seagrass and bare substratum habitats in Crooked River estuary. Source: The Ecology Lab (1999)

Family name	Species name	Common name	Crooked River Estuary				
			Seagrass			Bare Substratum	
			Mean	S.E.		Mean	S.E.
Hemiramphidae	*Hyporhamphus sp.*	Garfish*	0.0	0.0		2.2	0.9
Platycephalidae	*Platycephalus fuscus*	Dusky Flathead*	0.0	0.0		0.5	0.3
Sillaginidae	*Sillago ciliata*	Sand Whiting*	0.0	0.0		22.5	21.5
Pomatomidae	*Pomatomus saltatrix*	Tailor*	0.0	0.0		0.3	0.2
Sparidae	*Rhabdosargus sarba*	Tarwhine*	57.2	29.1		0.0	0.0
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream*	2.2	1.6		0.0	0.0
Girellidae	*Girella tricuspidata*	Luderick*	380.1	67.5		0.0	0.0
Mugilidae	*Mugil cephalus*	Sea mullet*	60.5	15.5		9.3	8.7
Mugilidae	*Myxus elongatus*	Sand Mullet*	0.0	0.0		4.8	2.3
Mugilidae	*Liza argentea*	Flat-tail Mullet*	228.8	90.8		0.0	0.0
Bothidae	*Pseudorhombus jenynsii*	Small-toothed Flounder*	0.0	0.0		0.7	0.5
Monacanthidae	*Meuschenia trachylepis*	Yellow-finned Leatherjacket*	53.9	23.2		0.2	0.2
Monacanthidae	*Monacanthus freycineti*	Six-spined Leatherjacket*	10.5	6.7		0.0	0.0
Scorpaenidae	*Centropogon australis*	Fortescue	15.4	7.2		0.0	0.0
Ambassidae	*Ambassis sp.*	Perchlets	12.7	4.2		0.0	0.0
Terapontidae	*Pelates sexlineatus*	Eastern Striped Trumpeter	2.2	2.2		0.0	0.0
Gobidae	*Pseudogobius olorum*	Swan River Goby	386.7	200.8		0.0	0.0
Gobidae	*Redigobius macrostoma*	Large-mouth Goby	19.3	12.0		0.0	0.0

Family name	Species name	Common name	Crooked River Estuary				
			Seagrass			Bare Substratum	
			Mean	S.E.		Mean	S.E.
Gobidae	*Gobiopterus semivestita*	Glass Goby	1.7	1.1		0.0	0.0
Gobidae	*Favonigobius tamarensis*	Tamar River Goby	3.9	1.3		0.2	0.2
Gobidae	*Favonigobius exquisitus*	Exquisite Goby	0.6	0.6		0.0	0.0
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	8.3	4.1		0.0	0.0
Eleotridae	*Philypnodon sp.*	Dwarf Flathead Gudgeon	3.9	2.5		0.0	0.0
Tetraodontidae	*Tetractenos glaber*	Smooth Toadfish	0.0	0.0		1.5	0.4
Microcanthidae	*Microcanthus strigatus*	Stripey	2.8	1.6		0.0	0.0
Labridae	*Achoerodus viridis*	Blue groper	24.2	12.2		0.0	0.0
Carangidae	*Pseudocaranx dentex*	Silver Trevally*	0.6	0.6		0.3	0.2
Triglidae	*Chelidonichthys kumu*	Red Gurnard	0.0	0.0		0.2	0.2
Clupeidae	*Hyperlophus vittatus*	Sandy Sprat	0.0	0.0		11.8	7.6
Penaeidae	*Penaeus plebejus*	Eastern King Prawn*	172.2	89.7		0.3	0.3

** Indicates species of commercial importance.*

Table 3.3: Threatened and Protected Species listed under s248 of the Commonwealth *Environmental Protection and Biodiversity Conservation Act (EPBC) 1999*

a. Matters of National Environmental Significance		
Species name	**Common name**	**Status**
Mammals		
Eubalaena australis	Southern Right Whale	Endangered
Megaptera novaeangliae	Humpback Whale	Vulnerable
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Endangered
Caretta caretta	Loggerhead Turtle	Endangered
Chelonia mydas	Green Turtle	Vulnerable
Eretmochelys imbricata	Hawksbill Turtle	Vulnerable
Sharks		
Carcharias taurus	Grey Nurse Shark (east coast population)	Critically Endangered
Carcharodon carcharias	Great White Shark	Vulnerable
Rhincodon typus	Whale Shark	Vulnerable
Ray-finned fishes		
Macquaria australasica	Macquarie Perch*	Endangered
Prototroctes maraena	Australian Grayling*	Vulnerable

** MNES within the Broughton Creek catchment*

b. Migratory marine species		
Species name	**Common name**	
Mammals		
Balaenoptera edeni	Bryde's Whale	Protected
Caperea marginata	Pygmy Right Whale	Protected
Eubalaena australis	Southern Right Whale	Protected
Lagenorhynchus obscurus	Dusky Dolphin	Protected
Megaptera novaeangliae	Humpback Whale	Protected
Orcinus orca	Orca	Protected
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Protected
Caretta caretta	Loggerhead Turtle	Protected
Chelonia mydas	Green Turtle	Protected
Eretmochelys imbricata	Hawksbill Turtle	Protected
Sharks		
Carcharodon carcharias	Great White Shark	Protected
Rhincodon typus	Whale Shark	Protected

c. Listed marine species		
Species name	**Common name**	
Mammals		
Arctocephalus forsteri	New Zealand Fur-seal	Protected
Arctocephalus pusillus	Australian Fur-seal	Protected
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Protected
Caretta caretta	Loggerhead Turtle	Protected
Chelonia mydas	Green Turtle	Protected
Eretmochelys imbricata	Hawksbill Turtle	Protected
Ray-finned fishes		
Acentronura breviperula	Shortpouch Pygmy Pipehorse	Protected
Cosmocampus howensis	Lord Howe Pipefish	Protected
Heraldia nocturna	Upside-down Pipefish	Protected
Hippocampus abdominalis	Bigbelly Seahorse	Protected
Hippocampus breviceps	Shorthead Seahorse	Protected
Hippocampus whitei	White's Seahorse	Protected
Histiogamphelus briggsii	Crested Pipefish	Protected
Kimblaeus bassensis	Trawl Pipefish	Protected
Lissocampus runa	Javelin Pipefish	Protected
Maroubra perserrata	Sawtooth Pipefish	Protected
Notiocampus ruber	Red Pipefish	Protected
Phyllopteryx taeniolatus	Weedy Seadragon	Protected
Solegnathus spinosissimus	Spiny Pipehorse	Protected
Solenostomus cyanopterus	Robust Ghostpipefish	Protected
Stigmatopora argus	Spotted Pipefish	Protected
Stigmatopora nigra	Widebody Pipefish	Protected
Syngnathoides biaculeatus	Double-end Pipehorse	Protected
Urocampus carinirostris	Hairy Pipefish	Protected
Vanacampus margaritifer	Mother-of-pearl Pipefish	Protected
Vanacampus phillipi	Port Phillip Pipefish	Protected

d. Whales and other Cetaceans		
Species name	**Common name**	
Balaenoptera acutorostrata	Minke Whale	Protected
Balaenoptera edeni	Bryde's Whale	Protected
Caperea marginata	Pygmy Right Whale	Protected
Delphinus delphis	Common Dolphin	Protected
Eubalaena australis	Southern Right Whale	Protected
Grampus griseus	Risso's Dolphin	Protected
Lagenorhynchus obscurus	Dusky Dolphin	Protected
Megaptera novaeangliae	Humpback Whale	Protected
Orcinus orca	Orca	Protected
Tursiops aduncus	Indian Ocean Bottlenose Dolphin	Protected
Tursiops truncatus s. str.	Bottlenose Dolphin	Protected

3.2 Field site assessments

Assessment of waterways within the study area was conducted on 15 April 2009 to 17 April 2009. Observations were made following a period of relatively significant rainfall (ie 37.6 millimetres of rainfall at Kiama in the week preceding the survey). Field assessment of temporary waterway crossing sites was done on 28 June 2011. In addition to aquatic ecological assessments, an assessment of riparian and terrestrial plant community condition within the area potentially affected by the proposed diversion of Town Creek into Bundewallah Creek was carried out by one botanist from Biosis on 8 November 2011.

Each waterway was assessed using three classification systems (Section 2.2.2). For each watercourse **Table 3.4** presents fish habitat classification, RCE scores and DIPNR Riparian classification. Appendix A details the categories and descriptors used to calculate RCE scores (after Chessman *et al*., 1997). Criteria for fish habitat classification according to NSW Fisheries Guidelines are contained in Appendix B. DIPNR classification categories are described in Section 2.2.2 (after DIPNR, 2004). Where appropriate, recordings were made of water quality, macrophyte, macroinvertebrate and fish assemblages and existing waterway crossings.

3.2.1 Crooked River catchment

No sites were sampled in this section as there were no waterways (permanent or ephemeral) intersecting the project in the Crooked River catchment.

3.2.2 Broughton Creek catchment

Twenty two sites (sites 13 to 29 and five temporary creek crossing sites) within the Broughton Creek catchment were sampled along the project (**Table 3.4**, **Figure 2.1** and **Figure 3.2**).

Table 3.4: Sites established for the Foxground and Berry bypass. Suggested waterway crossing structures based on criteria established by Fairfull and Witheridge (2003)

Site	Easting	Northing	Catchment	Watercourse	Fish habitat classification	RCE score	Riparian category	Existing drainage structure	Suggested drainage structure
13	294853	6152838	Broughton Creek	Broughton Creek	1	37	1	Bridge - Two Span (Flood Overflow Box Culvert - Double)	Bridge, arch structure or tunnel
14	294534	6152719	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Double*	Culvert, causeway or ford
15	294313	6152364	Broughton Creek	Unnamed	4	23	3	None	Culvert, causeway or ford
16	294326	6152222	Broughton Creek	Broughton Creek	1	36	1	None	Bridge, arch structure or tunnel
17	294163	6152024	Broughton Creek	Broughton Creek	1	34	1	None	Bridge, arch structure or tunnel
18	293980	6151861	Broughton Creek	Unnamed	3/4	25	2	Box Culvert - Single*	Culvert or ford
19	293568	6151519	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Single	Culvert, causeway or ford
20	293340	6151384	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Single	Culvert, causeway or ford
21	293212	6151323	Broughton Creek	Unnamed	4	23	3	Box Culvert - Single	Culvert, causeway or ford
22	292790	6151089	Broughton Creek	Unnamed	3/4	25	2	Box Culvert - Triple	Culvert or ford
23	292270	6150868	Broughton Creek	Unnamed	4	26	3	Pipe Culvert - Single	Culvert, causeway or ford

Site	Easting	Northing	Catchment	Watercourse	Fish habitat classification	RCE score	Riparian category	Existing drainage structure	Suggested drainage structure
24	292042	6150896	Broughton Creek	Unnamed	4	25	3	Pipe Culvert - Single	Culvert, causeway or ford
25	290000	6149879	Broughton Creek	Broughton Mill Creek	2	33	1	None	Bridge, arch structure, culvert or ford
26	289956	6149873	Broughton Creek	Unnamed	4	21	3	None	Culvert, causeway or ford
27	289854	6149826	Broughton Creek	Bundewallah Creek	2	32	1	Bridge - Three Span*	Bridge, arch structure, culvert or ford
28	288497	6149713	Broughton Creek	Unnamed	4	22	3	None	Culvert, causeway or ford
29	288021	6149269	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Triple	Culvert, causeway or ford

**Drainage structure located short distance upstream/downstream of site at an existing road or Princes Highway crossing*

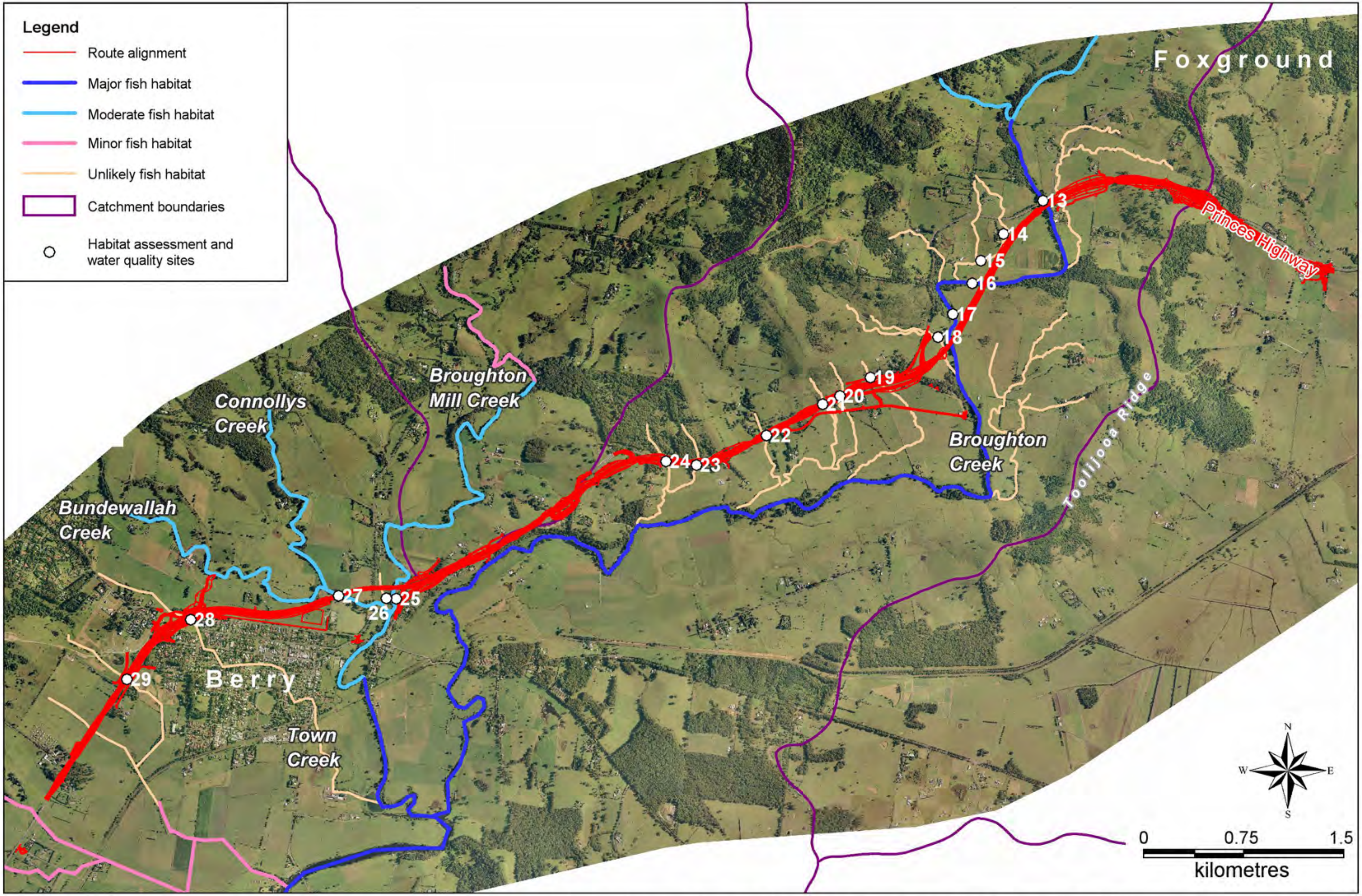

Figure 3.2: Waterways and aquatic ecology monitoring sites within the study area. Classifications are based on criteria established by Fairfull and Witheridge (2003)

Site 13 – Broughton Creek

Site 13 was established at the existing Princes Highway crossing of Broughton Creek 1.2 kilometres south of the intersection with Foxground Road. This site is one of the three proposed crossings of Broughton Creek by the project. The existing crossing is a two-span bridge and the bridge support piles are located in the wetted-width of the channel (Plate 1a provided at the end of this section). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.1**). The surrounding land had been cleared for agricultural use but there was considerable remaining riparian vegetation, although the understory was often dominated by exotic shrubs and annual weeds. There was frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble (Plate 1b provided at the end of this section). Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**). Forty metres west of the channel a twin box culvert had been installed in the highway embankment as a flood overflow measure (Plate 1c provided at the end of this section).

Water quality was moderate for the physical parameters measured *in situ* (**Table 3.5**). Dissolved oxygen and pH recorded from site 13 on Broughton Creek were within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) (**Table 3.5** and Appendix C). Conductivity and turbidity were outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

The composition of the aquatic macroinvertebrate assemblage indicates that Broughton Creek was moderately impaired due to pollution and/or local habitat degradation. A total of 34 unique taxa were recorded, 25 from pool edge habitat and 18 from riffle habitat (Nine taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from both pool edge and riffle habitat as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent, however edge habitat OE50 Taxa scores were at the upper limit for Band B and just below the lower limit for reference condition (Band A; **Table 3.6**). The O0Signal scores of 4.06 (edge habitat) and 4.50 (riffle habitat) signify a creek with moderate pollution and/or degraded habitat as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa. The OE0 Signal scores were less than one in both habitat types indicating that the assemblages in these habitats had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (**Table 3.6**).

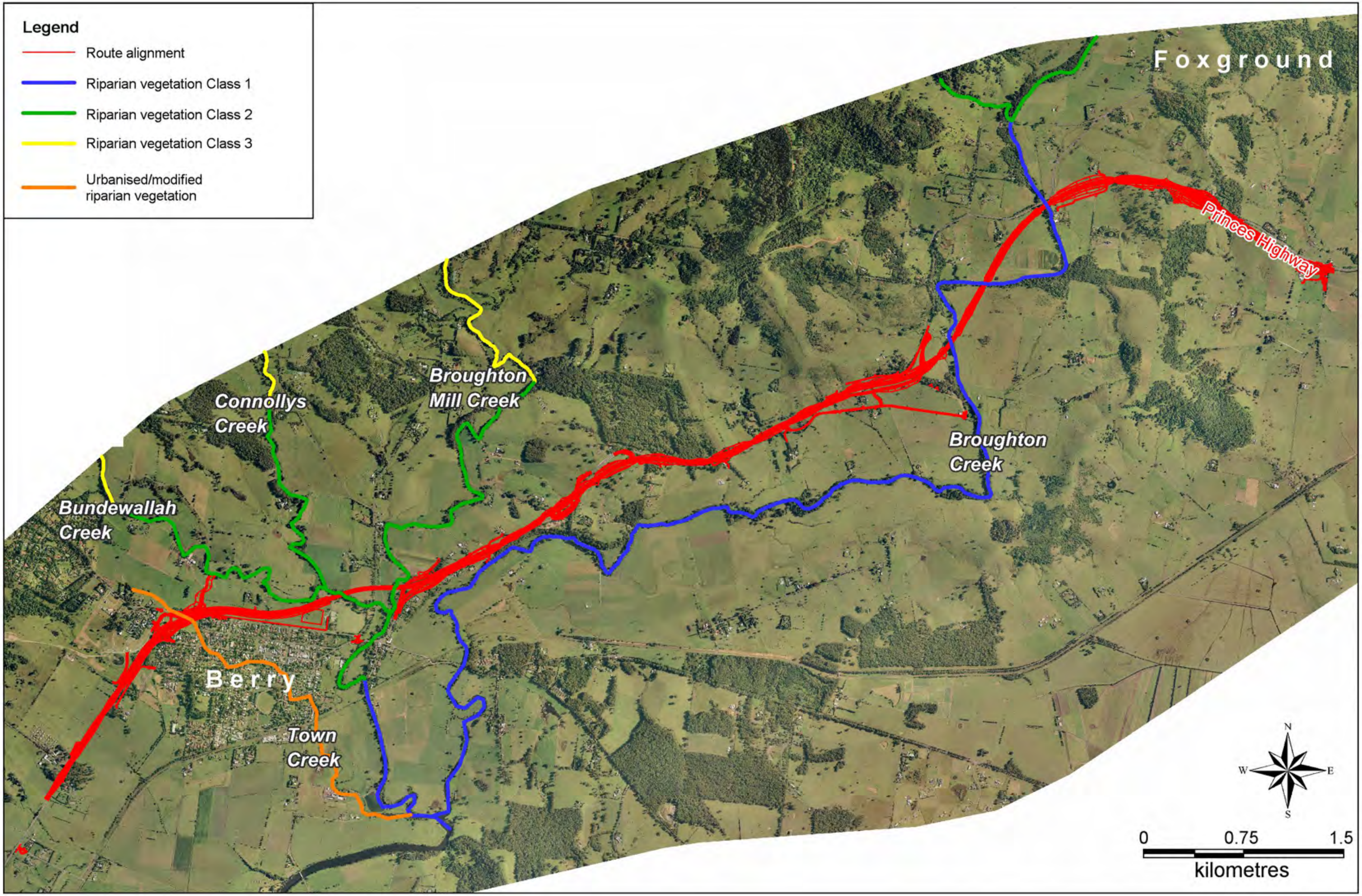

Figure 3.3: Map of waterways based on riparian habitat classification

Table 3.5: Water quality measured *in situ* in the study area in comparison with ANZECC (2000) guidelines for low-land watercourses in south-east Australia

Site	Watercourse	Conductivity (us/cm)	pH	Dissolved oxygen (% sat.)	Turbidity (NTU)
		1–5 - 2200	6.5 - 8.0	85 - 110	6 - 50
13	Broughton Creek	↓	✓	✓	↓
16	Broughton Creek	↓	✓	✓	↓
17	Broughton Creek	↓	✓	↑	↓
25	Broughton Mill Creek	↓	✓	↑	↓
27	Bundewallah Creek	✓	✓	✓	↓

↓= below guidelines, ↑= above guidelines, ✓ = within guidelines
Recorded by Cardno Ecology Lab (15/04/09 - 17/04/09)

Table 3.6: AusRivAS scores for macroinvertebrates from edge and riffle habitat in April 2009

Site	Watercourse	NTE50	NTP50	NTC50	OE50	E50Signal	O50Signal	OE50Signal	E0Signal	O0Signal	OE0Signal	Band
a. Edge habitat (Autumn 2009)												
13	Broughton Creek	13.65	19	11	0.81	4.36	3.82	0.87	4.36	4.06	0.93	B
25	Broughton Mill Creek	13.85	20	15	1.08	4.34	4.47	1.03	4.38	4.56	1.04	A
27	Bundewallah Creek	10.39	14	10	0.96	4.20	4.20	1.00	4.48	4.14	0.92	A
b. Riffle habitat (Autumn 2009)												
Site	**Watercourse**	**NTE50**	**NTP50**	**NTC50**	**OE50**	**E50Signal**	**O50Signal**	**OE50Signal**	**E0Signal**	**O0Signal**	**OE0Signal**	**Band**
13	Broughton Creek	16.25	21	13	0.80	5.53	5.15	0.93	5.53	4.50	0.81	B
25	Broughton Mill Creek	16.25	21	13	0.80	5.53	5.31	0.96	5.55	4.67	0.84	B
27	Bundewallah Creek	15.40	19	12	0.78	5.79	5.75	0.99	5.86	5.00	0.85	B

Note: AusRivAS band categories: Band X = macroinvertebrate assemblage at the site is richer (more taxa) than the reference condition; Band A = assemblage is similar to the reference condition; Band B = assemblage is significantly impaired relative to the reference condition; Band C = assemblage is severely impaired relative to the reference condition; Band D = the assemblage is impoverished. Source: field data recorded by Cardno Ecology Lab (15 April 2009 to 17 April 2009).

All seven species of fish recorded at site 13 were native (Appendix D). Site 13 had the greatest diversity of fish fauna among all sites sampled. Species observed included bullrout (*Notesthes robusta*) and Australian bass (*Macquaria novemaculeata*); the latter is an important species to recreational fishers. A number of young-of-year (YOY) bass were caught in deep pool habitat and under overhanging banks. Juvenile bass initially develop in estuaries where adults spawn and then migrate upstream into freshwater habitat where they mature. The timing of the field survey in April is considered to be towards the end of this period of upstream migration.

Site 14 – unnamed watercourse

The watercourse at site 14 was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The existing road crossing upstream at the Princes Highway was a double pipe culvert and a small stand of cumbungi (*Typha* sp.) had formed in a temporary pool section above the culvert (Plate 1d provided at the end of this section). The watercourse channel was devoid of riparian vegetation and has been colonised by pasture grasses. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 15 – unnamed watercourse

The watercourse at site 15 was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The channel was relatively undefined, devoid of riparian vegetation and had been colonised by pasture grasses and annual weeds (Plate 2a provided at the end of this section). The site was located near the confluence of the waterway that passed through site 14 and a parallel watercourse to the west, which was similarly ephemeral and highly degraded (**Figure 2.1**). The channel continued west before entering Broughton Creek. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 16 – Broughton Creek

Site 16 was the second of the three proposed crossings of Broughton Creek by the project and was located approximately 1.3 kilometres downstream of site 13 (**Figure 2.1**). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use. Riparian vegetation was composed of river oak and exotic shrubs and annuals and was sparse in places (Plate 2b provided at the end of this section). Livestock had access to the creek from the south which had degraded areas of bank and channel bed. There was frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble. Submerged woody debris was relatively abundant. Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was moderate for the physical parameters measured *in situ* (**Table 3.5**) Dissolved oxygen and pH were within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) (**Table 3.5** and Appendix C). Conductivity and turbidity were marginally outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

Site 17 – Broughton Creek

Site 17 was the third of the three proposed crossings of Broughton Creek by the project and was located around 400 metres downstream of site 16 (**Figure 2.1**). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use. Riparian vegetation was sparse and where present was composed primarily of river oak, annual weeds and pasture grasses. The channel bank on the eastern side of the creek was heavily eroded with frequent sections of collapsed bank (Plate 2c provided at the end of this section). Livestock had access to the creek from both the western and eastern bank. There were frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble. Submerged woody debris was relatively abundant. Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was variable for the physical parameters measured *in situ* (**Table 3.5**). pH was within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) whilst conductivity and turbidity were marginally outside the ANZECC lower thresholds (**Table 3.5** and Appendix C). Dissolved oxygen was well above the ANZECC upper limits and may have been indicative of relatively high local algal activity. This was not unexpected given the low shading in this section of the creek and high nutrient levels.

The project continues parallel to Broughton Creek for a number of kilometres downstream (**Figure 2.1**). The project does not cross Broughton Creek downstream of site 17 but does cross a number of tributaries upstream of their confluence with Broughton Creek.

Site 18 – Unnamed watercourse

The watercourse at site 18 had a low RCE score (**Table 3.4**) and was considered minimal to unlikely fish habitat (Class 3 – 4 Waterway; **Figure 3.2**). Riparian vegetation was sparse and where present was composed predominantly of exotic shrubs. Much of the banks were eroded and lined with pasture grasses. A narrow pooling section is present downstream for 120 metres downstream of the existing Princes Highway crossing (Plate 2d provided at the end of this section). The unnamed watercourse and its riparian zone 3). The road crossing at the Princes Highway is a single box culvert. were classed as a Category 2 waterway (Aquatic Habitat; **Table 3.4** and **Figure 3.3**).

Site 19 – Unnamed watercourse

The road crossing at site 19 was a single pipe culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and has been colonised by pasture grasses. Upstream of the Princes Highway crossing was a brief section of riparian vegetation including native trees and exotic shrubs. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 20 – Unnamed watercourse

The road crossing at site 20 was a single pipe culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses. Artificial dams were present upstream and downstream of the road crossing. The upstream dam contained a small stand of cumbungi (*Typha* sp.). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 21 – Unnamed watercourse

The road crossing at site 21 was a single box culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses. The section of the waterway at the road crossing was dominated by invasive weed lantana (*Lantana camara*). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 22 – Unnamed watercourse

The road crossing at site 22 was a triple box culvert. The waterway channel was degraded, had a low RCE score (**Table 3.4**) and was considered minimal to unlikely fish habitat (Class– 3 - 4 Waterway; **Figure 3.2**). Riparian vegetation was sparse on the section of waterway which crossed the Princes Highway and where present was dominated by exotic trees, shrubs and annuals (Plate 3a provided at the end of this section). There were small pooling sections in the channel and introduced mosquito fish (*Gambusia holbrooki*) were observed downstream of the crossing. The unnamed watercourse and its riparian zone were classed as a Category 2 waterway (Aquatic Habitat; **Table 3.4** and **Figure 3.3**).

Site 23 – Unnamed watercourse

The road crossing at site 23 was a single pipe culvert. The waterway had a moderate RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The upstream section of the watercourse had relatively complete riparian vegetation dominated by native trees with some exotic understorey species. Downstream of the Princes Highway crossing water flowed over a rock fall which was a significant barrier to upstream passage for non-climbing fish species (Plate 3b provided at the end of this section). The banks were relatively unstable and eroded. Further downstream the riparian vegetation disappeared and the channel became indistinct and colonised by pasture grasses as it crossed farmland. The unnamed watercourse and its riparian habitat were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 24 – Unnamed watercourse

The road crossing at site 24 was a single pipe culvert. The waterway had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The upstream section of the watercourse had relatively complete riparian vegetation comprised of mixed native and exotic trees and shrubs. A pool had formed on the downstream side of the road crossing. Downstream of this point the riparian vegetation became absent as the watercourse entered pasture. The channel eventually joins the watercourse from site 23 before discharging into Broughton Creek (**Figure 2.1**). The unnamed watercourse and its riparian habitat were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 25 – Broughton Mill Creek

Site 25 was the proposed crossing of Broughton Mill Creek by the project. The waterway had a moderate RCE score (**Table 3.4**) and was considered moderate fish habitat (Class 2 Waterway; **Figure 3.2**). The land to the west had been cleared for agricultural use and to the east there was a large maintained lawn. Riparian vegetation on the west bank contained a mixture of native and exotic trees and shrubs, but was largely absent on the eastern bank. There was a frequent alternation of riffle and pools and submerged woody debris was relatively abundant (Plate 3c provided at the end of this section). Broughton Mill Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was variable for the physical parameters measured *in situ* (**Table 3.5**). pH was within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) whilst conductivity and turbidity were outside the ANZECC lower thresholds (**Table 3.5** and Appendix C). Dissolved oxygen was above the ANZECC upper limits and may have been indicative of relatively high local algal activity.

The composition of the aquatic macroinvertebrate assemblage indicated that Broughton Mill Creek was relatively healthy but exhibited some evidence of pollution and/or local habitat degradation. A total of 32 unique taxa were recorded, 27 from pool edge habitat and 20 from riffle habitat. (15 taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from pool edge as equivalent to reference condition (Band A). Riffle habitat was assessed as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent. O0Signal scores of 4.56 (edge habitat) and 4.67 (riffle habitat) suggested that the reach at site 25 was moderately polluted or degraded as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (**Table 3.6**). The OE0 Signal score of less than one for the riffle indicated that the assemblages in this habitat had a greater proportion of pollution-tolerant taxa than at equivalent reference sites. The composition of pollution-tolerant and pollution-sensitive fauna in pool edge habitat was equivalent to that of reference sites (**Table 3.6**).

All three species of fish recorded at site 25 were native: Australian Bass (Plate 3d provided at the end of this section), Australian Smelt (*Retropinna semoni*) and Longfinned Eel (*Anguilla reinhardtii*) (Appendix D).

Site 26 – Unnamed watercourse

Site 26 was a small ephemeral watercourse or drainage ditch that ran parallel to, and in between, Broughton Mill Creek and Woodhill Mountain Road (**Figure 2.1**, Plate 4a provided at the end of this section). The waterway had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway: **Figure 3.2**). The channel was bordered by cut grass from a turf farm on either side and had been colonised by annual weeds and pasture grass (Plate 4a provided at the end of this section). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 27 – Bundewallah Creek

Site 27 was the proposed crossing of Bundewallah Creek by the project. The waterway had a moderate RCE score (**Table 3.4**) and was considered moderate fish habitat (Class 2 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use and recreation. The riparian vegetation was relatively continuous and composed of native trees (river oak) and exotic shrubs, climbers and annuals. There was a frequent alternation of riffle and pools and submerged woody debris was relatively abundant (Plate 3b provided at the end of this section). Bundewallah Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**). The existing Woodhill Mountain Road crossing of Bundewallah Creek downstream of the project crossing was a two span bridge with the bridge piles positioned within the channel wetted-width.

Water quality was generally good for the physical parameters measured *in situ* (**Table 3.5**). Conductivity, pH and dissolved oxygen were all within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC, 2000) whilst turbidity was outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

The composition of the aquatic macroinvertebrate assemblage indicated that Bundewallah Creek was relatively healthy but exhibited some evidence of pollution and/or local habitat degradation. A total of 33 unique taxa were recorded, 22 from pool edge habitat and 19 from riffle habitat. (Eight taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from pool edge as equivalent to reference condition (Band A). Riffle habitat was assessed as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent. O0Signal scores of 4.14 (edge habitat) and 5.00 (riffle habitat) suggest that the reach at site 25 was mildly to moderately polluted and/or degraded as the macroinvertebrate assemblage was characterised by pollution-tolerant taxa (**Table 3.6**). The OE0 Signal score of less than one for the riffle indicated that the assemblages in this habitat had a greater proportion of pollution-tolerant taxa than at equivalent reference sites. The OE0 Signal scores were less than one in both habitat types indicating that the assemblages in these habitats had a greater proportion of pollution-tolerant taxa than at equivalent reference sites, although the disparity was greater for riffle habitat (**Table 3.6**).

All four species of fish recorded at site 27 were native: Australian Bass, Common Jollytail (*Galaxias maculatus*), Australian Smelt and Longfinned Eel (Appendix D).

Site 28 – Town Creek

Site 28 was the proposed crossing of Town Creek by the project. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses and annual weeds (Plate 4c provided at the end of this section). Within the urbanised reaches of Town Creek the patches of vegetation present were characterised as disturbed riparian open woodland. South of the urban centre Town Creek flowed through pasture land with riparian vegetation consisting of closed grassland, then through a constructed wetland adjacent to the Berry Sewage Treatment Works, and subsequently through disturbed riparian open woodland habitat before its confluence with Broughton Mill Creek.

The water quality within Town Creek is expected to be characteristic of a watercourse with a developed residential and agricultural catchment. The long-term urban and agricultural land use in the area has likely lead to elevated nutrient levels (e.g. from fertilisers and livestock manure), low dissolved oxygen and raised suspended solids resulting from the erosion of soils.

Site 29 – Unnamed watercourse

The road crossing at site 29 was a triple pipe culvert. The site was located around 75 metres north-east of the Hitchcocks Lane intersection with the Princes Highway. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Upstream of the highway crossing the watercourse had a relatively undefined channel and had been colonised by pasture grasses (Plate 4d provided at the end of this section). Further downstream the channel straightened, crossed the railway line and eventually entered Broughton Creek downstream of Wharf Road Bridge (**Figure 2.1**). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

3.2.3 Temporary creek crossings

Temporary creek crossings are required at each proposed bridge structure during the construction period. Each proposed bridge location was surveyed and preferred temporary creek crossing sites were identified (**Figures 3.4**, **Figure 3.5** and **Table 3.7**). Preferred sites for temporary creek crossings were located such that impacts to terrestrial and aquatic ecology and water quality would be minimised. Important criteria considered during the temporary creek crossing identification process included (but were not limited to):

- Potential loss of native riparian vegetation. In particular, mature river oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*) which is part of the EEC River-Flat Eucalypt Forest on Coastal Floodplain.
- Channel form. Preferences were for crossings over deeper channel sections, such as pools or runs, rather than riffles. Allowing for deeper water under temporary bridge crossings would minimise potential behavioural impacts on upstream fish passage.

Bridge1 – Broughton Creek

The temporary crossing of Broughton Creek at Bridge 1 had been determined by RMS prior to the field assessment. The temporary crossing site was located immediately downstream of the proposed Bridge 1 crossing of Broughton Creek (Site 13), within the existing alignment footprint.

Broughton Creek was a Class 1 waterway (major fish habitat) with Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary crossing. The crossing would pass over riffle habitat dominated by cobble and boulder substrata. The riparian zone was dominated by river oak and the understorey was relatively sparse.

Bridge 2 – Broughton Creek

Broughton Creek was a Class 1 waterway with respect to fish habitat and riparian classification at the location of the proposed Bridge 2 crossing. See Site 16 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located to the east of the proposed bridge structure, around 20 metres upstream and within the concept design footprint (B2 BC in **Figure 3.4**, **Table 3.7**). The crossing would pass over pool habitat downstream of a cobble bar and associated riffle. There was a gap of around 24 metres separating mature river oak on the northern bank. Loss of riparian vegetation at this location would include some native and exotic shrubs. Depending on the orientation of the temporary crossing one mature river oak on the southern bank would likely be removed.

Bridge 3 – Broughton Creek

Broughton Creek was a Class 1 waterway with respect to fish habitat and riparian classification at the location of the proposed Bridge 3 crossing. See Site 17 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary crossing site was located south of the proposed bridge structure, about 10 metres downstream and within the concept design footprint (B3 BC in **Figure 3.4**, **Table 3.7**). The crossing would pass over pool habitat about 15 metres across and over one metre deep and a channel bed dominated by cobble and boulders. There was a narrow but continuous stand of mature river oak along the western bank.

Figure 3.4: Temporary creek crossing sites for Bridge 2 and Bridge 3 at Broughton Creek. B2 BC = temporary crossing of Broughton Creek near proposed bridge 2. B3 BC = temporary crossing of Broughton Creek near proposed bridge 3

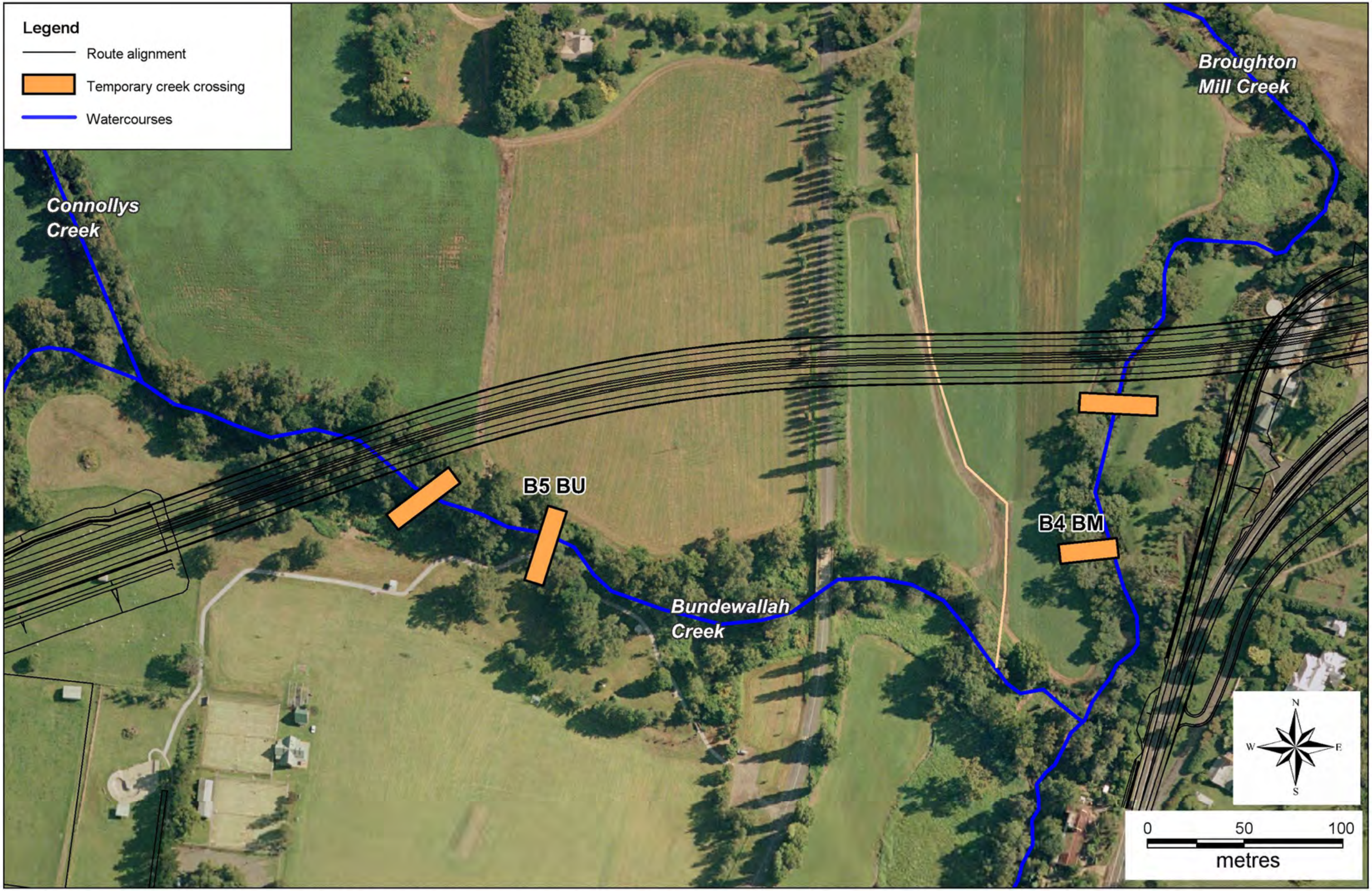

Figure 3.5: Temporary creek crossing sites for Bridge 4 at Bundewallah Creek and Broughton Mill Creek. B4 BM = temporary crossing of Broughton Mill Creek near proposed bridge 4. B4 BU = temporary crossing of Bundewallah Creek near proposed bridge 4

Table 3.7: Temporary creek crossing sites for the Foxground and Berry bypass project (suggested crossing drainage structures based on criteria established by Fairfull and Witheridge, 2003)

Bridge	Watercourse	Figure label	Easting	Northing	Fish habitat classification	Riparian category	Total area spanning vegetation and creek (sq. m)	Recommended temporary crossing structure
Bridge 1*	Broughton Creek	n/a	294889	6152780	1	1	700	Bridge
Bridge 2	Broughton Creek	B2 BC	294478	6152233	1	1	500	Bridge
Bridge 3	Broughton Creek	B3 BC	294150	6151749	1	1	500	Bridge
Bridge 4	Broughton Mill Creek	B4 BM	289994	6149851	2	1	300	Bridge, arch structure, culvert or ford
Bridge 4	Bundewallah Creek	B4 BU	289718	6149855	2	1	400	Bridge, arch structure, culvert or ford
						Total	2400	

** Estimated loss of riparian vegetation in addition to that represented by the project alignment and ancillary infrastructure footprint.*

Bridge 4 – Broughton Mill Creek

Broughton Mill Creek was a Class 2 waterway (moderate fish habitat) and Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary creek crossing. See Site 25 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located south of the proposed bridge structure, about 25 metres downstream and within the concept design footprint (B4 BM in **Figure 3.5**, **Table 3.7**). The crossing would traverse an eight metre wide and one metre deep section of pool habitat. The channel bed was composed primarily of pebble and sand substrata. There was a gap of about 15 metres separating mature river oak on the western bank. Introduced camphor laurel (*Cinnamomum camphora*) and privets (*Ligustrum* spp.) were also present within the riparian zone. In addition to the removal of introduced trees and shrubs some lower branches of the mature river oaks would likely be required for the temporary creek crossing.

The actual location of the temporary creek crossing of Broughton Mill Creek would be determined during detailed design with consideration of the final alignment and would be selected to minimise disturbance of existing riparian vegetation and aquatic habitat.

Bridge 4 – Bundewallah Creek

Bundewallah Creek was a Class 2 waterway (moderate fish habitat) and Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary creek crossing. See Site 27 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located east of the proposed bridge structure, around 20 metres downstream and within the concept design footprint (B4 BU in **Figure 3.5**, **Table 3.7**). The crossing would traverse a five metre wide and 0.8 metre deep section of run habitat. The channel bed was dominated by cobble and pebble substrata. There was a gap of about 11 metres separating mature river oak on the southern bank. Many of the younger native trees within the riparian zone were plantings and introduced groundcovers and annuals were common. Construction of the temporary creek crossing would require the removal of planted native trees and shrubs on the southern bank and trimming of some lower branches of retained river oaks.

The actual location of the temporary creek crossing of Broughton Mill Creek would be determined during detailed design with consideration of the final alignment and would be selected to minimise disturbance of existing riparian vegetation and aquatic habitat.

Temporary construction pads

Temporary constructions pads are likely to be required during the construction phase of the project to assist with bridge construction. Construction pads may involve the temporary placement of rocks or other construction materials within waterways. The main potential aquatic ecology impact would be the blockage of fish passage, in particular for Australian Bass.

The construction method employed should avoid complete blockage of the stream, be of minimum possible duration and involve full removal of all construction material from the waterway.

a

b

c

d

Plates 1a – 1d. (a) Site 13, view downstream of existing Princes Highway two span bridge crossing (b) Site 13, riffle habitat in the foreground and pool habitat upstream (c) Site 13, flood overflow culvert in Princes Highway embankment near the existing Broughton Creek bridge crossing (d) Watercourse at Site 14, view north from Princes Highway and stand of cumbungi (*Typha* sp.).

Plates 2a – 2d. (a) Site 15, view upstream from property road crossing (b) Site 16, view upstream from the proposed second crossing of Broughton Creek by the project (c) Deep pool at Site 17, area of proposed third crossing of Broughton Creek by the Foxground and Berry bypass project (d) Site 18, view downstream from Princes Highway. Larger trees in the background mark the channel of Broughton Creek.

a

b

c

d

Plates 3a – 3d. (a) Site 22, view upstream from Princes Highway (b) Site 23, view downstream from Princes Highway crossing (c) Site 25, alternating riffle and pool habitat in Broughton Mill Creek (d) Australian bass (*Macquaria novemaculeata*) caught at Site 25, Broughton Mill Creek.

Plates 4a – 4d. (a) Site 26, ephemeral watercourse or drainage ditch lying in between Broughton Mill Creek and Woodhill Mountain Road (b) Site 27, Bundewallah Creek, view upstream (c) Site 28, Town Creek, view upstream to North Street (d) Site 29, view upstream from Princes Highway.

3.3 Threatened and protected species, populations, communities and key threatening processes

3.3.1 Listings under the EPBC Act

Threatened species

The DSEWPaC Protected Matters Search Tool linked to the EPBC Act indicated that one endangered fish species, the Macquarie Perch and one vulnerable fish species, the Australian Grayling may either occur in the study area or suitable habitat for them may occur in the study area.

Macquarie Perch

There are two distinct populations of Macquarie Perch in NSW, a western form found in the Murray-Darling Basin, and an eastern form found in south-eastern coastal NSW, including the Hawkesbury-Nepean catchment and the adjacent Shoalhaven catchment (DPI NSW 2005a). Macquarie Perch have also been translocated into a number of river systems. They are found in lake and river habitats, particularly in the upper reaches of rivers and their tributaries. This species spawns in spring or summer in shallow upland streams or flowing parts of rivers. The eggs settle among stones and gravel of the stream or river bed. This species is threatened by:

- Changes in water quality associated with agriculture and forestry.
- Modification of natural river flows and temperatures as a result of the construction of dams and weirs.
- Spawning failures resulting from cold water releases from dams.
- Competition from introduced fish species.
- Diseases, such as epizootic haematopoietic necrosis, which is carried by Redfin Perch.
- Over-fishing in the past.

Australian Grayling

The historical distribution range of Australian Grayling included coastal streams from the Grose River, west of Sydney, southwards through NSW, Victoria and Tasmania (DPI NSW 2006a). On mainland Australia, this species has been recorded from rivers flowing east and south of the main dividing ranges. Grayling has been recorded historically in the Broughton catchment (**Table 3.1**). Australian Grayling form fast-moving shoals in clear stream and rivers with moderate flow. Eggs of Australian Grayling develop in gravel beds, and once hatched the larvae are swept downstream to marine habitat where they develop before returning upstream to freshwater at six months of age (DPI NSW 2006a). Threats to Australian Grayling include:

- Construction of weirs and dams, which prevent downstream and upstream migration.
- Land clearing that degrades water quality and causes siltation.
- Smothering of gravel beds by fine sediment.
- Competition from the introduced brown trout.

Expanded threatened species search

An expanded search which included the distant downstream Shoalhaven/Crookhaven estuary identified nine additional aquatic threatened species; two mammals, four reptiles and three sharks (**Table 3.3**). One is listed as critically endangered, three as endangered and five as vulnerable.

Invasive species

The Environmental Reporting Tool identified Alligator Weed (*Alternanthera philoxeroides*) as potentially occurring in the region. Alligator Weed is a *Weed of National Significance*. It poses a significant environmental and economic threat and is highly invasive. Infestations can take over wetlands such as creeks and drainage channels, displacing native vegetation, preventing flow and reducing oxygen exchange. It can also invade land and displace or cause the failure of agricultural crops. Alligator Weed does not produce viable seed in Australia but instead grows through vegetative reproduction and is spread easily from fragments. It has been spread in landfill and attached to machinery and vehicles (eg bulldozers).

Alligator Weed is a Class 2 Noxious Weed in the Shoalhaven and Kiama LGAs, and as such the land must be kept free of Alligator Weed and it must be eradicated when identified.

Migratory marine species, listed marine species, whales and other cetaceans

An expanded search which included the distant downstream Shoalhaven/Crookhaven estuary identified 49 species that are given general protection and listed under s248 of the EPBC Act, as either (i) migratory marine species, (ii) listed marine species, or (iii) whales and other cetaceans (**Table 3.3** Migratory marine species, listed marine species and whales and other cetaceans).

Twelve species are listed as migratory marine species, comprising six mammals, four reptiles and two sharks (**Table 3.3** Migratory marine species). There are 26 listed marine species, comprising two mammals, four reptiles and 20 ray-finned fish from the order Syngnathiformes (including pipefish, pipehorses, seahorses, seadragons, and ghost pipefish) (**Table 3.3** Listed marine species). A number of the Syngnathiformes can be found in coastal embayments or estuaries, often associated with seagrass habitat. Eleven species are listed as whales and other cetaceans (**Table 3.3** Whales and other cetaceans). Several species of marine mammals are listed under both migratory marine species and whales and other cetaceans categories.

3.3.2 Listings under the TSC Act

Endangered ecological communities (EECs)

Geographic Region Search tool identified two EECs as present within the Illawarra and Jervis sub-regions of the Southern Rivers Catchment Management Region:

- Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions (Coastal Saltmarsh).
- Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (Freshwater Wetlands).

Coastal Saltmarsh

About 0.017 square kilometres and 2.06 square kilometres of Coastal Saltmarsh is present downstream of the study area in the Crooked River and Shoalhaven/Crookhaven estuaries respectively. "*Coastal Saltmarsh is a mostly treeless plant community recognised by a low mosaic of succulent herbs, salt tolerant grasses and sedges, found in the tidal flats of estuaries and on edges of intermittently opened coastal lagoons*" (p1 DECC 2007). Saltmarsh is usually found in the upper limits of the intertidal zone and are only intermittently flooded by medium to high tides.

Threats to saltmarsh include:

- In-filling for development.
- Modification of tidal flows by artificial structures.
- Changes to salinity and increasing nutrient levels from stormwater discharge.
- Weed invasion, particularly by *Juncus acutus*.
- Physical damage from human disturbance, domestic and feral animals.
- Pollution.
- Invasion by mangroves.
- Inappropriate fire regimes.

Freshwater Wetlands on Coastal Floodplains

Freshwater Wetlands on Coastal Floodplains are "*an ecological community associated with periodic, semi-permanent or permanent inundation by freshwater, although there may be minor saline influence in some wetlands*" (p1 DECC 2008). Freshwater Wetlands typically occur on silts, muds or humic loams in low-lying parts of floodplains, alluvial flats, depressions, drainage lines, backswamps, lagoons and lakes but may also occur in back barrier landforms where floodplains adjoin coastal sand plains. They generally occur below 20 metres elevation on level areas. The structure and composition of the community varies both spatially and temporally depending on the water regime. They are dominated by herbaceous plants and have very few woody species. Meadows of grasses, sedges and rushes occur where submersion is not prolonged, while aquatic herbs dominate where semi-permanent or permanent standing water is present. Under the influence of saline water tall reeds and rushes dominate.

Threats to this community include:

- Land clearing.
- Fragmentation and degradation.
- Flood mitigation and drainage works.
- Filling associated with urban and industrial development.
- Pollution and eutrophication from urban and agricultural runoff.
- Weed invasion.
- Overgrazing, trampling by livestock.
- Activation of acid sulfate soils.
- Dumping of landfill, rubbish and garden refuse.
- Native fauna is threatened by predation, particularly by mosquito fish.
- Anthropogenic climate change.

Only two areas of potential coastal floodplains freshwater wetland occur within the Crooked River catchment: the Willowvale and Gerringong Wetlands; although they are small, highly degraded and located on the fringes of the Crooked River floodplain, extending up into the foothills. Whilst the Coomonderry Swamp constitutes significant coastal freshwater wetland habitat it lies outside of the catchments traversed by the project and therefore would be unaffected by associated works.

Key threatening processes

"*Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands*" is listed as a KTP on Schedule 3 of the TSC Act (DECC 2005). Human activities that reduce or increase flows, change the seasonality of flows, change the frequency, duration, magnitude, timing, predictability and variability of flow events, alter surface and subsurface water levels and change the rate of rise or fall of water levels can all alter the natural flow regimes of water courses. The project requires the crossing of a number of water courses. Inappropriate road crossing structures can change the natural flow regime of a waterway.

The flow regime is a key driver of river ecology, and changes to flow can alter the geomorphological process of sediment erosion, transport and deposition that structure a variety of important channel habitat forms, change macrophyte communities, influence water properties important to biological assemblages and alter in-stream connectivity, isolating habitats and populations.

Examples of impacts on aquatic biota associated with altering natural flow regimes include:

- Restricted access to habitat for foraging, refuge or reproduction (eg reduced fish passage).
- Disruption of natural environmental cues necessary for reproductive cycles.
- Reductions in flow can decrease the amount of organic matter on which invertebrates and vertebrates depend on.
- Changes in flow can increase erosion and lead to sedimentation impacts on aquatic communities and degradation of the riparian zone.
- Deeper and more permanent standing water can facilitate the establishment and spread of exotic species.

These alterations can pose a threat to species, populations or ecological communities which rely on natural flow regimes for their short-term and long-term survival and thereby contribute to loss of biological diversity and ecological function in aquatic ecosystems.

3.3.3 Listings under the FM Act

Threatened species

One endangered species, Macquarie Perch and one vulnerable species, Black Cod (*Epinephelus daemelii*), listed under the FM Act potentially occur within the region of the study area, or in aquatic habitats downstream of the study area. Another endangered species, the Sydney Hawk Dragonfly (*Austrocordulia leonardi*), has been recorded from coastal catchments south of Sydney. The Macquarie Perch is described in Section 3.3.1 of this report.

Black Cod

Black Cod is a large carnivorous reef-dwelling species. They are generally found in warm temperate and subtropical parts of the south-western Pacific. Adults are usually found in caves and gutters on rocky reefs. Small juveniles are often found in coastal rock pools and larger juveniles around rocky shores and estuaries (DPI 2007a). BioNet had a record for Black Cod near Gerringong Harbour in 2001. Threats to Black Cod include:

- Impacts on juvenile Black Cod due to the loss or degradation of estuarine nursery habitats.
- Overharvesting by line, net and spearfishers.
- Accidental capture by hook and line fishing.

Sydney Hawk Dragonfly

This species was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney, and has subsequently been found in the Nepean River at Maldon Bridge near Wilton. The species is also known to occur in the Georges River and Port Hacking catchments. This dragonfly spends most of its life as an aquatic larva, with adults emerging from the water and living for only a few weeks or months. The larvae appear to have specific habitat requirements and have only been found under rocks in deep, cool, shady pools (NSW DPI, 2007b). This species is threatened by:

- River regulation and changes in flows that cause the disappearance of natural deep pools.
- Habitat degradation associated with removal of riparian vegetation, drainage works and sedimentation.
- Water pollution and sedimentation due to land clearing, waste disposal and stormwater runoff from urban, industrial and agricultural development in the catchment.
- Chance events such as natural disasters (drought) that eliminate the remaining local populations.

The Sydney Hawk Dragonfly is extremely rare. Despite extensive sampling it has only been collected in small numbers at only a few locations in a small area to the south of Sydney, between Audley and Picton, suggesting it has a highly restricted distribution (NSW DPI 2007). There are no records for this species within the Illawarra sub-catchment of the Southern Rivers Catchment Management Region, nor the adjacent Shoalhaven sub-catchment. It is therefore considered unlikely that this species occurs within the study area and as such it is not included in the assessment of potential impacts provided in Chapter 4.

Protected species and habitats

Listed protected species under the FM Act that may inhabit the study area (including distant downstream aquatic habitats), include:

- Australian Grayling.
- All Syngnathiformes (seahorses, seadragons, pipefish, pipehorses, ghost pipefish and seamoths).

There are currently 31 syngnathids (seahorse, pipefish, pipehorses and seadragon), four solenostomids (ghost pipefish) and two species of pegasids (seamoths) known to exist in NSW waters. Syngnathiformes are found in a variety of habitats, including seagrass beds, coastal embayments and artificial structures such as jetties or mesh nets. Threats to Syngnathiformes in NSW include degradation of habitats, such as seagrass and soft-bottom habitats through pollution, urban runoff, dredging and sewerage.

Protected aquatic habitat in NSW (Fish Habitat Protection Plan No.1 and Fish Habitat Protection Plan No. 2) that may be present in the study area includes: seagrass, mangroves, saltmarshes, wetlands, mudflats, sand and gravel substrata, reed beds and other aquatic plants, large woody debris and rocks.

The Estuary Cod (*Epinephelus coioides*) is also a listed protected species in NSW. Estuary Cod occur in tropical and warm temperate marine waters of the Indo-Pacific. In Australia they are most common in Queensland, the Northern Territory and Western Australia, and NSW represents the southern extend of their distribution. Whilst juvenile Estuary Cod inhabit shallow estuaries, the species has not been recorded in waters south of Sydney and therefore will not be considered in the assessment of potential impacts (DPI, 2006b).

Key threatening processes

Three KTPs listed under the FM Act, "*Degradation of Riparian Vegetation*", "*The Removal of Large Woody Debris from NSW Rivers and Streams*" and "*Instream Structures and Mechanisms that Alter Natural Flow*" are relevant to the project (DPI NSW 2005b, 2005c).

Degradation of riparian vegetation

The term "riparian vegetation" refers to the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains. Riparian vegetation is important ecologically because it provides a source of organic matter; shade and large woody debris. Riparian vegetation stabilises river beds and banks, protecting the channel against erosion and acts as a filter for sediments and nutrients entering watercourses. For example; Australian Bass show a relatively high degree of reliance on terrestrial food sources and therefore the destruction of riparian habitat may affect inputs of allochthonous matter and have serious implications for food availability (Pusey *et al.*, 2004).

Native riparian vegetation within the study area forms part of the EEC *River Bank Eucalypt Forest on Coastal Floodplain* listed under the TSC Act.

Removal of large woody debris

Instream woody debris provides complex habitat for macroinvertebrates and particularly fish, including refuge from predation, habitat for prey and as damming structures that create pools.

Instream structures and mechanisms that alter natural flow

Instream structures, such as floodgates, bridges, culverts, flow regulators, erosion control structures and causeways, can all modify natural flow regimes of waterways (Section 3.3.2 KTPs). Of particular concern can be the impacts these structures have upon the passage of fish. Crossings of watercourses, or construction in the vicinity of a watercourse, would minimise potential impacts on aquatic habitat and biota if they comply with the NSW Fisheries 'Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' and 'Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings' (Fairfull and Witheridge, 2003).

4 Assessment of potential impacts

The assessment of potential impacts of the project is based on the information provided in Concept Design report (RMS 2012), Foxground and Berry Bypass Preliminary Environmental Assessment (PEA) (RTA 2010), provisional location of ancillary infrastructure (as of 14 July 2011) and through correspondence with AECOM and RMS.

The potential environmental impacts from the construction and operation of the project on aquatic ecology relate to: sedimentation; pollution; ASS; changes to hydrology; obstructions to fish passage; degradation of riparian habitat; removal of large woody debris and impacts on threatened species, populations and EECs.

4.1 Potential environmental constraints

4.1.1 Sediment mobilisation

The project would be a major works project. Sediments may be mobilised into the study area's aquatic habitats from earthworks required for the construction of the project and from ongoing erosion of disturbed areas during operation. Relevant works include:

- Excavation, drilling and blasting of road cuttings.
- Preparation of the highway surface.
- Excavation associated with installation of drainage structures such as culverts, bridges, stormwater drains.
- Construction of bridge piers within the wetted-width of waterways.
- Construction of ancillary infrastructure such as site compounds, temporary creek crossings, temporary construction pads and temporary traffic facilities and diversion networks.
- Construction of a large raised earth embankment connecting Bridge 2 and Bridge 3.
- Landscaping works.
- Run off from stockpiles of construction materials and spoil. Particularly the proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane which covers two upstream tributaries of a small unnamed watercourse that crosses the alignment to the south of the project area.
- Operation of crushing plant and transport of materials.
- Creation of airborne dust and use of dust suppression/washdown facilities.
- Erosion of earth embankments, particularly embankment connecting Bridge 2 and Bridge 3 from changes to the flooding regime caused by Bridge 2 (see Section 4.2.3).
- Runoff and erosion of exposed cutting faces, particularly the more dispersive rock and soil types such as Berry Siltstones and soft alluvial soils.
- Ground conditioning works such as possible replacement of alluvial soils with engineered fill.
- Removal of riparian vegetation.
- Excavation and potential erosion associated with creation of permanent creek bed to facilitate the diversion of flows from Town Creek into Bundewallah Creek.

Downstream aquatic habitats in the Broughton Creek catchment may also be at risk as increases in suspended sediment have been detected for long distances (kilometres) downstream of construction sites (Wheeler *et al*., 2005). Compaction in works areas may reduce infiltration of surface waters and also contribute to sediment load in runoff.

In a worst case scenario, an increase in sediment load can degrade water quality and important habitat features resulting in a loss of biodiversity and a shift towards a more pollution-tolerant biotic assemblage. For example, sedimentation can cause:

- Mortality and decreased growth. Suspended particles could clog respiratory gills and/or feeding apparatus of fish and macroinvertebrates.
- Degradation of habitat. Siltation could infill deep water refugia and interstitial spaces in the stream bed and smother aquatic macrophytes beds and spawning grounds.
- Reduced water quality. Increased light attenuation could decrease primary productivity and nutrients bound in mobilised sediments could increase eutrophication.

Increased sedimentation is considered a threat to Australian Grayling, Macquarie Perch and Freshwater Wetlands (EEC).

Increased sedimentation would be a concern for significant local freshwater habitat and biota downstream of the construction works, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. The sections of Broughton Mill Creek and Bundewallah Creek crossed by the project supported pool edge macroinvertebrate communities equivalent to reference condition and are both Class 2 waterways for fish habitat. There would be works associated with three proposed crossings of Broughton Creek and at a number of smaller watercourses in the catchment that subsequently discharge into Broughton Creek. The reaches of Broughton Creek crossed by the project were classed as major fish habitat (Class 1 Waterways). AusRivAS assessment found macroinvertebrate communities at the existing Princes Highway crossing of Broughton Creek were impaired, reflecting elevated nutrient levels in water and localised degradation of habitat, however there are significant downstream sections with relatively intact riparian vegetation and aquatic habitat. Major fish habitat was also located further downstream, outside the project area in the Crooked River estuary, the estuarine reach of lower Broughton Creek and the Shoalhaven/Crookhaven estuary.

A considerable amount of freshwater habitat within the study area was relatively degraded, particularly the smaller more ephemeral streams. Channel substratum was affected by loose accumulations of soft-sediments, covering and sometimes infilling interstitial spaces of underlying larger-sized substrata (eg cobble, pebble and gravel). This indicated a historical and ongoing mobilisation of sediments from the disturbed catchment into the waterways. As such, the fish and macroinvertebrate taxa more commonly observed in these areas were relatively tolerant to sedimentation and degraded habitat. Fish have the added advantage of being relatively mobile and therefore have a better opportunity to seek out more favourable conditions during short-term elevations in suspended sediments and to recolonise areas following the disturbance.

In the absence of mitigation measures a typical scenario for disturbance of these degraded waterways would result in further degradation of existing habitat and impairment of biotic assemblages. The likelihood and magnitude of impacts would be greater closer to the construction sites, with aquatic habitat furthest downstream, particularly the Shoalhaven/Crookhaven estuary, least likely to be affected.

The Concept Design report (RMS, 2012) and the environmental assessment outline a number of strategies designed to mitigate sediment mobilisation into waterways. These include:

- No bridge pier placements within the wetted-width of waterways (under average flow conditions) where practicable. (Note: Four bridge piers would be required in Bundewallah Creek).
- Protection of surfaces at risk from erosion, for example:
  - Energy dissipaters provided to outlets of drainage structures that have the potential to cause scour.
  - Control of surface water flow into cuttings.
  - Scour protection of raised embankment between Bridge 2 and Bridge 3.
  - Protection of banks and bed of newly created channel for diversion of flow from Town Creek into Bundewallah Creek.
- Permanent spillage containment basins and vegetated swales to capture and treat first flush from pavement surfaces. MUSIC (model for urban stormwater improvement conceptualisation) modelling suggests that 300 cubic metres of sediment basin (or vegetated swale equivalents) would remove 81 per cent of total suspended solids (TSS). Although the Concept Design notes that vegetated swales may not provide complete spill capture capability for larger flow events.
- Sediment and erosion control measures on construction sites such as silt fences, and sediment basins.
- Dispersion testing of excavated soils to determine suitability for use in earthworks.
- Location and layout of ancillary infrastructure at least 50 metres from waterways where possible.
- Dust suppression and washdown.

Conclusion

Mobilised sediments are unlikely to pose a significant threat to the aquatic ecology of the study area, provided standard sediment and erosion control measures are implemented (see proposed mitigation strategies (Sections 5.1.1 and 5.1.2)). Similarly, regionally significant aquatic habitat in the Shoalhaven/Crookhaven estuary is too far downstream to be affected by controlled works associated with the project.

4.1.2 Pollution

In a typical scenario in the absence of mitigation measures the construction and operation of the project has the potential to mobilise contaminants into aquatic habitat. Possible pollution may include (but not limited to):

- Pollutants associated with materials used in the process of road construction. There is a diverse array of materials used in the construction and maintenance of roads, for example: asphalt materials, asphalt additives, cementitious materials, cement admixtures, dust palliatives and aggregates. Industrial waste by-products are also increasingly being approved for road construction, such as petroleum refinery residuals, coal combustion fly ash, scrap tyres/recycled rubber, mining waste and reclaimed concrete pavement (Eldin, 2002). Many of these materials can be toxic in their pure (non-amended) states, eg fly ash and asphalt cement crumb rubber elutriates (Eldin, 2002). Contamination may result from spills on site or after construction from long-term runoff directly into aquatic habitats.

- Pollutants associated with heavy vehicles used on site during construction and from ongoing traffic use of the project, such as aromatic hydrocarbons (lubricating oils and fuels) and heavy metals (eg copper in brake linings, and zinc and cadmium in tyres).
- Contaminant spills of materials transported via the highway. For example, large tank trucks are used to transport a variety of potentially hazardous liquid goods, such as gasoline, diesel and industrial chemicals.
- Heavy metal leachate and runoff (eg aluminium, iron and zinc) from disturbed ASS.
- Leachate from waste dumps established onsite.
- Overflow from dams/ponds used to trap and recycle contaminated/'dirty' water onsite.
- Organic pollutants in stormwater runoff (eg nitrogen and phosphorus).
- Pollutants bound to disturbed sediments may be mobilised into aquatic habitat.

Pollution impacts from road construction and operation can be either 'pulse' impacts (impacts that occur immediately, eg from spills) or 'press' impacts (impacts that accumulate over time, eg from long-term runoff). Aquatic biota vary in their sensitivity to pollutants. In a typical scenario in the absence of mitigation measures contamination of aquatic habitats can cause a loss of biodiversity, a shift towards biotic assemblages dominated by pollution-tolerant taxa and degradation in ecological function. Pollution is considered a threat to Coastal Saltmarsh and Freshwater Wetlands on Coastal Floodplain, both EECs under the TSC Act.

Increased pollution would be a concern for the significant local freshwater habitat and biota downstream of the construction within the study area, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. Whilst previous studies have suggested that regional agricultural land use has had a detrimental impact on water quality within the study area, the major waterways still represent major to moderate fish habitat (Class 1-2 Waterways) and function as significant environmental corridors (Category 1 waterway and riparian zones). Further pollution would increase the stress on these aquatic ecosystems.

The Concept Design report (RMS, 2012) and the environmental assessment outline a number of strategies designed to mitigate contamination of aquatic habitat and biota. These include:

- Operational runoff would be collected in a longitudinal drainage system and treated using non-point source or dispersed techniques. For example, the use of grass swales, table drains, grass buffer strips, edge drains and grassed median strips.
- The bridge drainage system has been designed so that all collected water is conveyed longitudinally to the abutments, rather than allowing scuppers to discharge directly into receiving waters.
- In sensitive environmental locations and where required, sedimentation basins installed for the construction phase would be converted to water quality treatment basins for the operational phase.
- Ancillary infrastructure would be located at least 50 metres away from waterways where possible.

It is recommended that vegetated swales of one metre base width, 80 metres in length with three per cent longitudinal grade and 250 millimetre vegetation height be used, as this configuration would remove 81 per cent of TSS, 65 per cent of total phosphorus (TP) and 16 per cent of total nitrogen (TN) (based on MUSIC modelling). Whilst the Concept Design notes that vegetated swales may not provide complete spill capture capability for larger flow events, the runoff would not contain levels of TSS, TN or TP in excess of receiving waters (AECOM, 2011). No concrete batching plants for the construction of bridges are proposed.

Conclusion

The project is expected to have a relatively minor impact on water quality through careful design and best practice environmental management. See proposed mitigation strategies (Sections 5.1.1 and 5.1.2).

4.1.3 Acid sulfate soils

ASS are widespread in estuaries, coastal floodplains, backswamps and coastal wetlands. ASS are formed when the naturally occurring iron sulphides (pyrite) in the soil become exposed to air through drainage or excavation and subsequently oxidise, forming sulphuric acid.

The project generally passes over geological conditions mapped by the then Department of Land and Water Conservation (DLWC, 1997) as having no known occurrence of ASS, with only one area of low ASS risk occurring at depths greater than four metres close to a section of the project south of Berry (refer to Figure 8-1 of the environmental assessment which shows ASS in the project area). Areas of no known occurrence generally correspond with landforms above 10 metres AHD and based on an assessment of the geomorphic processes occurring there.

Following further consideration of the known geological information for the project area, an additional area of low risk of PASS being encountered has been identified. This corresponds with areas with alluvial floodplain soils at the Broughton Creek floodplain, and to a lesser extent at the bypass of Berry (refer to Figure 8–2 of the environmental assessment which shows additional areas of PASS risk).

The Broughton Creek floodplain to the east and north of Berry would be disturbed during construction of the project. The pH measured at Bundewallah Creek and Broughton Mill Creek was marginally within the ANZECC lower threshold values for the protection of aquatic ecosystems (Appendix C). The section of project corridor between the Bridge 3 crossing of Broughton Creek and the Bridge 4 crossing of Broughton Mill Creek traverses the lower foothills at the base of the Illawarra Ranges and has a much lower risk of disturbing ASS.

Project works that risk disturbing ASS include:

- Excavation and construction of transverse drainage structures, eg culverts and bridges.
- Excavation of sediment basins and installation of swales.
- Excavation and removal of soft alluvial soils for ground conditioning.
- Stockpiling of excavated ASS.
- Dewatering in ASS areas (eg during installation of drainage structures).
- Excavation required to create permanent channel for the diversion of flows from Town Creek north of the upgrade into Bundewallah Creek.

In a worst case scenario ASS can have major environmental impacts and constrain development and construction in affected areas if not properly managed. Impacts on aquatic ecology caused by ASS include: habitat degradation, fish kills, reduced aquatic food resources, reduced migration potential of fish, reduced fish recruitment, altered macrophyte communities, weed invasion by acid-tolerant plants and secondary water quality changes. ASS can also increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome or ‘red spot disease’. Red spot disease is considered a threat to Macquarie Perch.

Conclusion

In the worst case scenario there is a risk of disturbing unknown ASS in areas that may intersect with relevant project works.

Any development in areas with ASS risk requires extensive consideration of construction methodology to avoid or minimise the potential impacts on the aquatic ecology in the study area and in downstream environments. See proposed mitigation strategies (Sections 5.1.1 and 5.1.2).

4.1.4 Groundwater dependent ecosystems

Works associated with the project that have the potential to impact on GDEs within the study area are the same as those that could affect groundwater flows (Section 4.2.3). These include:

- Ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep where the project traverses Toolijooa Ridge.

The shallow alluvial groundwater systems within the study area support GDEs such as hyporheic habitat, base flow to significant waterways such as Broughton Creek, Broughton Mill Creek, Bundewallah Creek and Connollys Creek and riparian forest. Native riparian forest within the study area is often the EEC *River Flat Eucalypt Forest on Coastal Floodplains*.

The natural variability of shallow alluvial groundwater systems can make them more robust and able to tolerate fluctuating water levels but in the worst case significant changes to groundwater hydrology (eg groundwater falling below a threshold or falling too quickly) can lead to ecosystem damage (DLWC, 2002). The exact importance of groundwater to these GDEs is unknown and therefore it is difficult to accurately predict impacts associated with the project. GDEs most sensitive to changes in the groundwater regime would be: hyporheic ecosystems; shallow aquatic habitat (and associated biota) such as riffles and discontinuous pool refugia; and low-lying riparian forest.

Groundwater seepage into road cuttings would be collected by a longitudinal drainage system and transferred to vegetated swales or sediment basins within the Broughton Creek catchment. The *Foxground and Berry bypass Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012) prepared for this environmental assessment and provided at Appendix H of the environmental assessment found that typically soft-soils treatments may cause some reduction of permeability of underlying soils but groundwater would still flow, particularly through the sandy soil horizon.

Conclusion

It is anticipated that the project would have a minor and localised effect on groundwater flows and therefore is unlikely to cause any significant impacts to GDEs within the study area.

4.1.5 Invasive species

Alligator Weed was not observed at any site within the study area, nor were any records found for its occurrence within the study area. The species is known to be present within the Illawarra region.

In a worst case scenario if Alligator Weed became established within the study area it is possible that its distribution could be increased by construction activities associated with the project. See proposed mitigation strategies (Section 5.1.2).

4.2 Listed key threatening processes

4.2.1 Degradation of riparian vegetation

Project works that could degrade riparian vegetation include:

- Clearings made within the project corridor at each waterway crossing.
- Clearings at each of five temporary creek crossings.
- Clearings associated with temporary constructions pads.
- Clearings made for ancillary infrastructure: eg the proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane. The stockpile covers two upstream tributaries and riparian habitat of a small unnamed watercourse that crosses the alignment to the south of the project area.
- Works that could alter the groundwater contribution to riparian forest (Section 4.1.4).
- Clearing made on the western bank of Bundewallah Creek to connect the channel which would divert water from Town Creek into Bundewallah Creek.

The benefits of riparian vegetation to freshwater biota are outlined in Section 3.3.2 *Key threatening processes*.

Typically, riparian vegetation was already extremely degraded along many of the smaller waterways that intersect the project. Large woody vegetation was often absent or composed of exotic species. Therefore, it is unlikely that the project could further degrade riparian habitat at these locations such that it would cause a significant impact on aquatic ecology.

Riparian vegetation was generally more intact at the larger creeks in the catchment, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. These creeks and their adjacent riparian zones were considered Category 1 waterways (Environmental Corridors) under the RCMS classification system (**Table 3.4**). Native riparian vegetation within the study area forms part of the EEC *River Bank Eucalypt Forest on Coastal Floodplain* listed under the TSC Act.

The estimated loss of riparian vegetation due to direct and indirect edge effects associated with construction of the project is outlined in **Table 4.1**.

Table 4.1: Estimated loss of riparian vegetation associated with construction of the project

Project works	Area of riparian forest (hectares)
Permanent roadway	2.6
Ancillary facilities	0
Temporary creek crossings	0.2
Town Creek diversion	0.1
Total direct effects	**2.9**
Indirect edge effects	7.1
Total direct and indirect effects	**10**

Indirect edge effects were measured as the amount of riparian vegetation lost within a 50 metre buffer of the project footprint, and are independent of the condition of the vegetation condition (Refer to the *Terrestrial Flora and Fauna Assessment* (Biosis, 2012) provided at Appendix F to the environmental assessment).

The diversion of Town Creek would require the creation of a permanent channel from the diversion point to the western bank of Bundewallah Creek. The diversion channel would provide new aquatic habitat, assuming that its design would incorporate:

- A natural alignment (ie curved, not linear).
- A creek bed form that mimics those of natural creeks.
- Appropriate channel definition.
- Bank configuration suitable for planting riparian vegetation.

Given appropriate riparian vegetation communities are planted and maintained, the diversion channel would create approximately 0.4 linear kilometres of habitat, compared to the approximately 2.9 linear kilometres of habitat in the existing Town Creek alignment that would be further degraded as a result of the flow diversion.

Conclusion

The project would cause an estimated loss of riparian habitat within the study area of 2.9 hectares (**Table 4.1**). See recommended offsets and mitigations measures (Sections 5.1.1, 5.1.2 and 5.2).

4.2.2 Removal of large woody debris

The benefits of instream large woody debris to freshwater biota is outlined in Section 3.3.2 *Key threatening processes*.

There is little large woody debris in many of the smaller waterways that intersect the project. Therefore it is unlikely that the project could further degrade large woody debris habitat at these locations such that it would cause a significant impact on aquatic ecology.

There is large woody debris present within the larger watercourses in the catchment, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. Bridge pier placement within Bundewallah Creek and the temporary crossings constructed near each bridge site would potentially involve instream works. For example, removal of a large snag extending from the bank into the water to facilitate placement of pier footings would require instream disturbance. In a worst case scenario it is possible that project works could lead to the removal of large woody debris. See recommended mitigation strategy (Section 5.1.2).

4.2.3 Alteration to natural flow regimes of rivers, streams, floodplains and wetlands

The TSC Act listed KTP *Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands* is equivalent to *Instream Structures and Mechanisms That Alter Natural Flow* and they are considered as one in this section. The ecological importance of maintaining natural flows and fish passage is outlined in Section 3.3.2 *Key threatening processes*.

Project works that may affect surface water and groundwater flows

The following works could affect surface and groundwater flows within the study area:

- Ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep where the project traverses Toolijooa Ridge.
- Provision of drainage structures (such as culverts and bridges) within the road embankment for flood mitigation during flow events.
- Bridge pier placement within the wetted-width of Bundewallah Creek (under average flow conditions).
- Five temporary creek crossings in the vicinity of the proposed bridge structures (above) during the construction phase.
- Temporary construction pads in the vicinity of the proposed bridge structures during the construction phase.
- Longitudinal drainage and retention basin/swale system to control and discharge drainage from cuttings, embankments and construction sites.
- Construction of a raised embankment linking Bridge 2 and Bridge 3.
- Ancillary infrastructure constructed near or over existing waterways. For example: RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane; landscaping and creation of hard stand areas at site compounds.
- Diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.

It has been estimated that around 100 megalitres of water per year of construction would be required. Water for construction purposes would be sourced as follows in order of priority:

- Recycled effluent from the tertiary treatment plant at Gerringong Gerroa and/or Berry.
- Surface water, sourced from on-site detention basins.
- Surface water, sourced from watercourses where it would not be detrimental to the aquatic environment of the waterway.
- Potable water.
- Groundwater, sourced from de-watering that may be required at the Toolijooa Ridge cutting.

The re-use of treated water from sediment basins would have negligible effects on surface water and groundwater flows.

Construction of Bridge 4 would include the placement of bridge piers within Bundewallah Creek which would potentially impact on surface water flows. There would be no instream works associated with the construction of Bridges 1, 2 and 3. Any significant changes to these aspects of the concept design would need to be assessed for potential impacts on aquatic ecology and water quality.

Impact of project works on surface water and groundwater flows

The *Foxground and Berry bypass Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012) prepared for this project and provided at **Appendix H** of the environmental assessment addressed impacts on surface water and groundwater flows. Relevant impacts have been summarised here. For more detail and quantification of the impacts, refer to **Appendix H** of the environmental assessment.

The project would have an insignificant effect on groundwater flows within the study area. Groundwater seepage into road cuttings would be collected by a longitudinal drainage system and transferred to vegetated swales or sediment basins within the Broughton Creek catchment.

Placement of the pier structure in Bundewallah Creek would alter the hydrology of the creek. A general decrease in velocity (0.1 to 0.2 m/s) immediately upstream of the piers would be observed, with a corresponding slight increase in water levels. There would also be localised increases in velocity downstream of the piers, of a similar magnitude to those identified above. The increases in velocity would not extend across the entire flow width at the pier cross section and are relative to predevelopment velocities.

The five proposed temporary creek crossing structures or the potential impacts they may have on surface flows are not considered in the concept design, as it relates to the design of the project and drainage structures not associated with construction.

The longitudinal drainage and retention basin/swale system to control and discharge drainage from cuttings, embankments and construction sites would have a negligible effect on the hydrology of the major waterways within the study area.

The proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane appears to have an unnamed watercourse and its tributary flowing through it. The waterway intersects the proposed Princes Highway upgrade outside of the project area, at the beginning of the Hitchcocks Lane to Bomaderry stage. Further downstream, this waterway is joined by the watercourse that passed through Site 29 before eventually discharging into the estuarine reach of Broughton Creek downstream of the Coolangatta Road bridge crossing. Details of the stockpile within this location were not available at time of writing, however the environmental criteria adopted for the project specify that project works and ancillary infrastructure (including stockpiles) would not take place within 50 metres of any waterway. There is sufficient space on the site to stockpile outside this exclusion zone.

The diversion of Town Creek from a point north of the upgrade into Bundewallah Creek would alter hydrology in the catchment, with changes including:

- Increases in frequency, volume and velocity of flows in Bundewallah Creek, with potential for erosion of creek beds near the point of confluence.
- Increase in flow volume in Bundewallah, Connollys and Broughton Mill Creek.
- Significant decrease in catchment area of Town Creek. After diversion the decrease in Town Creek's total catchment area would be approximately 47 per cent AECOM (2012).
- Slight increase in area for the catchments of Bundewallah, Connollys and Broughton Mills creeks.
- Significant decrease in flow in the reach of Town Creek south of the diversion point.
- Sediment accumulation within the creek as a result of the decrease in overall and flushing flows.

Potential impacts to aquatic ecology and water quality

Longitudinal and transverse drainage structures would not have a significant impact on aquatic ecology or water quality within the study area. The negligible effect on in-channel flows would have minimal impacts on aquatic habitat and biota.

The proposed transverse drainage structures in the Concept Design (RMS, 2012) conform to DTIRIS 'minimum' recommended crossing types outlined in '*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*' (Fairfull and Witheridge, 2003) and as such should have little or no impact on fish passage and aquatic ecology. Providing recommended crossing types are used at the temporary creek crossing sites, these structures should have minimal impacts on aquatic ecology and water quality.

The decrease in flow and associated sediment accumulation within the creek bed in Town Creek after diversion would alter the aquatic ecology of the creek, with aquatic habitats nearest the diversion point reduced to isolated pools with associated declines in water quality. By reducing water flow, the diversion has potential to degrade approximately 0.1 hectare of riparian forest vegetation along the creekline (see **Table 4.1**).

Aquatic habitats in the southernmost reaches of the creek are expected to change less noticeably because they would receive inflow in the urbanised reach consisting primarily of stormwater runoff. Estimated at a point near the confluence with Broughton Mill Creek, the conservative predicted overall flow volume in Town Creek would decrease to 33 per cent (based on 50 percentile occurrence: AECOM 2012). However, alterations in aquatic habitats, the loss of connected aquatic habitat and reductions in overall flows in Town Creek may have little additional impact on aquatic ecology and water quality, as the waterway is currently ephemeral, has been extremely degraded by agricultural development in its upper catchment and residential development downstream of the upgrade and is not considered important as fish habitat. As there is no aquatic ecological benefit to overbank flooding in large flood events within the Berry township, there would be no loss of ecological function caused by the diversion of flooding flows into Bundewallah Creek.

The comparatively small increase to flow volumes in Bundewallah, Connollys and Broughton Mill creeks would have minor effects on aquatic ecology and water quality in those creeks. The loss of riparian vegetation to facilitate the diversion channel into Bundewallah Creek would be minor.

The changes to hydrology caused by Bridges 1, 3 and 4 would have an insignificant effect on aquatic ecology and water quality. Bridge 2 and the raised earth embankment would increase flood levels upstream for large flood flow events and reduce the floodplain storage and capacity. Overbank flooding provides infrequent but critical lateral connectivity to adjacent habitats for aquatic biota and can drive temporary booms in productivity that can be important for long term population persistence. Flood flows can be particularly important for recharging adjacent wetland areas. A number of native aquatic species spawn at particular times so that their juveniles can benefit from the increased productivity during seasonal flood flows. Although the floodplain area that would be lost to the earth embankment is cleared agricultural land, the reduction in floodplain storage and lateral connectivity could result in some productivity decreases for aquatic assemblages.

The altered hydrology caused by the placement of the bridge pier structures within Bundewallah Creek would not have a significant impact on aquatic ecology and water quality provided appropriate mitigation measures are implemented (Sections 5.1.1 and 5.1.2). The bridge piers are not likely to significantly impede upstream fish passage as velocities and water levels are similar to predevelopment conditions. The expected change in velocity is 0.12 m/s which is within the swimming ability of Australian Bass.

The use of bridges as temporary creek crossings would have an insignificant effect on aquatic ecology given that support structures are located landward of the creek banks and no other in-stream structures are used. The use of appropriate structures for temporary crossings, such as culverts or fords, over Broughton Creek (Class 1 waterway) and Broughton Mill Creek and Bundewallah Creek (during low or zero flow periods), would ensure upstream fish passage and longitudinal connectivity is maintained.

The unnamed waterway between Schofields Lane and Andersons Lane was ephemeral, extremely degraded and only flows during rain events. It drained cleared agricultural land, had a relatively indistinct channel colonised by pasture grass and was considered unlikely to provide fish habitat. This creek flows through the proposed RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane. The creek would not be redirected as part of the project.

Conclusion

The potential impacts to aquatic ecology and water quality resulting from project changes to surface water and groundwater hydrology relate primarily to bridge pier placement in Bundewallah Creek and to the diversion of Town Creek flows, longitudinal and lateral connectivity and floodplain productivity. See recommended mitigation strategies and offsets (Sections 5.1.1, 5.1.2 and 5.2).

4.3 Threatened and protected species, communities and populations

No aquatic threatened or protected species, populations or communities were observed in the study area during field surveys.

4.3.1 Macquarie Perch, *Macquaria australasica*

The Macquarie Perch is listed as endangered under the FM Act and the EPBC Act.

Macquarie Perch usually inhabit the upper reaches of clear, freshwater water courses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen *et al*., 2003; DPI NSW, 2005a). They migrate upstream to spawn in October to November and their eggs settle and develop in the gravel and cobble found in riffle habitat. The distribution of the eastern form can also be a function of interactions with other species. For example, if Australian Bass are found in a watercourse then typically Macquarie Perch would only be found upstream of them (McDowall, 1996).

There are no records of Macquarie Perch from within the study area, which has a low coastal elevation. Records for Macquarie Perch do exist in upper tributaries of the adjacent Shoalhaven catchment (eg near Kangaroo River in Kangaroo Valley). However, there were two old records of Macquarie Perch from the Shoalhaven River just below Tallowa Dam. One is an Australian Museum record dated from 1980, which may indicate that a population of perch persisted in the lower Shoalhaven (for a time) after the completion of the dam in 1976. Gehrke *et al*., (2001) only observed Macquarie Perch at 550 metres AHD in the Mongarlowe River but suggested that *M. australasica* was a likely pre-Tallowa Dam inhabitant of a relatively low elevation reaches on the Shoalhaven River (around 30 metres AHD). Bishop (1979) lists *M. australasica* as one of the fish inhabiting the “Lower Reaches to Estuary” zone of the Shoalhaven catchment and also reported that during the 1960s Macquarie Perch were commonly found in the lower Shoalhaven River. Bishop and Bell (1978) collected one Macquarie Perch in December 1976 in a pool below the dam after water flow had been terminated for a period. Gehrke *et al*., (2001) assert that prior to the construction of the Tallowa Dam fish species in the Shoalhaven River formed relatively continuous communities from about 500 metres AHD down to the tidal limit influence.

The study area is considered unlikely to support a viable Macquarie Perch population even though there is low-elevation aquatic habitat similar to that of the Shoalhaven River Macquarie Perch sightings in 1976 and 1980. The only freshwater waterway classed major fish habitat (Class 1 Waterways) within the study area is Broughton Creek. The Broughton catchment is relatively small and flow can be ephemeral in many of the upper reaches. Bass are also common within Broughton Creek and have been observed in the reach just upstream of the existing Princes Highway crossing. Although occasionally observed at lower elevations, Macquarie perch preferentially inhabit and migrate to spawn in relatively undisturbed higher elevation reaches, such as those found in the Mongarlowe River. The reaches upstream of the bass distribution in Broughton Creek are considered unlikely to provide sufficient appropriate habitat for the persistence of a Macquarie Perch population. In addition there have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment.

However, an assessment of significance for the potential impact of the highway upgrade on the Macquarie Perch was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the project would be unlikely to affect Macquarie Perch, particularly if mitigation measures are implemented. The federal assessment of significance concluded that the project is unlikely to have a significant impact on this species and therefore, a referral under the EPBC Act is not required. It is not necessary to modify the project with respect to the conservation of this species.

4.3.2 Australian Grayling, *Prototroctes maraena*

The Australian Grayling is listed as Protected under the FM Act and Vulnerable under the *EBPC Act.*

Australian Grayling prefer watercourses with low turbidity and gravel substrata, and occupy lowland rivers through to high elevation reaches at 1000 metres AHD (McDowall 1996). Grayling occur in streams and rivers on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria, and Tasmania (McDowall 1996, DPI NSW 2006a).

The species has an amphidromous life cycle; newly hatched larvae are attracted to the light and swim to the surface where they are swept downstream to estuarine/marine waters and only migrate back to adult freshwater habitats at the age of six months. Populations are therefore very susceptible to barriers to passage. Adults suffer heavy post-spawning mortality so it is possible after a few years without juvenile recruitment to result in local extirpation (Morris *et al*., 2001).

The Australian Grayling has been recorded by the Australian Museum from Broughton Mill Creek, to the south-east of Berry and from the lower section of Jaspers Creek, just upstream of its confluence with Broughton Creek (**Table 3.1**). No date was given with the records but they are likely to have been prior to 1976 as Morris *et al*. (2001) report that since the completion of the Tallowa Dam in 1976 only one grayling specimen has been collected in the Shoalhaven River catchment, in Yalwal Creek outside the Broughton catchment. No Australian Grayling were recorded by the NSW Rivers Survey (Harris and Gehrke, 1997) nor the Tallowa Fishway study (Faragher, 1999).

It is considered unlikely that the Broughton catchment still supports a viable population of Australian Grayling. The Broughton Creek catchment is relatively small and only one individual has been observed over the entire Shoalhaven catchment in the last 30 years. Australian Grayling are relatively sensitive to the degradation of freshwater habitat and water quality that has occurred in the region. Australian Grayling are particularly vulnerable to barriers to passage, such as the flood gates that have been used within the Broughton floodplain in various tributaries and the Tallowa Dam on the Shoalhaven River. However, an assessment of significance for the potential impact of the project was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the project would be unlikely to affect Australian Grayling, particularly if mitigation measures are implemented. The federal assessment of significance concluded that the project is unlikely to have a significant impact on this species and therefore, a referral under the EPBC Act is not required. It is not necessary to modify the project with respect to the conservation of this species.

4.3.3 Black Cod, *Epinephelus daemelii*

The Black Cod is listed as Vulnerable under the *FM Act*.

Black Cod have previously been identified on the coast near Gerringong. Larger juveniles inhabit estuaries and threats to the species include loss or degradation of nursery habitat. It is possible that Crooked River and Shoalhaven/Crookhaven estuary are habitat for juvenile black cod.

Impacts on Black Cod relate to potential impacts of the project on downstream estuarine habitat. These include changes to hydrology, increased sediment loads and pollution. Assuming the installation of appropriate drainage structures at highway crossings, the use of effective erosion and stormwater runoff controls and proper handling of hazardous substances on site, it is considered unlikely that the project would generate significant downstream impacts that might significantly degrade estuarine habitat and potentially affect Black Cod. However, an assessment of significance for the potential impact of the project was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance concluded that the proposed works would be unlikely to have a significant impact on the Black Cod.

4.3.4 Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions

Coastal Saltmarsh is listed as an EEC under the TSC Act.

Saltmarsh is present downstream of the project within Crooked River and the Shoalhaven/Crookhaven estuaries and covers an estimated area of 0.017 square kilometres and 2.06 square kilometres respectively (West *et al*., 1985; The Ecology Lab, 1999). Threats to Coastal Saltmarsh relevant to the project include pollution and changes to salinity from stormwater discharge.

The section of the project within the Crooked River catchment does not intersect with any significant or even ephemeral waterways as it ascends a spur to the Toolijooa Ridge and as such there is little chance of contaminant spill reaching downstream receiving waters. In addition, the use of sediment ponds and/or vegetated swales would greatly reduce the risk of contaminants or polluted water (transported by the project longitudinal drainage system) reaching sensitive receiving waters within the study area including the distant downstream saltmarsh habitat within the Crooked River and Shoalhaven/Crookhaven estuaries. Groundwater and surface water studies indicate that there is unlikely to be a significant change to hydrology that would affect salinity downstream in the vicinity of the saltmarsh communities.

An assessment of significance for the potential impacts of the project on Coastal Saltmarsh was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the proposed works would be unlikely to have a significant impact on Coastal Saltmarsh.

4.3.5 Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions

Freshwater Wetlands on Coastal Floodplains are listed as an EEC under the TSC Act.

Two small wetlands (areas) were identified by Chafer (1997) within the Crooked River catchment; the Willow Vale wetlands west of the Princes Highway and the Gerringong Wetlands east of the Princes Highway. Coomonderry Swamp lies outside of the catchment potentially impacted by the project. Potential threats to Freshwater Wetlands on Coastal Floodplains relevant to the project include pollution, changes to hydrology and infilling from sedimentation.

The Willow Vale wetlands are highly degraded and are found at the upper elevation limits of what has been defined as Freshwater Wetlands of Coastal Floodplains. They are upstream of the project and are therefore unlikely to be affected by potential downstream impacts. Similarly, the small Gerringong Wetlands are a highly degraded series of pondages and swampland associated with degraded creeks that pass through and near south-west Gerringong. These creeks are considered unlikely to provide fish habitat (Class 4 Waterways) and are infested with annual weeds. This habitat is also at the upper elevations limits of Freshwater Wetlands of Coastal Floodplains and is in a part of the Crooked River catchment associated with the Gerringong upgrade.

The project is not anticipated to have any significant effects on surface or groundwater hydrology that might affect sensitive aquatic habitat within the study area or distant downstream habitats. Similarly, appropriate erosion and stormwater control measures would eliminate potential downstream impacts related to sedimentation and pollution. The section of the project within the Crooked River catchment does not intersect with any significant or even ephemeral waterways as it ascends a spur to the Toolijooa Ridge and as such there is little chance of downstream impacts on the two freshwater wetlands within the Crooked River catchment.

An assessment of significance for the potential impacts of the project on Freshwater Wetlands was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the proposed works would be unlikely to have a significant impact on Freshwater Wetlands of Coastal Floodplains.

4.3.6 All Syngnathiformes (seahorses, seadragons, pipefish, pipehorses, ghost pipefish and seamoths)

All Syngnathiformes are protected species in NSW under the FM Act.

Some Syngnathiformes inhabit coastal embayments and estuarine habitats, particularly seagrass beds. Seagrass habitat is present in estuaries downstream of the project. The Crooked River lagoon supports 0.046 square kilometres of *Z. capricorni* and the Shoalhaven/Crookhaven estuaries supports 4.24 square kilometres of seagrass beds (*Z. capricorni* and *Halophila ovalis*).

Impacts on Syngnathiformes relate to potential impacts of the project on downstream estuarine habitat. These include changes to hydrology, increased sediment loads and pollution. The project is not anticipated to have any significant effects on surface or groundwater hydrology that might affect sensitive Syngnathiformes inhabiting distant downstream habitats. Similarly, appropriate erosion and stormwater control measures would eliminate potential downstream impacts related to sedimentation and pollution.

Conclusion

The project would have no impact on Syngnathiformes.

4.3.7 Marine species identified by the expanded EPBC search

The primary search area for EPBC listed threatened and protected species was defined as the Broughton Creek catchment downstream to its confluence with Shoalhaven River (around 16 kilometres downstream of Berry) and the section of the Crooked River catchment traversed by the project. A second expanded search was done which included the ecologically significant but distant downstream aquatic habitat of the Shoalhaven/Crookhaven estuary (a further four to 10 kilometres downstream of the Broughton Creek/Shoalhaven River confluence).

The results of this second search highlighted 58 previously unidentified species that were listed as threatened or protected under the EPBC Act (**Table 3.3**). Nine species were listed as threatened in addition to Macquarie Perch (Section 4.3.1) and Australian Grayling (Section 4.3.2) (**Table 3.3**). Forty nine species were also identified as having general protection under s248 of the *EPBC Act* as they were either (i) Migratory marine species, (ii) Listed marine species, or (iii) Whales and other cetaceans (**Table 3.3**). Migratory marine species, Listed marine species and whales and other cetaceans). A number of species were listed under more than one category.

Macquarie Perch and Australian Grayling were identified as potentially occurring within the Broughton Creek catchment by the primary EPBC search and the Assessment of Significance is included in Appendix E. An assessment of potential impacts on the 20 species of Syngnathiformes in the Listed Marine Species (Ray-finned fishes) is covered in Section 4.3.6 as the same species are protected under the FM Act. The remaining 29 species identified in the expanded EPBC search are protected in some form.

There are few records of EPBC threatened and protected species within the Shoalhaven/Crookhaven estuary. There was one record each for Green Turtle and Pygmy Right Whale and several for Bottlenose Dolphins from inside the Shoalhaven/Crookhaven estuary. Outside the Shoalhaven Heads and Crookhaven Heads (and therefore outside the expanded search area) there are records for Grey Nurse Shark, Humpback Whale, Common Dolphin, Southern Right Whale and Bottlenose Dolphin.

A formal Assessment of Significance was not considered necessary for the threatened taxa identified in the expanded EPBC search. Potential downstream impacts relate to increased sedimentation and pollution, however given the implementation of mitigation measures it is extremely unlikely that works associated with the project would cause significant effects on the aquatic habitats and biota of the Shoalhaven/Crookhaven estuary, given their distance downstream. Moreover, the Shoalhaven/Crookhaven estuary does not constitute critical habitat for any of these species, as they are all predominantly either coastal or oceanic, and therefore only likely to use the estuary intermittently (if at all), as demonstrated by the limited records.

Given the implementation of mitigation measures recommended in this report (Section 5.1.1 and 5.1.2) and the Concept Design (RMS, 2012) it is considered unlikely that the project would affect habitat, fragment a population, reduce an area of occupancy, lead to a long-term population decrease, disrupt breeding cycles, introduce disease or invasive species or inhibit recovery of the EBPC listed threatened species in the Shoalhaven/Crookhaven estuary. As such a Referral to the Federal Minister for Sustainability, Environment, Water, Population and Communities is not required.

5 Proposed aquatic ecology and water quality mitigation

The major issues affecting aquatic ecology and water quality that need to be addressed in the detailed design and construction of the project are:

- Mobilisation of sediment into waterways.
- Mobilisation of pollutants into aquatic habitats.
- Disturbance of ASS.
- Establishment of invasive species within the study area.
- Degradation and removal of riparian vegetation.
- Removal of large woody debris.
- Changes to the natural flow regime.
- Obstructions to fish passage.

The majority of potential impacts arising from these issues can be minimised or mitigated by measures recommended in Section 5.1. Project-related impacts that are unavoidable and would fail to 'maintain or improve' biodiversity include:

- Loss of riparian habitat within the project corridor, temporary creek crossings and ancillary infrastructure footprint.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Changes to flood hydrology at Town Creek, Bundewallah Creek and Broughton Creek from diversion and installation of transverse drainage structures.
- Slight changes to hydrology due to placement of pier structures within the waterway at Bundewallah Creek.
- Possible reduced longitudinal connectivity at temporary creek crossings during low flows.

Compensation measures for these impacts are proposed in the biodiversity offset strategy (refer to the *Terrestrial Flora and Fauna Assessment* (Biosis, 2012) provided at Appendix F of the environmental assessment).

Providing the recommended mitigations and biodiversity offset strategy are implemented the project is unlikely to have a significant net impact on aquatic ecology and water quality within the study area.

5.1 Mitigation strategy

5.1.1 Design

The following measures are recommendations to mitigate potential operational impacts related to the project design.

Mobilisation of sediment

Operational sediment issues can be effectively managed through the development of a project specific Erosion and Sediment Control Plan (ESCP). It is recommended that the design of the ESCP follow the RMS *Procedure for Erosion and Sedimentation Management* (RTA, 2008).

Project design should aim to minimise stormwater and disturbed surface runoff entering adjacent waterways by diversion into sediment basins/vegetated swales. These can act as filters, absorbing mobilised sediments potentially carried in runoff. It is recommended that the drainage system preserve existing elements where possible, such as natural channels and riparian vegetation, with treatment being as close as possible to the source of drainage outlets. It is recommended that the longitudinal drainage system on bridges direct runoff into the sediment basin/swale system rather than allowing scuppers to discharge directly into receiving waters untreated.

The Concept Design Report (RMS, 2012) indicated that a series of vegetated swales (Scenario 3a: 80 metres in length, one metre width, three per cent longitudinal grade and 250 millimetres of vegetation height) or sediment basins (Scenario 2a: 300 cubic metres per hectare) could achieve the operational objectives for runoff water quality. However, in areas close to, or upstream from sensitive receiving waters, these vegetated swales may not provide complete capture capability during large rainfall events (RMS, 2012). Therefore, independent post-construction monitoring is required to ensure that the longitudinal drainage and swale system can achieve operational sediment capture objectives. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC trigger values for the protection of aquatic ecosystems (turbidity range of 6 – 50 NTU for lowland rivers and 0.5 – 10 NTU for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response. In addition, consideration could be given to increasing the size of the vegetated swales and/or the use of sediment basins.

The following measures are also recommended to adequately address sedimentation issues relevant to project design:

- Clean water should be redirected around disturbed areas. For example, the use of catch drains to prevent inflow of clean surface water from the outside of cuttings. The catch drains could then convey clean water to the transverse drainage system.
- Energy dissipaters should be provided to outlets to drainage structures that have the potential to cause scour. The dimensions of energy dissipaters or scour protection up and downstream of culverts can vary depending upon site specific factors (eg velocity, tail water conditions, soil type and erodibility).
- Design of suitable batter treatment along the toe of the embankment between Bridge 2 and Bridge 3 to prevent scour from floodwaters.
- Appropriate use of dissipaters and/or batter treatment to ensure the diversion of flows from Town Creek into Bundewallah Creek does not cause scour and erosion.
- Testing of materials for organic content and dispersion to determine their suitability for use in landscaping and embankment construction.
- Appropriate erosion protection measures for Berry Siltstone Rock and other dispersive soils in steep or vertical cuts (eg soil nailing and/or retaining structures).

- Avoid instream works where practicable. For example, position bridge piers (for both permanent and temporary bridges) outside the channel wetted width. (Note: Four bridge piers would need to be located within Bundewallah Creek.
- Stockpiled materials should not be placed over ephemeral creek or drainage lines.

Pollution

Project operational objectives for runoff water quality with respect to contamination can be met through the longitudinal drainage system and water treatment by vegetated swales and sediment basins at discharge points. However, in areas close to, or upstream from, sensitive receiving waters, the vegetated swale system may not provide complete capture capability during large rainfall events (RMS, 2012). Therefore, independent post-construction monitoring is required to ensure that the longitudinal drainage and swale system can achieve operational water quality objectives. ANZECC trigger values for pollutants associated with road runoff (eg heavy metals, hydrocarbons and organics) can be used as a starting point to develop locally appropriate trigger values for the protection of aquatic ecosystems. Sampling should take place after rainfall events, utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in pollutants. An outline for the recommended surface water quality monitoring program is given in Appendix F.

The following measures are also recommended to adequately address contamination issues relevant to project design:

- Procedures in place to detect and respond to an emergency spill incident. Retention methods for a spill should include an oil baffling system and a standard retention capacity for basins/swales. Standard capacity of the basin/swale system (eg Scenario 4c, RMS, 2012) would provide for removal of TSS, TN and TP from stormwater runoff, although it may involve trade-offs with respect to loss of riparian vegetation and/or disturbance of ASS.
- Longitudinal drainage system on bridges should direct runoff into sediment basin/swale system rather than allowing scuppers to discharge directly into receiving waters untreated.

Acid sulfate soils

Best design principles should be implemented to manage ASS in accordance with the RMS '*Guidelines for the Management of Acid Sulphate Materials: Acid Sulfate Soils, Acid Sulphate Rock and Monosulfidic Black Ooze'* (RTA 2005). The RMS '*Guidelines for the Management of Acid Sulphate Materials'* recommend (in order of preference): avoidance of ASS where possible, followed by minimisation strategies and finally neutralisation.

Design-related considerations include:

- Redesign earthworks where possible to avoid/minimise impacts in areas with high risk of ASS.
- Cover *in situ* soils with clean fill to provide adequate depth for infrastructure excavations without disturbing ASS. For example: in areas considered a high ASS risk, water quality structures such as vegetated swales formed from clean fill placed over existing ground would be preferable to excavated sediment basins.
- Where appropriate, diversion channels and transverse drains (eg culverts) could be redesigned to be wider and shallower if it meant that penetrating the ASS layer could be avoided.
- Testing of soils for ASS to determine their suitability for use in landscaping and embankment construction.
- Ground conditioning to avoid settlement: preference for preloading over excavation and replacement with engineered fill.

Degradation of riparian vegetation

The removal of riparian vegetation should be limited to areas within the concept design footprint including those identified for temporary creek crossings and to facilitate diversion channel construction. Compensation for the unavoidable loss of riparian vegetation within the project alignment, ancillary infrastructure and temporary crossing sites is addressed in the Biodiversity Offset Strategy (Section 5.2).

Where possible the construction of vegetated swales should not replace existing native riparian vegetation.

Changes to the natural flow regime

To minimise impacts on the natural surface and groundwater flow regime of the study area, it is therefore recommended that:

- Groundwater seepage into road cuttings be transferred to receiving dependent aquatic habitats via a longitudinal drainage system.
- Transverse drainage structures allow the unrestricted passage of the vast majority of natural flows and allow for changes in the natural flow regime expected as a result of climate change. This would be achieved by design of bridges and culverts to provide flood immunity from 100 year ARI and 50 year ARI respectively.
- Temporary creek crossings structures provide at least two year ARI flood immunity.
- No bridge piers or abutments be positioned within the section of waterway channel (wetted width) that carries median flows, where practicable.

Compensation for the unavoidable changes to the natural flow regime caused by the project is addressed in the Biodiversity Offset Strategy (Section 5.2).

Obstructions to fish passage

Specific guidelines for the design and construction of waterway crossings to maintain fish passage have been developed and are outlined in 'Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999) and '*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*' (Fairfull and Witheridge, 2003). These guidelines include requirements for:

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

Appendix B details the classification criteria for watercourses and recommended waterway crossings that minimise obstruction to fish according to fish habitat class, based on Fairfull and Witheridge (2003). An assessment of minimum recommended crossing requirements for each site assessed in this study has been summarised in **Table 3.4**. This information is provided as input to the detailed design.

Although bridges would generally be preferred to arch structures, culverts, fords and causeways (in this order), as bridges have the least disturbance to fish passage, the cost, geotechnical and engineering considerations are also important in deciding the selection of a crossing. It is recommended that bridges are used for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. Where practicable, bridge piers should be placed outside the main channel to avoid formation of turbulence and bed erosion, and abutments placed away from the bank.

Culverts are considered adequate crossings for the remaining waterways (**Table 3.4**). Fish passage may be maintained by minimising changes to the natural flow, channel width and water depth through the culvert cells. Additionally designs should consider flow rates and substratum that would facilitate movement and provide resting areas (Fairfull and Witheridge 2003). One option is to utilise multiple and differentiated cell designs. A central sunken box cell (or without a bottom) would preserve the natural channel bed level and facilitate fish passage during low flows. Adjacent culvert cells would facilitate the transfer of higher volume flows. Such designs should be considered for Class 3 Fish Habitat waterways or for crossings that have an existing multiple cell culvert. Engineering guidelines in relation to different crossing designs are detailed in Witheridge (2002) and Fairfull and Witheridge (2003).

Compensation for the unavoidable changes to the lateral connectivity caused by the project is addressed in the Biodiversity Offset Strategy (Section 5.2).

5.1.2 Construction

The following measures are intended to mitigate potential construction impacts.

Mobilisation of sediments

Best environmental practice should be implemented to manage erosion and sedimentation during construction in accordance with Landcom's (2004) Soils and Construction: Managing Urban Stormwater and DECCW's *Managing Urban Stormwater – Soils and Construction, Volume 2D – Main Road Construction* (DECCW, 2008). The ESCP should include (but not be limited to):

- Erosion and sediment controls, such as bunding, silt fences/curtains, sediment basins and vegetated swales. These measures should be able to operate effectively during high rainfall events.
- Diversion of runoff from disturbed areas, stockpiles and dust suppression/washdown facilities into erosion and sediment controls.
- Diversion of clean water around disturbed areas.
- Use of appropriate measures to minimise sedimentation from possible instream works associated with the construction of temporary creek crossings (eg silt curtains).
- Minimisation of the area and duration of exposed unconsolidated soils on landforms constructed as part of the works, including the proposed embankment linking Bridge 2 and Bridge 3, construction material and spoil stockpiles, surface of cuttings etc.
- Revegetation and restoration of disturbed areas as quickly as possible. Erosion and sediment control measures should be in place to treat runoff from these areas until adequate cover is established.
- Project works and ancillary infrastructure should not take place within 50 metres of waterways with Category 1 (Environmental Corridor) riparian habitat. The objective for Category 1 waterways is to maintain or rehabilitate 40 metres of riparian vegetation either side of the waterway with an additional 10 metre buffer zone. The 40 metre exclusion zone for construction and ancillary works outlined in the concept design (RMS 2012) would be adequate for Category 2 and Category 3 waterways.

- Ancillary infrastructure sites should be established only on sites already cleared of native vegetation.
- Restricting work within disturbed areas during rainfall.
- Batching plants comply with relevant environmental requirement regarding dust collection and waste management.
- Construction pads would be constructed to minimise environmental impact and impacts would be identified and minimised during the detailed design phases of the project.
- Flood proof stockpiles or locate them outside flood zone. A number of stockpiles are positioned within the flood affected area of the 100 year ARI event.

It is recommended that independent surface water quality monitoring be incorporated into the ESCP with protocols in place for guideline breaches. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC trigger values for the protection of aquatic ecosystems (turbidity range of 6 – 50 NTU for lowland rivers and 0.5 – 10 NTU for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response. The monitoring program should involve daily sampling over the construction period, utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in turbidity. An outline for the recommended surface water quality monitoring program is given in Appendix G.

Pollution

The majority of measures recommended above to minimise sedimentation during construction would have a similar mitigating effect on pollution. Additional measures required to achieve construction water quality objectives include:

- Proper handling, storage, transport and disposal of hazardous substances within the study area.
- Management of any on-site waste dump to prevent any leaching of contaminants.
- Regular inspections of work practices.
- Independent surface water quality monitoring should be carried out during construction with protocols in place for guideline breaches. ANZECC trigger values for pollutants associated with road construction (e.g. heavy metals, hydrocarbons and organics) can be used as a starting point to develop appropriate thresholds that would trigger a mitigating management response. The monitoring program should involve regular sampling over the construction period (including rainfall events), utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in contamination.

Acid sulfate soils

Best environmental practice should be implemented to manage ASS during construction in accordance with the RMS 'Guidelines for the Management of Acid Sulphate Materials: Acid Sulfate Soils, Acid Sulphate Rock and Monosulfidic Black Ooze' (RTA 2005). Where disturbance of ASS is unavoidable, preferred management strategies are minimisation of disturbance and neutralisation. Construction-related considerations include:

- Minimise project-related activities that would cause groundwater fluctuations, such as removal of vegetation and dewatering.
- Receiving waters are not to be used as a means of diluting and/or neutralising ASS or associated contaminated waters.
- Stockpiling of untreated ASS above the permanent groundwater table with (or without) containment is not an acceptable long-term management strategy (RTA 2005). ASS that are to be stockpiled, disposed of, used as fill, placed as a temporary or permanent cover on land should be treated or managed. Neutralisation treatments include use of alkaline materials or hydraulic separation. Stockpiling after excavation and prior to treatment is still a risk in the short term if there is sufficient time for oxidation to occur. Leachate and runoff must be collected and treated. The Construction Environmental Management Plan (CEMP) should detail the timing, methods and location for treatment, storage and disposal of ASS.
- Neutralisation methods can represent a significant environmental risk and should be managed appropriately.
- Monitoring of ASS and receiving waters should be incorporated into the independent water quality monitoring program undertaken during construction. ANZECC trigger values for the protection of aquatic ecosystems (pH range of 6.5 – 8 for lowland rivers and 7 – 8.5 for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response.
- Where ASS would be disturbed during excavation works (eg diversion channel construction, installation or upgrade of drainage structures), the ASS should either be (i) removed and replaced with clean fill or (ii) strategically reburied back under the groundwater table. Strategic reburial is the least preferred option and should not occur if the ASS have had time to oxidise.

Invasive species

Positive identifications of Alligator Weed within the construction area should be reported to Kiama and Shoalhaven councils. Staff should be trained in the identification and disposal of Alligator Weed and heavy machinery should be regularly inspected to ensure that the species is not spread to new areas.

Degradation of riparian vegetation

Compensation for the unavoidable loss of riparian vegetation within the project alignment, ancillary infrastructure or temporary creek crossing sites is addressed in the Offset Strategy (Section 5.2).

Construction-related mitigation measures include:

- Temporary creek crossings should be located immediately south of the proposed bridge alignments and within the existing footprint. Such positioning would minimise the requirement for additional clearing of riparian habitat in the approaches to temporary crossings.
- Ancillary infrastructure should only be established on sites where native vegetation has already been cleared. For example, the layout of the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should be structured so that there is no loss of riparian vegetation.
- Cleared areas, new creek channels and landforms in riparian zones should be rehabilitated where possible following the completion of works. Rehabilitation includes replanting of native riparian species and/or removal of exotic species and regeneration.

Removal of large woody debris

Where large woody debris is encountered, lopping should be considered the first management response with removal only adopted as a last resort.

Should removal be required then consideration should be given to the introduction of engineered log jams or submerged woody debris as compensation within the offset strategy. Subject to relevant approvals and conditions, there is potential for trees removed as a consequence of the project to be utilised for fish habitat and bank stability within the creeks of the project area. The plan for tree reuse should consider factors such as stream width, bank slope, flow regime and long term stability of the reused trees.

Changes to natural flow regime

The structure of the five temporary creek crossings would have minor effects on surface water flow if they provide flood immunity for the in-channel two year ARI. It is recommended that low bridges are used for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. Where practicable, bridge piers should be placed outside the main channel to avoid formation of turbulence and bed erosion, and abutments placed away from the bank. Bridges are generally preferred to arch structures, culverts, fords and causeways (in this order) as they cause the least disturbance to flow.

Placement of bridge piers in waterways would represent an obstruction to flows and will result in a localised change in velocity and water levels. These impacts should be mitigated through provision of scour protection which would assist in upstream fish passage.

The layout of the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should be structured to minimise effects on the flow regime of waterways that run through the property. A realignment or within-site crossing of this waterway was not identified in the Concept Design report (RMS 2012). A culvert providing flood immunity from the 50 year ARI would provide sufficient protection to the natural flow regime for this waterway should the need for a crossing be identified in the detailed design phase.

Temporary creek crossings used during construction should adhere to guidelines for the design and construction of waterway crossings to maintain fish passage (Smith and Pollard 1999, Fairfull and Witheridge 2003). The preference is for low hollow-core bridge structures to be used for all five temporary creek crossings. Broughton Creek is major fish habitat and a bridge is the recommended crossing structure (**Table 3.4**). Broughton Mill Creek and Bundewallah Creek are Class 2 Waterways and the recommended crossing structures include bridges, arch structures, culverts or fords. Of these options, the preference is for bridge structures to be used for the two temporary creek crossings at Bridge 4.

If culverts are considered for the Broughton Mill Creek and Bundewallah Creek temporary creek crossings, they should conform to design criteria outline in Section 5.1.1. The preferred locations for the temporary creek crossings (**Table 3.7**, **Figures 3.4** and **3.5**) were selected to maximise water depth under the crossing and minimise the head differential therefore reducing behavioural impacts on fish passage. Instream works associated with the construction of temporary creek crossing should be staged so that upstream passage is always possible (eg that silt curtains do not create a complete barrier across the waterway).

A culvert or ford is the recommended structure for the Class 4 waterway passing through the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should the need for a crossing be identified in detailed design phase.

The design of the diversion channel from Town Creek to Bundewallah Creek should overall aim to mimic a natural creek in alignment, depth, creek bed formation and bank configuration. Locally sourced, native riparian species should be used to vegetate creek banks and appropriate methodology and techniques employed to reduce erosion while riparian vegetation is established. If adjacent landuse includes grazing livestock, measures should be included to exclude grazing from riparian vegetation areas.

Ecological monitoring

It is recommended that regular aquatic ecological monitoring be done in conjunction with water quality monitoring (refer to Appendix G). A monitoring program should include sampling in the pre-construction, construction and operational periods.

Aquatic macroinvertebrates and Australian Bass would be appropriate biota to sample given their ecological and social importance and the type of impacts potentially associated with the project. AusRivAS method uses the composition of aquatic macroinvertebrates assemblages as a metric of waterway ‘health’ or condition. Samples could be collected twice a year, during the two AusRivAs periods of ‘Spring’ (15 March – 15 June) and ‘Autumn’ (15 September – 15 December). Declining AusRivAS scores (and the presence of pollution-sensitive taxa) could indicate environmental impacts and trigger management action. Similarly, population trends for macroinvertebrate taxa could be monitored by more frequent sampling using quantitative methods.

Monitoring locations should include the created diversion channel between Town Creek and Bundewallah Creek in order to provide an indication of the successful establishment of a natural creek ecosystem.

Australian Bass is an important species to recreational fishers and is a common large predator within the study area that has a significant structuring effect on aquatic biotic assemblages. Australian Bass populations should be monitored at regular intervals to identify potential trends that might indicate impacts associated with the construction and/or operation of the project.

5.2 Biodiversity offset strategy

Residual impacts on aquatic ecology and water quality that cannot be adequately mitigated and fail to 'maintain or improve' biodiversity include:

- Loss of 2.9 hectares of riparian habitat within the project area, ancillary infrastructure and temporary crossing footprint.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Slight changes to hydrology due to placement of pier structures within the waterway of Bundewallah Creek.
- Potential reduced longitudinal connectivity at temporary crossings during low flows.
- Changes to hydrology at Town Creek, Bundewallah Creek and Broughton Creek from creek diversion and the installation of transverse road drainage structures.

DTIRIS has a policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat (Smith and Pollard 1999). Compensation for the unavoidable loss of riparian habitat caused by the project is addressed in the Biodiversity Offset Strategy. This strategy is detailed in the *Terrestrial Flora and Fauna Assessment (*Biosis, 2012) which is provided at Appendix F of the environmental assessment.

The primary action that would be implemented in the strategy is additional revegetation and rehabilitation of riparian vegetation in strategic locations. As the majority of riparian vegetation that would be lost in the project is part of the *River-Flat Eucalypt Forest on Coastal Floodplain* EEC, this action would compensate for impacts on aquatic ecology and water quality as well as losses to terrestrial biodiversity.

Restoration works would be carried out by accredited organisations and include where appropriate: revegetation of native riparian species, removal of exotic species and restoration/protection of existing riparian habitat (eg fencing protection from livestock etc).

Should the recommended mitigation measures and Biodiversity Offset Strategy be implemented as outlined, then the project should result in no net/residual/long term impacts on aquatic ecology and water quality.

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Terms and acronyms used in this assessment

Term	Definition
AHD	Australian Height Datum
ANZECC	Australia and New Zealand Environment and Conservation Council
ASL	Above sea level
ASS	Acid sulfate soils
AusRivAS	Australian River Assessment System (http://ausrivas.canberra.edu.au)
CEL	Cardno Ecology Lab Pty. Ltd.
CEMP	Construction environmental management plan
CMZ	Core Riparian Zone
DEC	NSW Department of Environment and Conservation
DECCW	NSW Department of Environment, Climate Change and Water
DGRs	Department of Planning and Infrastructure Director-General's requirements
Diadromous (fish)	A migratory fish that travels between salt and fresh water
DIPNR	NSW Department of Infrastructure, Planning and Natural Resources
DLWC	Department of Land and Water Conservation
DP&I	NSW Department of Planning and Infrastructure
DPC	NSW Department of Premier and Cabinet
DPI	NSW Department of Primary Industries
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
DTIRIS	Department of Investment, Regional Infrastructure and Services
EEC	Endangered ecological community
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). Provides for the protection of the environment, especially matters of national environmental significance, and provides a national assessment and approvals process
ESCP	Erosion and Sediment Control Plan
FM Act	*Fisheries Management Act 1994*
FMA Act	*Fisheries Management Amendment Act 1997*
GDE	Groundwater Dependent Ecosystem
I&I NSW	Industry and Investment NSW
KTP	Key threatening process
LEP	Local Environmental Plan
LGA	Local government area

Term	Definition
Macroinvertebrate (aquatic)	An animal without a backbone that spends all or part of its life in water that can be seen with the naked eye
Mg/L	Milligrams per litre
MNES	Matters of national environmental significance. Refers to the seven matters
NPWS	NSW National Parks and Wildlife Service
ntu	Turbidity
OEH	NSW Department of Environment and Heritage
ORP	Oxygen Reduction Potential
PASS	Potential acid sulfate soils
pH	A measure of the activity of the (solvated) hydrogen ion (acidic/alkaline)
ppt	Parts per thousand. Measure of salinity
RAM	Rapid assessment method
RCE	Riparian, Channel and Environmental inventory
RCMS	Riparian Corridor Management Study
RCP	Regional Conservation Plan
RMS	NSW Roads and Maritime Services -known as RTA prior to 2011
RTA	NSW Roads and Traffic Authority
SEPP	State Environmental Planning Policy. A type of planning instrument made under Part 3 of the EP&A Act.
SEPP 14	State Environmental Planning Policy No.14 – Coastal Wetlands
SEPP 71	State Environmental Planning Policy No. 71 – Coastal Protection
SIGNAL	Stream Invertebrate Grade Number Average Level
SIS	Species impact statement
SPM	Suspended particulate matter
Study Area	The subject site and any additional areas which are likely to be affected by the project, either directly or indirectly. In the case of the project, the study area includes the subject site and a 50 metre buffer to account for any indirect impacts
Subject Area	The area to be directly affected by the project (ie the development "footprint"
Taxon (singular) Taxa (plural)	A taxonomic category or group, such as a family or a species
TN	Total Nitrogen
TP	Total Phosphorus
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
TSS	Total suspended solids
WM Act	*Water Management Act 2000*
YOY	Young-of-year

Appendix A

River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) from Chessman *et al.* (1997)

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		**8. Riffle / pool sequence**	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		**9. Retention devices in stream**	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		**10. Channel sediment accumulations**	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		**11. Stream bottom**	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		**12. Stream detritus**	
Banks fully stabilised by trees, shrubs etc	4	Mainly unsilted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1

Descriptor and category	Score
6. Bank undercutting	
None, or restricted by tree roots	4
Only on curves and at constrictions	3
Frequent along all parts of stream	2
Severe, bank collapses common	1
7. Channel form	
Deep: width / depth ratio < 7:1	4
Medium: width / depth ratio 8:1 to 15:1	3
Shallow: width / depth ratio > 15:1	2
Artificial: concrete or excavated channel	1

Descriptor and category	Score
13. Aquatic vegetation	
Little or no macrophyte or algal growth	4
Substantial algal growth; few macrophytes	3
Substantial macrophyte growth; little algae	2
Substantial macrophyte and algal growth	1

Appendix B

Fish habitat classification criteria for watercourses and recommended crossings types

Appendix B

Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003)

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

Appendix C

Raw data for water quality measured *in situ* in the study area

Appendix C

Raw data for water quality measured *in situ* in the study area. Recorded by Cardno Ecology Lab 15 April 2009 to 17 April 2009

Site	13		16		17		25		27	
Watercourse	Broughton Creek		Broughton Creek		Broughton Creek		Broughton Mill Creek		Bundewallah Creek	
Replicate	1	2	1	2	1	2	1	2	1	2
Temperature (°C)	17.69	17.69	18.23	18.24	19.25	19.3	19.62	19.6	18.25	18.25
Conductivity (ms/cm)	0.06	0.06	0.06	0.06	0.06	0.06	0	0.05	0.12	0.06
Conductivity (us/cm)	97	61	105	104	102	102	16	25	166	96
Salinity (ppt)	0.05	0.05	0.03	0.03	0.03	0.03	0	0.03	0.06	0.03
pH	7.17	7.17	7.05	7.05	6.91	6.9	6.67	6.65	6.57	6.54
ORP (mV)	419	423	398	404	379	381	498	496	313	326
Dissolved oxygen (% sat.)	109.3	109.8	108.9	109.8	157.8	156	122	125.1	108.9	109.4
Dissolved oxygen (mg/L)	10.5	10.5	10.2	10.4	14.6	14.4	11.1	11.4	10.3	10.4
Turbidity (NTU)	0	0	0	0	0	0	1.5	5.1	1.1	0.6
Turbidity (NTU)	0	0	0	0	0	0	2.1	4.6	1.7	1.1
Turbidity (NTU)	0	0	0	0	0	0	1.2	5.3	2.2	1.4

Appendix D

Field data for fish and mobile macroinvertebrate sampling

Appendix D

Field data for fish and mobile macroinvertebrate sampling. See Figure 2.1 for site locations. Recorded by the Ecology Lab 15 April 2009 to 17 April 2009

Family name	Species name	Common name	Site 13	Site 22	Site 25	Site 27
			Broughton Creek	Unnamed watercourse	Broughton Mill Creek	Bundewallah Creek
Anguillidae	*Anguilla reinhardtii*	Longfinned Eel	✓		✓	✓
Galaxiidae	*Galaxias maculatus*	Common Jollytail	✓			✓
Retropinnidae	*Retropinna semoni*	Australian Smelt	✓		✓	✓
Poeciliidae	*Gambusia holbrooki*	Mosquito Fish#		✓		
Scorpaenidae	*Notesthes robusta*	Bullrout	✓			
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	✓		✓	✓
Gobiidae	*Philypnodon grandiceps*	Flathead Gudgeon	✓			
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon	✓			
Atyidae	-	Freshwater Shrimp	✓			

 # = alien species

Appendix E

Assessments of significance

Appendix E – Assessments of significance

Assessments of significance were conducted for the potential impact of the project on three threatened species and two endangered ecological communities (EECs): Macquarie Perch, Australian Grayling, Black Cod, Coastal Saltmarsh and Freshwater Wetlands on Coastal Floodplains. Where relevant, assessments were made in accordance with the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA 2009), the *Guidelines for Threatened Species Assessment* (DEC/DPI 2005) for Part 3A development applications and referral guidelines for specific species (where applicable).

EPBC Act impact assessments

Macquarie Perch, *Macquaria australasica*

The Macquarie Perch (*Macquaria australasica*) is currently listed as endangered under the national EPBC Act. The assessment below was undertaken with reference to *Draft referral guidelines for the endangered Macquarie Perch, Macquaria australasica* (DSEWPaC 2011).

Macquarie Perch was not recorded during field survey nor are there any formal records of it occurring within the study area. Perch are usually found at higher elevations than are generally present in the study area (DPI 2005a); however some researchers have suggested that the Macquarie Perch was possibly a historic inhabitant of low elevation reaches of the Shoalhaven River system (Bishop 1979, Gehrke *et al*. 2001). However, the Broughton catchment is relatively small, competitive Australian Bass are abundant in the lower reaches and habitat is ephemeral at higher elevations. As such the study area is considered unlikely to sustain a viable population of Macquarie Perch.

Is the action likely to lead to a long-term decrease in the size of a species?

Causes of the decline of the Macquarie Perch include; barriers to spawning migrations, overfishing, habitat degradation and fragmentation, impacts on invertebrate food fauna and infection by the epizootic haematopoietic necrosis virus (EHN) (Morris *et al*. 2001, McDowall 1996).

Threatening processes potentially associated with the project include the creation of barriers to fish passage created by the installation of inappropriate channel crossings. Macquarie Perch migrate upstream in spring to spawn and barriers to this migration would create a reduction in available spawning habitat that could lead to subsequent reductions in recruitment and population size.

Earthworks associated with the construction of roads and channel crossing structures may mobilise sediments into waterways that could result in the downstream smothering habitat and deep holes. Due to the low elevation of the upper reaches of waterways in the project area it is unlikely that sufficient spawning habitat exists for perch reproduction. Given that perch migrate upstream to reproduce it is uncertain if any reach within the study area is of sufficient elevation to constitute potential spawning habitat.

These potential impacts can be minimised or eliminated by implementing the suggested recommendations, and as such it is considered unlikely that the project would lead to a long-term decrease in populations of *M. australasica*.

Would the action reduce the area of occupancy of the species?

Barriers to passage created by inappropriate channel crossings could conceivably reduce the area of occupancy downstream of the structure if there was little or no spawning habitat available (especially as perch migrate a distance upstream to spawn). Recruitment failure would ensure the eventual local extinction of the downstream population. If Macquarie Perch did occupy lower reaches of the Shoalhaven catchment this might explain the failure to record any fish in the catchment beneath Tallowa Dam in the last 25 years.

A temporary reduction in occupancy is possible in downstream areas during construction if there is an increase in the volume of suspended sediments. Large volumes of suspended sediments can be a direct cause of mortality due to the inability of the fish to respire through clogged gills. However this is also unlikely to cause long-term declines in populations as the incidents would only last as long as the duration of the high sediment loads.

These potential impacts can be minimised or eliminated by implementing the suggested recommendations (Section 5.1), and as such it is considered unlikely that the project would lead to a reduction in the area of occupancy of *M. australasica*.

Would the action fragment an existing important population into two or more populations?

Populations of the western catchment form of the Macquarie Perch have become fragmented across much of their previous range due to the creation of barriers such as dams and weirs (Morris *et al*. 2001). In instances where regulated flows have inhibited spawning cues or barriers have prevented access to spawning habitat, these isolated populations have declined (Morris *et al*. 2001).

If Gehrke *et al*. (2001) are correct in their observations that historically fish in the Shoalhaven formed a continuous community from 500 metres AHD to tidal level, then populations of Macquarie perch were fragmented by the construction of the Tallowa Dam. It is possible that the construction of inappropriate channel crossings that create a barrier to fish passage could similarly fragment populations should they be present in the study area.

Loss of spawning habitat to sedimentation is unlikely to fragment a population unless a considerable length of a watercourse has been affected such that even migrating groups of fish became reproductively isolated. This is even less plausible in the project area given that the majority of watercourses downstream of the alignment are at fairly low elevations and are therefore unlikely to contain perch spawning grounds.

It is possible that increased siltation could cause shallow sections of a channel to become more effective barriers to fish movement during periods of low flow and similarly diminish the frequency and/or effectiveness of deeper holes to provide refuge. However, variable flow and the resulting periodic fragmentation of populations are natural phenomena in Australian freshwater systems.

If suggested recommendations are implemented to minimise sediment loads and install drainage structures that allow fish passage it is unlikely that the isolation of currently interconnecting areas of habitat would be greater than is currently experienced.

Would the action adversely affect habitat critical to the survival of a species?

Macquarie Perch are generally found in freshwater reaches with low sediment loads that contain sequences of pools and riffle habitat with occasional deep holes with snags. Failure to adequately control sediments could result in the infilling of deep holes and the smothering of shallow riffle habitat found downstream of construction sites.

These potential impacts can be minimised if the recommended mitigation measures are implemented.

Would the action disrupt the breeding cycle of a population?

Macquarie Perch begin a migration upstream during spring when water temperatures reach 16^0C and form spawning aggregations in pools at the head of riffles (Morris *et al*. 2001). Their eggs are carried downstream and lodge among pebbles and gravel in riffles, usually about 0.50 metres to 0.75 metres deep with a flow rate of ~one metre per second (McDowall 1996). Barriers to passage created by crossings can prevent the perch reaching this spawning habitat.

Increased sedimentation from earthworks during construction (and unprotected spoil piles after) can result in smothering the riffle habitat of cobble and gravel where the perch's adhesive eggs would normally become lodged. Studies have also demonstrated that suspended sediments can negatively impact egg and fry development and disrupt the ability of some freshwater fish to migrate to spawning sites. However, given the relatively low elevation of the study area it is considered unlikely that there would be any perch spawning sites downstream of a construction site placed anywhere along the project corridor.

These potential impacts from barriers to passage can be avoided by the selection of appropriate channel crossing for the class of watercourse.

Would the action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Channel crossing structures that create barriers to fish passage can potentially isolate downstream populations from refuge, foraging and spawning habitat above the crossing although these would still be accessible to populations above the structure (and vice versa).

High sediment loads can degrade foraging and refuge habitat below the construction site and a loss of riparian vegetation may result in a decline in the abundance of aquatic macroinvertebrate prey.

However it is unlikely these impacts would occur if the proposed safeguards are adopted.

Would the action result in invasive species that are harmful to an endangered species becoming established in the endangered species' habitat?

There is a possibility that the distribution of Alligator Weed would be increased locally by construction activities associated with the project. Alligator Weed is an environmental pest that can choke waterways and severely degrade habitat.

Alligator Weed grows vegetatively and can be spread from fragments attached to machinery. It is therefore possible that fragments might be transported on machinery from an area of infestation to an area where it is not yet established.

However, whilst Alligator Weed was reported by the EPBC Environmental Reporting Tool, no other records could be found for its presence within the study area.

The project is considered unlikely to result in an invasive species becoming established if the suggested recommendations are implemented (Section 5.1). Examples include training workers how to identify and dispose of Alligator Weed and to conduct regular inspections of machinery used on site.

Would the action introduce disease that may cause the species to decline?

Acid sulfate soils (ASS) are known to occur within the low lying areas of the Broughton Creek catchment. The resulting low pH waters can damage the surface of fish's skin and gills. Skin damage can increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome, also known as 'red spot' disease. The Macquarie Perch is particularly susceptible to the red spot disease (Morris *et al*. 2001, McDowall 1996).

The probability of ASS within the project corridor is low and measures to address potential runoff from acid sulfate soils would be implemented and hence the project is considered unlikely to introduce or enhance the risk of disease.

Would the action interfere substantially with the recovery of the species?

Recovery objectives for the Macquarie Perch relative to this region include the prevention of siltation, the preservation of natural flows and removal of existing barriers to fish passage (Morris *et al*. 2001). It is possible that the project could interfere with these objectives, for instance if soil and erosion were poorly managed, but this is considered unlikely if the suggested recommendations are adopted.

Conclusion

Macquarie Perch are unlikely to occur in the study area. If Macquarie Perch were present, potential impacts of the project can be effectively minimised or eliminated by the adoption of recommendations to design and construction methods, and hence no direct or indirect impacts on populations or habitat are predicted. Referral of this project in relation to this species to DSEWPaC is therefore not required (DSEWPaC 2011).

Australian Grayling, *Prototroctes maraena*

The Australian Grayling is listed as a Vulnerable Species under the EPBC Act. No grayling were recorded during the current survey but previous Australian Museum collections have identified the Australian Grayling within the adjacent Broughton Creek catchment. However, the study area catchment is relatively small, freshwater habitat is degraded and is considered unlikely to sustain a viable population of grayling. The assessment of significance for the potential impact of the project was carried out as a precautionary measure.

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

The Australian Grayling is believed to have suffered a severe decline during the latter half of the 20th Century throughout most of its range (Morris *et al*. 2001). It has not been recorded in the northernmost extent of its range (the Grose River) since the 1950s and only one specimen has been found in the Shoalhaven River catchment since the completion of the Tallowa Dam in 1976 (Morris *et al*. 2001). Subsequent significant sampling in the Shoalhaven River by the NSW Rivers Survey (Harris and Gehrke 1997) and the Tallowa Fishway study (Gehrke *et al*. 2001) failed to find any grayling. Similarly, Faragher (1999) found no grayling in Broughton Creek or the Shoalhaven River but was responsible for the sole capture of an individual from the Shoalhaven system (in the last 30 years) in Yalwal Creek to the south.

The major cause of this decline is river regulation and barriers to fish passage created by dams, weirs and inappropriate channel crossings. Barriers disrupt the diadromous life cycle of *P. maraena*, preventing larvae being swept downstream to estuarine and marine waters and juveniles migrating back upstream to adult freshwater habitat (Morris *et al*. 2001). Tallowa Dam has been estimated to restrict the access of migrating fish to 80 per cent of the Shoalhaven River (Harris 1984). Adult grayling suffer heavy post-spawning mortality so local extirpation is possible after only a few years without juvenile recruitment (Morris *et al*. 2001).

The construction of instream structures can also directly cause mortality events. During the construction of the Tallowa Dam the flow of the Shoalhaven River was completely blocked on a number of occasions for associated work to take place (Bishop and Bell 1978). During one such stoppage in 1976, 312 grayling were killed after being stranded when water levels beneath the dam dropped so rapidly that much of the river bed became dry (Bishop and Bell 1978). Only one grayling has been captured in the entire Shoalhaven catchment since.

Increased siltation and the loss of riparian vegetation are also believed to have contributed to the grayling's decline (Morris *et al*. 2001). Increased volumes of suspended sediment can smother gravel on the streambed which the grayling use for the development of their eggs and the loss of riparian vegetation can negatively affect macroinvertebrate communities which the grayling feed upon.

Threatening processes associated with the project could potentially cause a decrease in local populations of grayling (should they be present). The installation of inappropriate waterway crossings may alter natural flows and/or restrict fish passage. The construction of these structures could mobilise sediments into the watercourse that results in the loss of spawning habitat or expose acid sulfate soils that would reduce the water quality in lowland reaches inhabited by larvae and juveniles.

The project is considered unlikely to cause a long-term decrease in Australian grayling populations if the suggested recommendations are implemented (Section 5.1). These include the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action reduce the area of occupancy of an important population?

The installation of crossings that create a barrier to fish passage could potentially reduce occupancy in areas upstream of the structure and possibly downstream (depending on the adequacy of remaining habitat beneath the barrier). For example, given that the grayling can be found in elevations up to 1000 metres ASL (McDowall 1996), the construction of the Tallowa Dam restricted access to ~80 per cent of the Shoalhaven River (Harris 1984). The dam represents an absolute barrier to the grayling and because grayling migrate between fresh and salt water (diadromous lifecycle), populations above the dam have completely disappeared. Despite rigorous sampling (Harris and Gehrke 1997, Faragher 1999, Gehrke *et al*. 2001) only one individual has been collected in the catchment beneath the dam since 1976, suggesting that populations downstream of the barrier have declined dramatically.

A temporary reduction in occupancy is possible in downstream areas during construction if there is an increase in the volume of suspended sediments. Large volumes of suspended sediments can be a direct cause of mortality due to the inability of the fish to respire through clogged gills. This is unlikely to cause long-term declines in populations as the incidents would only last as long as the duration of the high sediment loads. Increased sedimentation can also smother available spawning habitat downstream of the construction. This may affect downstream occupancy if there is little alternative spawning habitat.

The project is considered unlikely to reduce the Australian Grayling's area of occupancy if the suggested recommendations are implemented (Section 5.1). These include the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action fragment an existing important population into two or more populations?

It is unlikely that the construction or operation of the project would lead to the fragmentation of grayling populations. Because grayling migrate between fresh and salt water (diadromous), a crossing that created a barrier to passage would lead to the local extinction of the species upstream of the structure, not the creation of two separate populations.

The degradation of possible spawning habitat downstream of the construction site from sedimentation may reduce recruitment but would not separate populations as juveniles could still recolonise upstream and adults would be able to move freely. Increased siltation could cause existing shallow sections of the channel to become more effective barriers to fish movement during periods of low flow perhaps increasing the temporary or seasonal fragmentation of populations. However variable flow and the resulting seasonal fragmentation of populations are natural phenomena in Australian freshwater systems.

If suggested recommendations to minimise sediment mobilisation are implemented it is unlikely that the isolation of currently interconnecting areas of habitat would be greater than is currently experienced.

Would the action adversely affect habitat critical to the survival of a species?

Channel crossing structures that impede fish passage would not physically harm critical habitat upstream but would restrict or remove access to it.

Increased sedimentation during construction could lead to loss of downstream spawning habitat from smothering. The extent of possible spawning habitat in Class 2 watercourses within the study area is expected to be limited.

The project is considered unlikely adversely affect critical habitat if the suggested recommendations are implemented (Section 5.1).

Would the action disrupt the breeding cycle of an important population?

Adult grayling do not migrate to breed but spawn in the same general area they normally inhabit. Grayling prefer watercourses with moderate flows and gravel beds (McDowall 1996). After spawning the eggs settle into the gravel substrate where they develop and the larvae hatch (Morris *et al*. 2001). Newly hatched larvae are positively photo tactic and swim to the surface where they are swept downstream to estuarine or marine waters and only migrate back to adult freshwater habitats at the age of six months (Morris *et al*. 2001). Channel crossing structures that create barriers to passage would prevent the downstream flow of grayling larvae in autumn and the upstream migration of juveniles in spring. The recruitment failure in the population above the barrier and high post-spawning mortality of adults would likely cause extirpation after a few years.

Increased sedimentation would also affect the availability of spawning habitat downstream of construction with concomitant reductions in recruitment.

The project is considered unlikely to disrupt the breeding cycle of the Australian Grayling's area if the suggested recommendations are implemented (Section 5.1). These include; the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

There are a number of Class 1 and Class 2 watercourses in the catchment providing major to moderate fish habitat. Inappropriate road crossings could prevent grayling passage upstream to refuge, foraging and spawning habitat. High sediment loads from construction earthworks could also potentially degrade downstream spawning habitat.

The project is considered unlikely to affect grayling habitat if the suggested recommendations are implemented (Section 5.1).

Would the action result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

There is a possibility that the distribution of Alligator Weed would be increased locally by construction activities associated with the project. Alligator Weed is an environmental pest that can choke waterways and severely degrade habitat.

Alligator Weed grows vegetatively and can be spread from fragments attached to machinery. It is therefore possible that fragments might be transported on machinery from an area of infestation to an area where it is not yet established.

However, whilst Alligator Weed was reported by the EPBC Environmental Reporting Tool, no other records could be found for its presence within the study area.

The project is considered unlikely to result in an invasive species becoming established if the suggested recommendations are implemented (Section 5.1). Examples include training workers how to identify and dispose of Alligator Weed and to conduct regular inspections of machinery used on site.

Would the action introduce disease that may cause the species to decline?

Acid sulfate soils (ASS) are known to occur within the low lying areas of the Broughton Creek catchment. The resulting low pH waters can damage the surface of fish's skin and gills. Skin damage can increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome, also known as 'red spot' disease.

The probability of ASS within the project corridor is low and measures to address potential runoff from acid sulfate soils would be implemented and hence the project is considered unlikely to introduce or enhance the risk of disease.

Would the action interfere substantially with the recovery of the species?

Priority recovery objectives for the Australian Grayling that are relevant to the project include improving fish passage, ensuring navigable migration corridors during construction, reducing erosion and siltation, and the rehabilitation of degraded riparian vegetation (Morris *et al*. 2001).

Key components of the National Recovery Plan for Australian Grayling include identification of important populations and catchment management to restore and protect habitat (Backhouse *et al. 2008a).* It is unlikely that the threatening processes associated with the project would affect the potential recovery of the Australian grayling providing the suggested recommendations are implemented. Restoration of riparian habitat (as recommended in the Biodiversity Offset Strategy, Section 5.2) is consistent with key strategies of the national recovery plan for Australian Grayling (Backhouse *et al. 2008b)*

Conclusion

The key threats that the project poses to the Australian Grayling include disruption to the grayling's diadromous life cycle where it migrates between fresh and salt water and the loss of spawning habitat. These potential impacts can be minimised or eliminated by implementing the suggested recommendations. Referral of this project in relation to this species to DSEWPaC is therefore not required.

Part 3A Assessment of Threatened Species, Populations and Ecological Communities

The potential impacts of the project on aquatic species, populations and EECs listed in Schedules of the TSC Act and FM Act were assessed according to OEH and DTIRIS "*Guidelines for Threatened Species Assessment*" (DEC/DPI 2005). The guidelines identify important factors and/or heads of consideration that must be considered by proponents when assessing impacts on threatened species, populations, or ecological communities for development applications assessed under Part 3A of the EP&A Act.

Macquarie Perch, *Macquaria australasica*

The Macquarie Perch (*Macquaria australasica*) is currently listed as Vulnerable under the FM Act and as such it is necessary to assess the potential impacts of the project under the *Guidelines for Threatened Species Assessment*.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Macquarie Perch usually inhabit the upper reaches of clear, freshwater water courses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen *et al*. 2003, DPI NSW 2005a). They migrate upstream to spawn in October to November and their eggs settle and develop in the gravel and cobble found in riffle habitat. The distribution of the eastern form can also be a function of interactions with other species. For example, if Australian Bass (*Macquaria novemaculeata*) are found in a watercourse then typically Macquarie Perch would only be found upstream of them (McDowall 1996).

Threatening processes potentially associated with the project include barriers to fish passage created by the installation of inappropriate channel crossings. During spring when water temperatures reach 16 degrees celcius, Macquarie Perch migrate upstream to spawn (Morris *et al*. 2001). They form spawning aggregations in pools at the head of riffles and their eggs are carried downstream and lodge among pebbles and gravel in riffles where they would develop (McDowall 1996). Barriers that impede this breeding migration can lead to a reduction in recruitment and eventual decline in population size. Earthworks required in the construction of roads and water crossings may mobilise sediments that results in the smothering of spawning habitat or deep holes. Studies have also demonstrated that suspended sediments can negatively impact egg and fry development and the survival of macroinvertebrate prey.

There have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment and furthermore, it is unlikely that the project would have an adverse effect on the life cycle of the Macquarie Perch if the recommended mitigation measures to address sedimentation and siltation are adopted.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

Macquarie Perch are generally found to inhabit freshwater reaches with low sediment loads that contain deep holes with snags and adjacent riffle habitat.

Earthworks associated with the construction of roads and crossings can result in the mobilisation of sediments into the waterway. Given that Macquarie Perch are generally found in clear waters a temporary reduction in occupancy is possible in downstream areas during construction if there is a large increase in the volume of suspended sediments. Furthermore, increased sedimentation can potentially degrade habitat utilised for refuge, foraging and spawning. Refugia such as deep holes can infill and riffle habitat, where fertilised eggs lodge and develop, can become smothered. However given the low elevation of most watercourses within the study area it is considered unlikely that they contain spawning sites.

It is considered unlikely the project would substantially affect perch habitat if the recommended mitigation measures are implemented.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

There are no records of Macquarie Perch from within the study area, which has a low coastal elevation. Macquarie Perch preferentially inhabit and migrate to spawn in relatively undisturbed higher elevation reaches, such as those found in the Mongarlowe River. The reaches upstream of the bass distribution in Broughton Creek are considered unlikely to provide appropriate habitat for the persistence of a Macquarie Perch population. In addition there have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment. In the unlikely event that Macquarie Perch did occur within the study area it could be possible that it was at the limit of its eastern, lowland distribution. As there is no evidence to suggest that Macquarie Perch occurs within the study area, it is not considered that the proposal would affect a proposal at the limit of its distribution.

How is the proposal likely to affect current disturbance regimes?

Freshwater habitat within the study area is considered to be variable, ranging from relatively healthy to significantly degraded. The riparian vegetation was extremely degraded or absent along most waterways that intersect the project. Similarly, there was little large woody debris present. Therefore, it is unlikely that the project could further degrade riparian areas such that it would cause a significant impact on Macquarie Perch.

Water quality in the catchment is typical of aquatic ecosystems that have been disturbed by agricultural practices. Downstream of the study area, in the low-lying floodplain, the tributaries of Broughton Creek have been highly modified by flood mitigation works.

The threatening processes listed under the FM Act relevant to the project that require consideration include:

- The removal of large woody debris.
- The degradation of riparian vegetation.
- The installation of instream structures (ie bridges and culverts) and other mechanisms that alter natural flow regimes of rivers and streams.

The operation of instream drainage structures constructed during the project should have little or no impact on Macquarie Perch given they also conform to ‘minimum’ recommended crossing types outlined in ‘*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*’ (Fairfull and Witheridge 2003).

It is possible that the project could have a cumulative impact on the current disturbance regime although this is considered unlikely if the recommended mitigation measures are implemented.

How is the proposal likely to affect habitat connectivity?

Of the habitats potentially affected by the project, access to upstream spawning sites would be the most critical. Without suitable breeding habitat beneath a barrier to passage, which appears to be the case given the low elevation of the study area, the continuous recruitment failure would quickly lead to the collapse of the downstream population.

Barriers to passage created by inappropriate water crossings can reduce access to upstream spawning, refuge and foraging habitat for perch populations beneath the barrier and downstream refuge and foraging habitat for perch above it. The degree to which a channel crossing acts as a barrier would vary with the type of structure and flow conditions. The effect it has on status of perch would depend on the fragmented population’s access to remaining habitat. If there was little remaining spawning habitat for the downstream fish, recruitment failure and local extinction could result. If Macquarie Perch did historically occupy lower reaches of the Shoalhaven River this could explain the failure to record any beneath the dam in the last 25 years. Upstream populations although isolated could persist if there were adequate habitat and resources, as they have done above the Tallowa Dam.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for Macquarie Perch

Conclusion:

The key threats that the project poses to the Macquarie Perch include the creation of barriers to perch spawning migrations and the smothering of spawning habitat by siltation. Potential impacts on local populations can, however, be effectively minimised or eliminated by the implementation of the recommended mitigation measures, such that the proposal is unlikely to have a significant impact on this species.

Black Cod *Epinephelus daemelii*

The Black Cod (*Epinephelus daemelii*) is currently listed as Vulnerable under the FM Act and as such it is necessary to assess the potential impacts of the proposal under the NSW Guidelines for Threatened Species Assessment. Black Cod was not recorded during field survey nor are there any formal records of it occurring within the study area.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Large juvenile Black Cod inhabit estuaries along coastal NSW. Within estuarine systems they are often caught in association with rocky reefs but it is possible that they also utilise seagrass habitat (I&I NSW 2009). There are records of Black Cod from the region and potential seagrass habitat in the lower reaches of the estuary.

Threats to Black Cod include the loss or degradation of nursery habitat (DPI 2007a). Potential impacts on Black Cod nursery habitat from the proposal relate to pollution and increased sediment loads. However, assuming the use of effective sediment controls and proper handling of hazardous substances, it is considered unlikely that the proposal would generate downstream impacts that might significantly degrade Black Cod nursery habitat and hence affect the life cycle of the species.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

The Crooked River lagoon and Shoalhaven/Crookhaven estuary are Potential habitat for large juvenile Black Cod. This area would not, however, be removed, modified, fragmented or isolated providing the recommended mitigation measures are adopted and properly implemented.

The proposal is consistent with the objectives of the Black Cod draft recovery plan (I&I NSW 2011) providing recommendations relating to sediment and pollution control are implemented.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

The distribution of Black Cod is known to extend across the NSW coastal zone and the proposal is not likely to affect a population at the limit of this distribution.

How is the proposal likely to affect current disturbance regimes?

The existing level of disturbance in the lower estuary is variable but may include surface runoff from urbanisation and development. Provided that measures to mitigate sedimentation and erosion in relation to the construction works are implemented, the proposal is not likely to affect existing levels of disturbance.

How is the proposal likely to affect habitat connectivity?

The proposal is unlikely to affect the connectivity of Black Cod habitat as it would not modify, fragment or isolate known populations.

How is the proposal likely to affect critical habitat?

Black Cod are listed as a vulnerable species and as such their habitat is not eligible to be listed as critical habitat.

Conclusion:

The key threat that the proposal poses to the Black Cod is the potential degradation of estuarine nursery habitat caused by sedimentation and pollution. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this species.

Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions

Freshwater wetlands are listed as an EEC under the TSC Act and as such, it is necessary to assess the potential impacts of the proposal under the Guidelines for Threatened Species Assessment.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Freshwater wetlands are not a listed threatened species or population.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

Two small freshwater wetlands areas were identified by Chafer (1997) within the Crooked River catchment; the Willow Vale wetlands west of the Princes Highway and the Gerringong Wetlands east of the Princes Highway. Coomonderry Swamp lies outside of the catchment potentially impacted by the proposed works. Potential threats to freshwater wetlands on coastal floodplains relevant to the proposal include; pollution, changes to hydrology and infilling from sedimentation.

The Willow Vale wetlands are highly degraded and are found at the upper elevation limits of what has been defined as Freshwater Wetlands of Coastal Floodplains. They are upstream of the proposal and are therefore unlikely to be affected by potential threats associated with the proposal which would only affect downstream reaches.

The small Gerringong Wetlands are a highly degraded series of pondages and swamp associated with degraded creeks that pass through and near south-west Gerringong. These creeks are considered unlikely to provide fish habitat and are infested with exotic weeds. This habitat is also at the upper elevations limits of for Freshwater Wetlands of Coastal Floodplains.

Proper handling, storage, transport and disposal of hazardous substances used on site would minimise the chance of a spill during construction causing downstream pollution. The proposal is unlikely to cause significant changes to the hydrology of waterways within the Crooked River catchment if recommendations to (i) maintain the natural form of Crooked River realignment (ii) install appropriate drainage structures at road crossings are implemented. Implementation of recommended sediment controls would minimise mobilisation of sediments into waterways and downstream aquatic habitats.

It is considered unlikely that the proposal would affect the habitat of a threatened species, population or ecological community associated with freshwater wetlands downstream of the study area.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

Freshwater wetlands are not a listed threatened species or population.

How is the proposal likely to affect current disturbance regimes?

The freshwater wetlands potentially affected by the proposed works are already moderately to highly disturbed. Provided that the proposed works are carried out in accordance with the mitigation methods outlined during the construction phase of works, the proposal would not be expected to have any long term impact on the current disturbance regime.

How is the proposal likely to affect habitat connectivity?

Freshwater wetlands on coastal floodplains within the Crooked River catchment are unlikely to be removed, modified, fragmented or isolated as a result of the proposal. It is not therefore expected that the proposal would impact upon habitat connectivity.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for freshwater wetlands on coastal floodplains.

Conclusion:

Potential threats to freshwater wetlands on coastal floodplains relevant to the proposal include; pollution, changes to hydrology and infilling from sedimentation. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this threatened ecological community.

Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions

Coastal Saltmarsh is listed as an EEC under the TSC Act and as such it is necessary to assess the potential impacts of the proposal under the Guidelines for Threatened Species Assessment.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is not a listed as a threatened species or population.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

There is no significant saltmarsh habitat within Werri Lagoon (Williams et al. 2006). Saltmarsh is present within the Crooked River estuary and covers an estimated area of 0.017 square kilometres (West et al. 1985, The Ecology Lab 1999, Williams et al. 2006).

Potential threats to coastal saltmarsh relevant to the proposal include pollution, changes to salinity from stormwater discharge and invasion by mangroves. However, geotechnical studies have indicated that the proposal is unlikely to cause significant changes to hydrology and therefore patterns in salinity downstream in the Crooked River estuary would remain unaffected. Proper handling, storage, transport and disposal of hazardous substances used on site would minimise the chance of a spill during construction causing downstream pollution (Recommendations, Section 5). Similarly, appropriate design of stormwater runoff structures would minimise possibilities of contamination of aquatic habitats from highway runoff. Increased sedimentation can facilitate the invasion of mangroves but the implementation of recommended sediment controls (Section 5) would minimise mobilisation of sediments into waterways and downstream aquatic habitats.

It is considered unlikely that the proposal would affect the habitat of a threatened species, population or ecological community associated with coastal saltmarsh downstream of the study area.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

Coastal saltmarsh is not a threatened species or population.

How is the proposal likely to affect current disturbance regimes?

The proposal is unlikely to significantly affect the existing level of disturbance to coastal saltmarsh. Coastal saltmarsh habitat would not be directly affected by the proposal and no long term impacts to these habitats downstream of the proposed construction works would be affected.

How is the proposal likely to affect habitat connectivity?

Coastal saltmarsh within the vicinity of the study area is unlikely to be removed, modified, fragmented or isolated as a result of the proposal such that habitat connectivity would be affected.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for coastal saltmarsh.

Conclusion:

Threats to coastal saltmarsh relevant to the proposal include pollution, changes to salinity from stormwater discharge and invasion by mangroves. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this threatened ecological community.

Appendix F

Outline of surface water quality monitoring program

Appendix F – Outline of surface water quality monitoring program

Background

The following sampling program would be proposed to monitor water quality impacts of the project during both construction and operational phases. The program takes a similar approach to the Surface Water Monitoring Program that is currently being implemented by Cardno for the Tintenbar to Ewingsdale Pacific Highway upgrade within that sensitive receiving environment. This proposed approach underwent significant stakeholder consultation with Office of Environment and Heritage (OEH) and Department of Investment, Regional Infrastructure and Services (NOW and Fisheries) and has been approved by RMS and the Department of Planning and Infrastructure for the Tintenbar to Ewingsdale Pacific Highway upgrade.

The primary objective of the program would be to minimise the impacts to downstream surface water quality to protect aquatic ecology and ecosystem characteristics. During the construction phase of the project, the greatest risk to water quality would likely be from the mobilisation of exposed sediments. Potential impacts are more likely to be detected during wet weather as a result of exceedance/failure of the proposed control measures. During the operational phase, the greatest risk to water quality would likely be as a result of increased pollutant loads resulting from road surface runoff.

Performance standards

ANZECC guidelines

The ANZECC guidelines provide a management framework, guideline water quality triggers, protocols and strategies to assist water resource managers in assessing and maintaining aquatic ecosystems. The guidelines recommend numerical and descriptive water quality guidelines to help managers establish water quality objectives that would maintain the environmental values of water resources. They are not standards, and should not be regarded as such. Of particular importance is the approach for using the ANZECC guidelines of: '*protect environmental values by meeting management goals that focus on concerns or potential problems'* (ANZECC, 2000). That is, development of a water quality monitoring program should focus on site specific issues rather than on pre-determined guideline values.

Application of these values as triggers for management action associated with the project is not considered to be appropriate as they do not take into account the external influences of the catchment on water quality. The framework and principles of ANZECC guidelines would however be utilised in the development of a project specific approach to performance standards as outlined below.

Proposed project performance standards

The surrounding land use within the catchment has potential to impact the surface water quality. As such, this potential source of pollution should be recognised in the development of project performance standards. As such the assessment should be based on the impacts directly associated with the project, not on the health of the greater catchment. For many road upgrades, monitoring during construction involves sampling water quality upstream and downstream of the construction activity.

This approach would be utilised for the project as it allows for an assessment of impacts that can be attributed to the construction /operation activities rather than the impacts related to the catchment.

For each of the proposed monitoring sites, a site specific control chart would be developed to provide a suitable reference criteria and performance standard. The control chart would be produced by plotting the median concentration from the test site (ie downstream of the bypass) against the 80th percentile of the reference site (ie upstream of the bypass). The control chart would be based on the collection of baseline data and may be kept up-to-date by recalculating the 80th percentile each month with the most recent 24 monthly observations.

The trigger criteria recommended by the ANZECC guidelines for physio-chemical stressors would be adopted for this project, comprising:

- A trigger for further investigation would be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the eightieth percentile of the same indicator at a suitably chosen reference site.

The ANZECC guidelines also note that 'the statistical significance associated with a change in condition equal to or greater than a measurable perturbation (ie median of downstream sample exceeding 80th percentile of upstream sample] would require a separate analysis (ANZECC, 2000a)). This would be undertaken using a paired t-Test or Sign Test to determine whether the observed difference is statistically significant. Where a statistically significant difference is observed, the trigger criteria is deemed to be exceeded and further mitigation and management actions would be implemented.

Monitoring sites and parameters

The selection of monitoring sites would be prioritised using a risk based approach where the areas with the highest potential to impact on aquatic ecosystems would be identified and selected for monitoring. Selection of sites would represent a downstream gradient from the identified source to enable an estimation of the geographic extent of potential water quality exceedances.

The monitoring parameters proposed, as outlined below have been selected as these are considered the most likely pollutants to be generated as a result of the construction and operation of a major road.

Parameter	Unit	Monitoring approach
Dissolved Oxygen (DO)	mg/L	In-situ readings using portable probe
Electrical Conductivity (EC)	µs/cm	In-situ readings using portable probe
Oxygen Reduction Potential (ORP)	mv	In-situ readings using portable probe
pH		In-situ readings using portable probe
Temperature	^{o}C	In-situ readings using portable probe
Turbidity	NTU	In-situ readings using portable probe
Total Suspended Solids (TSS)	mg/L	Laboratory Analysis
Oils and grease	mg/L	Laboratory Analysis
Total Petroleum Hydrocarbons (TPH)	mg/L	Laboratory Analysis
Total Phosphorus (TP)	mg/L	Laboratory Analysis
Total Nitrogen (TN)	mg/L	Laboratory Analysis
Ammonia	mg/L	Laboratory Analysis
Metals (Aluminium, Cadmium, Copper, Lead, Zinc)	mg/L	Laboratory Analysis

Sampling frequency

The sampling program would focus on wet weather monitoring as this is when pollutants would most likely be mobilised and enter the receiving water environment. The following sampling frequency is proposed:

Construction monitoring

- Monthly sampling of minor wet weather events (ie where greater than 15 millimetres of rainfall is recorded in a 24 hour period). Three replicate samples would be taken every 15 minutes.
- Event based sampling of major wet weather events (ie where greater than 50 millimetres of rainfall is recorded in a 24 hour period). Three replicate samples would be taken every 15 minutes. A maximum of three major events would be sampled per year for the duration of the construction phase.

Operational monitoring

- Sampling of minor wet weather events (as defined above) above for one, or 12 sampling events, whichever is greater.

Appendix G

Outline of aquatic ecology monitoring program

Appendix G – Outline of aquatic ecology monitoring program

Background

The following sampling program would be proposed to monitor impacts of the project on aquatic biota. The program takes the “current best practice” approach of establishing baseline conditions, sampling before, during and after construction with comparisons of relevant indices to baseline indices, and incorporating replication within yearly periods to incorporate seasonality.

The primary objective of the program would be to detect any impacts on ecological receptors and estimate their geographical scale. During the construction phase of the project, the greatest risk to receptors such as aquatic macroinvertebrates would likely be from the mobilisation of exposed sediments. Potential impacts are more likely to be detected during wet weather as a result of exceedance/failure of the proposed control measures. During the operational phase, the greatest risk to aquatic assemblages would likely be as a result of increased pollutant loads resulting from road surface runoff.

Performance standards

AusRivAS assessment

The ecological health of rivers and their catchments can be assessed by using tools based on biological indicators. One such tool is “AusRivAS”, an interactive software package that provides an assessment of the condition of freshwater macroinvertebrate assemblages in a stream by comparing them to those from reference (undisturbed) streams of the same type (Davies, 1994). The AusRivAS model uses information collected for ‘predictor variables’ to predict the assemblage of macroinvertebrates that could be expected to occur at a particular location. The expected assemblage is then compared to the actual observed assemblage of taxa providing a basis to assess health of the stream. Predictor variables are variables that are considered unlikely to be affected by anthropogenic impacts (Norris, 1997).

Physico-chemical water quality parameters would be recorded using a portable multi-head probe prior to each sampling event to record background conditions that may help interpret biological results. Properties recorded would include:

- Conductivity (Ωs/cm).
- Salinity (ppt).
- Temperature (^{o}C).
- Turbidity (ntu).
- Dissolved oxygen (mg/L and % saturation).
- pH.
- ORP (oxidation reduction potential)(mV).

Proposed project performance standards

Application of the AusRivAS model is based on collection of field data from specific aquatic habitats using standardised, semi-quantitative techniques within two timeframes: Spring (15 September to 15 December) and Autumn (15 March to 15 June). Macroinvertebrates are identified to established levels of taxonomic resolution and, along with physico-chemical site data mainly recorded in the field, entered into the model and compared to appropriate reference streams. The following changes in AusRivAs indices for macroinvertebrate assemblages would identify impacts from road construction or operation (refer Section 2.3.2 for details of model outputs):

Index	Change required to identify impact due to road construction /operation
OE50 taxa	Reduction by one or more bands (X, A, B, C, D) relative to index established during baseline monitoring based on model output using two seasons (Spring and Autumn) for the site.
SIGNAL2	Reduction by one or more grades: • SIGNAL > 6 = Healthy habitat. • SIGNAL 5 – 6 = Mild pollution. • SIGNAL 4 – 5 = Moderate pollution. • SIGNAL < 4 = Severe pollution. relative to grade established during baseline monitoring based on model output using two seasons (Spring and Autumn) for the site.

This approach would identify the impacts directly associated with the bypass, not on the health of the greater catchment, by comparison to baseline conditions.

Monitoring sites and frequency

The selection of monitoring sites would be based on sites where construction activities are likely to have the highest potential to impact on aquatic ecosystems. Selection of sites would represent a downstream gradient from the identified sources to enable an estimation of the geographic extent of potential water quality exceedances. Site selection should include the created creek channel between Town and Bundewallah creeks with the aim of providing an indication of the time taken for the new aquatic habitat to develop natural populations of macroinvertebrates.

Sampling frequency

The sampling program relies on the establishment of sufficient baseline data against which during and post construction conditions can be compared. The following sampling frequency is proposed:

- Pre-construction: Two sampling events in Spring (15 September to 15 December) and two sampling events in Autumn (15 March to 15 June).
- During construction: Two sampling events in Spring (15 September to 15 December) and two sampling events in Autumn (15 March to 15 June), beginning as soon as riparian habitat clearing/disturbance is initiated.
- Post-construction: Two sampling events in each of two seasons Spring (15 September to 15 December) and Autumn (15 March to 15 June) for a minimum of one year after commencement of road operation.