Bolivia Hill Upgrade - Assessment of Route Options

# APPENDIX E

## AQUATIC ECOLOGY REPORT

# Aquatic Flora and Fauna Biodiversity Investigation

## Bolivia Hill Upgrade
## Assessment of Route Options

NA89913018

Prepared for
Roads and Maritime Services

July 2013

Cardno
Shaping the Future

# Document Information

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# Document Control

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# Glossary of terms and abbreviations

| | |
|---|---|
| AHD | Australian Height Datum |
| AUSRIVAS | Australian River Assessment System |
| AWS | Automated Weather Station |
| DECCW | Department of Environment, Climate Change and Water (functions are now within the Office of Environment and Heritage or the Department of Primary Industries) |
| DPI | NSW Department of Primary Industries |
| EEC | Endangered Ecological Community |
| EIS | Environmental Impact Statement |
| EP&A Act | NSW Environmental Planning and Assessment Act 1979 (NSW) |
| EPBC Act | Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth) |
| FM Act | Fisheries Management Act 1994 (NSW) |
| ITW | Internal Technical Workshop |
| Key stakeholder | The key stakeholders are groups who are proactively engaged during the project |
| LEP | Local Environmental Plan |
| Level of service | A measure of the quality of road operating conditions, including speed, travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience |
| LGA | Local Government Area |
| NEH | New England Highway |
| MNES | Matters of National Environmental Significance |
| NHL | National Heritage List |
| NPWS | National Parks and Wildlife Service |
| NSW | New South Wales |
| OEH | NSW Office of Environment and Heritage (formerly known as Department of Environment and Climate Change and Water) |
| PAC | Planning Assessment Commission |
| PEI | Preliminary Environmental Investigation |
| Project | Bolivia Hill Upgrade |
| Project team | The team, comprising representatives of RMS, Cardno (as the lead technical consultant) and other technical specialists, that is working on the project |
| RAM | Rapid Assessment Methodology |

| | |
|---|---|
| Reduced level | The vertical distance between a survey point and the Australian Height Datum (AHD) |
| RMS | Roads and Maritime Services (formerly known as RTA: Roads and Traffic Authority) |
| RMS (Maritime) | The maritime services division of Roads and Maritime Services (RMS) |
| SEPP | State Environmental Planning Policy |
| SIGNAL2 | Stream Invertebrate Grade Number Average Level |
| Study Area | The area confined to the five sites visited during the field-survey |
| TfNSW | Transport for New South Wales |
| The Tributary | The unnamed tributary running parrallel to the NEH through the Study Area, starting near the top of Bolivia Hill and connecting the Brickyard Creek to the east of the Study Area. |
| TSC Act | Threatened Species Conservation Act 1995 (NSW) |

# Executive Summary

Cardno (NSW/ACT) Pty Ltd was engaged by Roads and Maritime Services (RMS) in September 2012 to carry out an options and route assessment study and preliminary environmental assessment for four Route Options shortlisted for the re-alignment and upgrading of approximately three kilometres of the New England Highway (NEH) at Bolivia Hill between Glen Innes and Tenterfield.

This study focused specifically on the section of Brickyard Creek and one tributary creek where the majority of direct impact associated with the four options is expected to occur. Brickyard Creek runs perpendicular to the NEH crossing at the base of Bolivia Hill. The tributary creek runs parallel to the NEH from near the top of Bolivia Hill. Consideration has also been given to the aquatic environment upstream and downstream of this section, where impacts may also occur.

This report includes a desktop review, field investigation and aquatic ecology impact assessment for the construction of the four proposed re-alignment options. The desktop review identified a total of 692 species (along with some populations and communities) listed as endangered, vulnerable or protected under the *Threatened Species Conservation Act 1995*, the *Fisheries Management Act 1994* and/or the *Environmental Protection and Biodiversity Conservation Act 1999* that have potential to occur, or have previously been recorded, within 10 km of the proposed works. These included five species of aquatic flora, ten species of aquatic fauna, one Endangered Population, and two Endangered Ecological Communities.

Field investigations were undertaken and completed in February 2013 at five sites located on Brickyard Creek and an unnamed Tributary along the length of the proposed re-alignment. Field investigation included assessment of water quality, aquatic habitat, macrophytes, macroinvertebrates and fish. No threatened, endangered or protected flora or fauna were observed during the investigation. One potential Endangered Ecological Community, Carex Sedgeland, was identified at the western end of the proposed re-alignment works. The waterways investigated were also found to provide key potential habitat for one protected fish species, Purple Spotted Gudgeon.

The condition of the existing aquatic ecosystem within and downstream of the proposed works was identified as reasonably diverse to moderately degraded based on the interpretation of data concerning flora, fauna, water quality and habitat collected during this investigation. Despite its degraded condition, Brickyard Creek and the unnamed Tributary provide valuable aquatic habitat for resident organisms and are part of an interconnected ecosystem stretching from ephemeral creeks into the catchment.

Key potential impacts on aquatic biodiversity from the proposed works may include:

> Aquatic habitat degradation;

> Increased sedimentation and decreased water quality;

> Changes to water flow; and

> Restriction of fish passage.

Further degradation of this ecosystem could be minimised by implementing effective controls on potential causes of impacts to water quality, hydrology and the aquatic habitat associated with the proposed re-alignment works.

All four shortlisted Route Options for the re-alignment of the NEH would likely result in adverse impacts to the aquatic biodiversity in the area of proposed works. In terms of minimising impacts to aquatic biodiversity, a route re-alignment that follows the current alignment of the NEH as closely as possible would be preferable. On this basis, the four shortlisted Route Options for the re-alignment of the Bolivia Hill section of the NEH may be ranked based on the relative magnitude of potential impacts to aquatic biodiversity, from least impact to most impacting, as:

> Route Option 7b;

> Route Option 7;

> Route Option 6; and

- Route Option 10.

The selected proposed Route Option may have a significant impact upon species listed under the *Fisheries Management Act*, particularly Purple Spotted Gudgeon, due to the presence of key habitat resources within the Study Area and previous records of the species occurring within the general locality of the Study Area.

# Table of Contents

# Appendices



# Tables



# Figures

# 1 Introduction

Cardno (NSW/ACT) Pty Ltd was engaged by Roads and Maritime Services (RMS) in September 2012 to carry out an options and route assessment study and preliminary environmental assessment for the upgrade of approximately three kilometres of the New England Highway (NEH) at Bolivia Hill between Glen Innes and Tenterfield in New South Wales (NSW).

The NEH (1025 m) passes through the Bolivia Range approximately 55 km north of Glen Innes. The Bolivia Range runs east-west within the local government area of Tenterfield, connecting with the Great Dividing Range to the east and bounded by Deepwater River to the west. Both the NEH and the Great Northern Railway line (disused) pass through gaps in the range just west of the highest elevation within the range, Bolivia Hill (1225 m).

This report outlines findings of desktop and field-based assessments of aquatic biodiversity in the vicinity of the four shortlisted Route Options proposed for the upgrade works and provides an assessment of potential impacts to aquatic biodiversity associated with each option.

## 1.1 Background

The NEH is a major link from the Hunter region to the New England area and beyond. The western side of Bolivia Hill is traversed by a steep winding section of the NEH. The existing highway corridor is narrow with a rock face to the east and a steep drop to the west.

The Australian Government has committed $6 million for planning of safety works at Bolivia Hill and a future Tenterfield heavy vehicle bypass as part of the Nation Building Program. The Bolivia Hill upgrade project includes development of Route Options and identification of a preferred route. Preliminary investigations were carried out in order to identify a preferred option for the Bolivia Hill upgrade for further investigation.

An Internal Technical Workshop (ITW) was held on 21 November 2012. The purpose of the workshop was to provide a forum for discussion on the potential options for the upgrade and associated constraints and involved input from stakeholders including RMS and Transport for NSW (TfNSW). A number of preliminary Route Options were developed using MX road design software (**Figure 1-1**). The ITW concluded with a shortlist of four Route Options to be investigated in more detail.

An update to the ITW options evaluation resulted in the development of an additional option, Option 7b, which replaced Option 2 in the final list of four shortlisted options (**Figure 1-2**).

## 1.2 Scope of Work

The field assessment component of this study focused specifically on one section of Brickyard Creek, including one tributary creek, where the majority of direct impacts associated with the upgrade works are expected to occur. Brickyard Creek runs perpendicular to the NEH, crossing at the base of Bolivia Hill, while the tributary creek runs mostly parallel to the NEH from near the top of Bolivia Hill to its junction with Brickyard Creek (**Figure 3-1**). Consideration has also been given to the aquatic environment upstream and downstream of these creek sections, where indirect impacts may occur.

## 1.3 Aims

The general objective of the study and focus of this report is to assess potential impacts to aquatic biodiversity associated with each of the four Route Options proposed for the NEH re-alignment.

The specific aims of the study are to:

> Undertake background research and compile existing information on the aquatic habitats, biota and fisheries of Brickyard Creek, relevant tributaries and catchment area (‘Study Area’);

> Identify legislative requirements and guidelines that are relevant to the effects of the proposed works on aquatic ecology;

> Review current listings of species identified on Schedules to the *Threatened Species Conservation Act 1995* (TSC Act), the *Fisheries Management Act 1994* (FM Act) and the *Environment Protection and Biodiversity Act 1999* (EPBC Act), and assess the likely presence of protected aquatic species including a list of such species, populations, communities and processes;

> Assess the relevance of Key Threatening Processes (KTP's) as defined in the TSC Act with consideration to communities, populations and processes that are listed on the relevant TSC Act Schedules;

> Consider potential impacts in relation to Commonwealth requirements and international agreements, including the EPBC Act, wetlands policies and migratory bird agreements;

> Undertake field studies to describe the aquatic habitat provided by, and aquatic species utilising, Brickyard Creek and relevant tributaries, including the collection of data on water quality, aquatic macroinvertebrates, habitat quality, aquatic macrophytes and vertebrates (eg fish);

> Provide a preliminary assessment of the impacts to aquatic biodiversity associated with each of the proposed Route Options relevant to the aquatic ecology of Brickyard Creek and relevant tributaries;

> Identify any permits that may be required; and

> Make recommendations on any further work and further monitoring, if required.

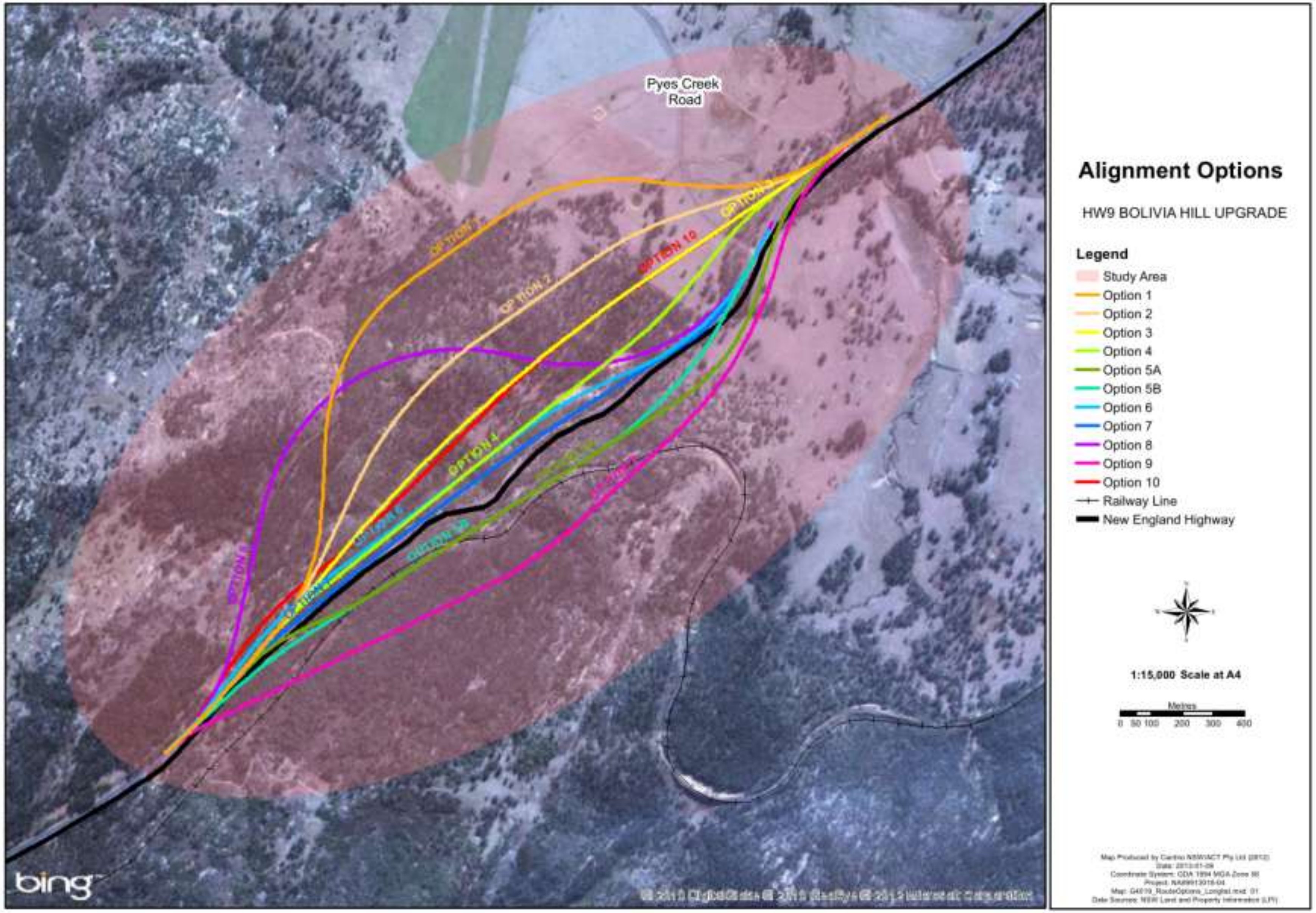



**Figure 1-1 Proposed Route Options for the NEH Re-Alignment Plan**

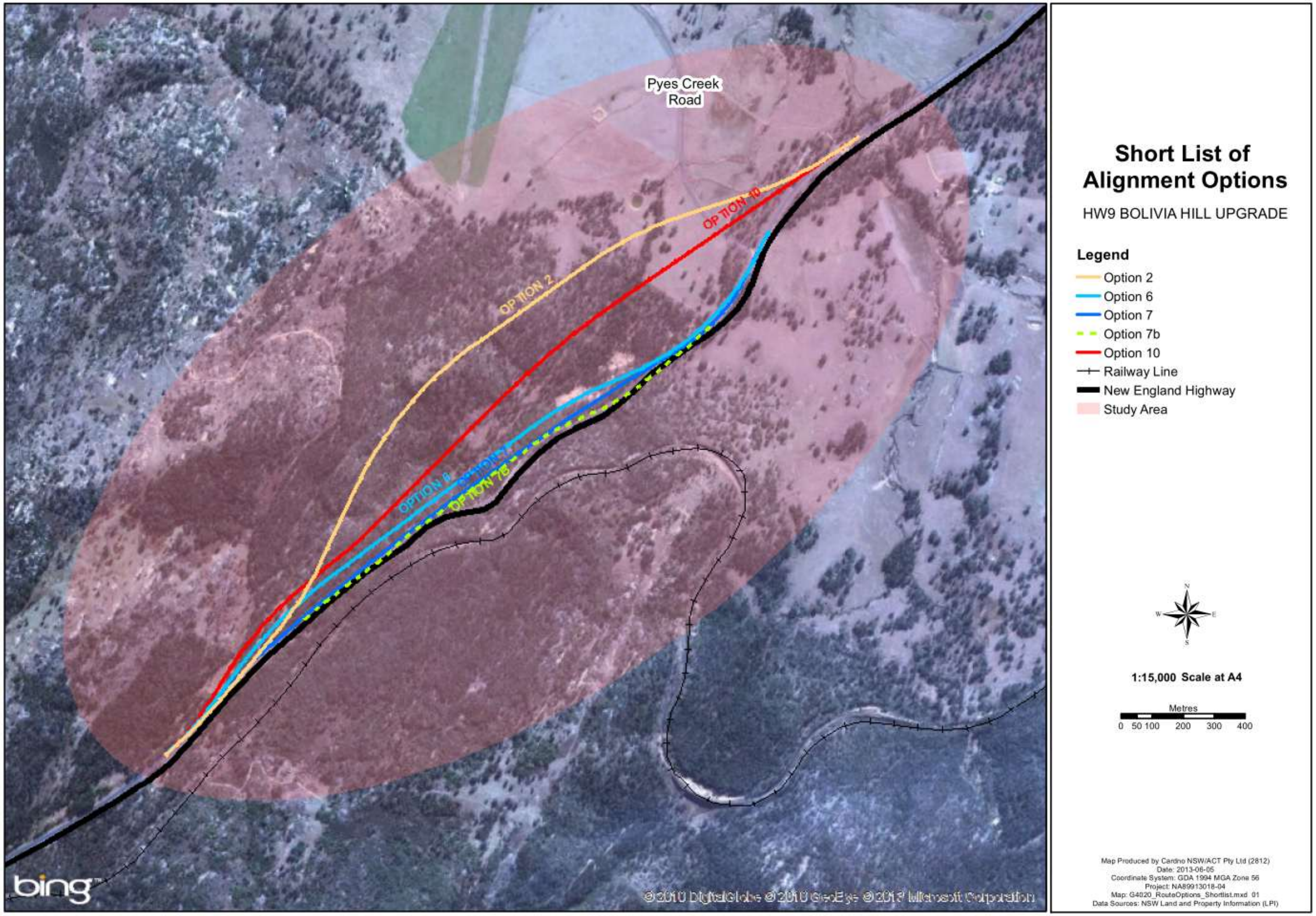



**Figure 1-2 Four shortlisted Route Options for the NEH Re-Alignment**

# 2 Legislative Context

## 2.1 Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is administered by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC). The aims of the Act are to:

> Provide for the protection of the environment, especially those aspects of the environment that are Matters of National Environmental Significance (MNES);

> Promote ecologically sustainable development through conservation and ecologically sustainable use of natural resources;

> Promote conservation of biodiversity; and

> Provide the protection and conservation of heritage.

In the aquatic environment, the Act lists the following MNES relevant to this study:

> Nationally threatened species, ecological communities, critical habitats and Key Threatening Processes (KTP's);

> Migratory species; and

> Ramsar wetlands of national significance.

Under the EPBC Act, any action that will have, or is likely to have, a significant impact on a MNES must be referred to the Australian Government Minister for a decision on whether assessment and approval is required under the EPBC Act. To assist proponents in determining whether an action is likely to have a significant impact on a MNES, DSEWPAC's reference 'Matters of National Environmental Significance, Significant Impact Guidelines 1.1' (DEWHA 2009) is available.

The EPBC Act also provides for the identification and listing of KTPs. A KTP may be identified and listed if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

To comply with the EPBC Act, a survey of the Study Area needs to be conducted targeting any MNES (nationally threatened species, ecological communities, critical habitats, migratory species and/or Ramsar wetlands). If any of these items are identified within, or are relevant to the Study Area, they will need to be assessed under the EPBC Act.

## 2.2 The Environmental Planning and Assessment Act 1979 (EP&A Act)

The EP&A Act is the principal piece of legislation overseeing the assessment and determination of development proposals in NSW. It also establishes the framework under which environmental planning instruments (eg State Environmental Planning Policies and Local Environmental Plans) are guided and planning decisions are prepared.

The EP&A Act contains several pathways under which development can be assessed and determined.

Under the EP&A Act, any development that will have a significant impact on the environment requires preparation of an environmental impact assessment. This preliminary environmental assessment of potential impacts to aquatic biodiversity has been prepared to support the wider Route Options Assessment for the proposed NEH re-alignment works.

## 2.3 Threatened Species Conservation Act 1995 (TSC Act)

In NSW, the TSC Act, administered by the Office of Environment and Heritage (OEH) includes provisions to declare threatened species, populations, ecological communities and KTP's. Aquatic birds, mammals and reptiles are included in Schedules of the TSC Act, whereas fish, aquatic vegetation and some aquatic invertebrates are listed under the FM Act (see Section 2.4). Species, populations and communities identified as 'endangered' are listed in Schedule 1 of the TSC Act. Species, populations and communities identified as 'critically endangered' are listed in Schedule 1A of the TSC Act, while species, populations and communities identified as 'vulnerable' are listed in Schedule 2 of the TSC Act. In addition, the TSC Act provides for the identification and listing of habitat that is critical to the survival of an endangered species, population or ecological community.

Any organisms found within the Study Area that are listed in the TSC Act will require specific assessment under this legislation to assess any potential impact by the proposed NEH re-alignment works.

## 2.4 Fisheries Management Act 1994 (FM Act)

The FM Act administered by the NSW Department of Primary Industries (DPI) seeks to conserve fish stocks and key fish habitats, as well as threatened species, populations and ecological communities of fish, aquatic vegetation and some aquatic invertebrates. Species, populations and communities identified as 'endangered' are listed in Schedule 4 of the FM Act. Species, populations and communities identified as 'critically endangered' are listed in Schedule 4A, while species, populations and communities identified as 'vulnerable' are listed in Schedule 5 of the FM Act. The FM Act also lists KTPs that may threaten the survival of those species, populations and ecological communities.

Section 19 of the FM Act allows for the declaration of specified species of fish or invertebrate as protected. Although not currently considered to be in decline, these animals must be protected so they do not become threatened in future. Provisions for the protection of aquatic habitats and aquatic reserves are included under Part 7 of the Act. In addition, Division 3 of the FM Act provides for the identification of habitat that is critical to the preservation of an endangered species, population or ecological community.

State legislation requires that developments likely to have a significant effect on threatened species prepare a Species Impact Statement (SIS). This would need to be completed for any communities found within the Study Area containing species that are listed under the FM Act. To assist proponents in the process of determining whether a development is likely to have a significant impact on a threatened species, DPI has developed 'Assessment of Significance' guidelines (NSW DPI 2008).

# 3 Methodology

## 3.1 Sampling Sites

A desktop investigation was done to gain an appreciation of the potential for impacts to aquatic biodiversity by the proposed re-alignment routes. Three sampling sites were selected to represent the length of the Brickyard Creek tributary (hereafter referred to as the Tributary) running off Bolivia Hill into Brickyard Creek, while two sites were selected to represent the section of Brickyard Creek within the Study Area. The three Tributary sites are distributed along approximately 5 km of that waterway, while the two Brickyard Creek sites are located approximately 600 m apart. Site locations, descriptions, GPS coordinates and topographic map are provided in **Table 3-1** and **Figure 3-1**.

**Table 3-1 Site descriptions and locations**

| Site Name | Sampling Site Code | Description | Easting (UTM 56J)* | Northing (UTM 56J)* |
|---|---|---|---|---|
| Brickyard Creek Upstream | BC US | Existing highway crossing with bridge | 6757491 | 0396962 |
| Brickyard Creek and Splitters Swamp Creek Confluence | BC CON | Downstream of all proposed Route Options | 6758562 | 0396525 |
| Tributary 1 | TRIB 3 | Base of Bolivia Hill | 6756838 | 0396128 |
| Tributary 2 | TRIB 4 | Halfway down Bolivia Hill | 6756076 | 0394984 |
| Tributary 3 | TRIB 5 | Top of tributary | 6755366 | 0394373 |

*Coordinate datum is WGS84

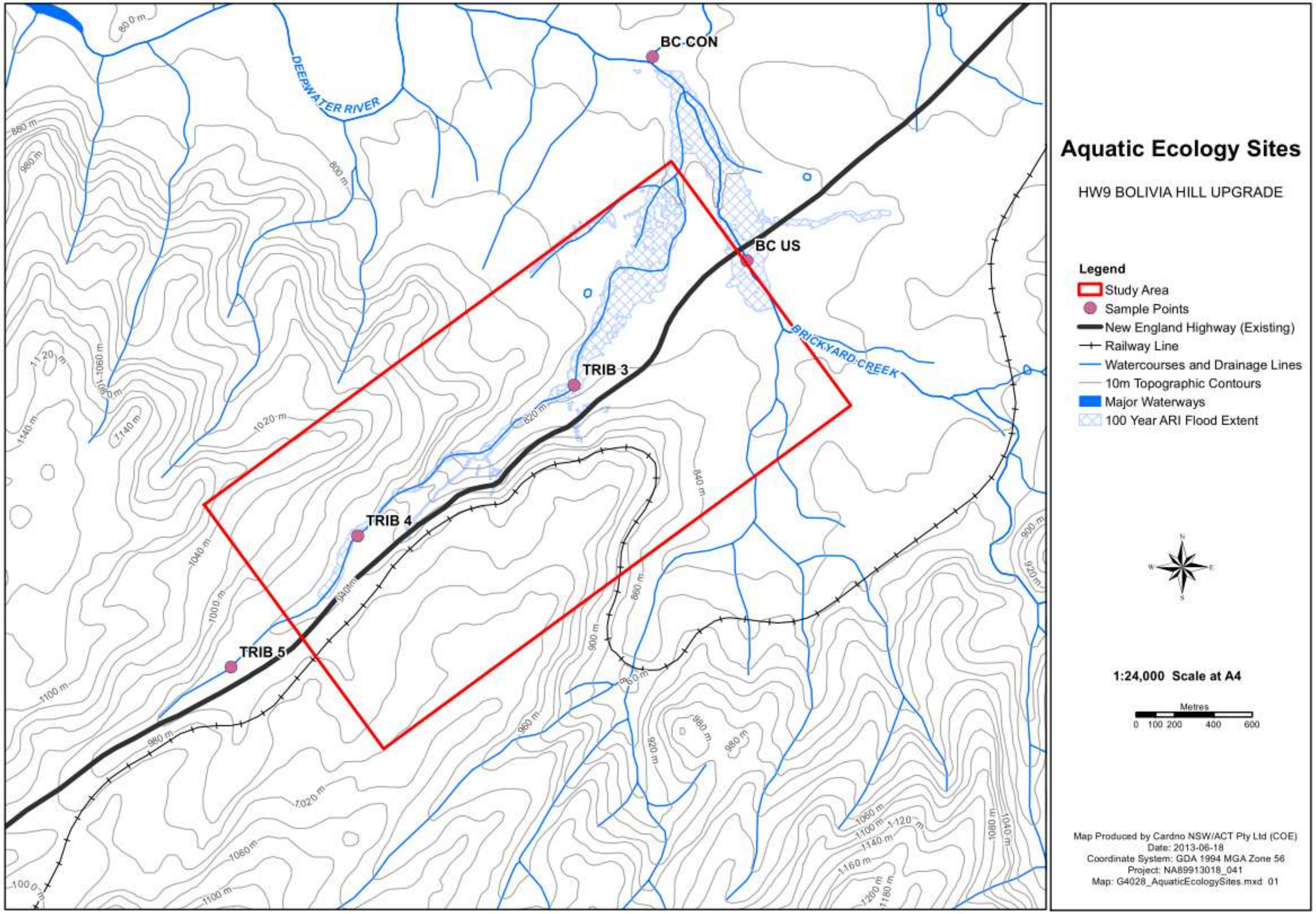



**Figure 3-1 Locations of sampling sites**

## 3.2 Sampling Methodology

### 3.2.1 Aquatic Habitat Assessment

The condition of the aquatic habitat at each site was assessed using a modified version of the Riparian, Channel and Environmental (RCE) Inventory Method (Chessman *et al.* 1997). This assessment involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site (**Appendix A**). The maximum score (52) indicates a waterway with little or no obvious physical disruption and the lowest score (13) indicates a heavily channelled waterway without any riparian vegetation. This methodology, originally developed by Peterson (1992), was 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 to 1-4.

Barriers to fish movement and the potential for sites to provide fish habitat were assessed according to criteria developed by DPI (Fairfull and Witheridge 2003).

### 3.2.2 Water Quality

Water quality was measured *in situ* with a YSI 6920 Datasonde water quality multi-parameter probe coupled with a 650MDS handheld display unit. The probe was fully calibrated before deployment. Two replicate readings of each water quality component were taken in accordance with Australian Guidelines (ANZECC/ARMCANZ 2000). Six replicate readings were taken for turbidity as this measure tends to be more variable. Water quality components measured by the probe were:

> Temperature (°C);

> Electrical Conductivity (EC) (µs/cm);

> pH (pH units);

> Dissolved Oxygen (DO) (mg/L and per cent saturation);

> Oxidation Reduction Potential (ORP) (mV); and

> Turbidity (NTU).

Water quality data were compared to the ANZECC/ARMCANZ (2000) default trigger values for upland rivers (**Table 3-2**). These values provide a point of reference for aquatic ecosystem protection and are derived from past ecotoxicology investigations.

**Table 3-2 ANZECC/ARMCANZ (2000) default trigger values for south east Australian upland rivers**

| Parameter | Trigger value | Comments |
|---|---|---|
| **Phys-Chem** | | |
| DO | 90-110% saturation | Daytime measurements |
| pH | 6.5-8.0 | |
| EC | 350 µS/cm | |
| Turbidity | 25 NTU | High values may be observed in high flow event |

### 3.2.3 Aquatic Macroinvertebrates

Two replicate samples of aquatic macroinvertebrates associated with edge habitats were collected at each site using the AUSRIVAS (Australian River Assessment System) rapid assessment methodology (RAM) (Turak *et al.* 2004). Riffle habitat was not sampled because this habitat was not adequately represented within any of the stretches of creek surveyed. Samples were collected using dip nets (250 µm mesh) over a period of 3-5 minutes along a 10 m length of edge habitat along the creek. The dip net was used to agitate and scoop up material from vegetated river edge sub-habitats including trailing vegetation, submerged macrophytes, rocky substrate, large woody debris and detritus, where present. Where habitat was discontinuous, multiple patches of habitat of a cumulative total length of 10 m were sampled. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour, or until no new taxa had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. The animals collected at each site were placed into a labelled jar containing 70% ethanol.

In the laboratory, each sample of picked animals was sorted under a binocular microscope (at 40× magnification). Macroinvertebrates were extracted, identified to family level using standard references and counted up to a maximum of ten animals per family, in accordance with the latest AUSRIVAS protocol (Turak *et al.* 2004). Samples were stored in 70% ethanol in containers appropriate for long-term storage.

The AUSRIVAS model was not used to interpret the macroinvertebrate data collected, as the sampling was done well outside the sampling seasons specified by the model.

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was 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 to each macroinvertebrate family or taxa, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat was 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.

The SIGNAL2 outputs were plotted to display the number of macroinvertebrate taxa and the SIGNAL2 index on separate axis to provide a graphical representation of these data. This diagram is referred to by Chessman (2003) as a SIGNAL2 bi-plot and is usually separated into quadrants representing the level of biological impairment at each survey site (**Figure 3-2**). Definition of the biological impairment using these two values (number of taxa and SIGNAL2 index) is somewhat arbitrary and depends on factors such as geographical location and the condition of the aquatic habitat. In general, SIGNAL2 values indicate that the quality of the water was clean (>6), mildly degraded (5-6), moderately degraded (4-5) or severely degraded (<4). Taxa richness values generally indicate a rich assemblage (>20), moderately degraded (15-20), severely degraded (10-15) and depauperate community (<10).

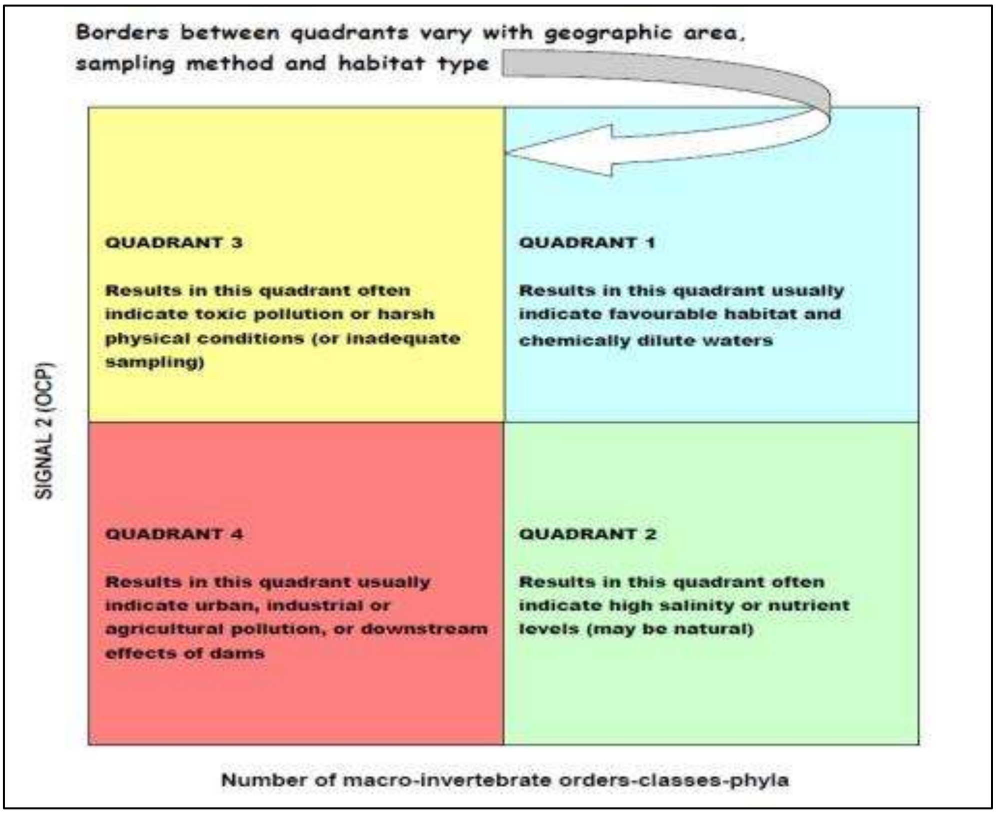



**Figure 3-2 SIGNAL2 quadrat descriptions from Chessman (2003).**

### 3.2.4 Fish

Finfish and freshwater crayfish/yabbies were surveyed using a Smith-Root LR24 backpack electrofisher at all sites. 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 shallow pools and beneath overhanging banks and vegetation along the 100 m reach of each site. The electrofisher on-time (time that the electrical circuit is open) was recorded at each site to provide an indication of sampling effort.

At the Brickyard Creek upstream (BC US) site only, two collapsible bait traps were deployed overnight in discrete locations on the creek bed, amongst vegetation and near submerged logs or within dense vegetation. The traps used were 350 mm long and 200 mm wide and constructed of 3 mm mesh, with two entrances, each tapering to a 15 mm diameter opening. Traps were not used at other sites due to inherent unsuitability of habitat for trap deployment. It was determined that these other sites had been surveyed sufficiently using electrofishing.

All fish caught were placed into a tub containing creek water, identified, counted, checked for abnormalities and then released as quickly as practicably possible. The numbers of each species of fish captured at each site were recorded on data sheets. Non-native species were humanely disposed of, as per DPI guidelines. All fish captured and their fates were reported to the DPI and the Director General's Ethics Committee as per the conditions of the NSW Fisheries permit F86/670(A) held by Cardno (NSW/ACT) to sample fish.

### 3.2.5 Aquatic Macrophytes

Aquatic macrophytes occurring in-stream and in close proximity to the wetted bank edge were surveyed at each site. This was done by walking the length of the site along both banks of the creek line and recording plant growth forms (eg grasses, sedges, trees) and habitat (eg in-stream, bank-side, riparian). Where achievable, plant identifications were made to species or genus in the field by an experienced aquatic ecologist. Due to the time of year of the survey, however, numerous plants were not flowering and were therefore difficult to identify to species level. Where this was not possible, identification was made to the lowest level of taxonomic resolution achievable and subsequent checks of literature were made to exclude any threatened or endangered species from the identification.

## 3.3 Assumptions and Limitations

The topography and land use of Brickyard Creek and Tributary Creek catchments were assessed using satellite imagery and topographic maps before the field visit to determine site access and identify locations along Brickyard Creek and the Tributary that may potentially contain survey sites that would provide a thorough understanding of the aquatic ecosystem associated with the Study Area. During the field visit, those locations were visually assessed for spatial variability in vegetation, habitat or creek structure, and sites were subsequently chosen to provide an adequate representation of the aquatic ecosystem within the Study Area. It was assumed that data collected from the five survey sites were representative of the entirety of aquatic habitats throughout the Study Area at the time of the survey. This survey was limited temporally, with only one survey event completed shortly after moderate to heavy rainfall. The data collected should be interpreted as such, with temporal replication required to provide information concerning variability in aquatic assemblages through time.

# 4 Results and Discussion

The field survey was done between 27 February and 1 March 2013. Conditions at the time of sampling were fine to overcast. Heavy rainfall was recorded at the Bureau of Meteorology's (BoM) Deepwater Post Office Automated Weather Station (AWS) during the week before commencement of the survey (70.6 mm in total between 21 and 27 February 2013) and heavy rainfall was recorded around a month prior (104, 21 and 18 mm on 29 January, and 4 and 11 February 2013, respectively). A plot illustrating the pattern of rainfall within the period preceding sampling is provided in **Appendix D**.

## 4.1 Physical Setting

The main watercourse within the Study Area (by length) is a tributary of Brickyard Creek (the Tributary), which flows in a north-easterly direction roughly parallel to the NEH on the western side and joins Brickyard Creek at the no north-eastern end of the Study Area (**Figure 3-1**). The headwaters of the Tributary lie at an elevation of approximately 940 m AHD (Australian Height Datum) at the western end of the Study Area. The creek then descends to approximately 820 m AHD towards the base of Bolivia Hill. It then meanders across flat terrain forming a local floodplain, crossing Pyes Creek Road approximately 400 m north-west of the NEH. The Tributary has gouged a deep (approximately 20 m) steep sided gorge exposing fresh granite outcrop, approximately 200 m north-west of the current road alignment.

The Tributary has a minor tributary flowing into it in the upper part of its catchment, just west of Site TRIB 5. The minor tributary runs parallel to the main gully, which is situated close to the western side of the NEH, but is separated from the main gully by a small ridge line. This minor tributary diverges from the ridge and joins the Tributary approximately 150 m west of the highway. Overall, the Tributary watercourse, including all minor tributaries, has an approximate catchment of 533 ha and comprises forested and vegetated land. At the north-eastern end of the Study Area is Brickyard Creek, which is primarily a fourth order stream. The Brickyard Creek catchment upstream of the NEH has an area of approximately 1,700 ha.

## 4.2 Literature Review

A review of available information on the aquatic ecosystem associated with Brickyard Creek and Bolivia Hill Tributaries in the context of the proposed re-alignment works was undertaken for this assessment. The key documents reviewed were:

> Cardno (2013) Bolivia Hill Upgrade – Preliminary Route Options Report; and

> Cardno (2013) Bolivia Hill Upgrade – Internal Technical Workshop Report.

### 4.2.1 Threatened, Vulnerable and Protected Species

A desktop study and field inspection were conducted to establish the existing local environment with respect to aquatic flora and fauna at the site. Ecological databases searched during the desktop study and focused on threatened species listed under the EBPC, TSC and FM Acts included:

> EPBC Protected Matters Search Tool Database (with a 10 km radial buffer around the proposed re-alignment works);

> NSW FM Act list of threatened, endangered and protected fish species in NSW;

> NSW OEH Wildlife Atlas (Bionet) with a 10 x 10 km buffer around the proposed re-alignment works; and

> OEH Critical Habitat Register.

Note that these databases provide indicative information of flora and fauna species recorded in the locality only and are not the result of a systematic flora and fauna survey. Therefore, they cannot be considered a comprehensive inventory and may contain errors and omissions.

#### 4.2.1.1 *Flora and Fauna*

A search of the Bionet NSW Wildlife Database identified a total of 692 species listed under the TSC Act and/or the EPBC Act that could occur or have previously occurred within 10 km of the Study Area. These included:

> Five species of flora associated with aquatic habitats (**Table 4-1**);

> Five species of aquatic fauna (**Table 4-2**);

> One endangered population; and

> Two endangered ecological communities.

An assessment of the likely presence of each of the ten specific flora and fauna species within the Study Area was conducted (Cardno 2013), with likelihood ratings for the occurrence of a species (**Table 4-1** and **4-2**) based on the following set of criteria:

**Confirmed** – Species recorded during current biodiversity assessment surveys of the Study Area.

**Likely** – Study Area supports known critical habitat resources for the species and a NSW Atlas record within 10 km of the Study Area exists for the species.

**Possible** – Study Area supports known critical habitat resources for the species and the EPBC Protected Matters Search Tool indicates the species is likely to occur within 10 km of the Study Area, but there is no NSW Atlas record of the species occurring within 10 km of the Study Area

**Unlikely** – Study Area contains very limited, degraded or no known habitat for the species.

**Table 4-1 Threatened Flora Species within 10 km of the Study Area potentially associated with aquatic habitats**

| Scientific Name | Common Name | Classification | | Likelihood of Occurrence |
|---|---|---|---|---|
| | | EPBC Act | TSC Act | |
| *Almaleea cambagei* | Torrington Pea | E,P | V | Possible |
| *Callistemon pungens* | | P | V | Confirmed |
| *Cryptostylis hunteriana* | Large Tongue Orchid | P | | Unlikely |
| *Diuris pedunculata* | Small Snake Orchid | E,P | E | Possible |
| *Thesium australe* | Austral Toadflax | V,P | V | Possible |

P = Protected; V = Vulnerable; E = Endangered
Assessments of listed flora can be found in the Biodiversity Impact Assessment (Cardno 2013).

**Table 4-2 Threatened Aquatic Fauna Species within 10 km of the Study Area**

| Scientific Name | Common Name | Classification | | Likelihood of Occurrence |
|---|---|---|---|---|
| | | EPBC Act | TSC Act | |
| *Myxophyes balbus* | Stutturing Frog | P | | Possible |
| *Philoria sphagnicolus* | Sphagnum Frog | V,P | | Likely |
| *Elseya belli* | Bell's Turtle | V | V | Unlikely |
| *Ornithorhynchus anatinus* | Platypus | P | | Unlikely |
| *Petalura gigantea* | Giant Dragonfly | E1 | | Likely |

P = Protected; V = Vulnerable; E = Endangered
Assessments of listed fauna can be found in the Biodiversity Impact Assessment (Cardno 2013).

There are known critical habitat resources for the Giant Dragonfly within the Study Area and a NSW Atlas record exists for the species within 10 km of the Study Area. Therefore, this species was considered for assessment.

The Giant Dragonfly is the third largest dragonfly in Australia and one of the largest in the world. It is found along the east coast of NSW from the Victorian border to northern NSW, including the area of the proposed alignment. It occurs in permanent swamps and bogs with some free water and open vegetation. The main threats to the Giant Dragonfly are:

> Changes to natural fire regimes;

> Clearing and development of land resulting in habitat loss and/or degradation;

> Weed invasion;

> Decreased water quality through pollution;

> Eutrophication and sedimentation; and

> Impacts on swamp hydrology from factors such as construction of works.

#### 4.2.1.2 ***Populations***

A search of the Bionet NSW Wildlife Database identified one Endangered Population listed under the TSC Act and associated with aquatic habitat that could occur or have previously occurred within 10 km of the Study Area – the Tusked Frog (*Adelotus brevis*) population in the Nandewar and New England Tableland Bioregions.

The Endangered Tusked Frog population of the Nandewar and New England Tableland Bioregions is known to occur (or have occurred) in that part of the Border Rivers-Gwydir Catchment Management Region, which encompasses the Study Area. However there are no records of the Tusked Frog (*Adelotus brevis*) within Atlas of NSW Wildlife search results for the Study Area and no Tusked Frogs were recorded during field surveys. In this respect the formal NSW Scientific Committee listing of this population notes that "*The New England Tablelands and Nandewar population of Tusked Frog represents a distinct and disjunct high-elevation population that is at the western limit of the species' range in NSW. Given the apparent lack of records from this population in the last 25 years, its numbers are likely to be reduced to a critical level, if it is not already extinct*." Given the above facts and circumstances, the Tusked Frog is considered to be unlikely to occur within the Study Area.

#### 4.2.1.3 ***Communities***

A search of the Bionet NSW Wildlife Database identified two communities protected under the TSC Act and/or the EPBC Act that could occur or have previously occurred within 10 km of the Study Area. Endangered Ecological Communities (EECs) identified to potentially be located within 10 km of the Study Area according to the EPBC Database were:

> Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions; and

> Upland wetlands of the Drainage Divide of the New England Tableland Bioregion.

Carex Sedgeland mainly occurs in association with drainage depressions in valley floors, frost hollows, and undulating terrain between 440 m and 1360 m in altitude. It occurs on a variety of lithologies including granite, basalt, metasediments, acid volcanics, sandstone and Aeolian sands (Hunter and Bell 2009). Carex Sedgeland occurs as a part of a mosaic of native vegetation communities including swamps, bogs, wetlands, grasslands, and sclerophyll forests (Benson and Ashby 2000; Bell *et al*. 2008). It is mostly found at higher altitude on tablelands but may extend onto the slopes. Threats to such communities include clearing, changes in groundwater flow, fertiliser application, trampling and grazing by domestic stock.

Upland Wetlands of the Drainage Divide of the New England Tableland Bioregion is the name given to the ecological community associated with shallow, temporary to near-permanent wetlands restricted to the higher altitudes (above about 900 m) associated with the Great Dividing Range in northern NSW. These wetlands are important habitat for a diverse range of vertebrate and invertebrate fauna, with water birds, frogs, turtles and eels common inhabitants when the wetlands are flooded. Comparatively little, however, is known about the invertebrate fauna. Major ongoing threats to those wetlands include alteration of water regimes that make these wetlands more predictably flooded or dry (Brock *et al.*1999). Such alterations can be made intentionally by draining or damming, or unintentionally through sedimentation from catchment erosion as a result of soil surface crust damage from stock hooves or clearing of catchment vegetation (Gale *et al*. 1995; Haworth 1994; Haworth *et al*. 1999).

#### 4.2.1.3.1 Fish

A search of the DPI fishing and aquaculture species protection records identified five vulnerable or endangered fish species in the catchment of the proposed works (**Table 4-3**).

**Table 4-3 Threatened Fish Species within 10 km of Study Area**

| Scientific Name | Common Name | Classification | | | Likelihood of Occurrence |
|---|---|---|---|---|---|
| | | EPBC Act | TSC Act | FM Act | |
| *Tandanus tandanus* | Freshwater Catfish | V | | V | Unlikely |
| *Maccullochella peeli* | Murray Cod | V | | E | Possible |
| *Ambassis agassizii* | Olive Perchlet | | P | E | Unlikely |
| *Mogurnda adspersa* | Purple Spotted Gudgeon | | P | E | Likely |
| *Bidyanus bidyanus* | Silver Perch | | P | V | Unlikely |

V = Vulnerable; E = Endangered; P = Protected; M = Migratory

Of the five fish identified as vulnerable, endangered or protected within the catchment area, two have been previously sighted within a 10 km radius of the proposed re-alignment works – Murray Cod and Purple Spotted Gudgeon.

Murray Cod occurs in a diverse range of habitats, including clear rocky streams (such as those found in the upper western slopes of NSW), to slow-flowing, turbid rivers and billabongs. It is usually found in association with complex structural cover such as large rocks, snags, overhanging vegetation and other woody structures, and is frequently found in the main channel and larger tributaries of rivers. It is sometimes found in floodplain channels when they contain water, although this usage appears limited. Given the small size of the waterways surveyed and the known habitat of the species, it is unlikely to be found in the Study Area, despite the suitability of the sampling methods employed in the survey to detect its presence.

Purple Spotted Gudgeon occurs in inland drainages of the Murray-Darling basin and coastal drainages of northern NSW and Queensland. They live among weeds, rocks and snags in rivers, streams and billabongs, where they feed on small fish, insect larvae, worms, tadpoles and plant matter. Due to the presence of previous records of Purple Spotted Gudgeon, specifically from downstream of the Study Area (around the confluence of Deepwater River and Pyes Creek), and its known habitat being similar to that being surveyed, this species was targeted during the survey as requested by the DPI (NSW DPI 2012).

#### 4.2.1.4 *Key Threatening Processes*

Ten KTPs have been identified through the Bionet NSW Wildlife Atlas as having the potential to apply in the Study Area:

> Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands;

> Clearing of native vegetation;

> Infection of frogs by amphibian chytrid causing the disease chytridiomycosis;

> Invasion and establishment of exotic vines and scramblers;

> Invasion and establishment of the cane toad (*Bufo marinus*);

> Invasion of Native plant communities by African Olice *Olea europea* L. subsp. *Cuspidate* (Wall ex G. Don Cirferri);

> Invasion of native plant communities by exotic perennial grasses;

> Invasion, establishment and spread of Lantana (*Lantana camera* L. sens Lat);

> Loss of degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants; and

> Predation by *Gambusia holbrooki* Girard 1859.

All construction activities associated with the proposed re-alignment works must be completed in accordance with DPI Policy for these KTPs. In particular, any construction of bridges or other works that may have an impact on the natural flow regime of the Tributary or of Brickyard Creek must be completed in accordance with DPI Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI 2013).

## 4.3 Field Survey

### 4.3.1 Aquatic Habitat

Habitat assessment scores based on the Riparian, Channel and Environmental Inventory (RCE) were assigned for each of the sampling sites associated with Brickyard Creek (BC US and BC CON) and the Tributary (TRIB 3, TRIB 4, and TRIB 5) (**Table 4-4**). These values provide a numeric interpretation of the written descriptions (**Appendix A**).

**Table 4-4 RCE scores for survey sites**

| Designation | | BC US | BC CON | TRIB 3 | TRIB 4 | TRIB 5 |
|---|---|---|---|---|---|---|
| 1 | Land use pattern beyond the immediate riparian zone | 3 | 2 | 3 | 3 | 3 |
| 2 | Width of riparian strip of woody vegetation | 3 | 1 | 4 | 4 | 4 |
| 3 | Completeness of riparian strip of woody vegetation | 3 | 1 | 3 | 3 | 3 |
| 4 | Vegetation of riparian zone within 10m of channel | 3 | 1 | 3 | 4 | 4 |
| 5 | Stream bank structure | 2 | 1 | 3 | 3 | 4 |
| 6 | Bank undercutting | 2 | 3 | 3 | 3 | 4 |
| 7 | Channel form | 3 | 3 | 3 | 3 | 2 |
| 8 | Riffle/pool sequence | 2 | 2 | 2 | 2 | 2 |
| 9 | Retention devices in stream | 3 | 2 | 3 | 3 | 4 |
| 10 | Channel sediment accumulations | 2 | 1 | 3 | 2 | 2 |
| 11 | Stream bottom | 1 | 1 | 3 | 2 | 2 |
| 12 | Stream detritus | 2 | 2 | 3 | 2 | 2 |
| 13 | Aquatic vegetation | 2 | 4 | 2 | 4 | 2 |
| **Total** | | **31** | **24** | **38** | **38** | **38** |

The RCE index used provides a simplified description of the aquatic habitat and does not fully represent the complex nature of aquatic habitats such as, for example, temporal changes in habitat structure in response to periods of elevated flow. The score also has equal weightings for each of the indices, so certain elements and differences in the habitat of each site may be masked. The scores should therefore be used as a general assessment only.

All three sites along the Tributary (TRIB 3, TRIB 4 and TRIB 5) and BC US scored similar total RCE indices; these being within the average habitat quality range. In contrast, BC CON scored a low RCE total score, categorised in the poor habitat quality range, which was driven by surrounding agricultural landuse.

Detailed descriptions of the riparian aquatic habitats associated with each site are provided below.

#### 4.3.1.2 ***Brickyard Creek Upstream (BC US)***

BC US was located upstream of the existing NEH Brickyard Creek crossing, in a broad valley surrounded by previously cleared land currently in agricultural use. There was a pool located 200 m upstream of the crossing against a property boundary fence. This pool diverged into several narrow channels, which collectively comprised the majority of the aquatic habitat and converged into a large pool at the downstream boundary of the site. The channels were on average 0.5 m deep, while the pools had a maximum depth greater than 1 m. The creek wetted-width ranged between 1 m and 10 m with an average of approximately 1.5 m along the channels and reaching the maximum in the pools. The water level at the time of sampling was above the apparent high water mark. The banks from maximum depth were 1 m to 2 m high and surrounded by a small plain 5 m to 20 m in width. The substratum within the watercourse consisted predominantly of silt, with sand and finer clay also present. Images of BC US can be found in **Appendix F.**

The visibility of the water at BC US was poor during the survey, though there were no visible signs of water pollution such as foaming or proliferation of algae. This site was classified as minimal to moderate fish habitat value using the Fairfull and Witheridge (2003) classification and received an RCE score of 31 (**Table 4-4**). This site scored a moderate RCE due to the substratum consisting of loose, mobile, fine sediment with only fine detritus present and a moderate density of macrophytes. The macrophytes observed included *Paspalum* sp., *Juncus* sp., *Cyperus* sp., *Schoenoplectus* sp and *Ludwigia* sp. The riparian zone was sparsely covered by a canopy of tall *Eucalyptus* sp. (> 20 m) and several smaller trees and shrubs, mainly *Salix* sp. and *Eucalyptus* sp. Ground cover consisted of grasses and weeds. Downstream of the current highway creek crossing, in-stream aquatic flora was dominated by a *Phragmites* sp. bed down to the boundary of the Bolivia Station property, which has been cleared for agricultural use.

#### 4.3.1.3 ***Brickyard Creek and Splitters Swamp Creek Confluence (BC CON)***

BC CON was located in Splitters Swamp Creek adjacent to its confluence with Brickyard Creek, which was approximately 600 m downstream of BC US. The site was characterised by quickly flowing water approximately 50 cm deep, with edge and bend pooling ranging from 10 cm to 70 cm deep. Splitters Swamp Creek joins Brickyard Creek from the southeast. The wetted-width at the site ranged between 2 m and 6 m, with an average of approximately 4 m. This site was devoid of any woody riparian vegetation and there was heavy historic erosion present. Banks from maximum depth ranged from 1 m to 2.5 m tall with an average of 1.5 m, while bank-full width ranged from 3 m to 6 m. The substratum consisted predominantly of sand and silt, with larger gravel and pebbles also present. Images of BC CON can be found in **Appendix F**

The water at BC CON was clear during the survey. This site was classified as minimal to moderate fish habitat value with an RCE score of 24 (**Table 4-4**). A low RCE score was given due to the complete lack of woody riparian vegetation and unstable, eroded creek banks, most likely a consequence of convergence of surrounding pastoral land. Minimal quantities of in-stream macrophytes were observed, with those found including *Paspalum* sp., *Juncus* sp., *Ranunculus* sp. and *Persicaria* sp. The riparian area had been completely cleared and was in use as pasture for livestock. Groundcover was densely populated by grasses.

#### 4.3.1.4 ***Tributary 3 (TRIB 3)***

TRIB 3 was located at the downstream end of the Tributary coming off Bolivia Hill, approximately 1.5 km from the junction of the Tributary and Brickyard Creek (**Figure 3-1**). The Tributary joins Brickyard Creek approximately 500 m upstream of Site BC CON. TRIB 3 consisted of small pools connected by a slowly moving, narrow creek, with a rocky area in the upstream section of the site and a ford crossing near the middle of the site. The average depth was around 25 cm, with a minimum of 5 cm and a maximum depth of approximately 0.5 m in the pools. The creek wetted-width varied from 0.5 m to 4 m, with an average of around 2 m, while the banks were approximately 1 m high from maximum depth. The substratum was predominately sand but also consisted of cobbles, pebbles, gravel and some silt. Images of TRIB 3 can be found in **Appendix F**

The water appeared relatively clear at this site, with no obvious signs of water pollution. The site was classified as moderate fish habitat value and received an RCE score of 38 (**Table 4-4**). Sparsely distributed in-stream macrophytes were observed, including *Paspalum* sp., *Eleocharis* sp. and *Cyperus* sp. The riparian zone was densely covered in *Acacia* shrubs, grasses and herbs, with sparse *Eucalyptus* sp. trees interspersed.

#### 4.3.1.5 ***Tributary 4 (TRIB 4)***

TRIB 4 was located approximately 1.5 km upstream from TRIB 3 in a broad valley approximately 200 m from NEH. A dirt road crossed the creek, impounding a large pool on the upstream side, in which a dead kangaroo was floating. Two water dragons were also observed during the survey. Downstream of the road there was a lot of woody debris, while the downstream end of the site comprised exposed bedrock characterised by faster flowing water. Downstream of the site boundary the creek channel had a steep gradient and flowed over several falls (>1 m tall). The average depth within TRIB 4 was approximately 0.8 m, being shallowest (approximately 0.1 m) in the faster flowing rocky area and exceeding 1 m depth in the upstream pool. The creek wetted-width ranged between 0.5 m and 5 m and averaged around 2 m, while the creek banks were approximately 0.5 high. The substratum in the pool was comprised of pebbles and gravel, but also consisted of cobbles and finer sand and silt, with some bedrock at the downstream end of the site. Images of TRIB 4 can be found in **Appendix F**.

Land upstream of the dirt road crossing had been cleared and was in agricultural use, while land downstream had moderate cover of riparian vegetation consisting of grasses, shrubs and trees. The water clarity was low, although there were no obvious signs of pollution. The site was classified as having moderate fish habitat value and received an RCE score of 38 (**Table 4-4**). Macrophytes were sparsely distributed, and included *Schoenoplectus validus*, *Paspalum* sp. and *Carex* sp. Weeds were densely abundant at ground level along the banks. *Eucalyptus* sp. and *Acacia* sp were the dominant shrubs and trees present.

#### 4.3.1.6 ***Tributary 5 (TRIB 5)***

TRIB 5 was located approximately 600 m upstream of TRIB 4, and consisted of swamplands containing several small pools, narrow creeks and channels. A minor tributary joined the Tributary after crossing the NEH. The surrounding vegetation consisted of woodlands, with the highway located approximately 100 m adjacent to the right bank. The average depth of the creek at TRIB 5 was approximately 0.2 m, but the depth reached greater than 2 m in the pools. The wetted-width of the creek ranged between 15 m and 20 m, with an average of approximately 10 m. The substratum consisted primarily of silt and sand, with some patches of uncovered bedrock present. Images of TRIB 5 can be found in **Appendix F**.

The water clarity at TRIB 5 was low, with some iron flocculent observed in some areas. The site was classified as unlikely fish habitat and received an RCE score of 38 (**Table 4-4**). It consisted mainly of swampland with dense emergent growth, comprising *Carex* sp. Some *Typha* sp. and *Paspalum* sp., along with other grasses, were also present. The riparian zone consisted of woodlands comprising mainly *Eucalyptus* sp., *Acacia* sp., and *Banksia* sp.

### 4.3.2 Water Quality

Summaries of the *in-situ* physicochemical water quality data collected during the survey are illustrated in **Figure 4-1**. All raw data are provided in **Appendix D**.

Water temperatures ranged from approximately 17 to 23 °C and were consistent with ambient temperatures and shading at the measurement points (**Figure 4-1a**). Values of pH were neutral to mildly acidic, with a higher value (mildly alkaline) recorded at Site TRIB 3 (**Figure 4-1b**). All sites were within pH ANZECC/ARMCANZ (2000) trigger values (6.5-7.5). Electrical conductivity (EC) was between 70 and 100 µS/cm at all sites, which is well below ANZECC/ARMCANZ (2000) high value (350 µS/cm) (**Figure 4-1c**). EC at Site BC CON was the highest recorded (100 µS/cm), while the lowest measurement was recorded at Site TRIB 5 (71.5 µS/cm).

With the exception of one replicate from Site TRIB 5, ORP measurements were all in the positive range, indicating an oxidative aquatic environment (**Figure 4-1d**). The ORP reading taken at TRIB 5 was -8.7 mV indicating a mildly reducing environment. This reading was taken in a deep stagnant pool with exposed bedrock and signs of iron flocculants on the surface. DO concentrations were highest at the two Brickyard Creek sites (means±SE between 80.7±2.55% and 86.3±1.28% saturation at BC US and BC CON, respectively) and steadily decreased TRIB3 to TRIB5 in the Tributary (**Figure 4-1e**). All DO readings were within the ANZEC/ARMCANZ (2000) trigger value range (90-110%). Turbidity was high, with NTU values above the ANZECC/ARMCANZ (2000) trigger values at all sites (25 NTU) (**Figure 4-1f**). These high NTU values could have resulted from heavy rainfall in the weeks prior to sampling (**Appendix C**).

The physicochemical water quality data collected during the field survey were indicative of waterways of the study region, these typically having a low to moderate level of catchment disturbance, mainly through agricultural land use. Elevation of turbidity and reduction of dissolved oxygen outside the ANZECC/ARMCANZ (2000) default trigger values are commonly associated with rainfall and runoff. These water quality effects and a reduction in salinity are normal physicochemical processes in flowing waterways following rainfall. Water quality data were therefore within the expected normal environmental range considering surface discharge preceding the measurement event and a low to moderate level of catchment disturbance.

ANZECC/ARMCANZ (2000) default trigger values were determined through laboratory ecotoxicology assessment and provide an indication of toxicity thresholds for selected organisms at specific environmental conditions only. Water quality in flowing streams is inherently variable and fluctuates diurnally, seasonally and in response to weather events. The ANZECC/ARMCANZ (2000) guidelines provide a benchmark for the interpretation of water quality, although cannot be used to provide a comprehensive assessment of water quality in the context of this project.

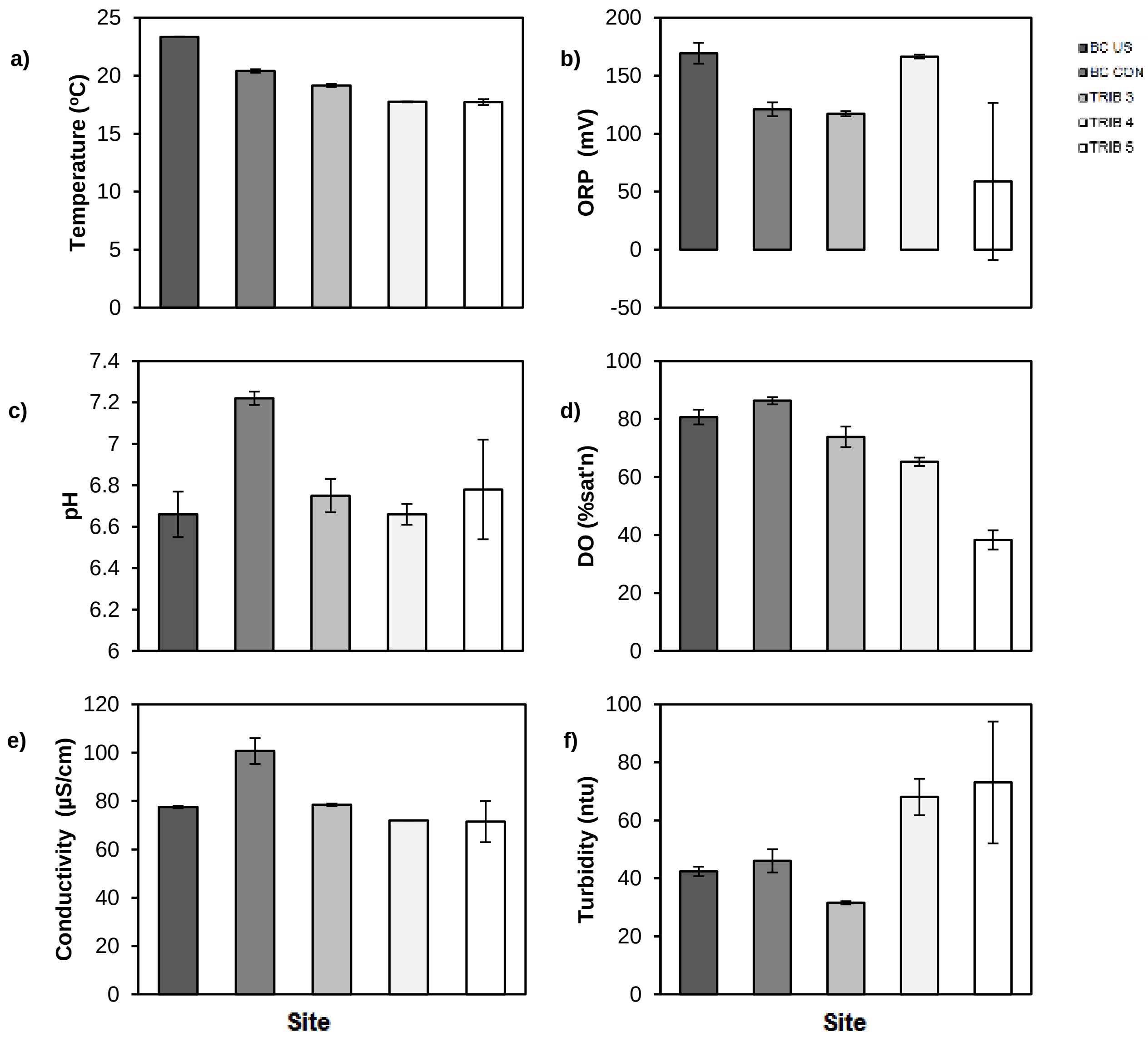



**Figure 4-1 Water quality data collected *in situ* during the February 2013 survey for (a) temperature, (b) pH, (c) electrical conductivity (d) ORP, (e) dissolved oxygen, and (f) turbidity.**

### 4.3.3 Aquatic Macroinvertebrates

#### 4.3.3.1 *Brickyard Creek and Tributary*

A total of 48 macroinvertebrate taxa were recorded from the 10 samples collected (**Appendix E**). The minimum number of taxa represented in an individual sample was 11 for sample TRIB 3a and the maximum was 25 for sample TRIB 4b. SIGNAL2 scores ranged from 3.3 for sample BC USa (12 SIGNAL2 taxa presented) to 4.1 for sample TRIB 4a (14 SIGNAL2 taxa represented) (**Figure 4-2**). Note that the number of SIGNAL2 taxa can be less than the total number of taxa, as some groups of organisms do not have SIGNAL2 values assigned.

Two families belonging to the generally more pollution-sensitive orders of Ephemeroptera (mayflies) and Trichoptera (caddis-flies) were observed across all sites. These were (SIGNAL2 values in brackets) the

Leptophlebiidae (8) and Leptoceridae (6). Other families with relatively high SIGNAL2 values observed in Brickyard Creek and the Tributary were the freshwater mites, Hydracarina spp. (6), and the beetle family, Scirtidae (6).

#### 4.3.3.2 *SIGNAL2 interpretation*

A graphical representation of the SIGNAL2 outputs is provided in **Figure 4-2**. Most samples had a SIGNAL2 score below 4, indicating potential pollution issues, while only one sample, from Site TRIB 4, had a score above 4 (4.1). SIGNAL2 outputs from most replicates taken from each site fell close to each other (**Figure 4-2**). Brickyard Creek had the highest difference among replicates with a variation in SIGNAL2 Score of 0.3. As can be seen in the plot, there was wide range in the number of SIGNAL2 taxa present in samples, however this had little influence on the scores.

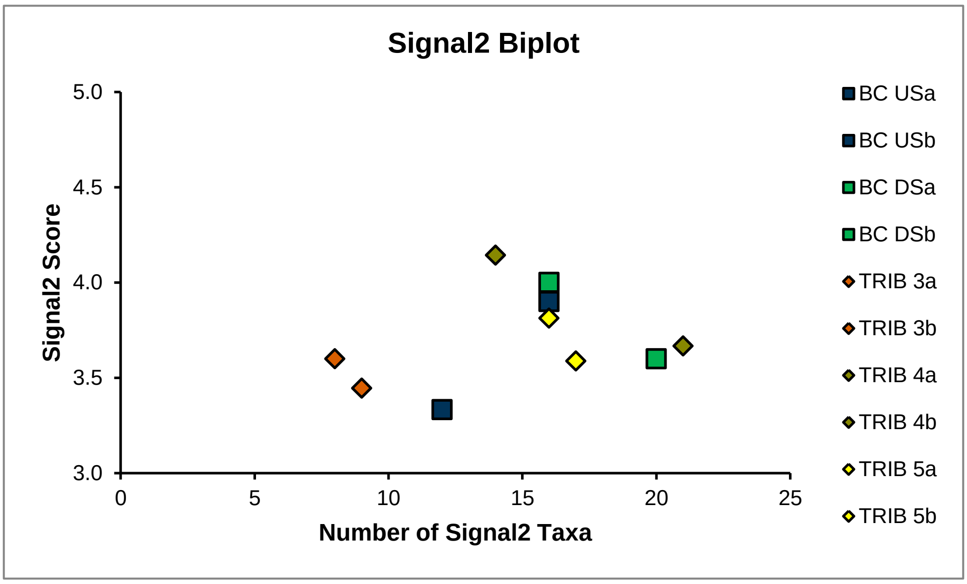



**Figure 4-2 SIGNAL2 bi-plot for samples collected from Brickyard Creek and the Tributary**

SIGNAL2 values for each taxa were derived from ecotoxicology investigations, and are therefore relevant to water quality sensitivity. The macroinvertebrates collected during this field survey are indicative of a degraded ecosystem, with many pollution-tolerant taxa present. Overall, the macroinvertebrate samples collected from Site TRIB 4 (the middle site on the Tributary) produced better results in terms of taxa diversity than those downstream, possibly due to the denser vegetation, more natural riparian area and lower pollution input from agricultural land use, compared with sites located downstream.

### 4.3.4 Fish

Three species of fish were found within the Study Area: Australian Smelt (*Retropinna semoni*), Mountain Galaxids (*Galaxia olidus*) and Eastern Mosquito Fish (*Gambusia holbrooki*) (**Table 4-5**). Mosquito Fish (invasive) were found at both Brickyard Creek sites but not at Tributary sites. Australian Smelt was found only at Site BC CON, while Galaxids were found only at Sites TRIB 3 and TRIB 4. At least one species of Yabby was also present at all sites apart from Site TRIB 5, while a Longneck Turtle was recorded at Site BC CON. No protected, endangered or vulnerable fish species were recorded.

Fish were found at all sites except for Site TRIB 5, indicating that any obstructions currently present downstream of Sites BC US and TRIB 4 are not barriers to fish movements. It is therefore possible that any creek crossings included in the proposed re-alignment options could hinder fish movement if barriers are created. Mountain Galaxids are a common native species of highland creeks, whereas eastern Mosquito Fish are an exotic species listed under the FM Act as a noxious pest.

**Table 4-5 Fish and mobile invertebrate species found at each survey site**

| Common Name | Scientific Name | BC US | BC CON | TRIB 3 | TRIB 4 | TRIB 5 |
|---|---|---|---|---|---|---|
| Australian Smelt | *Retropinna sermoni* | | 3 | | | |
| Mountain Galaxid | *Galaxia olidus* | | | 4 | 7 | |
| Mosquito Fish* | *Gambusia holbrooki* | ~500 | ~1,000 | | | |
| Yabby | *Cherax sp.* | 11 | 1-10 | 2-5 | 50-100 | |
| Longneck Turtle | *Chelodina longicollis* | | 1 | | | |

*Denotes a noxious species under the NSW Fisheries Management Act 1994

# 5 Overview of Potential Biodiversity Impacts

## 5.1 Potential Impacts

Potential impacts to aquatic biodiversity may occur at all phases of road infrastructure development. Consequently, there are management and mitigation measure which should be considered and, if necessary, implemented at each stage to minimise the chance of impacts occurring.

Broadly, the impacts on native aquatic flora and fauna associated with road infrastructure installation can be broken down into the two groups listed below:

> Construction impacts, including:
  - Mortality and habitat loss during clearing or construction;
  - Mortality and habitat loss due to sedimentation; and
  - Mortality and habitat loss due to changes to water quality.

> Operational impacts, including:
  - Barrier effects (eg bridges); and
  - Flow effects (eg from sedimentation).

Specific potential impacts on aquatic biodiversity of relevance to the Study Area and the proposed re-alignment works are discussed below. It should be noted that the impacts discussed are not exhaustive and further work during detailed design should take place to identify all relevant impacts.

### 5.1.1 Construction Impacts

All four re-alignment Route Options would involve works that have potential to lead to aquatic habitat loss. Compaction in work areas may reduce infiltration of surface waters and also contribute to sediment load in runoff. Runoff following rain may result in erosion in areas of earthworks or unprotected cleared land during construction, increasing sediment transported into the Tributary and Brickyard Creek. This could result in loss of habitat through a reduction in depth of available pools, which serve as refuge areas for aquatic biota, and the smothering of habitat features such as aquatic macrophyte beds, woody debris, riffles and spawning grounds. 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.

If sediments are released into the water column during construction, nutrient enrichment could occur, increasing the risk of algal blooms. Contaminants related to construction activities (oil or chemicals spillage for machinery or construction processes) may induce toxic effects on aquatic fauna. Depending on the type and quantity of contaminant involved, the level of toxicity to aquatic fauna could be high if the contaminant is allowed to enter the waterway.

Impacts to water quality would also be observed in the form of increased suspended solids and elevated turbidity. This would result in a decline in light penetration and a subsequent reduction in primary productivity, thus affecting submerged macrophytes, photosynthetic algae and other organisms for which these plant and algae groups provide food or habitat. Reduced primary productivity may also reduce the oxygenation of water resulting from photosynthesis by submerged macrophytes and algae. This could also have flow-on effects concerning biogeochemically mediated processes, such as sediment redox reactions and microbial metabolic processes.

Any construction works in the riparian zone and the construction of bridges would lead to riparian macrophyte loss. Riparian macrophytes provide important habitat for terrestrial and littoral organisms as well as being an integral part of the in-stream habitat by providing habitat structure in the form of woody debris. Downstream aquatic habitats may be at risk, as increases in suspended sediments have been detected for long distances (kilometres) downstream of construction sites (Wheeler *et al.*, 2005).

### 5.1.2 Operational Impacts

Waterway crossings such as bridges have impacts on fish and aquatic habitats. They can create long-term barriers to fish movement, bed and bank erosion, and intermittent pollution from erosion and sedimentation. Fish passage barriers can effectively stop many fish species from breeding and populating waterways by removing their ability to migrate around, thereby restricting access to breeding partners and spawning grounds. Fish attempting to negotiate barriers are forced to use up precious energy reserves. Local extinction is likely to occur where barriers prevent fish from undertaking migrations. Some barriers can also create excellent habitat for pest species such as Mosquito Fish (a species observed during this study) to proliferate.

Elevated bridges that avoid the use of in-stream structures such as piers generally have the least impact on fish passage as they normally involve limited disturbance to the natural flow of a waterway. Possible impacts may nevertheless include:

- Large scale turbulence resulting from bridge piers;
- Increased flood flow velocities through and downstream of archers or piers;
- Changes to in-stream and bank vegetation that may affect water shading, habitat values and water velocities;
- Blockage of fish passage along floodplains caused by elevated and in-filled approach roads; and
- Limited light penetration under the bridge deck creating a non-physical barrier for some fish species that may avoid dark areas during daylight hours.

Effective hydrological and water quality management will be required to reduce impacts on the local aquatic ecosystem that may occur as a result of the construction of the re-alignment.

### 5.1.3 Protected, Threatened and Endangered Species, Populations and Communities

No threatened or endangered species of aquatic flora or fauna were identified within the Study Area during the survey. Loss of aquatic flora and fauna from the construction work is therefore not anticipated to directly impact on species with legislative protection. Any losses of individuals would be expected to be common species along with possible reductions in available creek habitat. However, due to the presence of habitats suitable for several threatened/endangered species, they should be considered for further assessment.

Although no Purple Spotted Gudgeons were observed during this survey, they are known to exist in the area, and have been previously recorded downstream of the proposed works. There can be significant penalties for causing damage to the habitat of threatened species without approval, such as, for example, removing large woody debris from waterways or constructing barriers that block the free passage of fish. Increased sediment loads in the creeks may cause adverse impacts on the Purple Spotted Gudgeon, and therefore should be avoided, or reduced as much as possible. The impact of developments or activities that require consent or approval (in accordance with the EP&A Act) must be assessed and considered by consent by determining authorities.

Although no Giant Dragonflies were observed during this survey, the marshland around Site TRIB 5 is potential habitat for this species and therefore should not be cleared, with any possible sources of damage avoided. Water flows to this habitat should be preserved, and it should be protected from pollution.

All proposed Route Options would potentially have an adverse impact on Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions. The habitat described at Site TRIB 5 is suitable for this EEC to be found, and Carex was noted as the dominant species at that site. Clearing of Carex Sedgeland is the most obvious of threats, and should be avoided. This community is also sensitive to small changes in groundwater flow – a factor that should be considered when selecting a Route Option.

The wetland described at Site TRIB 5 is potentially an endangered community of Upland Wetland of the Drainage Divide of the New England Tableland Bioregion – an ECC known to exist around Tenterfield. Clearing, soil erosion, sedimentation and altered drainage patterns are the biggest threats to this community type, and therefore such consequences from construction activities should be avoided at the eastern end of the proposed works.

### 5.1.4 Mitigation

#### 5.1.4.1 *Sedimentation*

Risk management and adequate control measures would be required to mitigate potential harm of accidental spills or losses of oils and other chemicals to watercourses.

The likelihood and scale of impacts associated with an increased sediment load in the creeks would depend on the quantity and duration of sediment mobilisation. Given the geography at the worksite (ie steeply sloping banks, proximity of earthworks to the waterway, potential for high rainfall), a detailed sediment and erosion control plan should be considered to ensure that risks are adequately addressed.

#### 5.1.4.2 *Water Quality*

A construction environmental management plan for the development site should be considered to assist in mitigating the risk of negative consequences to nearby aquatic biodiversity caused by compromised water quality. Appropriate erosion control and water management practices during construction should be considered through this plan. Erosion control measures should include the construction of sediment control fences and work being undertaken only during appropriate weather conditions.

### 5.1.5 Fauna Passage Provisions

All waterway crossings, including 'fish-friendly' crossings, have the potential to impact upon the natural passage of aquatic and terrestrial wildlife. Therefore, a primary objective when developing the detailed concept option should be to minimise the total number of crossings.

#### 5.1.5.1 *Location of Creek Crossings*

> Avoid crossing waterways at or near sharp bends, sections of unstable channel, or major 'riffle' systems. Riffles are shallow areas where water flows swiftly over rocks, gravel or timber. They act as channel stabilisers, so by altering their stability essential habitat pools may be lost or severe bed erosion can occur;

> Avoid locating crossings over 'meandering' waterways where such meandering is likely to continue in the future and cause damage to the structure, erosion of the waterway channel, or future misalignment of the channel with the crossing;

> Avoid works that may change the frequency or spacing of an existing pool / riffle system;

> Avoid disturbances to sections of a waterway channel or its associated bank vegetation, particularly where such areas represent either a unique, endangered or highly valued section of the waterway; and

> Avoid the removal of essential shade trees especially on waterways that have already experienced a significant loss of natural vegetation cover.

#### 5.1.5.2 *Bridge Design Considerations*

The area of the Tributary that will be impacted directly by construction works (ie between Sites TRIB 3 and 4) was classified as 3–4 under Fairfull and Witheridge (2003) characteristics of waterway type classifications (**Appendix B**). Under these guidelines and recommendations, the minimum culvert design using the 'Low Flow Design' procedures are required for any bridge construction. However the outlines for the proposed Route Options all contain major bridges – designs well above the recommendations for watercourses of this quality. This being said, the following should be considered with respect to bridge design:

> Avoid locating bridge piers or foundations within the main waterway channel;

> Design and orientate bridge piers, including those located within overbank areas, such that they won't cause the formation of large-scale turbulence or erosion of the bed and banks of the waterway;

> Maximise light penetration under the bridge or arch to encourage fish passage, possibly by increasing the spacing between divided bridge decks or via the use of skylights or grates in the median strip; and

> Minimise the use and extent of those bed and bank erosion control measures that may reduce aquatic habitat values or inhibit the regrowth of natural in-stream and bank vegetation.

### 5.1.6 Protected, Threatened and Endangered Species, Populations and Communities

> It is recommended that a detailed 7-part tests be prepared in accordance with the *Environmental Planning and Assessment Act 1979* (EP&A Act) Part 1, Section 5A(2) in order to ascertain the potential of significant impact on Purple Spotted Gudgeon .

> A vegetation management plan should be considered for Carex Sedgeland, and that groundwater flows are disturbed as little as possible to avoid disturbance to this potential EEC.

# 6 Overview of Route Options

A total of ten Route Options for the re-alignment of the Bolivia Hill section of the NEH were subjected to initial assessment and a short-list of four Route Options was derived for further detailed assessment. The four shortlisted Route Options are briefly described below.

## 6.1 Route Option 6

The re-alignment associated with Option 6 would be 2610 m long with a maximum conforming vertical angle of 8 per cent. The first 300 m east to west would consist of minor cut and fill, with the next 600 m going into a cut of up to 23 m deep. The re-alignment would then follow the eastern side of the gully to the west of the highway in-fill for 300 m, and includes construction of a retaining wall up to 12 m high. A major bridge up to 350 m long would then keep the roadway above the Tributary. From the west end of the bridge, in-fill and a retaining wall up to 15 m high would tapering back to the existing highway for approximately 550 m. The final 510 m (to just past Pyes Creek Road intersection) would involve an upgrade to the existing highway (**Figure 6-1**).

Route Option 6 will include the construction of a 350 m long bridge downstream of Site TRIB 4. This site was allocated class 3-4 (ie unlikely to minimal fish habitat value) under Fairfull and Witheridge (2003) characteristics of waterway type classifications (**Appendix B**). Waterway classifications are used by DPI to recommend types of bridge structures.

## 6.2 Route Option 10

The re-alignment route associated with Option 10 will follow the ridgeline to the west of the existing highway but just east of the Tributary. It is 3015 m long, with a maximum conforming vertical grade of 8 per cent. The first 350 m from east to west will involve minor cut and fill. It will then move into extensive cut up to 32 m deep for 800 m. The alignment will then progress into 150 m of in-fill supported by a retaining wall up to 18 m high to keep the fill out of the creek line. A major bridge up to 190 m long is then required to keep the road out of the creek line. The alignment will then move into fill for 600 m with a retaining wall up to 15 m high for 200 m of that length to avoid the creek line. Another bridge up to 90 m long would be constructed over the watercourse to the west of the existing highway, with fill for 720 m up to the west end of the bridge. The last 160 m will involve an upgrade of the existing highway (**Figure 6-2**).

The two bridges associated with Option 10 would be located near survey sites – a 190 m long bridge near Site TRIB 4 and a 90 m long crossing downstream of Site TRIB 3. Site TRIB 4 was allocated class 3–4 under Fairfull and Witheridge (2003) characteristics of waterway type classifications while Site TRIB 3 was allocated class 3 (ie minimal fish habitat value). Waterway classifications are used by DPI to recommend types of bridge structures.

## 6.3 Route Option 7

Route Option 7 would involve an upgrade to the existing highway, utilising as much of the existing pavement as possible. While it would achieve a conforming horizontal alignment, it will have a non-conforming vertical alignment. It would be 2375 m long, with the first 650 metres from east to west involving an upgrade of the existing highway in minor cut and fill, followed by a further 390 m of upgrade to the existing highway requiring an up to 10 m retaining wall on the western side to keep fill out of the creek line. A major bridge up to 330 m long will then be constructed to keep the road out of the Tributary. The alignment will then move into fill which would taper back 550 m to the existing highway, with the final 255 m to the Pyes Creek Road intersection an upgrade to the existing highway (**Figure 6-3**).

The major bridge associated with Option 7 is located near Site TRIB 4, which was allocated class 3–4 under Fairfull and Witheridge (2003) characteristics of waterway type classifications (ie unlikely to minimal fish habitat). Waterway classifications are used DPI to recommend types of bridge structures.

## 6.4 Route Option 7b

Route Option 7b is a ‘road safety Option’ and a sub-Option of Option 7. It would be characterised by a cross section consisting of one northbound lane and one southbound lane, with 2 m wide shoulders on either side. It would be 1635 m long, starting approximately 500 m further north and finishing approximately 685 m further south than Option 7, and with a non-conforming vertical grade of up to 8.1 per cent. The first 210 m east to west will consist of simple widening of the existing carriageway, with in-fill to the west to provide the required shoulder widths. The next 265 m would include a retaining wall of up to 3 m high to keep the fill out the creek line. As the alignment plan diverges from the existing carriageway over the following 75 m, the road would be widened by a cantilevered concrete structure on concrete piles. The cantilevered concrete structure would lead into a major bridge up to 360 m long, required to keep the road out of the Tributary. At the southern abutment of the bridge, a 60m long cantilevered concrete structure on concrete piles would ease the alignment back towards the existing carriageway. The next 110 m would widen out the existing carriageway, with a retaining wall of up to 2m high on the western side. The next substandard bend would be straightened out by gently diverging from the existing alignment to the west and then re-joining the existing carriageway 145 m further along. To straighten out the bend, the alignment would divert to the east of the existing carriageway over the next 150 m by cutting into the rock face. At this location, the angled rock face beside the road would be flattened out, requiring only minor cut. Fill would then taper back 255 m to the existing highway (**Figure 6-4**).

As with Option 7, the bridge planned as part of Option 7b would be located near Site TRIB 4, which was allocated class 3–4 under Fairfull and Witheridge (2003) characteristics of waterway type classifications (ie unlikely to minimal fish habitat). Waterway classifications are used by DPI to recommend types of bridge structures.

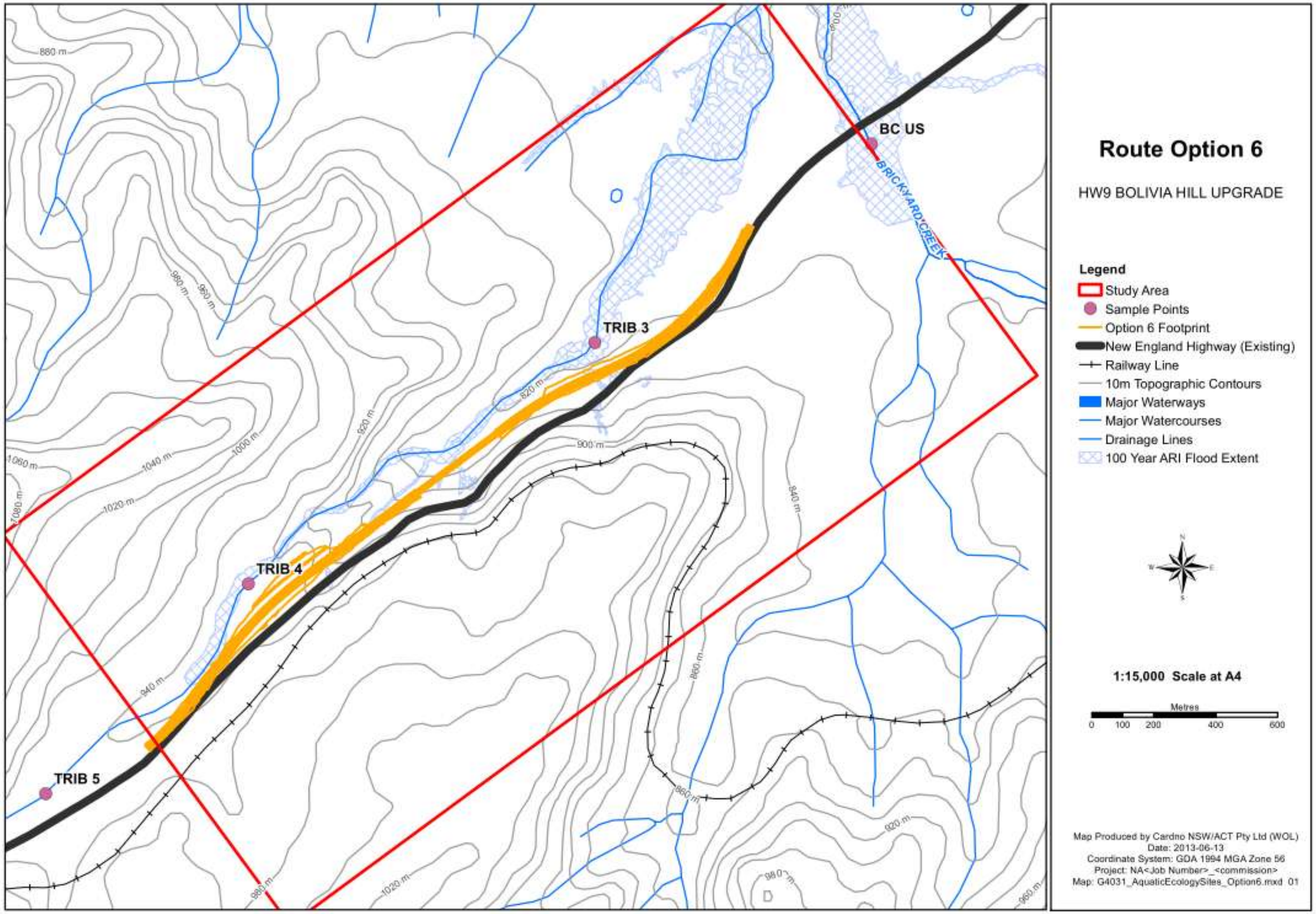



**Figure 6-1 NEH Re-Alignment Route Option 6**

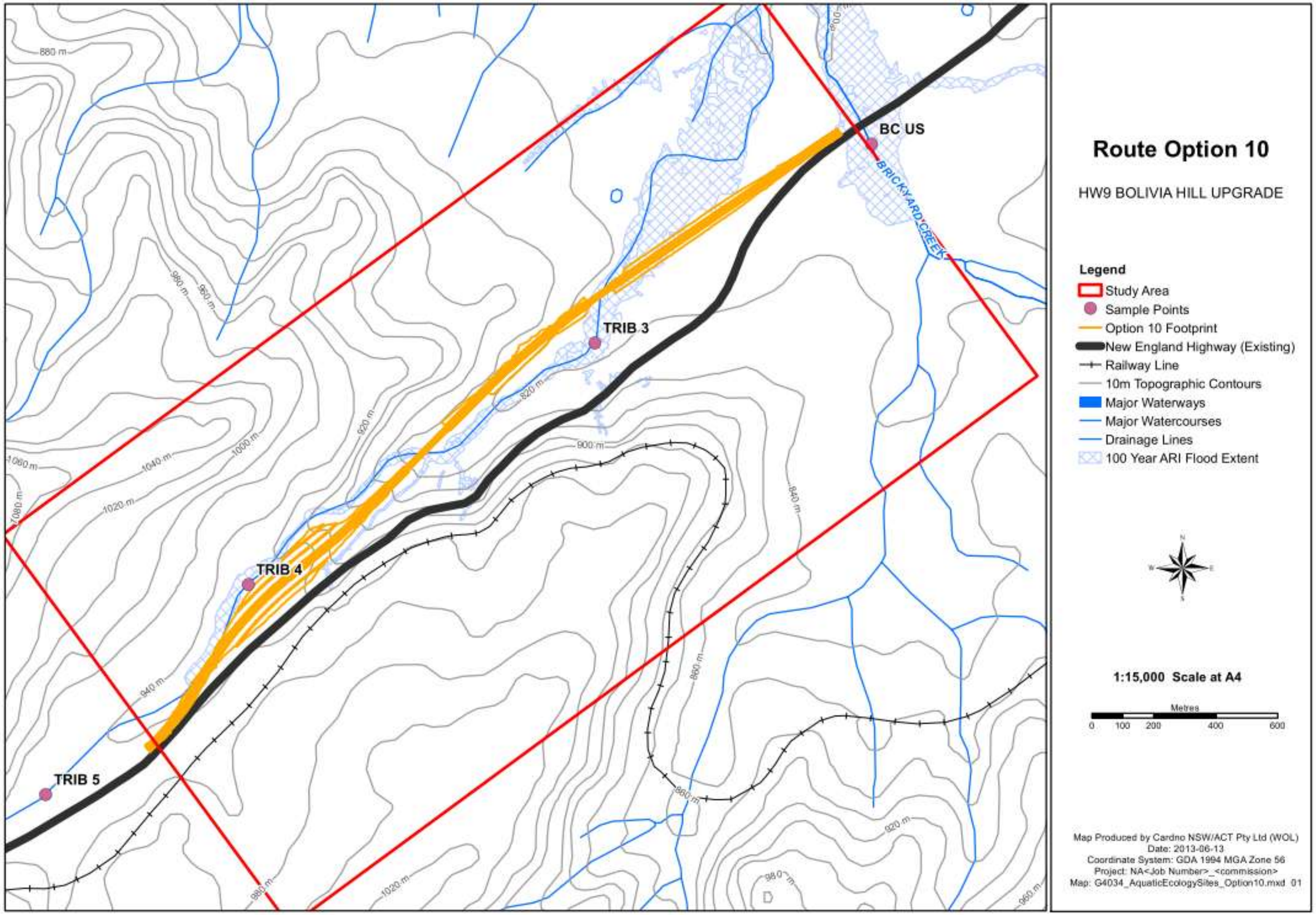



**Figure 6-2 NEH Re-Alignment Route Option 10**

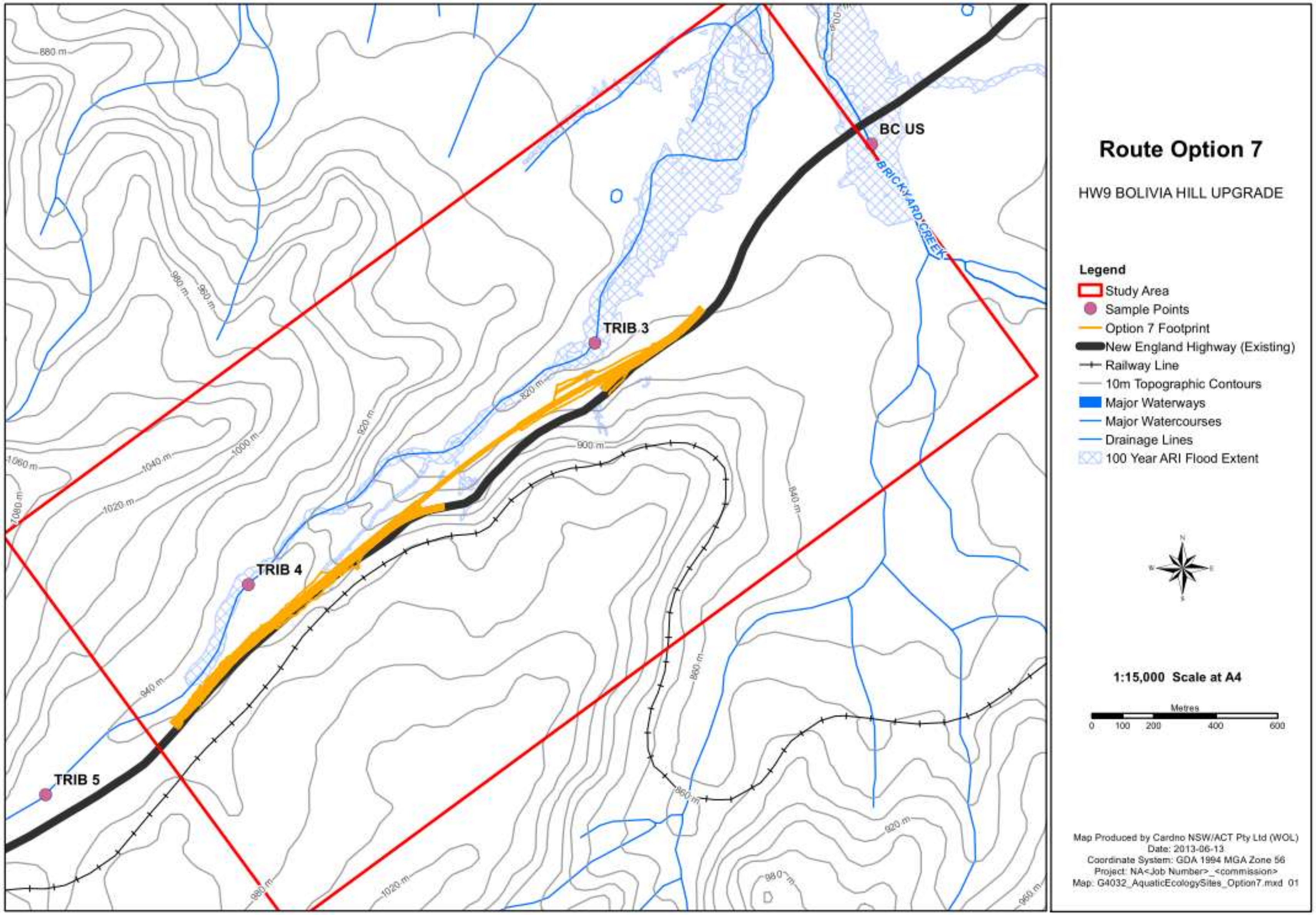



**Figure 6-3 NEH Re-Alignment Route Option 7**

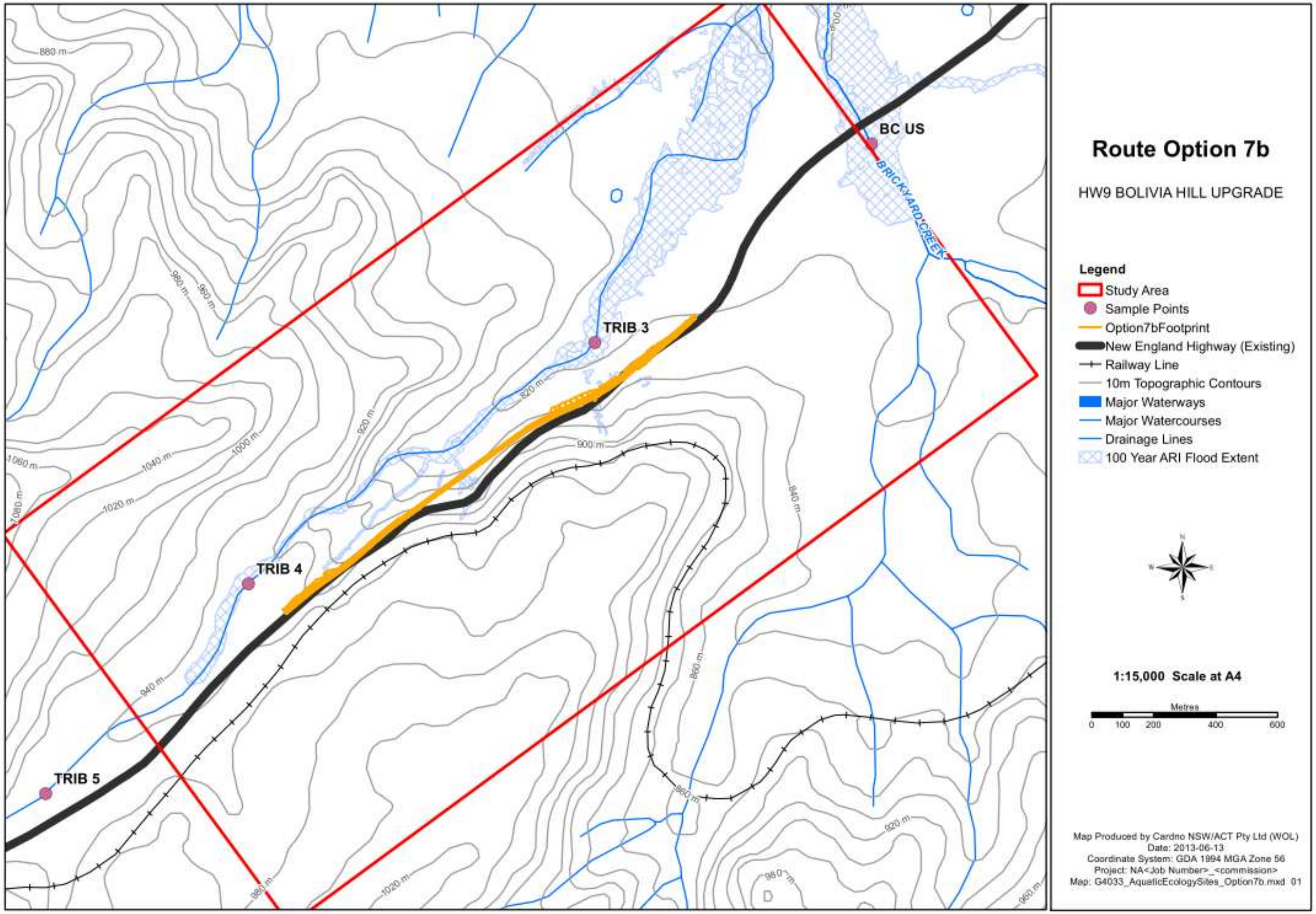



**Figure 6-4 NEH Re-Alignment Route Option 7b**

Potential impacts from the NEH re-alignment works outlined in **Section 5** apply to all four of the shortlisted route options. It is possible to rank the shortlisted route options based on the relative magnitude of aquatic biodiversity impacts that would be associated with each option, based primarily on the potential extent of impacts outlined in **Section 6**. Based on such considerations, the aquatic biodiversity impact rankings of the shortlisted options, in order of increasing impact, are provided with rationale in **Table 6-1**.

**Table 6-1 Aquatic Biodiversity Impact Ranking of Shot-Listed Options.**

| Ranking | Route Option | Rationale for Ranking |
|---|---|---|
| 1 | 7b | Route Option 7b is the shortest of all the shortlisted options and is most closely aligned to the existing alignment of the NEH. As such the extent of potential impacts to aquatic habitat associated with this option is likely to be substantially less than that associated with any of the alternative Route Options.<br>In addition, Option 7b starts 500 m further north than Route Option 7, taking it further away from possible Carex Sedgeland habitat. |
| 2 | 7 | Route Option 7 is very similar to option 7b in respect of its alignment, however it is approximately 40% longer that option 7b |
| 3 | 6 | Route Option 6 would likely involve additional impacts to aquatic habitat and water quality to those involved with options 7 or 7b, but possibly fewer than those likely to be associated with option 10.<br>This option involves 600 m of excavation up to 23 m deep and 850 m of retaining wall up to 15 m high. Therefore, considerable earthworks would be involved such that sediments may be mobilised into aquatic habitats during construction and via ongoing erosion. |
| 4 | 10 | Route Option 10 would involve consideration vegetation loss leading to sedimentation and reductions in water quality. The potential for impacts from this option is greater than that from options 6, 7 and 7b.<br>This option deviates significantly from the current NEH, and would involve the clearing of a large amount of vegetation – almost the entirety of the route plan (3015 m). Loss of vegetation would lead to increased erosion and sediment mobilisation, possibly causing reductions in water quality and loss of habitat.<br>The two major bridges associated with this option may also create barriers to fish movements and have impacts on water flow. |

# 7 Summary

The aquatic habitat survey undertaken within the Study Area found one flora species of biodiversity significance listed under the TSC and EPBC Act, Callistemon pungens, which has been assessed in the Biodiversity Impact Assessment (Cardno 2013). Several other matters of biodiversity significance are also considered likely based on the presence of key habitat resources within the Study Area and previous records of the species occurring within the general locality of the Study Area. These were:

> Two Endangered Ecological Communities:
  - Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions; and
  - Upland wetlands of the Drainage Divide of the New England Tableland Bioregion.

> One Endangered Population:
  - Tusked Frog (*Adelotus brevis*) population in the Nandewar and New England Tableland Bioregions.

> Three fauna species of conservation significance:
  - Sphagnum Frog;
  - Giant Dragonfly; and
  - Purple Spotted Gudgeon.

Based on the findings of the aquatic habitat surveys and in considering potential impacts associated with the re-alignment of the Bolivia Hill section of the NEH, it is recognised that adverse impact on biodiversity would occur in the cases of the four Route Options being considered. Consequently, mitigation and offsetting of the potential impacts associated with the Route Option ultimately selected will be important considerations for the proposed works in order to minimise the degree of impact to the native aquatic biodiversity.

It is noted that there is not a re-alignment option through the Study Area that would result in no or negligible impacts to aquatic biodiversity. However, in order to maintain existing levels of aquatic biodiversity and connectivity while minimising impacts to valuable aquatic habitat, any re-alignment which follows as closely as possible the current alignment of the NEH is preferable to options that will result in much clearing and relatively extensive construction.

Based on these considerations, the final four shortlisted Route Options for the re-alignment of the Bolivia Hill section of the NEH may be ranked based on the relative magnitude of likelihood of potential impacts to aquatic biodiversity, from least impact to most impact, as:

> Route Option 7b;

> Route Option 7;

> Route Option 6; and

> Route Option 10.

It is also recognised that the selected route will require further consideration, assessment and approval under applicable State regulatory instruments. It is further noted that the selected Route Option may have a significant impact upon species listed under the FM Act, particularly Purple Spotted Gudgeon, due to the presence of key habitat resources for this species within the Study Area and previous records of the species occurring within the general locality of the Study Area. In this regard, it is recommended that a thorough Species Impact Statement be produced to assess potential impacts on Purple Spotted Gudgeon populations from the re-alignment works. If the impacts are determined likely to be significant, or if critical habitat is likely to be affected, the Director-General of DPI must agree to the development approval and the Minister for Primary Industries may also need to be consulted.

# 8 Acknowledgements

This report was written by Blaise Bratter with much assistance from Max Best, and reviewed by Will Macbeth and Tanja Mackenzie. Field work was conducted by Max Best and Blaise Bratter. Figures were produced by Shani Archer and Oliver Silver.

# 9 References

*ANZECC and ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4. Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand, October 2000.*

*Bell D.M., Hunter J.T. and Haworth R.J. (2008). Montane lakes (Lagoons) of the New England Tablelands Bioregion. Cunninghamia 10, pp. 475-492.*

*Benson J.B. and Ashby E.M. (2000). Vegetation of the Guyra 1: 100 000 map sheet New England Bioregion, New South Wales. Cunninghamia 6, pp. 747-872.*

*Berger L., Speare R. and Hyatt A.D. (1999). Chytrid fungi and amphibian declines: overview, implications and future directions. (In) A. Campbell (ed.). Declines and Disappearances of Australian Frogs. (Environment Australian, Canberra).*

*Brock M.A. (1998). Are temporary wetlands resilient? Evidence from seed banks of Australian and South African wetlands In A.J. McComb and J.A. Davis (Eds.) Wetlands for the Future. pp. 193-206, (Gleneagles Publishing, Adelaide).*

*Cardno (2013). Bolivia Hill Upgrade: Biodiversity Impact Statement. 14 June 2013*

*Chessman (2003). SIGNAL 2.iv A Scoring System of Macroinvertebrates (Water Bugs) in Australian Rivers – User Manual, Monitoring River Health Initiative Technical Report No. 31. Department of the Environment Heritage*

*Chessman, B.C Growns, J.E and Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales in Marine and Freshwater Research, 48, pp. 159-172.*

*Cogger H.G. (1994). Reptiles and Amphibians of Australia. (Reed Books, Chatswood).*

*DEWHA (2009). Matters of Nationally Environmental Significance, Significant Impact Guidelines 1.1. Environmental Protection and Biodiversity Conservation Act 1999. Commonwealth of Australia, October 2009*

*DPI (2013). Policy Guidelines for Fish Habitat Conservation and Management. NSW DPI*

*Gale S.J., Haworth R.J. and Pisanu P.C. (1995). The Lead-210 chronology of late Holocene deposition in an east Australian lake basin. Quaternary Science Reviews*

*Haworth R.J. (1994). Lake sedimentation in upland eastern Australia: case studies from the New England tablelands of New South Wales. PhD thesis, University of New England, Armidale.*

*Haworth R.J., Gale S.J., Short S. and Heinjes, H. (1999). Land use and lake sedimentation on the New England Tablelands of NSW, Australia. Australian Geographer 30, pp. 51-73*

*Hunter J.T. and Bell D.M. (2009). The Carex Fen vegetation of northern New South Wales. Cunninghamia 11, pp. 49-64.*

*Turak, E., Waddell, N. and Johnstone, G. (2004). New South Wales (NSW) Australian River Assessment System (AUSRIVAS). Sampling and Processing Manual. Environmental Protection Authority. pp. 45.*

*NSW DPI, 2012. Letter regarding Environmental Study Requirements for New England HWY Upgrade At Bolivia Hill. TRIMV12/874, OUT12/30997*

*Peterson, R. C. Jr. (1992) The RCE: A riparian, channel and environmental inventory for small streams in the agricultural landscape. Freshwater Biology 27, pp. 295-306.*

*LMCC (2010) LT Creek Sustainable Neighbourhood Community Attitudes Survey. Available at: http://www.sustainableneighbourhoods.org.au/uploads/6/7/0/6/6706950/lt_creek_survey_report_august_2010.pdf*

# APPENDIX A

## RIPARIAN, CHANNEL AND ENVIRONMENT (RCE) SCORED MODIFIED FROM CHESSMAN (1997)

| | Description and Category | Value | | Description and Category | Value |
|---|---|---|---|---|---|
| **1** | **Land us pattern beyond the immedate riparian zone** | | **8** | **Riffle / pool sequence** | |
| | Undisturbed native vegetation | 4 | | Frequent alternation of riffle and pools | 4 |
| | Mixed native vegetation and pasture/exotics | 3 | | Longpools 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 damning 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 onvious 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, leave 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 |
| **6** | **Bank undercutting** | | **13** | **Aquatic vegetation** | |
| | None, or restricted by tree roots | 4 | | Little or no macrophyte or algal growth | 4 |
| | Only on curves and constrictions | 3 | | Substantial algal growth; few macrophytes | 3 |
| | Frequent along all parts of stream | 2 | | Substantial macrophyte growth; little algae | 2 |
| | Severe, bank collapses common | 1 | | Substantial macrophyte and algal growth | 1 |
| **7** | **Channel form** | | | | |
| | Deep: width / depth ratio less than 7:1 | 4 | | | |
| | Medium: width / depth ratio 8:1 to 15:1 | 3 | | | |
| | Shallow: width / depth ratio greater than 15:1 | 2 | | | |
| | Artificial: concrete or excavated channel | 1 | | | |

# APPENDIX B

FAIRFULL AND WITHERIDGE (2003) HABITAT CLASSIFICATION AND RECOMMENDED CROSSING TYPE

| Classification | Characteristics of Waterway Type | Minimum Recommended Crossing Type |
|---|---|---|
| Class 1 Major fish habitat | Major permanently or intermittently flowing waterway (eg river or major creek), habitat of a threatened fish species. | Bridge, arch structure or tunnel. |
| Class 2 Moderate fish habitat | Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks 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 [2] 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 (eg 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 [3] or ford. |
| Class 4 Unlikely fish habitat | Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (eg dry gullies or shallow floodplain depressions with no permanent aquatic flora present). | Culvert [4], causeway or ford. |

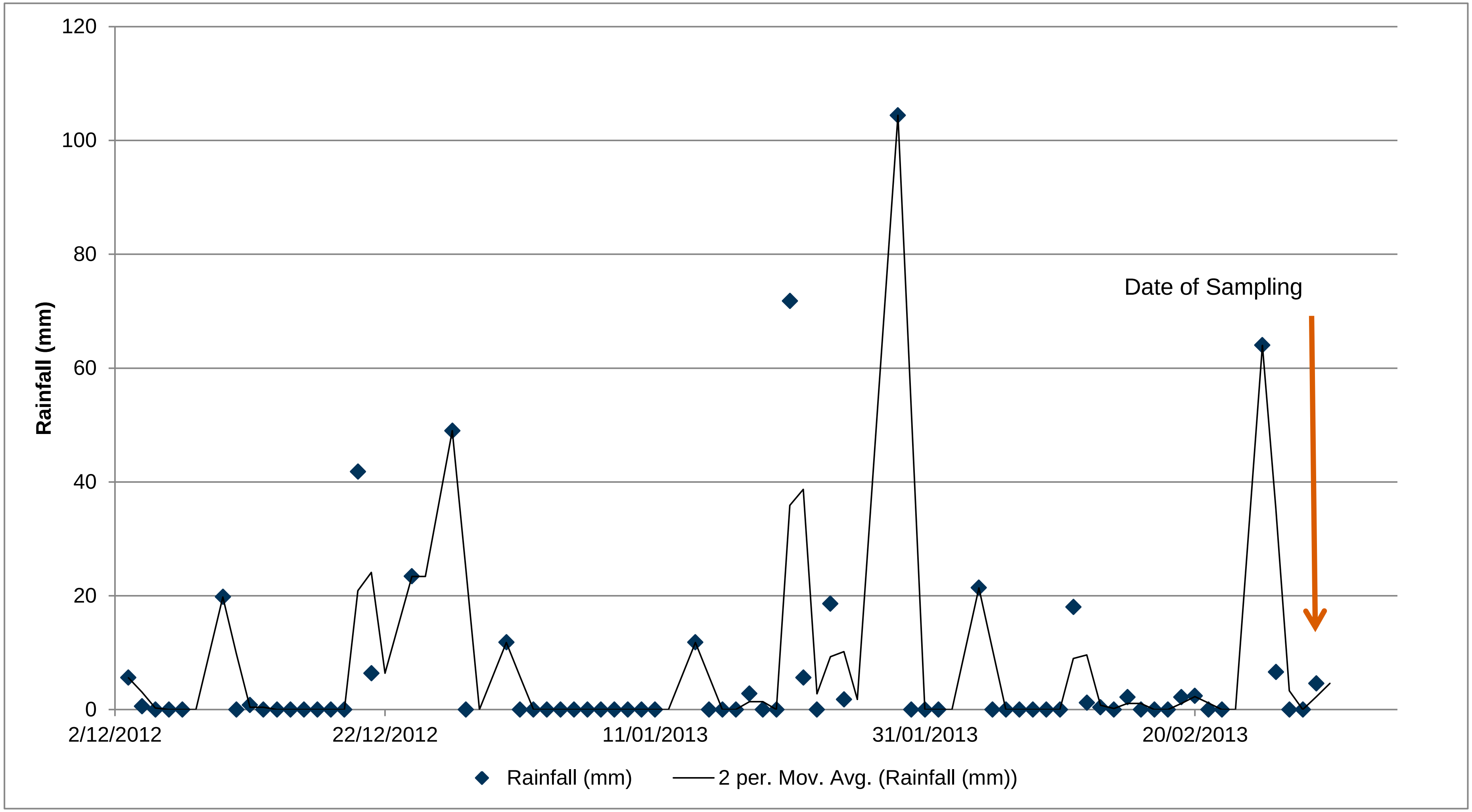
[1] In all cases bridges are preferred to arch structures, culverts fords and causeways (in that order)

[2] High priority given to the "High Flow Design" procedures presented for the design of these culverts - refer to Design Considerations section of this document, or engineering guidelines (Witheridge, 2002).

[3] Minimum culvert design using the "Low Flow Design" procedures; however, "High Flow Design" and "Medium Flow Design" should be given priority where affordable (refer to Witheridge (2002)).

[4] Fish friendly waterway crossing designs possibly unwarranted. Fish passage requirements should be confirmed with the local fisheries department/authority

# APPENDIX C
## RAINFALL DATA




**Rainfall data for the three months prior to sampling taken from the Deepwater AWS (BOM, 2013)**

# APPENDIX D
## WATER QUALITY DATA

| Variable | Units | DTV | BC US | | BC CON | | TRIB 3 | | TRIB 4 | | TRIB 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| Temperature | ˚C | | 23.35 | 0.01 | 20.41 | 0.16 | 19.16 | 0.12 | 17.74 | 0.04 | 17.73 | 0.26 |
| Conductivity | µS/cm | 350 | 78.00 | 0.50 | 101.00 | 5.36 | 79.00 | 0.50 | 72.00 | 0.00 | 72.00 | 8.50 |
| Salinity | ppt | | 0.04 | 0.00 | 0.05 | 0.00 | 0.04 | 0.00 | 0.03 | 0.00 | 0.04 | 0.00 |
| pH | units | 6.5-8 | 6.66 | 0.11 | 7.22 | 0.03 | 6.75 | 0.08 | 6.66 | 0.05 | 6.78 | 0.24 |
| ORP | mV | | 169.40 | 9.05 | 121.00 | 6.06 | 117.20 | 2.30 | 166.50 | 1.65 | 58.90 | 67.60 |
| DO | % Sat | | 80.70 | 2.55 | 86.30 | 1.28 | 73.90 | 3.55 | 65.30 | 1.45 | 38.30 | 3.30 |
| DO | mg/L | - | 6.87 | 0.22 | 7.78 | 0.14 | 6.81 | 0.31 | 6.20 | 0.15 | 3.54 | 0.32 |
| Turbidity | NTU | 25 | 42.40 | 1.63 | 46.00 | 4.02 | 31.60 | 0.58 | 68.10 | 6.25 | 73.10 | 21.01 |

(SE = Standard Error, n = 2, except for turbidity where n = 6). Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers of South East Australia. Grey shading indicates values outside of DTV.

# APPENDIX E
## AQUATIC MACROINVERTEBRATES

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Aquatic macroinvertebrates collected at each of the two replicate samples at all sites.

| Order or Family | BC US | | BC CON | | TRIB 3 | | TRUB 4 | | TRIB 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **a** | **b** | **a** | **b** | **a** | **b** | **a** | **b** | **a** | **b** |
| Dugesiidae | | | | | | | | | 1 | |
| Temnocephalidae | | 1 | | | | | | 1 | | |
| Nematoda | | | | | | | | 1 | | |
| Lymnaeidae | | | | | | | | 1 | | |
| Planorbidae/Physidae | 2 | 2 | 3 | 4 | 2 | | | | 3 | 2 |
| Oligochaeta | | | | | 1 | | 1 | 2 | | |
| Cladocera | | | | | | | 10 | 10 | | |
| Copepoda | | | | | | | 10 | 2 | | |
| Ostracoda | | 3 | | 1 | | 2 | 1 | 1 | 1 | 4 |
| Atyidae | | 1 | | 1 | | | 2 | 2 | | |
| Parastacidae | 1 | 1 | | | | | 1 | 1 | | |
| Araneae | 1 | | | | 1 | 1 | 1 | | 2 | |
| Hydracarina | | | | | | | 10 | 10 | 4 | 3 |
| Hypogastruridae | | | | | | 1 | | 1 | | |
| Caenidae | 1 | | 9 | 10 | | | | | | |
| Baetidae | 2 | 1 | 1 | | | 1 | 5 | 4 | | |
| Leptophlebiidae | 1 | 3 | 1 | 2 | 1 | | 6 | 2 | 1 | 2 |
| Coenagrionidae | 4 | 5 | 3 | 4 | | | | | | |
| Lestidae | | 1 | | | | | | | 1 | 3 |
| Aeshnidae | | | | | | | | | 5 | |
| Cordulephyidae (=Corduliidae) | | | | | | | 1 | | | |
| Hemicorduliidae (=Corduliidae) | | 1 | 3 | 6 | | | | 1 | 1 | 2 |
| Synthemistidae (=Corduliidae) | | | | | | | | | 1 | |
| Hebridae | | | 1 | | | | | | | |
| Hydrometridae | | | | | | | 1 | 1 | 2 | |
| Veliidae | | | | | 1 | 1 | 1 | 2 | | |
| Gelastocoridae | | | | 2 | | | | | | |
| Corixidae | 2 | 1 | 4 | 2 | 1 | 1 | 10 | 5 | | |
| Naucoridae | | 2 | 1 | | | | | | | |
| Notonectidae | 1 | | 1 | | | | | 3 | 1 | 1 |
| Sialidae | | | | | | | 2 | | | |
| Dytiscidae | 9 | 4 | 5 | 1 | 2 | 3 | | 9 | | 1 |
| Gyrinidae | | | 1 | | | | | | | |
| Hydrochidae | | | | | | | | | 1 | 1 |

**Continued. Aquatic macroinvertebrates collected at each of the two replicate samples at all sites.**

| Order or Family | BC US | | BC CON | | TRIB 3 | | TRIB 4 | | TRIB 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b | a | b |
| Hydrophilidae | | | 1 | 2 | 2 | 1 | 1 | | | 2 |
| Scirtidae (= Helodidae, Cyphonidae) | | | | | | | | | 1 | 1 |
| Elmidae | | 1 | | | | | | | | |
| Dixidae | | | | | | | | | | 1 |
| Chironomidae/Chironominae | 3 | 10 | 3 | 6 | 1 | 1 | 7 | 10 | 1 | 2 |
| Chironomidae/Tanypodinae | 2 | 8 | | 3 | 2 | 1 | 1 | 1 | 2 | 1 |
| Ceratopogonidae | 3 | 4 | 2 | 1 | | 1 | 1 | 8 | | |
| Simuliidae | | | 6 | 1 | | | | | | |
| Tabanidae | | | 1 | | | | | | | |
| Hydroptilidae | | | 3 | 2 | | | | | | |
| Hydropsychidae | | | 2 | 2 | | | | | | |
| Ecnomidae | | | | | | | | 1 | | |
| Leptoceridae | | 4 | 2 | 4 | 3 | 4 | 3 | 6 | 4 | 1 |
| Pyralidae | | | | | | | | 1 | 1 | 1 |

# APPENDIX F
## SURVEY SITES

a)

b)

c)

d)

**Brickyard Creek Upstream (BC US): a) Upstream boundary of the site facing upstream; b) Middle of site facing upstream; c) Middle of site facing downstream; d) Upstream boundary of site facing downstream.**

**a)**

**b)**

**b)**

**d)**

**Brickyard Creek and Splitters Swamp Creek Confluence (BC CON): a) Upstream boundary of the site facing upstream; b) Middle of site facing upstream; c) Middle of site facing downstream; d) Downstream boundary of site facing downstream.**

a)

b)

c)

d)

**Tributary 3 (TRIB 3): a) Upstream boundary of the site facing upstream; b) Middle of site facing upstream; c) Middle of site facing downstream; d) Downstream boundary of site facing downstream.**

a)

b)

c)

d)

**Tributary 4 (TRIB 4): a) Upstream boundary of the site facing upstream; b) Middle of site facing upstream; c) Middle of site facing downstream; d) Downstream boundary of site facing downstream**

**a)**

**b)**

**c)**

**d)**

**Tributary 5 (TRIB 5): a) Upstream boundary of the site facing upstream; b) Middle of site facing upstream; c) Middle of site facing downstream; d) Downstream boundary of site facing downstream**