Technical Paper 6b

Riparian Ecology

Riparian Assessment for the North West Rail Link

Final Report

Prepared for
AECOM on behalf of Transport for NSW

March 2012

DOCUMENT TRACKING

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Prepared by	Ian Dixon, Nathan Kearnes, Vivian Hamilton, Kathryn Korbel
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Cover photos: Top – Devlins Creek, Cheltenham (Reach 02); Bottom – Elizabeth Macarthur Creek, Kellyville (Reach 15). Photos by Kathryn Korbel.

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Abbreviations

ABBREVIATION	DESCRIPTION
CRZ	Core Riparian Zone
DP&I	Department of Planning and Infrastructure
ELA	Eco Logical Australia
NOW	NSW Office of Water
NWRL	North West Rail Link
RCMS	Riparian Corridor Management Study
SEPP	State Environmental Planning Policy
ToB	Top of Bank
VB	Vegetated Buffer
VMP	Vegetation Management Plan

Glossary

Bank- Left and right banks are determined when facing downstream.

Bridge Underpass- Section under bridge between pylons and abutments.

Core Riparian Zone (CRZ)- Area adjacent to watercourse that is required to be revegetated and restored to maintain riparian function and connectivity.

Modified/Dry Culvert- A culvert modified to improve fauna movement capacity (i.e. the addition of ledges or rails above the ground, wooden structures or 'natural' flooring to aid the movement of fauna).

Riparian Corridors- Lands directly adjacent to (or surrounding) a waterway.

Top of Bank (ToB)- Top of Bank (ToB) indicates the level at which the channel changes to floodplain. That is, when high flows occur and the water level gets higher than the ToB, the floodplain starts to flood.

Vegetated Buffer (VB)- Area adjacent to the CRZ to protect the CRZ from edge effects.

1 Introduction

1.1 BACKGROUND

The proposed North West Rail Link (NWRL) travels near numerous creeks of varying size, condition and regional importance. Eco Logical Australia (ELA) was commissioned to undertake a riparian assessment of each creek traversed or adjacent to the rail alignment.

The objectives of this study are to determine potential impacts on riparian and aquatic ecology and make recommendations to mitigate those impacts.

The study area for this report is shown in **Figure 1**. Figures of the riparian reaches assessed are provided in **Appendix A**, and are referred to as **Tiles** in this report. The tiles are numbered 01 (from Epping) to 20 (Tallawong Stabling Facility).

1.2 PROJECT DESCRIPTION

NWRL comprises the provision of new electrified passenger railway between Epping and Tallawong Road extending the city rail network to North West Sydney. It would be a two track rail corridor 23km in length, comprising the following main components:

- A direct underground connection into the existing Epping to Chatswood Rail Line at Epping
- A service facility at Epping
- A service facility at Cheltenham
- Two tunnel stubs to safeguard for Parramatta to Epping Rail Line
- Eight stations – Cherrybrook Station, Castle Hill Station, Hills Centre Station, Norwest Station, Bella Vista Station, Kellyville Station, Rouse Hill Station and Cudgegong Road Station
- An underground section of route comprised of 15.5km of two track railway in a twin tunnel configuration with cross passages at regular intervals between Epping and Bella Vista
- The remaining 7.5km surface section of route from Bella Vista to Tallawong Road train stabling facility would be a combination of viaduct, embankment, at grade and cutting, and,
- A stabling facility at Tallawong Road for 16 eight-car trainsets with provision for later expansion to 24 eight-car trainsets.

1.3 SITE NAMING

Table 1 identifies the relationship between the construction sites referred to in the environmental impact statement (EIS) project description and the nomenclature adopted by Eco Logical Australia (ELA) in this riparian assessment. The study sites (see **Figure 1**) referred to in the remainder of this document are according to the 'ELA Study Site Name' column of **Table 1**.

Table 1: Construction site and ELA Study Site Nomenclature

CONSTRUCTION SITE NUMBER AND NAME	SITE BOUNDARY	ELA STUDY SITE NAME
1. Epping Services		Epping
2. Epping Decline		
3. Cheltenham Services Facility		Cheltenham
4. Cherrybrook Station		Cherrybrook
5. Castle Hill Station		Castle Hill Station
6. Hills Centre Station		Hills Centre Station
7. Norwest Station		Norwest Station
8. Bella Vista Station	Celebration Drive	Celebration Drive to Balmoral Road
9. Balmoral Road	Bella Vista Station to Balmoral Road	
10. Memorial Ave	Balmoral Road to Memorial Avenue (Burns Rd)	Balmoral Road to Burns Road
11. Kellyville Station	Memorial Avenue (Burns Rd) to Samantha Riley Drive	Burns Road to Samantha Riley Drive
12. Samantha Riley Drive to Windsor Road	Samantha Riley Drive to Windsor Road	Samantha Riley Drive to Windsor Road
13. Old Windsor Road to White Hart Drive	Old Windsor Road to White Hart Drive	Windsor Road to Sanctuary Drive
14. Rouse Hill Station	White Hart Drive to Rouse Hill Drive	Rouse Hill Station
15. Windsor Road Viaduct	Rouse Hill Drive to End of viaduct	Area 20 - Windsor Road Viaduct
16.Windsor Road Viaduct to Cudgegong Road	End of viaduct to Cudgegong Road	Area 20 - Windsor Road Viaduct to Tallawong Road
17. Cudgegong Road Station and Tallawong Stabling Facility	Cudgegong Road to Tallawong Stabling Facility	Tallawong Road to First Ponds Creek

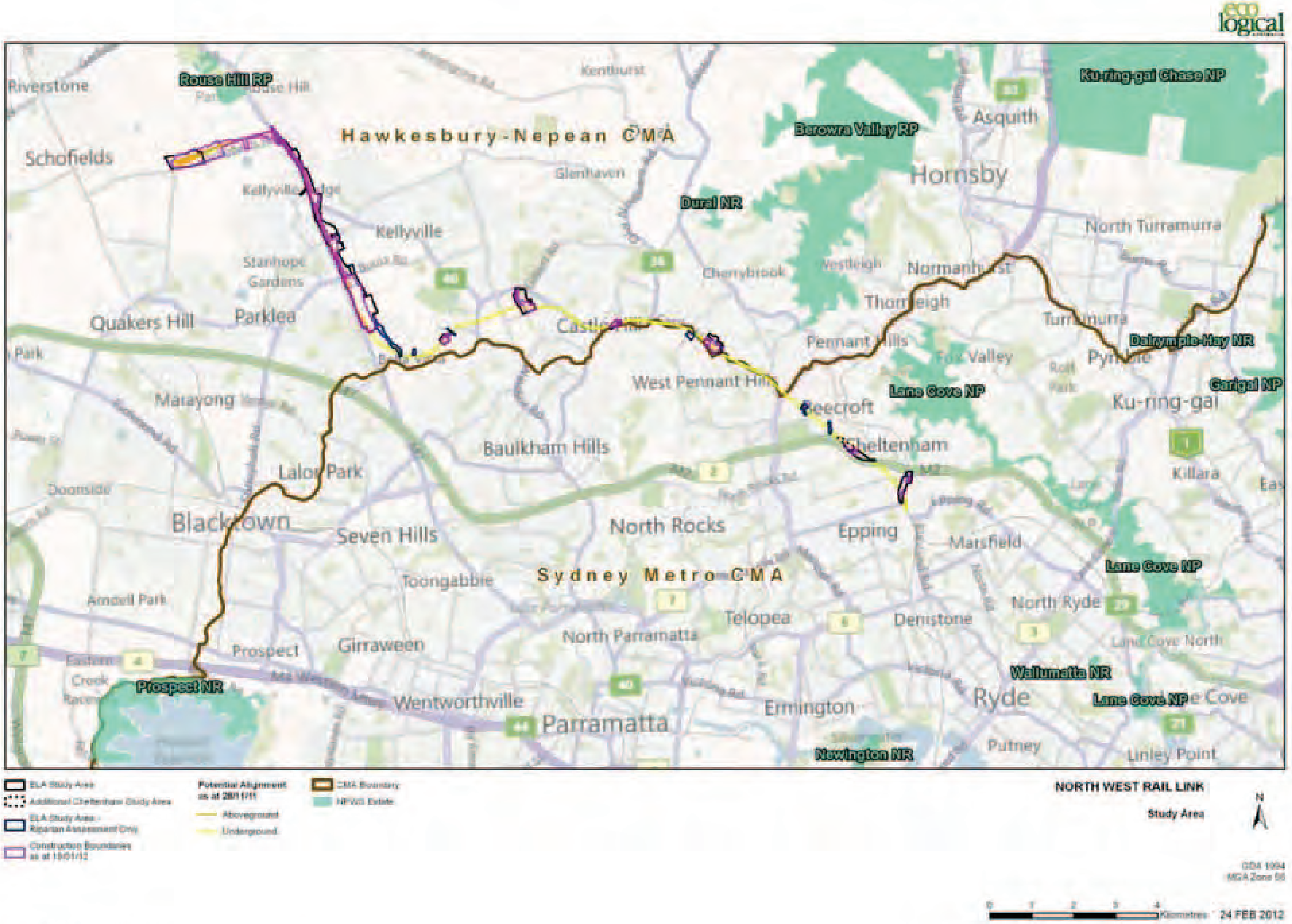

Figure 1: Study Area

1.4 STATUTORY FRAMEWORK

The specific riparian and water regulatory requirements and policies were reviewed to determine their application to the NWRL project and are summarised below as:

- *Fisheries Management Act 1994*
- *Water Management Act 2000*
- *NSW State Rivers and Estuaries Policy*
- *NSW Wetlands Management Policy*
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*
- *Australian and New Zealand Guidelines for Water Quality Monitoring and Reporting*
- NWRL Concept Plan Approval (2008) under the *Environmental Planning and Assessment Act 1979*

1.4.1 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) aims to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations. The FM Act defines 'fish' as any marine, estuarine or freshwater fish or other aquatic animal at any stage of their life history, excluding whales, mammals, reptiles, birds, amphibians or other species specifically excluded.

In accordance with section 115ZG(1)(b) of the *Environmental Planning and Assessment Act 1979* (EP&A Act), applications for separate permits under sections 201, 205 or 219 of the FM Act are not required for State Significant Infrastructure (SSI).

No threatened fish species or endangered populations are known or expected to occur within the NRWL development area.

1.4.2 Water Management Act 2000

The NSW *Water Management Act 2000* (WM Act) has replaced the provisions of the *Rivers and Foreshores Improvement Act 1948*. The WM Act controls the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in NSW. 'Water sources' are defined very broadly and include any river, lake, estuary, place where water occurs naturally on or below the surface of the ground and coastal waters.

In accordance with section 115ZG(1)(g) of the EP&A Act a water use approval under section 89, a water management work approval under section 90 or an activity approval (other than an aquifer interference approval) under section 91 are not required for State Significant Infrastructure (SSI). However, in order to inform a comparative and acceptable assessment of riparian impacts, the regulatory framework of the WM Act has been adopted for this assessment.

Under WM Act framework, activities and works proposed on 'waterfront land' are regulated. These activities include:

- the construction of buildings or carrying out of works;
- the removal of material or vegetation from land by excavation or any other means;
- the deposition of material on land by landfill or otherwise; or
- any activity that affects the quantity or flow of water in a water source.

'Waterfront land' is defined as the bed of any river or lake, and any land lying between the river or lake and a line drawn parallel to and forty metres (40 m) inland from either the highest bank or shore (in relation to non-tidal waters) or the mean high water mark (in relation to tidal waters).

Guidelines have been provided for the protection of waterfront land in the *Riparian Corridor Management Study* (RCMS) (DIPNR 2004) that identify core riparian zones (CRZs). The regulated widths for CRZs are generally determined by stream order and functionality as outlined in **Table 2**.

Table 2: Water Management Act CRZ Widths

TYPES OF WATERCOURSES	CRZ WIDTH
Any first order[1] watercourse and where there is a defined channel where water flows intermittently	10 metres
Any permanent flowing first order watercourse, or any second order[1] watercourse where there is a defined channel where water flows intermittently or permanently	20 metres
Any third order[1] or greater watercourse and where there is a defined channel where water flows intermittently or permanently. Includes estuaries, wetlands and any parts of rivers influenced by tidal waters.	20 – 40 metres[2]

[1] as classified under the Strahler System of ordering watercourses and based on current 1:25,000 topographic maps.

[2] merit assessment based on riparian functionality of the river, lake or estuary, the site and long-term land use.

1.4.3 NSW State Rivers and Estuaries Policy

The State Rivers and Estuaries Policy complements the State Soils, State Trees and State Groundwater Policies to form the Total Catchment management Framework. The policy is based on the fundamental principle that government agencies, private landholders, resource users and the community must all share responsibility for managing natural resources. It aims to prevent degradation of rivers, ensure long term sustainability and maintain beneficial uses. To achieve its objectives, the policy outlines three inter-related activities: development of component policies (e.g. wetlands, estuary, stream, riparian, water quality); State Rivers and Estuaries Reporting; and Pilot River and Estuary Resource Information Studies. Since its publication in 1993 a number of institutional arrangements have changed as well as the legislation, however the overarching objectives and principles of the policy remain the same today.

Mitigation measures outlined in this impact assessment are in line with the policy's principles.

1.4.4 NSW Wetlands Management Policy

The NSW Wetlands Management Policy aims to provide for the protection, ecologically sustainable use and management of NSW wetlands. Wetlands include lakes, lagoons, estuaries, rivers, floodplains, swamps, bogs, billabongs, marshes, coral reefs and seagrass beds. For the sustainable management of wetlands, the NSW Government adopts 12 principles to guide decision-making. Themes include: Catchment scale; Water regimes; Floodplain connectivity; Wetlands of significance; Land management practices; Cultural values; Rehabilitation; Climate change; Research; Protection and offsetting; Cooperation and incentives; and Monitoring and reporting.

Mitigation measures outlined in this impact assessment are in line with the policy's guiding principles.

1.4.5 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The main objective of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality is: to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values (uses) for natural and semi-natural water resources in Australia and New Zealand. It outlines indicators of condition based on biological, physical and chemical parameters. Default environmental trigger values (where reference data are not available) are defined for aquatic ecosystems, irrigation, livestock drinking water, aquaculture, recreation water quality and aesthetics (ANZECC 2000a).

Mitigation measures outlined in this impact assessment are in line with default trigger values for aquatic ecosystems. Relevant default trigger values for the creeks found in the study area are listed in **Table 3**.

Table 3: Default trigger values for physical and chemical stressors for upland rivers in NSW for slightly disturbed ecosystems.*

Indicator	Chl *a* (µg L^{-1})	TP (µg P L^{-1})	FRP (µg P L^{-1})	TN (µg N L^{-1})	NO_x (µg N L^{-1})	NH_4^+ (µg N L^{-1})	Salinity (µS cm^{-1})		Turbidity (NTU)		DO (% sat)		pH	
							Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
Default trigger	-	20	15	250	15	13	30	350	2	25	90	110	6.5	8.0

*Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Australian states and territories. Chl a = chlorophyll a, TP = total phosphorus, FRP = filterable reactive phosphate, TN = total nitrogen, NOx = oxides of nitrogen, NH4+ = ammonium, DO = dissolved oxygen (ANZECC 2000a).

1.4.6 Australian and New Zealand Guidelines for Water Quality Monitoring and Reporting

The Australian and New Zealand Guidelines for Water Quality Monitoring and Reporting provides a comprehensive framework and guidance for the monitoring and reporting of the quality of fresh and marine waters and groundwater. It outlines all aspects of a monitoring program: setting monitoring program objectives; designing monitoring studies and an effective sampling program; the laboratory analyses; the choice of suitable data analyses in conjunction with monitoring and sampling program design; and reporting of the results and conclusions (ANZECC 2000b). It is based on current best practice monitoring approaches and offers guidance to those conducting water quality monitoring.

Mitigation measures outlined in this impact assessment are in line with best practice monitoring design and procedures outlined in the guidelines.

1.4.7 Director General's Requirements – Staged Infrastructure Project

The Minister for Planning granted concept plan approval for the NWRL under the EP&A Act on 6 May 2008. This approval was subject to further project applications and specific requirements. Those relevant to this riparian study are listed in **Table 4**.

Table 4: Conditions of Concept Plan Approval

KEY ISSUE	REQUIREMENT	RELEVANT SECTION OF THIS DOCUMENT
Geotechnical 3.8	The Proponent shall identify the following matters in relation to the bored tunnel components of the project: e) impacts to groundwater dependent ecological communities (affected by groundwater drawdown) and to riparian and instream ecology (affected by surface cracking and water flow impacts).	See separate Groundwater Dependent Ecosystem report
Surface Water and Hydrology 3.12	The Proponent shall identify impacts to riparian and instream ecology from any direct disturbances to waterways and to flora and fauna from changes to creek flow or flood behaviours, during construction or operation.	Section 4

A statement of commitments to address impacts was included as part of the Concept Plan and subsequent approval. The commitments relevant to this study are listed in **Table 5**.

Table 5: Statement of Commitments from Concept Plan Approval

KEY ISSUE	COMMITMENT	RELEVANT SECTION OF THIS DOCUMENT
Flora and Fauna	25. Design of waterway crossings and structures would be undertaken with reference to the *Guidelines for Design of Fish and Fauna Friendly Waterway Crossings* (Fairfull and Witheridge 2003) and *Fish Passage Requirements for Waterway Crossings* (2003) and considering the quality of riparian habitat present, in consultation with the Department of Primary Industries (NSW Fisheries) and other relevant Government agencies.	Section 5
Hydrology and Surface Water	37. Investigations into the construction and operational impacts on the Elizabeth Macarthur Creek would be undertaken in accordance with relevant NSW Government guidelines.	Section 4

2 Methodology

2.1 SCOPE OF ASSESSMENT

Within or near the study area (**Figure 2**), 20 reaches were identified for investigation and assessment. **Table 6** shows the 20 study reaches and their ELA-defined environmental categories as guided by the Riparian Corridor Management Study (RCMS) (DIPNR 2004), with details of the rail alignment type and works being considered near each watercourse.

ELA reviewed each reach through field inspection and desktop review and has provided recommendations on mitigation measures to reduce direct and indirect impacts on the waterways and fauna that may use these areas. ELA has also provided advice on the rehabilitation required if disturbance occurs near a reach. Where recommendations in this report include rehabilitation actions, these actions will only be undertaken within the project corridor as shown in **Figure 2**.

Table 6: Waterway reaches in close proximity to proposed rail alignment*.

REACH NO.	REACH NAME (LOCATION – SEE Table 1 and Figure 2)	FIELD RCMS CAT[1]	STREAM ORDER (Strahler)[2]	RAIL STRUCTURE AND WORKS*
01	Tributary to Devlins Creek (Edensor St)	3	1	Bored tunnel; surface works; water discharge to creek
02	Devlins Creek (downstream of M2)	1	3	Bored tunnel; surface works; water discharge to creek
03	Tributary to Devlins Creek (Chilworth/Beecroft Reserve)	1	1	Bored tunnel
04	Devlins Creek (Fearnley Park)	1	2	Bored tunnel
05	Pyes Creek (upstream of Roberts Road)	3	1	Bored tunnel; surface works; water discharge to creek; Cherrybrook Station
06	Excelsior Creek (upstream of Highs Road)	3	1	Bored tunnel
07	Cattai Creek (upstream of Showground Road)	1	2	Bored tunnel; surface works; water discharge to creek; Hills Centre Station

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[1] Riparian Corridor Management Study (RCMS) desktop categories were refined in the field. RCMS categories are defined by their habitat importance across the landscape. Category 1 stream are the most important. Category 3 streams are the least important.

[2] The Strahler system of classifying stream order is based on a hierarchical scheme, where headwater creek with no tributaries are 1st order. Stream order increases by one when two identical orders join (e.g. two 2nd order streams join to become a 3rd order stream).

REACH NO.	REACH NAME (LOCATION – SEE Table 1 and Figure 2)	FIELD RCMS CAT[1]	STREAM ORDER (Strahler)[2]	RAIL STRUCTURE AND WORKS*
08	Tributary to Cattai Creek (Anella Avenue)	3	1	Bored tunnel
09	Lake of Strangers Creek (Norwest Boulevard)	3	1	Bored tunnel
10	Tributary to Strangers Creek (Edgewater Drive)	3	1	Bored tunnel
11	Elizabeth Macarthur Creek (Norwest Boulevard to Celebration Drive)	1	2	Bored tunnel; open cut; Bella Vista Station
12	Elizabeth Macarthur Creek (Celebration Drive to Balmoral Road)	1	2	Open cut; support site
13	Elizabeth Macarthur Creek (Balmoral Road to Burns Road)	1	2	Open cut; embankment; viaduct; service road
14	Elizabeth Macarthur Creek (Burns Road to Samantha Riley Drive)	1	2	Viaduct; service road; Kellyville Station
15	Elizabeth Macarthur Creek (Samantha Riley Drive to Windsor Road)	1	3	Viaduct; service road
16	Caddies Creek (downstream of Windsor Road)	1	3	Viaduct; service road; support site
17	Tributary to Caddies Creek (opposite Ettamogah Pub)	2	1	Viaduct; service road
18	Tributary to Caddies Creek (White Hart Drive)	3	1	Viaduct; service road; Rouse Hill Station
19	Second Ponds Creek (downstream of Schofields Road)	1	2	250m long bridge/viaduct
20	First Ponds Creek (downstream of Schofields Road)	1	2	Embankment; Tallawong Stabling

*Works defined at 1st Dec 2011, verified 9th Feb 2012.

These 20 reaches were assessed between 24th October and 10th November 2011. One of these was a revised desktop assessment from a field visit in the previous year for a different project. The vast majority of reaches were accessible by foot for their entirety. Occasionally extrapolation from aerial photographs was used to supplement field verification.

Assessments were conducted along each reach to map the waterway and determine the current condition and extent of riparian and aquatic habitat:

1. **Top of Bank Mapping-** The geomorphic Top of Bank (ToB) for each watercourse was mapped using a highly accurate differential GPS unit (accuracy <1m). The ToB identifies the geomorphologic extent of each watercourse, and forms the basis for any Core Riparian Zone (CRZ) and associated Vegetated Buffer (VB) required for the watercourse (DIPNR 2004).

2. **Riparian Condition Assessment-** An assessment of riparian condition and recovery potential was conducted for each watercourse. This assessment considered native vegetation cover and quality, bed and bank stability and habitat diversity as described in the document 'Geomorphic Categorisation of Streams in the Hawkesbury Nepean Catchment' (Department of Land and Water Conservation, 2001).

3. **Ecological Assessment-** An assessment of the biodiversity values of each watercourse was conducted in conjunction with the two field tasks above. The quality of aquatic and riparian

habitats was assessed, including vegetation structure, regeneration, weed infestation, woody debris, fish habitat, patch size and connectivity potential (see **Appendix B** for field data sheets).

4. **Rehabilitation Assessment-** An assessment of the rehabilitation requirements of each of the watercourses was conducted. Appropriate endemic species for impacted waterways within the study area were identified. Significant weed species were also documented, and methods for removal recommended.

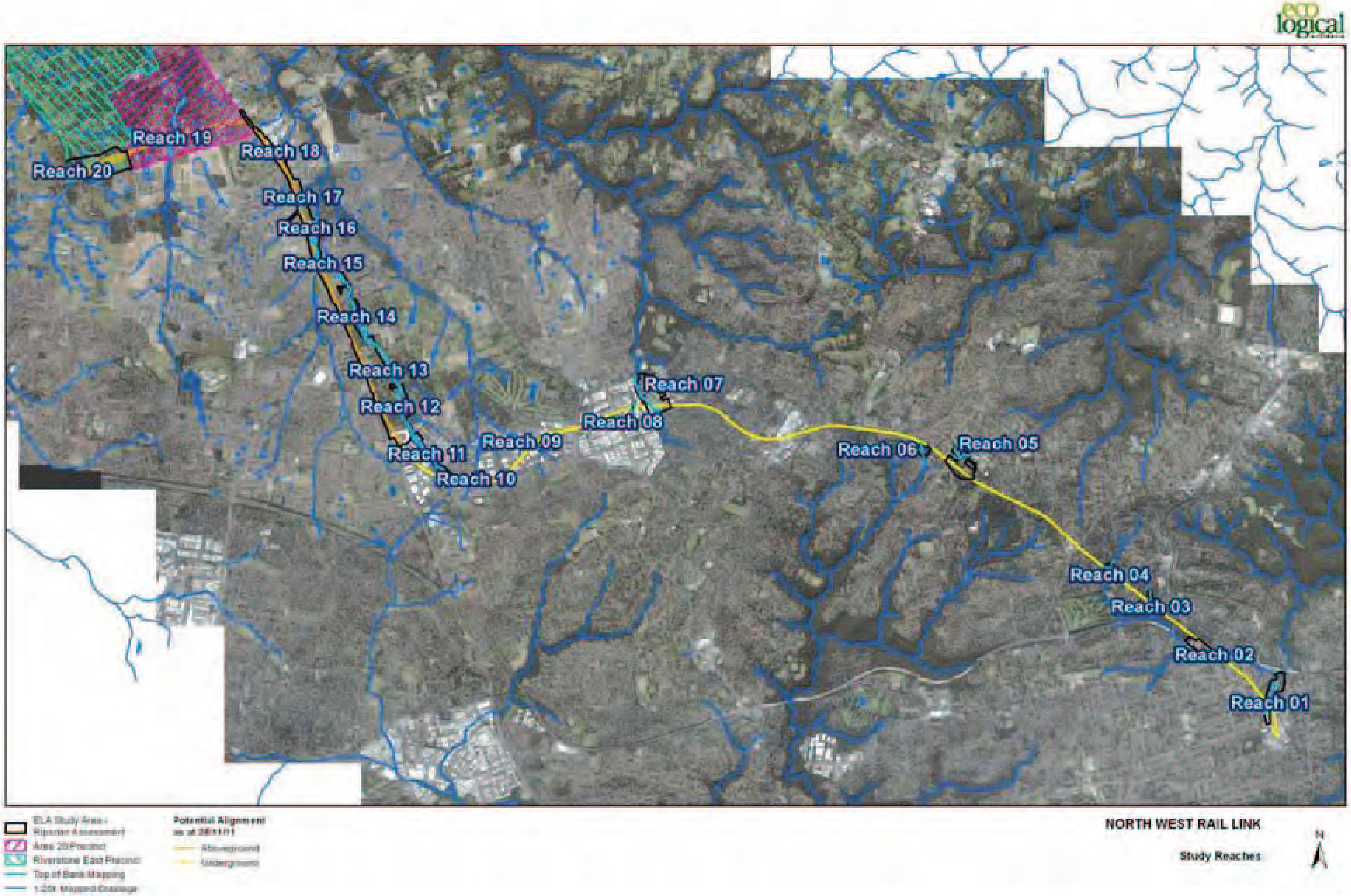

Figure 2: Study Reaches

The NSW Office of Water (NoW) administers the WM Act and utilises three environmental categories to define the relative importance of watercourses and riparian zones in NSW. These definitions are based on the *Riparian Corridor Management Study* (RCMS) undertaken by the then, Department of Infrastructure, Planning and Natural Resources (DIPNR) in 2004.

Using the additional data collected during field surveys, the RCMS categories for each watercourse were refined where required. A set of objectives for each riparian category is included in the RCMS reflecting their relative importance within their catchments. These environmental objectives are integral to the management of riparian land and are outlined below.

Category 1 watercourses

- Provide a continuous corridor to facilitate the movement of flora and fauna species through the catchment and beyond the catchment
- Provide and protect extensive habitat (and connectivity between habitat nodes) for both terrestrial and aquatic fauna
- Maintain viability of native riparian vegetation
- Manage edge effects at the riparian/urban interface

Category 2 watercourses

- Maintain and restore the natural functions of a stream and its aquatic and terrestrial qualities
- Maintain the viability of native riparian vegetation
- Provide suitable habitat for local terrestrial and aquatic fauna

Category 3 watercourses

- Retain, maintain and restore where possible the natural functions of a stream, including bed and bank stability to protect local water quality

The buffers required for each RCMS Category are provided in **Table 7**. Categories 1 and 2 require a Core Riparian Zone (CRZ) and associated Vegetated Buffer (VB) while Category 3 only requires a CRZ. These buffer zones differ to those outlined under the WM Act (**Table 2**) as the RCMS categories place emphasis on the stream's environmental value and connectivity across the landscape, rather than solely on physical hierarchy.

Table 7: RCMS categories and associated buffer distance

RCMS CATEGORY	ASSOCIATED BUFFER DISTANCE	TOTAL RIPARIAN BUFFER WIDTH (measured from top of bank along either side of the watercourse)
Category 1	40 m CRZ + 10 m VB	50 m
Category 2	20 m CRZ + 10 m VB	30 m
Category 3	10 m CRZ (no VB)	10 m

Note: these buffer widths vary slightly from the WM Act requirements (see **Table 2**).

Volumes of groundwater to be discharged from sub-surface construction sites (tunnels and stations) have been estimated by AECOM in their *Draft Groundwater Inflow Management Report* (Dec 2011). The amount and duration will vary throughout the project (construction and operational phases) and the volume to be expelled to natural creek systems has not been finalised. We have considered these estimates to be a maximum amount per day, assuming 24 hr works. Our recommendations to mitigate impacts to stream health are based on desired environmental outcomes, and apply to any amount actually discharged into creeks.

Potential for creek bed cracking due to tunnelling activity has also been evaluated by AECOM (Draft, Dec 2011). Factors that may influence cracking potential include geology, groundwater pressure, channel condition and depth of tunnel. We have not assessed the extent of cracking to bedrock, but have provided some recommendations to monitor any impacts to surface flows.

3 Existing Environmental Conditions

3.1 GENERAL ENVIRONMENT

The general environment of the study area, such as vegetation communities, flora, fauna, and threatened species are discussed in ELA's terrestrial report: *Ecological Assessment for the North West Rail Link* (ELA 2011).

3.2 RIPARIAN AND AQUATIC ENVIRONMENT

The proposed rail link traverses numerous sub-catchments of the Lane Cove River, Hawkesbury River and Parramatta River. Major creeks in and around the study area include Devlins Creek (flows to Lane Cove River), Pyes Creek (flows to Berowra Creek), Excelsior Creek (flows to Darling Mills Creek and then Parramatta River), Cattai Creek (flows to Hawkesbury River) and Strangers, Elizabeth Macarthur, Caddies, First Ponds and Second Ponds Creeks (all flowing to Cattai Creek) (see **Tiles** in **Appendix A**).

These headwater creeks are in residential suburbs of Hornsby, The Hills and Blacktown Local Government Areas. Further downstream, all creeks and their higher order rivers flow through at least one conservation reserve (e.g. Lane Cove National Park, Berowra Valley Regional Park, Cattai National Park) plus many other regional reserves and parks. The current condition of riparian and aquatic habitats was investigated during this study. Key observations recorded during this assessment included: top of bank mapping; spatial integrity; nativeness; structural integrity; age structure; woody debris; hydrology; physical form; water quality; habitat variability and aquatic flora. Results are presented in **Section 4.2** and supported by detailed site descriptions available in **Appendix C.**

As a preamble to the condition of the existing riparian environment, it is noted that the riparian communities and aquatic habitats vary dramatically across the study area. Areas east of Castle Hill have well-forested bush reserves across hilly terrain. The vegetation communities support large trees such as Sydney Red Gum, Sydney Blue Gum, Blackbutt and Turpentine. The largest creek, Devlins Creek, is locally identified as an important wildlife corridor for threatened species such as the Gang Gang Cockatoo, Powerful Owl and Eastern Bent Wing Bat. The creek and its tributaries have a long history of bush regeneration programs and community stewardship from local residents. Recently the Hills-M2 Transurban group has sponsored up to 16 Bushcare groups in the Devlins Creek area to undertake bushland regeneration, native tree plantings and noxious weed removal.

Contrasting these bushland creeks is a different landscape to the west of Castle Hill. Here, the topography is gentle and its long history of rural land use is transforming into dense suburbs and town centres. The creeks are dominated by Swamp She-Oak and scattered Forest Red Gum, with a weedy understorey of Lantana, Blackberry, Privet and exotic grasses. The largest creeks (Elizabeth Macarthur Creek, Caddies Creek, First Ponds Creek and Second Ponds Creek) are heavily modified from rural activities, with land clearing and instream dams common. The Hills Shire Council's water monitoring program documents a long pattern of high nutrient concentrations (nitrogen and phosphorus) in these creeks. As development unfolds in these areas, the streams will be subject to increased urban pressures that may impact water quality, aquatic habitats and species.

Centred between these two regions is Cattai Creek which dissects Castle Hill. Flowing north to the Hawkesbury River, the creek runs through a confined valley within a substantial bushland corridor. However, the headwaters are heavily modified and disturbed by urban and light industrial land uses. This land use contributes to poor water quality further downstream. The upper reaches are dominated by smothering weeds and erosion from fast stormwater runoff (e.g. near Showground Road).

Literature and database searches were undertaken to identify threatened aquatic species listed on the schedules of the *Fisheries Management Act* which may occur within the locality. No threatened aquatic species or endangered aquatic populations were identified as likely to occur within the reaches of the study area.

4 Identification of Impacts

4.1 SUMMARY OF REACH CONDITION AND POTENTIAL IMPACTS

The condition of study reaches ranged from degraded to near intact. Riparian and aquatic condition was best in the Devlins Creek catchment. Most other areas were in moderate condition. Existing key pressures in many reaches were associated with adjacent land clearing, extensive weed invasion and modifications to natural hydrology. Summary results of riparian and aquatic condition are presented in **Table** 8, supported by further discussion in **Section 4.2**, and detailed Site Profiles in **Appendix C**.

Potential impacts on stream condition due to the major civil and construction works, including the proposed rail line, construction works and associated infrastructure are outlined below. Each potential impact is manageable with appropriate controls in place. Cumulative impacts may have deleterious effects locally and further downstream, and each are considered in this assessment. Potential impacts to each of the study reaches (from a riparian and aquatic ecology perspective) are summarised in **Table 8** and include the following:

- **Encroachment into riparian buffer-** where the proposed construction footprint intersects with the 50 m, 30 m or 10 m core riparian zone and vegetated buffer from top of bank (as prescribed by RCMS category for each reach). Impacts may include loss of habitat and connectivity, introduction of weeds, increased sedimentation and water quality issues.
- **Creek crossing-** where the rail alignment crosses over or through a creek (not including bored tunnel sections under creeks). Impacts may include altered fluvial hydrology and obstruction to fauna passage (discussed below).
- **Loss of riparian habitat-** where the proposed construction footprint comes close to the top of bank and intersects with current riparian canopy trees. Impacts may include loss of habitat and connectivity, introduction of weeds, increased sedimentation and water quality issues.
- **Groundwater discharge-** where construction of bored tunnels and underground stations requires groundwater to be pumped to the surface and discharged into the creek. Impacts may include:
    - Bank erosion near the discharge point due to increased flow.
    - Increased velocity of stream flow may modify slow pools into fast flowing runs. This may disadvantage some flora and fauna, but may favour rheophilic organisms (those preferring faster moving water). Excessive velocities may prevent movement of fauna that are unable to ascend fast flowing reaches. Increased velocity may also scour benthic sediments and deposit them in pools further downstream.
    - Increased volume of stream flow may drown existing riffle habitats, create a sudden shift in habitat depth and flood terrestrial vegetation. Drowning of riffle habitats could severely alter the natural riffle-run-pool sequence that characterise these creeks. However, increased volume may provide greater connectivity and new riffles further downstream. A sudden shift in habitat depth may kill existing macrophytes that are sensitive to depth requirements. However, they would re-establish nearby in new

habitat. Increased flow height may flood terrestrial vegetation in or adjacent to the riparian corridor by physical inundation and/or water-logging soils. These areas may shift towards colonisation of aquatic and riparian vegetation. Although these impacts have a trade-off (i.e. a loss and gain) the sudden shift in condition at the commencement of works, and again at the completion of works, does not mimic a natural slow change. It is anticipated there will be a lag time for recovery of vegetation, during which time banks would be at risk of erosion and weed invasion.

  - The quality of released water may differ to that of the local streams, including higher turbidity, and varying pH, electrical conductivity, temperature and dissolved oxygen. Sudden changes in water quality may shock aquatic organisms or create unfavourable habitat.

- **Weed invasion-** where disturbance from construction provides bare ground for weed establishment, or the rail corridor provides a new vector for transport of weed propagules. Impacts include introduction of new weeds to the area and extended penetration of weeds into native plant communities. This may result in a loss of biodiversity and habitat value, smothering of native juvenile plants, harbouring of feral animals, and alteration of vegetation structure and riparian function.

- **Polluted surface water runoff-** where construction of new car parks, roads and amenities provides an increased risk of motor vehicle oils, litter and warmer surface water to enter the nearby creek. Impacts may include water quality issues (heavy metal pollution from vehicles), inorganic clogging of aquatic habitats (litter/rubbish) and destruction of macroinvertebrate communities (warm water inflows).

- **Increased velocity of surface runoff-** where impermeable surfaces are constructed over existing vegetation (e.g. proposed car parks at railway stations). Impacts may include inappropriate fast flows for aquatic biota (e.g. some macroinvertebrates and macrophytes prefer slow water) and increased bank erosion from fast discharge resulting in bank collapse, loss of riparian trees, loss of edge habitat and sedimentation of downstream pools.

- **Surface erosion and sedimentation-** where clearing vegetation during construction results in lack of soil stability. This may cause surface erosion (sheet and gully erosion) and transportation of sediment overland into the nearby creek. Impacts may include increased water turbidity, which would disrupt light penetration through the water column and impact on primary (plant) production, with flow on effects through the food web. Increased sediment loads may settle in downstream pools, causing a loss of deep habitat, promotion of dense reeds and changes to hydrologic connectivity.

- **Altered fluvial hydrology-** where construction of bridges and elevated viaduct structures interfere with instream water movement. This specifically refers to footings, pylons or embankments that support the rail crossing of creeks. Impacts may include changes in flood water extent (outwards and back upstream) and back-eddies causing bank erosion. This may affect riparian recruitment and bank stability, with flow on effects of loss of habitat and sedimentation.

- **Bedrock cracking-** where vibrations during the boring of tunnels for the underground sections of rail line cause cracking of bedrock beneath nearby creeks. This may be due to vibrations from drilling equipment, structural shifts in underlying foundations, or movement of sub-surface groundwater (following pressure gradients). Impacts may include leaching of surface water through the ground and loss of aquatic habitat. The total amount of water entering the ground would be dependent on the stream flows, the extent of stream bed cracking and the conditions of the stream bed channel (i.e. whether it is concrete lined or has clays/alluvium present in the base of the stream). Any cracks formed within the stream beds would also be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed. Such impacts are generally of short duration with long term impacts to the stream surface flows unlikely.

Table 8: Summary of reach condition and potential impacts due to rail infrastructure and construction methods.

REACH	WATERCOURSE NAME	PROPOSED RAIL STRUCTURE AND CONSTRUCTION WORKS	FIELD RCMS CATEGORY	RIPARIAN CONDITION	AQUATIC CONDITION	POTENTIAL IMPACTS TO REACH									
						Encroachment into riparian buffer	Creek crossing	Loss of riparian habitat	Groundwater discharge	Weed invasion	Polluted surface water runoff	Increased velocity of surface runoff	Surface erosion and sedimentation	Altered fluvial hydrology	Bedrock cracking
01	Tributary to Devlins Creek	Bored tunnel; surface works; water discharge to creek	3	Degraded	Degraded	✓			✓	✓			✓		
02	Devlins Creek	Bored tunnel; surface works; water discharge to creek	1	Moderate	Good					✓	✓		✓		✓
03	Tributary to Devlins Creek	Bored tunnel	1	Near intact	Good										✓
04	Devlins Creek	Bored tunnel	1	Moderate	Moderate										✓
05	Pyes Creek	Bored tunnel; surface works; water discharge to creek; Cherrybrook Station	3	Degraded	Degraded-Moderate	✓		✓	✓	✓	✓	✓	✓		
06	Excelsior Creek	Bored tunnel	3	Degraded	Degraded										✓
07	Cattai Creek	Bored tunnel; surface works; water discharge to creek; Hills Centre Station	1	Moderate	Degraded-Moderate	✓		✓	✓	✓	✓	✓	✓		✓
08	Tributary to Cattai Creek	Bored tunnel	3	Moderate	Degraded										✓
09	Lake of Strangers Creek	Bored tunnel	3	Moderate	Degraded										✓

REACH	WATERCOURSE NAME	PROPOSED RAIL STRUCTURE AND CONSTRUCTION WORKS	FIELD RCMS CATEGORY	RIPARIAN CONDITION	AQUATIC CONDITION	POTENTIAL IMPACTS TO REACH									
						Encroachment into riparian buffer	Creek crossing	Loss of riparian habitat	Groundwater discharge	Weed invasion	Polluted surface water runoff	Increased velocity of surface runoff	Surface erosion and sedimentation	Altered fluvial hydrology	Bedrock cracking
10	Tributary to Strangers Creek	Bored tunnel	3	Moderate	Moderate										✓
11	Elizabeth Macarthur Creek	Bored tunnel; open cut; Bella Vista Station	1	Moderate	Moderate										✓
12	Elizabeth Macarthur Creek	Open cut; support site	1	Degraded	Moderate	✓		✓		✓	✓	✓	✓		
13	Elizabeth Macarthur Creek	Open cut; embankment; viaduct; service road	1	Degraded	Degraded	✓		✓		✓	✓	✓	✓		
14	Elizabeth Macarthur Creek	Viaduct; service road; Kellyville Station	1	Moderate	Moderate	✓		✓		✓	✓	✓	✓		
15	Elizabeth Macarthur Creek	Viaduct; service road	1	Degraded-Moderate	Moderate	✓	✓	✓		✓	✓		✓	✓	
16	Caddies Creek	Viaduct; service road; support site	1	Moderate	Moderate	✓		✓		✓	✓	✓	✓		
17	Tributary to Caddies Creek	Viaduct; service road	2	Degraded-Moderate	Degraded-Moderate	✓	✓	✓		✓	✓		✓	✓	
18	Tributary to Caddies Creek	Viaduct; service road; Rouse Hill Station	3	Moderate	Degraded-Moderate	✓	✓	✓		✓	✓		✓	✓	

REACH	WATERCOURSE NAME	PROPOSED RAIL STRUCTURE AND CONSTRUCTION WORKS	FIELD RCMS CATEGORY	RIPARIAN CONDITION	AQUATIC CONDITION	POTENTIAL IMPACTS TO REACH									
						Encroachment into riparian buffer	Creek crossing	Loss of riparian habitat	Groundwater discharge	Weed invasion	Polluted surface water runoff	Increased velocity of surface runoff	Surface erosion and sedimentation	Altered fluvial hydrology	Bedrock cracking
19	Second Ponds Creek	250m long bridge/viaduct	1	Degraded	Degraded	✓	✓	✓		✓			✓		
20	First Ponds Creek	Embankment; Tallawong Stabling	1	Poor	Degraded	✓		✓		✓	✓	✓	✓		

4.2 DISCUSSION OF REACH CONDITION AND POTENTIAL IMPACTS

Below is a discussion of the current ecological condition for each reach and potential impacts of the NWRL project, with supporting Site Profiles in **Appendix C**. The following discussions per reach are also replicated within each Site Profile to consolidate individual reach information. All reach maps are presented as tiles in **Appendix A**. Mitigation measures are also briefly discussed below but are provided in more detail in **Section 5**. Reference to left and right banks are when facing downstream. Volumes of groundwater discharge are based on estimated rates per day produced by tunnel boring and road header works (as provided by TfNSW on 9/2/12).

Reach 01: Tributary to Devlins Creek (Edensor St)

The riparian and aquatic habitats are highly disturbed along the entirety of this reach. Urban development has transformed the creek into a concrete/brick channel. Riparian vegetation is mostly absent on the left bank due to residential units. The right bank is mostly regrowth bushland but does not function as a true riparian zone that benefits aquatic health because of the sealed channel (e.g. no roots can penetrate the channel to provide aquatic habitat). The greatest value of the reach is this bushland which forms a narrow suburban green corridor through Epping. The creek has little aquatic value and limited biotic functions to naturally improve water quality.

The proposed rail alignment at this reach will be a bored tunnel (**Tile 01**). A small area for above ground services will partially be located within the riparian buffer. The tunnel will have minimal impacts on Reach 01, but impacts arising from associated construction areas may include surface erosion and spread of weeds.

Tunnel construction operations (Epping Services Facility) may discharge groundwater into the creek at a rate of 432,000 L per day. Recommendations to mitigate impacts of water discharge during construction and operation are provided in **Sections 5.3** and **5.4**.

Reach 02: Devlins Creek (downstream of M2)

Devlins Creek is a large tributary of Lane Cove River that dissects Beecroft, Cheltenham and North Epping. It connects several bushland reserves with Lane Cove National Park. Devlins Creek and the surrounding reserves have a long history of bush regeneration and recreation. The most recent impacts to the creek are due to the construction and more recent upgrade of the M2 Motorway, which traverses Reach 02 and follows its right bank. The riparian zone is in moderate condition and has high potential for restoration. The aquatic habitat is in good condition and also has high potential for restoration.

The proposed rail alignment at this reach will be a bored tunnel. Potential impacts to the creek's water-holding capacity may occur if the tunnelling creates small rock fractures causing water leaching. Any cracks formed within the stream beds due to tunnelling would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated.

A construction staging area is proposed for the bushland to the west of Cheltenham Oval and does not encroach into the riparian buffer zone (**Tile 02**). Groundwater will not be discharged at this site. Other construction impacts may include weeds, erosion and sedimentation of the creek and riparian zone (due to minor surface runoff).

Reach 03: Tributary to Devlins Creek (Chilworth/Beecroft Reserve)

This small tributary of Devlins Creek runs through Chilworth and Beecroft Reserves. The riparian zone is intact and well protected with a forested surrounding. Nearby residential blocks may occasionally put pressure on the creek through weeds, sediment and water quality. The creek is a steep series of narrow rocky ledges with intermittent flows during rain events only. The aquatic habitat is in good condition (albeit dry at the time of survey).

The proposed rail alignment at this reach will be a bored tunnel (**Tile 03**). The tunnel will have no surface impacts on Reach 03. Potential impacts to the creek's water-holding capacity may occur if the tunnelling creates small rock fractures causing water leaching. However, due to the steepness and ephemeral nature of the creek, water flows would be fast and intermittent. At best, instream micro-topography may create small rock pools valuable to frogs and some aquatic insects. Cracks would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated.

Reach 04: Devlins Creek (Fearnley Park)

This reach forms the upper catchment of Devlins Creek in Fearnley Park. Upstream is a narrow riparian corridor surrounded closely by residential housing. Downstream is Pennant Hills Golf Course with a stabilised rocky channel and scattered Eucalypt habitat. Both the riparian zone and aquatic habitat are in moderate condition with urban pressures evident, especially weed invasion and some undercutting of banks due to fast flowing events. The rock and cobble substrate indicated that water flows swiftly during heavy rains, which is common in dense urban catchments. Aquatic flora did not occur, likely due to the steep banks and dense canopy shading the narrow channel. The value of this reach is likely important for frogs, reptiles and birds, especially as the corridor links urban bushland upstream and larger forest patches downstream. The riparian habitat has high restoration potential due to the adjacent reserve. However, the aquatic habitat has only moderate restoration potential due to the narrow channel, steep banks and sporadic fast flows.

The proposed rail alignment at this reach will be a bored tunnel (**Tile 04**). The tunnel will have no surface impacts on Reach 04. Potential impacts to the creek's water-holding capacity may occur if the tunnelling creates small rock fractures causing water leaching. Even though the creek would flow fast during heavy rain, the deep permanent pools would be at risk of draining if fissures occur. This would decrease the aquatic value to fauna dependant on permanent water, especially frogs. Any cracks formed within the stream beds due to tunnelling would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated.

Reach 05: Pyes Creek (upstream of Roberts Road)

This reach upstream of Roberts Road is divided into an open-canopy narrow channel, a small woodland creek and numerous drainage depressions eroded through dense bushland. Downstream of the road the creek is piped for nearly a kilometre. The lower portion of the reach is highly degraded with dense weed cover and a narrow incised channel. Slashing of vegetation occurs close to the right bank. This area provides little aquatic and riparian value, although has moderate potential for restoration. The upper portion of the reach is in relatively better condition within a small woodland reserve. Habitat here is improved and variable compared to the lower portion. Drainage depressions within the surrounding bushland are straight and incised, indicating they have been intentionally dug as part of the surrounding residential development. Dense bushland helps slow the flow of overland water, thus preventing significant erosion downstream. The intersection of all drainage depressions with the creek occurs upstream of a small culvert (vehicle access track) and forms a small weedy swamp, with numerous frogs.

The proposed rail alignment at this reach will be a below-ground station (Cherrybrook Station). An extended construction footprint will cover the northern area of the station to provide a staging area during construction, succeeded by a permanent commuter car park **(Tile 06**). This proposed footprint will likely clear much of the dense bushland within the small catchment, giving greater importance to the remaining woodland and creek. Tunnel construction operations may discharge groundwater into the creek at a rate of 1,728,000 L per day. Recommendations to mitigate impacts of water discharge during construction and operation are provided in **Sections 5.3** and **5.4**.

The footprint will extend into the buffer zone for Reach 05, therefore increasing the risk of impacts to the stream. Impacts may include pollution of water runoff (litter and motor vehicle oils), increased runoff velocity (risk of erosion), spread of weeds (especially around fringes of footprint) and loss of habitat.

Reach 06: Excelsior Creek (upstream of Highs Road)

This reach is a minor headwater gully with no aquatic habitat and limited riparian value. Regular slashing of the grass in and around the reach has prevented any understorey growth (besides lawn). Large *Eucalyptus* trees provide the most valuable terrestrial habitat, however these trees are not dependant on any waterway. The proposed rail alignment at this reach will be a bored tunnel (**Tile 06**). The tunnel will have no surface impacts on Reach 06. Potential impacts such as substrate cracking will not impact the reach as no aquatic habitat exists.

Reach 07: Cattai Creek (upstream of Showground Road)

Cattai Creek is a large tributary of the Hawkesbury River. The location of Reach 07 is nearly at the headwaters of its catchment. The riparian zone is in moderate condition, with surrounding pressures from urban/semi-industrial land uses. The aquatic habitats were variable but condition was overall degraded-moderate. The rock and cobble substrate indicated that water flows swiftly during heavy rains, common in dense urban catchments. Aquatic flora did not occur, likely due to the steep banks and dense canopy shading the narrow channel. The value of this reach is likely important for frogs, reptiles and birds, especially as the corridor links urban bushland upstream and larger forest patches downstream. Although weeds dominate the riparian zone, it has high potential for restoration, especially due to its width and isolation from public access.

The proposed rail alignment will be a bored tunnel passing beneath Cattai Creek (**Tile 10**). The adjacent Hills Centre Station will be a cut and cover construction. Potential impacts to the creek's water-holding capacity may occur if the tunnel creates small rock fractures causing water leaching. Any cracks formed within the stream beds due to tunnelling would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated. Tunnel construction operations may discharge groundwater into Cattai Creek at a rate of 1,728,000 L per day. Recommendations to mitigate impacts of water discharge during construction and operation are provided in **Sections 5.3** and **5.4**.

The alignment and construction footprint of the railway, station and car park may encroach the 50 m buffer zone from the top of bank therefore the risk of indirect impacts to the existing stream habitats are increased. Other indirect impacts from the car park include pollution of water runoff (litter and motor vehicle oils), increased runoff velocity (risk of erosion) and spread of weeds (especially around fringes of the footprint).

Reach 08: Tributary to Cattai Creek (Anella Avenue)

This small tributary of Cattai Creek is a unique refuge albeit in a heavily modified landscape. Both upstream and downstream reaches are piped underground. The remaining central patch is surrounded by development but fenced from public access. This provides a small but isolated patch of dense riparian habitat. Access to the site was not possible, but vantage points from the neighbouring land provided sufficient views of the variable rocky aquatic habitat, suitable for frogs and reptiles. The riparian vegetation has a dense canopy with a weedy understorey, suitable for an array of birds.

The proposed rail alignment at this reach will be a bored tunnel (**Tile 10**). The tunnel will have no surface impacts on Reach 08. Potential impacts to the creek's water-holding capacity may occur if the tunnelling creates small rock fractures causing water leaching. Any permanent pools would be at risk of draining if fissures occur. This would decrease the aquatic value to fauna dependant on permanent water, especially frogs. Any cracks formed within the stream beds due to tunnelling would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated.

Reach 09: Lake of Strangers Creek (Norwest Boulevard)

This reach is greatly modified from its original form. Upstream of Norwest Boulevard the creek is piped beneath/adjacent to small landscaped ponds. Downstream of the road is a large artificial lake with some fringing reeds and riparian revegetation.

The proposed rail alignment at this reach will be a bored tunnel (**Tile 12**). The tunnel will have no surface impacts on Reach 09. Potential impacts such as substrate fracturing from vibrations may compromise the water-holding capability of the lake and result in impacts on habitat viability. Groundwater will not be discharged at this site.

Reach 10: Tributary to Strangers Creek (Edgewater Drive)

This reach is greatly modified from its original form. Upstream of Norwest Boulevard the creek is piped beneath the suburb. Downstream of the road is a series of tiered artificial ponds with some fringing reeds and riparian revegetation. The stream bed is lined with concrete.

The proposed rail alignment at this reach will be a bored tunnel (**Tile 13**). The tunnel will have no surface impacts on Reach 10. Potential impacts such as concrete fracturing from vibrations may compromise the water-holding capability of the creek and result in impacts on habitat viability. Groundwater will not be discharged at this site.

Reach 11: Elizabeth Macarthur Creek (Norwest Boulevard to Celebration Drive)

This reach comprises of upstream and downstream portions of a rehabilitated stream channel centred by a large artificial lake. Both types have well-established reeds, shrubs and trees and form the headwaters of Elizabeth Macarthur Creek.

The proposed rail alignment at this reach will be a bored tunnel, raising to open cut and entering Bella Vista Station (**Tiles 13 and 14**). The tunnel will have no surface impacts on Reach 11. Potential impacts such as concrete fracturing from vibrations may compromise the water-holding capability of the creek and result in impacts on habitat viability. Any cracks formed within the stream beds due to tunnelling would be expected to eventually fill with fine material (alluvium) once the tunnel lining is installed, and no long term impacts to the stream surface flows are anticipated. Groundwater will not be discharged at this site.

Reach 12: Elizabeth Macarthur Creek (Celebration Drive to Balmoral Road)

This reach of Elizabeth Macarthur Creek has a mostly degraded riparian zone, with clearing up to the bank and weed invasion common. However, small patches of good riparian vegetation do occur. With good management this reach has very high potential for riparian restoration. Even in its mostly degraded state it is still of value as it contributes to a long green corridor that will eventually be constricted by development. Numerous small dams scatter the reach, which break the hydrological connectivity for fish movement. The aquatic habitat is in moderate condition and restoration potential instream is moderate.

The proposed rail alignment at this reach will be open cut construction running adjacent to Old Windsor Road (**Tile 14**). A construction plant (manufacture of precast concrete tunnel lining and viaduct platforms) is proposed for the area near Elizabeth Macarthur Creek. This construction footprint is within the 50 m buffer zone from the top of bank, therefore the plant increases the risk of impacts to riparian and aquatic habitats.

Reach 13: Elizabeth Macarthur Creek (Balmoral Road to Burns Road)

This reach of Elizabeth Macarthur Creek has a mostly degraded riparian zone, with clearing up to the bank and weed invasion common. With good management this reach has very high potential for riparian restoration. Even in its mostly degraded state it is still of value as it contributes to a long corridor that will eventually be constricted by development. Numerous weedy swamps scatter the reach, which breaks the hydrological connectivity for fish movement. The aquatic habitat is also degraded and restoration potential instream is moderate.

The proposed rail alignment at this reach will be partly open cut and partly elevated viaduct, connected by a short embankment (**Tiles 14-15**). A construction road will be created adjacent to the viaduct section. A small area of the construction footprint is within the 50 m buffer zone from the top of bank, therefore it increases the risk of impacts to riparian and aquatic habitats. Other indirect impacts include pollution of water runoff (litter and motor vehicle oils), increased runoff velocity (risk of erosion) and spread of weeds (especially around fringes of footprint).

Reach 14: Elizabeth Macarthur Creek (Burns Road to Samantha Riley Drive)

This reach of Elizabeth Macarthur Creek is in mostly moderate condition. The riparian zone is generally uncleared, but with a weedy understorey common. With good management this reach has very high potential for riparian restoration. This reach is of great value as it contributes to a long corridor that will eventually be constricted by development. In the southern portion of the reach several small dams and swamps break the hydrological connectivity for fish movement. Restoration potential for instream habitat is high, due to its mostly unmodified channel and stable banks.

The proposed rail alignment at this reach will be an elevated viaduct adjacent to Old Windsor Road (**Tiles 15-16**). A construction road will be created adjacent to the viaduct. Kellyville Station will be located near the north of this reach, and may include a car park. A small area of the construction footprint is within the 50 m buffer zone from the top of bank, therefore it increases the risk of impacts to riparian and aquatic habitats. Other indirect impacts include pollution of water runoff (litter and motor vehicle oils), increased runoff velocity (risk of erosion) and spread of weeds (especially around fringes of footprint).

Reach 15: Elizabeth Macarthur Creek (Samantha Riley Drive to Windsor Road)

This reach of Elizabeth Macarthur Creek varies in condition, with a degraded riparian zone to the south and a moderate riparian zone to the north. Clearing and continued slashing to the bank is common. Weeds are abundant, except under areas with dense canopy cover. With good management this reach has very high potential for riparian restoration. Even in its partly degraded state it is still of value as it contributes to the long corridor, however this will eventually be constricted by development. Aquatic habitat is in moderate condition and restoration potential instream is high, especially if coinciding with riparian restoration.

The proposed rail alignment at this reach will be an elevated viaduct running along the floodplain on the left bank (**Tile 16**). The elevated viaduct will enter the 50 m buffer zone from the top of bank and cross the channel twice, therefore it increases the risk of impacts to riparian and aquatic habitats. A construction road will also be created adjacent to the viaduct. Special attention should be paid to the northern-most area where a large wetland exists west of the creek. Care should be taken to prevent surface erosion and sedimentation of the wetland from construction activities.

Reach 16: Caddies Creek (downstream of Windsor Road)

This reach of Caddies Creek is in moderate condition. The left bank is highly disturbed in parts due to the adjacent land use. The right bank is relatively intact with a good cover of riparian trees and adjacent woodland. Understorey weeds are prevalent. With good management this reach has very high potential for riparian restoration. The reach is of great value as it contributes to a long green corridor that will eventually be constricted by development. The aquatic habitat is substantially vaster compared to that upstream in Elizabeth Macarthur Creek. Large carp were observed swimming here. The aquatic habitat is in moderate condition and restoration potential instream is high.

The proposed rail alignment at this reach will be an elevated viaduct adjacent to Windsor Road (**Tile 17**). A construction road will be created adjacent to the viaduct and a support site (material storage and offices) will be located between Windsor Road and Caddies Creek. The footprint of the support site is within the 50 m buffer zone from the top of bank, which increases the risk of impacts to riparian and aquatic habitats. The proposed support site appears to include most of the left bank and some of the channel. The proximity of the footprint to the stream is inappropriate and any material storage and facilities should be set outside the riparian buffer.

Reach 17: Tributary to Caddies Creek (opposite Ettamogah Pub)

This small tributary to Caddies Creek is in degraded-moderate condition. The sections that receive inflows from three culverts beneath Windsor Road are highly degraded, with no riparian vegetation and dense *Typha* and Blackberry stands within the channel. Further downstream, the riparian zone is in moderate condition with occasional weeds and some regeneration. Despite its condition, the reach has high potential for riparian restoration, especially if providing a wider vegetation corridor. The connectivity value of the riparian zone is important from a downstream perspective (links to The Outlook Nature Reserve). However from an upstream perspective, Windsor Road creates a significant break in riparian connectivity to the engineered upper reaches of this creek. Overall in Reach 17, the aquatic habitat is in degraded-moderate condition, with only small patches of valuable instream habitat. Restoration potential instream is low-moderate, with greater potential downstream.

The proposed rail alignment at this reach is an elevated viaduct with one crossing over the upper extent of the reach (**Tile 18**). Therefore, the alignment will enter the 30 m riparian buffer zone. This crossing will dissect the three channels inflowing from culverts beneath Windsor Road. Here, the reach is highly degraded and due to the close proximity of Windsor Road and the existing culverts upstream, potential impacts from this crossing would be indistinguishable from that already present.

Reach 18: Tributary to Caddies Creek (White Hart Drive)

This small tributary to Caddies Creek has a riparian zone in moderate condition and appears to be establishing well after restoration works. The reach has high potential for continued riparian restoration, especially if providing a wider vegetation corridor on the right bank. The connectivity value of the riparian zone is moderate as it provides a link to larger woodland habitats downstream. Upstream of this reach is a culvert beneath Windsor Road and then becomes heavily cleared with little to no riparian vegetation. The aquatic habitat in Reach 18 is engineered and includes curved channels and gentle steps stabilised by riprap. Generally the aquatic habitat is in degraded-moderate condition, with only small patches of valuable instream habitat, especially for frogs. Restoration potential instream is low-moderate.

The proposed rail alignment at this reach is an elevated viaduct with one crossing over the upper extent of the reach into the proposed Rouse Hill Station (**Tile 18**). Therefore, the alignment will enter the 10 m riparian buffer. This crossing will occur through a small basin immediately downstream of the culverts under Windsor Road. Due to the existing disturbance from the culverts and the close proximity to Windsor Road, potential impacts from this crossing would be minor. However, mitigation measures to prevent disturbance downstream during construction are still warranted.

Reach 19: Second Ponds Creek (downstream of Schofields Road)

This reach of Second Ponds Creek was assessed by ELA (2010) as part of the Area 20 Biodiversity Assessment. Eight reaches were assessed for hydrologic change, fringing vegetation condition, physical form, water quality and aquatic habitat. Half of the reaches were classed as degraded. The others were classed as being in moderate condition. The proposed rail alignment at this reach is a 250 m long elevated bridge similar to the viaduct design, with one creek crossing (**Tile 19**). The exact location of the crossing was not assessed as part of this study or by ELA (2010) due to access restrictions. However, ELA (2010) assessed the reaches immediately upstream and downstream of the proposed crossing and adjacent footprint. Both reaches were classed as degraded. After reviewing aerial photographs of this site, we conclude that Reach 19 is in no better condition than these adjacent reaches. Despite its current ecological condition, Seconds Pond Creek is an important riparian corridor and its value will increase as development encroaches in the future. Therefore, the proposed crossing structure should recognise this significance and be designed accordingly to minimise penetration into the 50 m buffer zone from top of bank.

Reach 20: First Ponds Creek (downstream of Schofields Road)

This reach of First Ponds Creek (and a small tributary) is outside of the study area but has been included because the proposed Tallawong Stabling Facility is upslope of the creek and may cause indirect impacts during construction (**Tile 20**). Potential impacts could arise unless appropriate erosion control and sediment fences are used during construction. Revegetation and/or soil stabilisation works will be necessary post stabling construction to prevent surface erosion and sedimentation of the creek.

5 Mitigation Measures

5.1 SUMMARY OF MITIGATION MEASURES

Impacts for each reach have been listed in **Table 8** and discussed in **Section 4.2**. Mitigation measures to address each impact are summarised in **Table 9**, followed by detailed descriptions of consolidated mitigation types. Mitigation recommendations per reach are listed in Table 10 with details in **Sections 5.2 - 5.6**.

Table 9: Mitigation measures recommended to address potential impacts to riparian and aquatic ecology.

	MITIGATION MEASURES									
POTENTIAL IMPACT	Habitat restoration	Minimise works in buffer zone	River health monitoring	Sediment fences	Off-stream settling ponds	Gross pollutant traps	Soil stabilisation	Footings away from channel and banks	Weed control	Minimal night construction works
Encroachment into riparian buffer	✓	✓		✓	✓		✓		✓	
Creek crossing	✓			✓			✓	✓	✓	✓
Loss of riparian habitat	✓			✓			✓		✓	✓
Groundwater discharge			✓		✓					
Weed invasion	✓								✓	
Polluted surface water runoff			✓		✓	✓				
Increased velocity of surface runoff					✓		✓			
Surface erosion and sedimentation	✓			✓			✓			
Altered fluvial hydrology	✓							✓		
Bedrock cracking			✓							

Table 10: Mitigation recommendations for each study reach within construction footprint.

REACH NEAR CONSTRUCTION SITE	MITIGATION MEASURES									
	Habitat restoration	Minimise works in buffer zone	River health monitoring	Sediment fences	Off-stream settling ponds	Gross pollutant traps	Soil stabilisation	Footings away from channel and banks	Weed control	Minimal night construction works
Reach 1	✓	✓	✓	✓	✓		✓		✓	
Reach 2	✓		✓	✓		✓	✓		✓	
Reach 3			✓							
Reach 4			✓							
Reach 5	✓	✓	✓	✓	✓	✓	✓		✓	✓
Reach 6			✓							
Reach 7	✓	✓	✓	✓	✓	✓	✓		✓	✓
Reach 8			✓							
Reach 9			✓							
Reach 10			✓							
Reach 11			✓							
Reach 12	✓	✓		✓	✓	✓	✓		✓	✓
Reach 13	✓	✓		✓	✓	✓	✓		✓	✓
Reach 14	✓	✓		✓	✓	✓	✓		✓	✓
Reach 15	✓	✓		✓	✓	✓	✓	✓	✓	✓
Reach 16	✓	✓		✓	✓	✓	✓		✓	✓
Reach 17	✓	✓		✓	✓	✓	✓	✓	✓	✓
Reach 18	✓	✓		✓	✓	✓	✓	✓	✓	✓
Reach 19	✓	✓		✓	✓		✓	✓	✓	✓
Reach 20	✓	✓		✓	✓	✓	✓		✓	✓

5.2 TIMING AND LOCATION OF WORKS

The proposed construction footprint often encroaches the riparian buffer zone especially along Elizabeth Macarthur Creek, Caddies Creek and Second Ponds Creek. Actual works within these areas are yet to be fully documented. It is recommended that higher-disturbance activities (such as noisy machinery, flood lights, generators and compounds) be located as far from the riparian buffer as practically possible. This is to avoid disturbance to fauna that rely on the riparian corridor for refuge, roosting, foraging and breeding. Likewise, the construction of bridges, culverts and viaducts within the riparian buffer zone should be minimised at night (i.e. reduction of floodlights and noise that may disturb nocturnal fauna such as mammals and bats).

5.3 PROTECTION OF WATER QUALITY AND HABITAT CONDITION

Water quality protection measures are recommended for use where the rail footprint and construction activities require:

- Clearing of groundcover (grasses, herbs and shrubs and weeds) to bare earth outside of the riparian buffer zone (e.g. the majority of grassland parallel to Windsor Road);
- Clearing of any native vegetation or mechanical weed removal within the riparian buffer zone (e.g. areas between Celebration Drive and Balmoral Road and patches north);
- Construction of any permanent car parks and roads;
- Temporary staging areas, compounds and storage areas of oils and chemicals; and
- Wastewater discharge points, including pumping of groundwater from tunnels and vehicle wash down bays.

Key protection measures suitable to mitigate the above activities include:

- Gross Pollutant Traps to capture litter from car parks and roads.
- Sediment fences to slow overland flow and trap sediments from surface erosion.
- Tunnel groundwater will be re-used for dust suppression (both in the tunnels and for surface works) where possible. Additional opportunities for re-using of groundwater on site or for construction will be investigated and implemented where feasible and reasonable.
- Off-stream settling ponds as a transition point between disturbance and instream discharge. Ponds vegetated with macrophytes help filter and uptake nutrients and pollutants bound to sediment. Ponds may need periodic cleaning to remove excessive sediment, especially in the early stages of development. Overflow points should lead through a secondary pond and/or slow channel planted with dense reeds.
- Where water is released into local creeks, constructed storage ponds should be used to first capture and settle the water before discharge. The discharge point should be at the upstream end of a large pool, to allow slowing of water before travelling further downstream. Where feasible, the velocity of downstream flows should not exceed natural seasonal flow velocities. Water released in dynamic pulses will give reprieve for fauna travelling upstream.
- Flow modelling of local creeks will help identify areas downstream that may be inundated from additional groundwater discharge. Water should first be stored in constructed settling ponds to

regulate the discharge. Where feasible, timed releases should mimic the natural flow regime with consideration given to high and low flows. Areas identified for increased inundation require monitoring for bank erosion and weed invasion. A riparian and aquatic vegetation planting program and management plan will reduce the lag time of natural re-colonisation due to the sudden shift in habitat conditions.

5.4 RIVER HEALTH MONITORING

Water released into local creeks needs to comply with requirements of an Environment Protection Licence for nutrients, pH, dissolved oxygen, temperature, electrical conductivity and turbidity (**Table 3**). At a minimum, water quality should mimic or improve on that in the local creek. Differences in water quality will be diluted further downstream.

Monitoring of river health is required downstream of certain construction and operational activities, including groundwater waste discharge via settling ponds (Devlins Creek), car parks that are located within the riparian buffer zone (near proposed rail stations), temporary support sites, material storage and construction plpants. Inspection of water quality mitigation controls (e.g. sediment fences, GPT, settling ponds) should be routine to detect any breach in performance. Strategic monitoring points downstream are to be compared with a location immediately upstream of the discharge point.

Undertake regular visual inspections of streams where tunnels will run under streamlines. Inspections are to target permanent pools, with inspections prior to boring to confirm pre-drilling baseline conditions, and inspections during and/or shortly after drilling, with comparison to non-impacted reference sites. Inspections may also include checks for unnatural ponding, changes in flow course, or monitoring of any existing bedrock cracks (by recording GPS locations, length, and width, of existing fractures).

Should substantial drops in the water level of permanent pools be detected, then further investigations to determine the cause of any changes observed should be performed. If changes are caused by, or suspected to be caused by, drilling, mitigation measures should be discussed with the NSW Office of Water, and appropriate measures implemented.

5.5 HABITAT RESTORATION AND WEED CONTROL

In order to ensure the riparian corridors are of most value for habitat connectivity, rehabilitation and revegetation of the corridors is required along the watercourses up to the project boundary. Initially all creek crossings will require primary weed control to limit the impact of the widespread weed species on site. Each site will then require ongoing maintenance to ensure areas remain relatively weed free. The amount of maintenance work will, in part, be dictated by the land use and associated condition of the watercourse upstream.

Vegetation management will be implemented in riparian areas to meet the management objectives and approaches listed in **Table 11**. Preparation of detailed Vegetation Management Plans is recommended where the construction footprint impinges on the mapped riparian zones, which applies to reaches 1, 5, 7, and 11 – 20.

Table 11: Management objectives and approaches

OBJECTIVES	APPROACH
Improve water quality and riparian vegetation	• Stock removal to prevent soil erosion • Slow water speed through strategically placed debris or structures • Revegetation of creek bed and banks
Improve ecological health and integrity by revegetating with native species	• Control woody weeds and grasses • Revegetate with terrestrial and wetland vegetation using appropriate species • Maintenance weed control
Maintain and enhance habitat values	• Protect existing native vegetation • Control weeds • Increase native plant cover
Ensure stable bed and banks of creeks	• 'Soft' engineering approach with a focus on planting locally native species, slowing flows before they reach the creek and attenuating peak and high frequency flows • Use of engineering structures (rip-rap, drop structures) to stabilise active erosion points

5.5.1 Revegetation of Creeks, Core Riparian Zones and Vegetated Buffers

The first phase of revegetation will include primary weed control which can be achieved through broad scale herbicide application. A likely minimum of two treatments will be required to exhaust weed seed present in the soil seed bank, however further treatments may also be required should weeds continue to germinate.

Creek banks lacking native cover will require revegetation works to provide immediate stabilisation. A high density of planting is required to provide rapid bed and bank stabilisation. Restoration of damaged creeks needs to also replicate habitat variety and micro-habitats, including riffles, runs, pools, fringing reeds, riparian vegetation, shading, variable depths, variable widths, large woody debris, and a variety of gravel, pebble, cobble and boulder substrate.

Species to be utilised and the density required are to be provided in a Vegetation Management Plan(s). Regular maintenance will be required to continue to control emerging weeds, such as pasture grasses, herbaceous species, aquatic weeds and woody weeds. Plantings within the rail corridor need to conform with railway guidelines on the maximum growth height and their proximity to a rail line.

5.5.2 Weed Control

Detailed weed management controls will be outlined in the Vegetation Management Plans prepared for this project. It is recommended weed control be conducted beneath the elevated viaduct to remove impenetrable stands of dense weeds that may hinder movement of fauna.

5.6 CREEK CROSSINGS

The proposed elevated viaduct sections over Elizabeth Macarthur Creek and Second Ponds Creek are the most suitable crossing types compared to bridges and culverts. Given the open design of the viaduct structure, there will be no impact to passage of aquatic fauna, as is often the case with culverts and road crossings (Fairfull & Witheridge 2003). Both Elizabeth Macarthur Creek and Second Ponds Creek form long green corridors through an increasingly developed landscape. They are likely to provide passage for an array of fauna, including reptiles, amphibians, mammals, birds and bats. While the crossing structures do not strictly meet the Core Riparian Zone (CRZ) and Vegetation Buffer (VB) widths provided by the NSW Office of Water (NoW), they do provide adequate fauna crossing points in the context of the study area. The viaduct will allow free passage of ground fauna along the riparian corridor and in and out of adjacent grassland. Pylons/footings should be placed out of the channel and away from the banks to allow free passage to fish, enhance streamside connectivity and prevent bank scouring and erosion from altered fluvial hydrology (e.g. creation of back eddies and flood dispersal). Pylons should be placed in such a way to allow the watercourse to run in the centre of the bridge/viaduct span.

Weed control should be conducted beneath the elevated rail line to remove impenetrable stands of dense weeds that may hinder movement (e.g. Blackberries). Native vegetation should be retained, and rehabilitated, in areas adjacent to and under the viaduct. Vegetation should be retained, as much as possible, during construction.

6 Conclusions

6.1 RIPARIAN AND AQUATIC CONDITION

Study reaches varied in condition. Streams between Epping Station and the proposed Castle Hill Station were in better condition than streams between Castle Hill and the proposed Tallawong Stabling Facility. The most common pressures in these areas were riparian clearing, weed invasion and existing poor water quality.

6.2 POTENTIAL IMPACTS

Potential impacts on riparian and aquatic ecology due to the construction and operation of the NWRL are varied. Over the length of the proposed rail corridor, a total of 11 reaches will have tunnels beneath them; three reaches will receive groundwater waste discharges of varying volumes above current flows; 13 reaches will have some form of construction footprint within the riparian buffer; and four reaches will be crossed by a viaduct. Across the 20 study reaches, additional potential impacts include:

- Loss of riparian habitat;
- Weed invasion;
- Polluted surface water runoff;
- Increased velocity of surface runoff ;
- Surface erosion and sedimentation;
- Altered fluvial hydrology; and
- Underground rock fractures & leaching.

6.3 MITIGATION MEASURES

Measures to mitigate potential impacts are manageable and are necessary to avoid compounding impacts downstream. Mitigation measures recommended in this report address the following:

- Timing and location of works;
- Protection of water quality;
- River health monitoring;
- Vegetation management;
- Habitat restoration; and
- Crossing design.

7 References

ANZECC 2000a. *National Water Quality Management Strategy: An Introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

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