TECHNICAL REPORT

2

Aquatic ecology assessment

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

ARTC Inland Rail

Narromine to Narrabri Project

Aquatic Ecology Assessment

Technical Report 2

2-0001-250-EAP-00-RP-0003

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Table of contents

Table index

Figure index

Appendices

Executive summary

The proposal

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail is a major national program that will enhance Australia's existing national rail network and serve the interstate freight market.

The proposal consists of about 306 kilometres of new single-track standard gauge railway with crossing loops. The proposal also includes changes to some roads to facilitate construction and operation of the new section of railway, and ancillary infrastructure to support the proposal.

The proposal would link the Parkes to Narromine section of Inland Rail located in central western NSW, with the Narrabri to North Star section of Inland Rail located in north-west NSW.

Australian Rail Track Corporation Ltd (ARTC) ('the proponent') is seeking approval to construct and operate the Narromine to Narrabri section of Inland Rail ('the proposal').

The proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also determined to be a controlled action under the Commonwealth *Environment and Protection Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment.

This report

This Aquatic Ecology Assessment has been prepared on behalf of ARTC for the proposal to support the environmental impact statement (EIS) for the proposal and responds to the Secretary's Environmental Assessment Requirements (SEARs) for aquatic ecology.

The assessment presented in this report has included a review of relevant legislation, consideration of the existing conditions, an impact assessment to determine the significance of impacts to aquatic ecology as a direct result of the construction and operation of the proposal, a cumulative impact assessment and the potential impacts of the proposal on threatened aquatic species which are predicted to occur within the region. Recommended mitigation and management measures were identified in response to the impact assessment findings.

This report builds on findings of the Biodiversity Assessment, Surface Water Quality Assessment and the Hydrology and Flooding Assessment prepared for the proposal, which are addressed in separate reports.

Existing aquatic environment

The proposal site is located within the Macquarie-Bogan, Castlereagh River and Namoi River catchments. The proposal alignment crosses 102 mapped watercourses and/or waterbodies, including drainage lines, farm dams, minor streams and major waterways. Thirty-six of these watercourses are identified as key fish habitat (KFH), however only three of these are permanently flowing (perennial) (Narrabri Creek, Namoi River, and Macquarie River). The remaining 33 watercourses mapped as KFH, and all other named and unnamed watercourses that are not KFH, only flow during and after significant rainfall (ephemeral).

Despite a lack of water, aquatic habitat characteristics were present at most of the watercourses visited in the field. Key habitat characteristics that were common along the watercourses were large fallen logs, uprooted trees and aquatic macrophytes. First and second order tributaries that were visited had minimal native riparian or aquatic vegetation and were significantly modified by agricultural land practices.

Threatened species, populations and ecological communities

Seven threatened species and two endangered populations, listed under the EPBC Act and/or *Fisheries Management Act 1994 (*FM Act), have been recorded or predicted to occur in watercourses within the proposal construction footprint (DAWE, 2020; EESG, 2020; ALA, 2020; DPI, 2016). The endangered populations predicted to occur are the Western population of the Olive Perchlet (*Ambassis agassizii*), and the Murray Darling Basin population of the Eel Tailed Catfish (*Tandanus tandanus)*. Threatened species that are predicted to occur are Silver Perch (*Bidyanus bidyanus*), Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*), Flathead Galaxias (*Galaxias rostratus*), Purple Spotted Gudgeon (*Mogurnda adspersa*) and Macquarie Perch (*Macquaria australasica*) (DAWE, 2020). All watercourses within the proposal area are also considered features of the Endangered Ecological Community known as the 'Natural Drainage System of the Darling River Catchment' (Darling River EEC), which is listed under the FM Act.

In accordance with the FM Act, a '7-part test' was carried out for the state listed Darling River EEC, threatened species, and endangered populations. The Murray Cod, which is a nationally listed species, was assessed against the 'Significant Impact Criteria for species listed as Vulnerable under the EPBC Act' (DoE, 2013). No assessment was undertaken for the Macquarie Perch, which was listed as potentially occurring within the region by the Protected Matters Search Tool (DAWE, 2020) but was not predicted to occur within the study area based on NSW Department Planning, Industry and Environment (DPIE) (Regions, Industry, Agriculture and Resources) distribution modelling (DPI, 2016). The assessments for each species concluded that construction and operation of the proposal would not result in any lasting impacts due to the design, mitigation measures and rehabilitation strategy proposed. Any temporary impacts during construction are expected to be minor and/or manageable through standard construction management practices. Further, temporary impacts to species during construction are only considered to be a risk at perennial watercourses. All other ephemeral watercourses would be dry when construction takes place, therefore species would not be present and are not at risk of being impacted.

Aquatic groundwater dependent ecosystems

Aquatic groundwater dependent ecosystems (GDEs) in the proposal area are associated with the riparian vegetation along watercourses. The proposal is expected to cross 11 high priority GDE vegetation areas at Macquarie River, Castlereagh River, Gulargambone Creek, Baradine Creek, Etoo Creek, Rocky Creek, Goona Creek, Bohena Creek, a small unnamed tributary of Bohena Creek, Namoi River and Narrabri Creek. Fourteen individual watercourses were also mapped as either low or moderate potential for GDEs (BOM, 2020) including Wallaby Creek, Kickabil Creek, Marthaguy Creek, Baronne Creek, Caleriwi Creek, Teridgerie Creek, Baradine Creek, Etoo Creek, Coghill Creek, Mollieroi Creek and Bohena Creek which been identified as having moderate GDE potential, and Macquarie River and Castlereagh River which have been identified as having low GDE potential. In addition, there are 10 mapped high priority GDE springs within the region however the closest is located about 10 kilometres from the proposal alignment. As such, all high priority GDE springs (DPI, 2017), as well as high potential (BOM, 2020) GDEs, are located a significant distance away from the proposal area and are therefore not expected to be impacted by the proposal.

Due to the prevailing drought conditions and ephemeral nature of most of the watercourses, there is limited water available in the proposal area. No direct water extraction from any creek is proposed during construction of the proposal, however water is proposed to be sourced from deep aquifer bores during construction. Without appropriate mitigation measures, pumping of the deep aquifers has the potential to reduce creek and river baseflows which could result in reduced environmental water availability (JacobsGHD, 2020b). Clearance of riparian vegetation that would occur within the proposal construction corridor may also impact the environmental condition of aquatic GDEs. However, due to the minor and temporary nature of the changes expected, it is unlikely that the proposal would significantly compromise the ecological processes within aquatic GDEs. In addition, all high potential and high priority aquatic GDEs are not expected to be impacted from water extraction activities due to their distance from the proposal.

Impacts from the proposal during construction

For the construction phase, potential direct impacts to aquatic ecosystems would be related to construction works undertaken in the riparian zone, along the riverbanks and within the channel, and particularly where water-crossing structures are proposed to be built. Direct impacts include temporary barriers to fish-passage, potential for injury or mortality of aquatic species due to interaction with equipment and machinery, or from poor water quality. Indirect impacts to aquatic ecology would be related to the mobilisation of poor-quality stormwater runoff from construction activities including vegetation removal, earthworks, establishment and use of construction compounds as well as riverbank and streambed disturbance that would result in sedimentation and pollution downstream. Potential impacts during construction are only considered to be a risk at perennial watercourses. However, these risks would be minimised as construction including bridge piling would be undertaken via barges, reducing the potential for disturbance of the watercourses. All other ephemeral watercourses would be dry when construction takes place, therefore water and aquatic species would not be present and are not at risk of being impacted.

Impacts from the proposal during operation

For the operational phase, the risks have been identified as being permanent barriers to fish-passage due to the water crossing structures, potential downstream pollution due to mobilisation of stormwater runoff from new impervious surfaces, as well as from possible leaks or spills from maintenance vehicles on the permanent access tracks or from cargo in train carriages. Maintenance works required during the life of the proposal could also result in dispersion of sediment, pollutants and pesticides from weed control and minor vegetation clearing. These potential risks were determined to be unlikely due to the following reasons:

- Water crossing structures have been designed to be fish-friendly in accordance with recommended crossing types outlined in relevant guidelines (Fairfull and Witheridge, 2003).
- The overall increase in impervious area would very small relative to the total area of the catchments, therefore overall impact to the volume of runoff would be minimal.
- Runoff from the proposal is expected to be low and not change export of annual pollutant loads to downstream watercourses.
- The rail track and trains would be maintained in accordance with ARTC standards and protocols, therefore risk of spills would be low.

Further, it was determined in consultation with the Department of Planning Industry and Environment (Regions, Industry, Agriculture and Resources) (DPIE (Regions, Industry, Agriculture and Resources) that permanent loss or disruption of habitat functionality in

watercourses which are identified as KFH is not anticipated provided the proposed design and alignment, construction methodology, mitigation measures, rehabilitation strategy and operational monitoring and management are implemented.

Recommended mitigation measures

It is expected that the potential for construction impacts would be substantially reduced through implementation of the following activities:

- undertaking relocation of aquatic habitat features from the instream construction footprint to downstream locations in the same reach prior to construction
- in watercourses (where water is available) that are potential breeding habitat for threatened species, instream construction works should be avoided during the breeding season (spring and summer)
- undertaking pre-clearance surveys and fauna salvage in enclosed areas for piling activities where required
- adoption of comprehensive erosion and sediment controls to capture stormwater and construction runoff
- establishment of construction drainage to direct flows to sedimentation basins
- discharge of sedimentation basins in accordance with national water quality guidelines (ANZG, 2018).

During operation, it is expected that potential impacts would be substantially reduced through implementation of the following recommended activities:

- adopting appropriately designed fish-friendly crossing structures, drainage and scour protection at all watercourse crossing structures
- re-establishment of riparian vegetation and aquatic habitat features within and on the banks of watercourses
- ongoing monitoring and maintenance to ensure that watercourse crossing structures and associated aquatic habitats in the proposal operational footprint are preserved.

Conclusion

On the basis of the assessment of the existing aquatic environment, the description of the proposal and construction methodology, and assuming that mitigation and management measures that have been described in this report (and in other assessments undertaken by other specialists) are implemented, the aquatic ecology assessment concludes that the impacts would not significantly compromise the functionality, long-term connectivity or viability of habitats, or ecological processes within assemblages of biota. The majority of potential impacts are associated with the construction phase and would therefore be temporary and manageable through the adoption of procedures and controls which have been described and would be further developed in the CEMP and associated biodiversity management plan. Any potential operational impacts would be sufficiently managed through appropriate design, rehabilitation efforts, and on-going maintenance and management of the operational footprint. Given successful implementation of these management controls, residual impacts to aquatic ecology would be negligible.

Glossary and abbreviations

Acronym/term	Definition
ALA	Atlas of Living Australia
ARTC	Australian Rail Track Corporation
BC Act	*Biodiversity Conservation Act 2016* (NSW)
BOM	Bureau of Meteorology
CAMBA	China Australia Migratory Bird Agreement
CEMP	Construction Environment Management Plan
DAWE	Department of Agriculture, Water and the Environment (formerly known as Department of Environment and Energy) (Commonwealth)
DECCW	(former) Department of Environment Climate Change and Water
DSEWPaC	(former) Department of Sustainability, Environment, Water, Population and Communities (Commonwealth)
DPIE (Regions, Industry, Agriculture and Resources)	Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) (formerly known as Department of Primary Industries – Fisheries) (NSW)
EEC	Endangered ecological community
EESG	Environment, Energy and Science Group of the Department of Planning, Industry and Environment (formerly known as the Office of Environment and Heritage)
EIA	Environmental impact assessment
EIS	Environmental Impact Statement
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FM Act	*Fisheries Management Act 1994* (NSW)
GDE	Groundwater dependent ecosystem
JAMBA	Japan Australia Migratory Bird Agreement
KFH	Key fish habitat
MNES	Matters of National Environmental Significance
NPWS	National Park and Wildlife Service
NSW	New South Wales
NTU	Nephelometric turbidity units
PCT	Plant community type
The proposal	Defined as the construction and operation of the Narromine to Narrabri section of Inland Rail.

Acronym/term	Definition
the proposal site	Defined as the area that would be directly affected by construction of the proposal (also known as the construction footprint). It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the compounds and laydown areas that would be used during construction.
Rail corridor	The corridor within which the rail tracks and associated infrastructure would be located.
Ramsar wetland	The Ramsar Convention intergovernmental environmental agreement is implemented by the Contracting Parties to protect Wetlands of International Importance (Ramsar Sites).
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SIS	Species Impact Statement
SSI	State Significant Infrastructure
SRE	Sensitive Receiving Environment
The Regulation	*Environmental Planning and Assessment Regulation 2000*
WM Act	*Water Management Act 2000* (NSW)

1. Introduction

1.1 Overview

1.1.1 Inland Rail and the proposal

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail is a major national program that will enhance Australia's existing national rail network and serve the interstate freight market.

The Inland Rail route, which is about 1,700 kilometres long, involves:

- using the existing interstate rail line through Victoria and southern NSW
- upgrading about 400 kilometres of existing track, mainly in western NSW
- providing about 600 kilometres of new track in NSW and south-east Queensland.

The Inland Rail program has been divided into 13 sections, seven of which are located in NSW. Each of these projects can be delivered and operated independently with tie-in points on the existing railway.

Australian Rail Track Corporation Ltd (ARTC) ('the proponent') is seeking approval to construct and operate the Narromine to Narrabri section of Inland Rail ('the proposal').

1.1.2 Approval and assessment requirements

The proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also determined to be a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment.

This report has been prepared by the JacobsGHD Joint Venture as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to support the application for approval of the proposal, and address the environmental assessment requirements of the Secretary of the NSW Department of Planning, Industry and Environment (the SEARs), dated 9 September 2020.

1.2 The proposal

The proposal consists of about 306 kilometres of new single-track standard gauge railway with crossing loops. The proposal also includes changes to some roads to facilitate construction and operation of the new section of railway, and ancillary infrastructure to support the proposal.

The proposal would be constructed to accommodate double-stacked freight trains up to 1,800 metres long and 6.5 metres high. It would include infrastructure to accommodate possible future augmentation and upgrades of the track, including a possible future requirement for 3,600 metre long trains.

The land requirements for the proposal would include a new rail corridor with a minimum width of 40 metres, with some variation to accommodate particular infrastructure and to cater for local topography. The corridor would be of sufficient width to accommodate the infrastructure currently proposed for construction, as well as possible future expansion of crossing loops for 3,600 metre long trains. Clearing of the proposal site would occur to allow for construction and to maintain the safe operation of the railway.

1.2.1 Location

The proposal would be located between the towns of Narromine and Narrabri in NSW. The proposal would link the Parkes to Narromine section of Inland Rail located in central western NSW, with the Narrabri to North Star section of Inland Rail located in north-west NSW.

The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key design features of the proposal include:

Rail infrastructure

- a new 306 kilometre long rail corridor between Narromine and Narrabri
- a single-track standard gauge railway and track formation within the new rail corridor
- seven crossing loops, at Burroway, Balladoran, Curban, Black Hollow/Quanda, Baradine, The Pilliga and Bohena Creek
- bridges over rivers and other watercourses (including the Macquarie River, Castlereagh River and the Namoi River/Narrabri Creek system), floodplains and roads
- level crossings
- new rail connections and possible future connections with existing ARTC and Country Regional Network rail lines, including a new 1.2 kilometre long rail junction between the Parkes to Narromine section of Inland Rail and the existing Narromine to Cobar Line (the Narromine West connection)

Road infrastructure

- road realignments at various locations, including realignment of the Pilliga Forest Way for a distance of 6.7 kilometres
- limited road closures.

The key features of the proposal are shown in Figure 1.2.

Ancillary infrastructure to support the proposal would include signalling and communications, drainage, signage and fencing, and services and utilities.

Further information on the proposal is provided in the EIS.

Figure 1.1 **Location of the proposal**

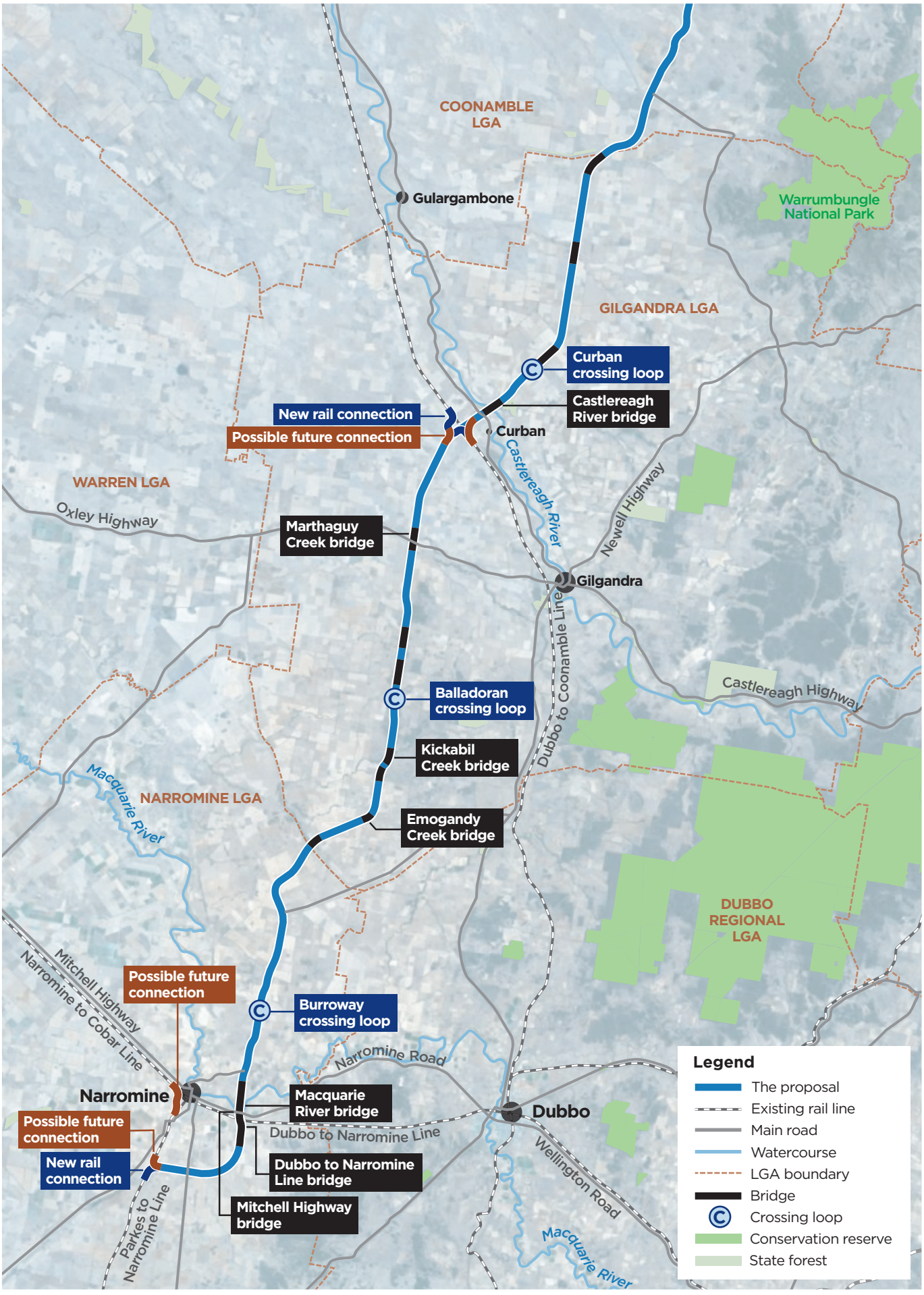

Figure 1.2a **Key features of the proposal**

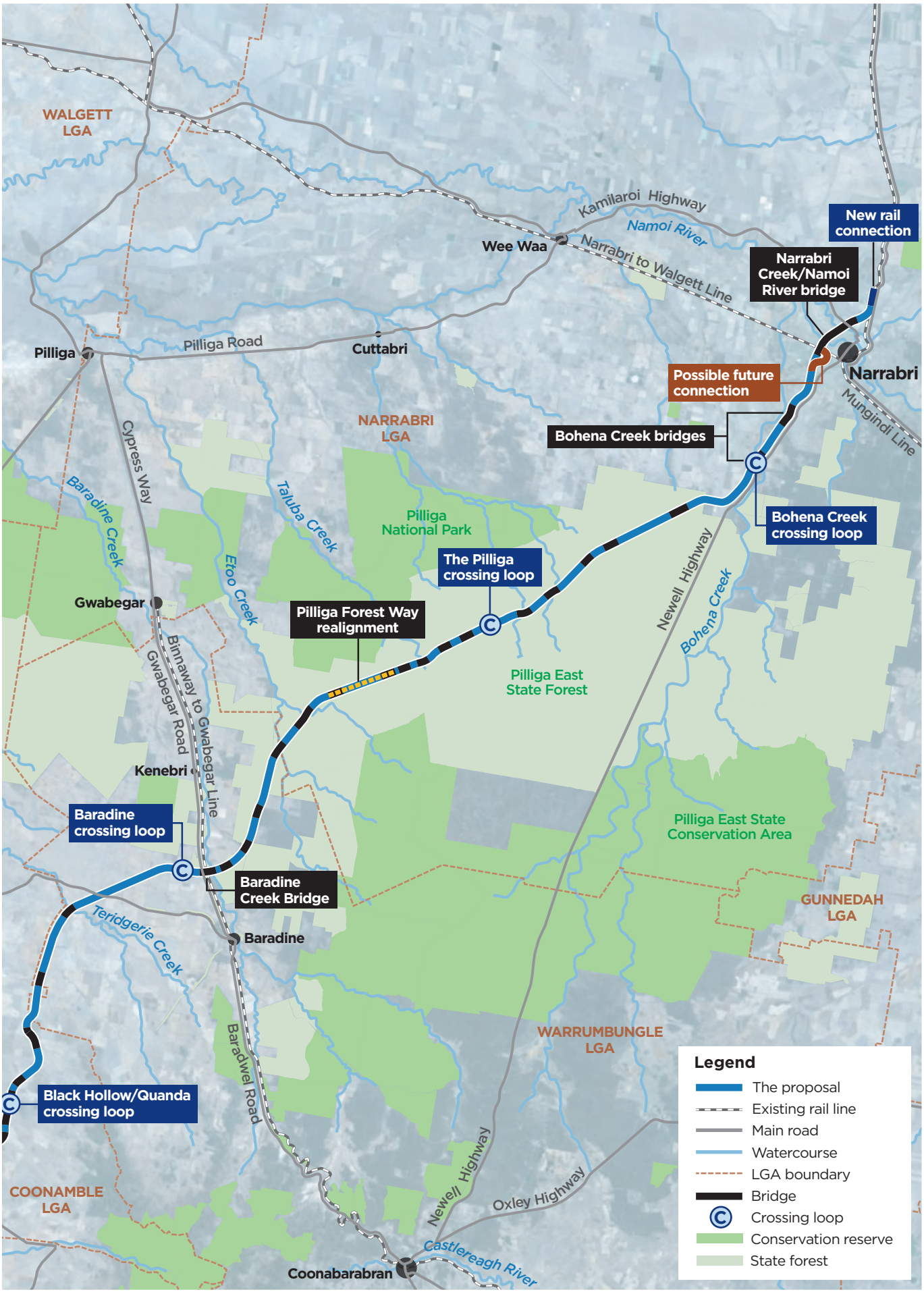

Figure 1.2b **Key features of the proposal**

1.2.3 Construction overview

An indicative construction strategy has been developed based on the current reference design to be used as a basis for the environmental assessment process. Detailed construction planning, including programming, work methodologies, staging and work sequencing would be undertaken once construction contractor(s) have been engaged and during detailed design.

Timing and work phases

Construction of the proposal would involve five main phases of work as outlined in Table 1.1. It is anticipated that the first phase would commence in late 2021, and construction would be completed in 2025.

Table 1.1 Main construction phases and indicative activities

Phase	Indicative construction activities
Pre-construction	• Establishment of areas to receive early material deliveries • Delivery of certain materials that need to be bought to site before the main construction work
Site establishment	• Establishment of key construction infrastructure, work areas and other construction facilities • Installing environmental controls, fencing and site services • Preliminary activities including clearing/trimming of vegetation
Main construction works	• Construction of the proposed rail and road infrastructure, including earthworks, track, bridge and road works
Testing and commissioning	• Testing and commissioning of the rail line and communications and signalling systems
Finishing and rehabilitation	• Demobilisation and decommissioning of construction compounds and other construction infrastructure • Restoration and rehabilitation of disturbed areas

Key construction infrastructure

The following key infrastructure is proposed to support construction of the proposal:

- borrow pits:
  - borrow pit A – Tantitha Road, Narromine
  - borrow pit B – Tomingley Road, Narromine
  - borrow pit C – Euromedah Road, Narromine
  - borrow pit D – Perimeter Road, Narrabri
- three main compounds, which would include a range of facilities to support construction ('multi-function compounds'), located at:
  - Narromine South
  - Curban
  - Narrabri West
- temporary workforce accommodation for the construction workforce:
  - within the Narromine South multi-function compound
  - Narromine North
  - Gilgandra
  - Baradine
  - within the Narrabri West multi-function compound.

The key construction infrastructure are shown in Figure 1.3.

Other construction infrastructure would include a number of smaller compounds of various sizes located along the proposal site, concrete batching plants, laydown areas, welding yards, a concrete pre-cast facility and groundwater bores for construction water supply.

1.2.4 Operation

The proposal would form part of the rail network managed and maintained by ARTC. Train services would be provided by a variety of operators. Inland Rail as a whole would be operational once all 13 sections are complete, which is estimated to be in 2025.

It is estimated that Inland Rail would be trafficked by an average of 10 trains per day (both directions) in 2025, increasing to about 14 trains per day (both directions) in 2040. This rail traffic would be in addition to the existing rail traffic using other lines that the proposal interacts with.

The trains would be a mix of grain, bulk freight, and other general transport trains. Total annual freight tonnages would be about 10 million tonnes in 2025, increasing to about 17.5 million tonnes in 2040.

Train speeds would vary according to axle loads, and range from 80 to 115 kilometres per hour.

1.3 Purpose and scope of this report

The purpose of this report is to assess the potential aquatic ecology impacts from constructing and operating the proposal. The report:

- addresses the relevant SEARs listed in Table 1.2
- describes the existing environment with respect to aquatic ecology
- assesses the impacts of constructing and operating the proposal on aquatic ecology
- recommends measures to mitigate and manage the impacts identified.

The methodology for the assessment is described in section 3.

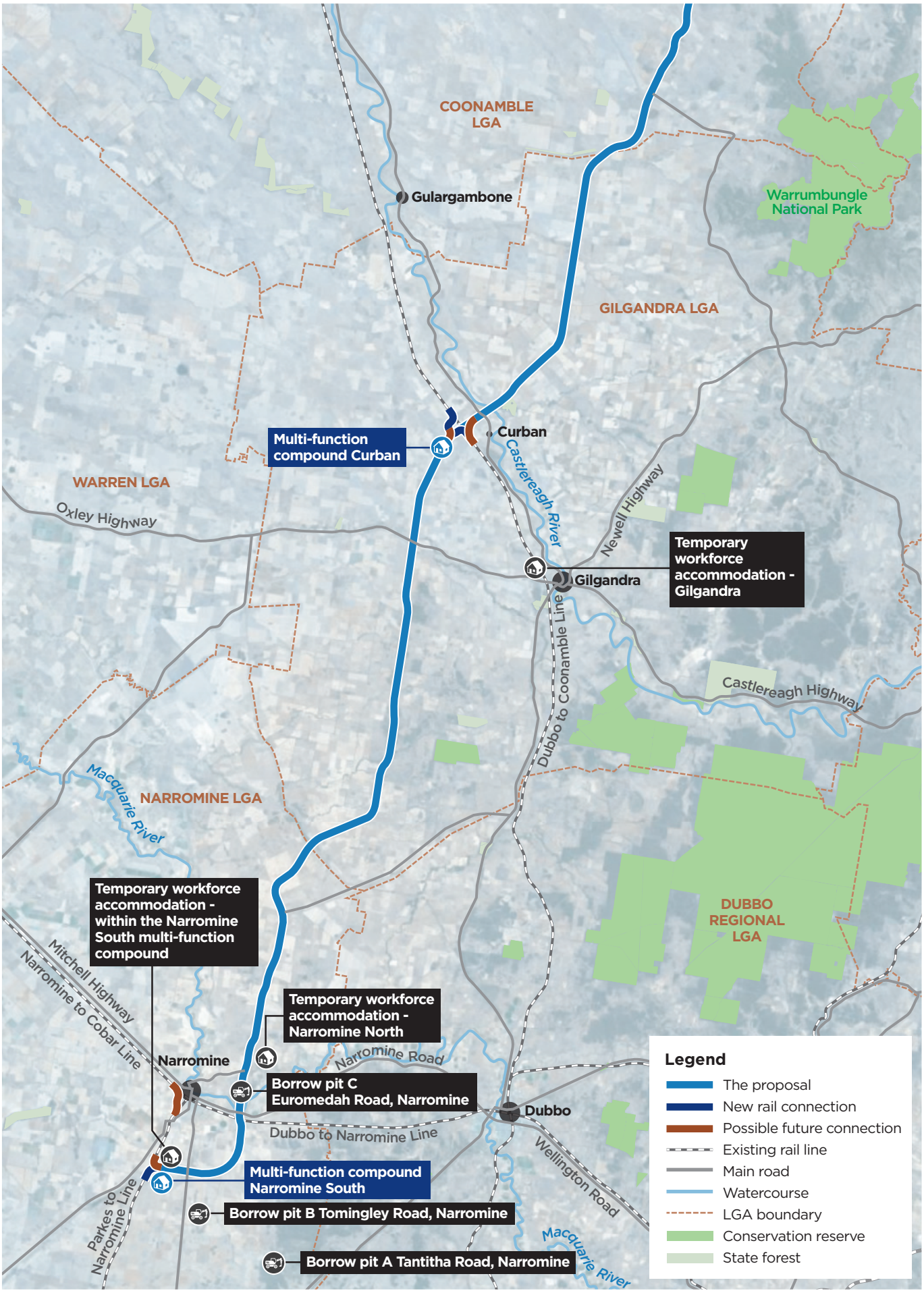

Figure 1.3a **Key construction infrastructure**

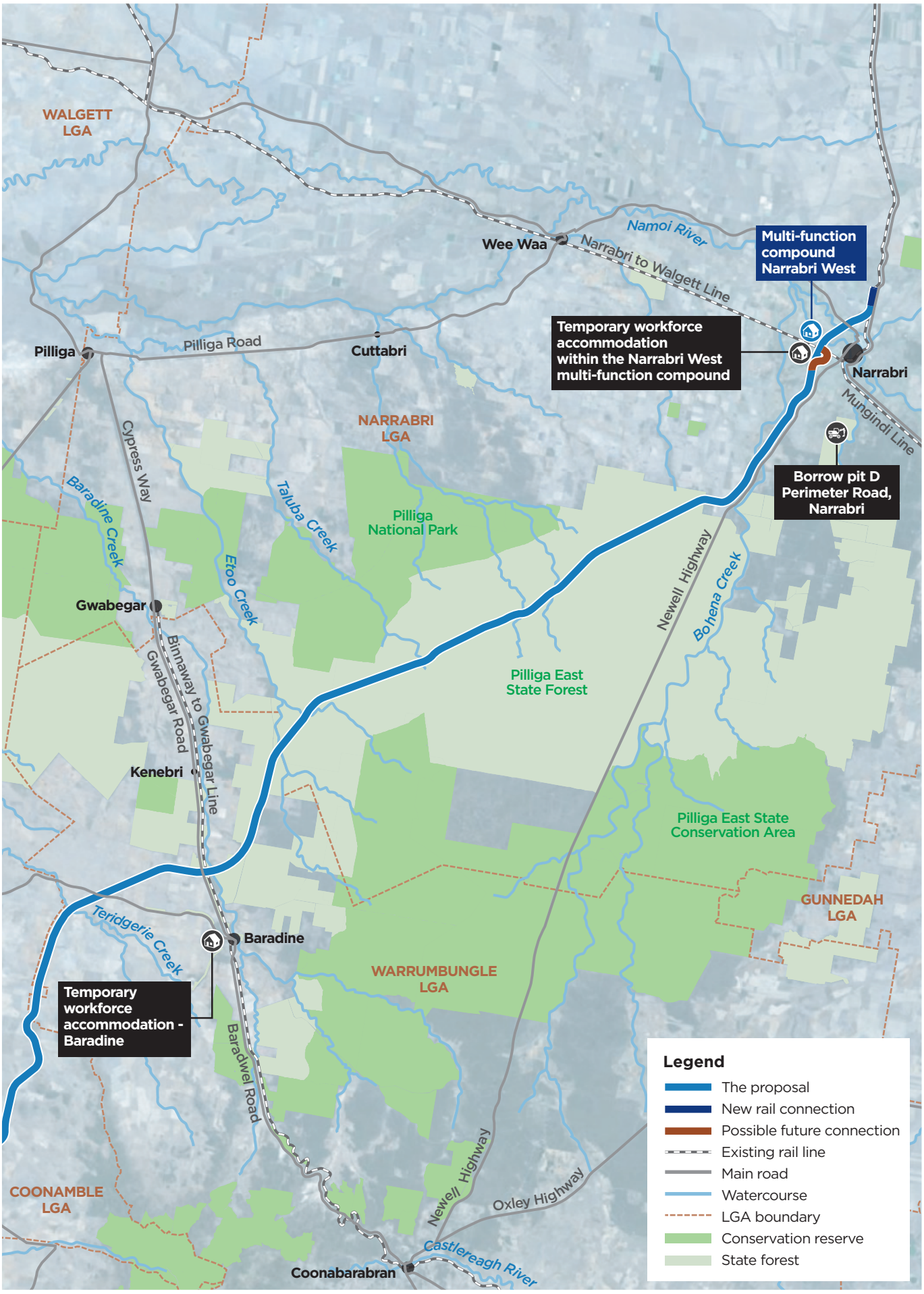

Figure 1.3b **Key construction infrastructure**

Table 1.2 SEARs relevant to this assessment

SEAR number	Requirements	Where addressed in this report
1.2	The project will impact matters of national environmental significance (MNES) protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and will be assessed under an Accredited Assessment. The Proponent must assess impacts to MNES protected under the EPBC Act. The assessment must be in accordance with the agency recommendations listed in Attachment A.	Section 7.3 includes a summary of the 'assessment of significance' undertaken for the Murray Cod, which is listed as a 'vulnerable' species under the EPBC Act. The assessment of significance for the Murray Cod is detailed in Appendix B.
6.6	The Proponent must assess any impacts on biodiversity values not covered by the BAM. This includes a threatened aquatic species assessment (Part 7A *Fisheries Management Act 1994*) to address whether there are likely to be any significant impact on listed threatened species, populations or ecological communities listed under the *Fisheries Management Act 1994* (FM Act).	Section 7.3 includes a summary of the '7-part tests' which have been undertaken for threatened aquatic species, populations and ecological communities (listed under the FM Act) that are predicted in the study area. The '7-part tests' for each species are detailed in Appendix B.
6.7	The Proponent must identify whether the project, or any component of the project, would be classified as a Key Threatening Process (KTP) in accordance with the listings in the BC Act, FM Act and EPBC Act.	Section 7.1 describes the proposal activities that constitute a KTP as outlined in the FM Act. Proposed activities that constitute a KTP in the BC Act and EPBC Act are addressed in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).
7.1	The Proponent must assess the impacts of the project on environmentally sensitive land and processes (and the impact of processes on the project) including, but not limited to:	
	(a) Protected areas (including land and water) managed by OEH and/or DPI Fisheries under the *National Parks and Wildlife Act 1974* and the *Marine Estate Management Act 2014*;	Section 7.2.1 addresses impacts to protected areas (water) in the proposal area. Impact to protected areas (terrestrial) are addressed in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).
	(b) Key Fish Habitat as mapped and defined in accordance with the FM Act;	Section 7.2.2 addresses the potential impacts to Key Fish Habitat (KFH).
	(c) Waterfront land as defined in the *Water Management Act 2000;*	Section 7.2.3 addresses impacts to waterfront land. Impacts to waterfront land are also addressed in the *ARTC Inland Rail Narromine to Narrabri Agriculture and Land Use Assessment* (JacobsGHD, 2020e).

SEAR number	Requirements	Where addressed in this report
	(d) Land or waters identified as Critical Habitat under the BC Act, FM Act or EPBC Act; and	Section 7.2.4 addresses impacts to critical habitat (water) in the proposal area. Impacts to critical habitat (land) is addressed in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).
10.3	The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	
	(a) Natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Section 5.4 and 6.3 describe the construction and operational impacts on natural processes within rivers and wetlands, particularly with regard to impacts to instream habitat, riparian vegetation and aquatic connectivity. Impacts to natural processes within river systems, landscape health and floodplains have also been addressed in *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d).
	(b) Impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Section 7.4 provides a summary of the potential impacts to aquatic groundwater dependent ecosystems (GDEs). Impacts associated with the permanent or temporary interruption of groundwater flow is described within the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020b).
	(d) Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Section 5.4 describes the impacts of erosion and sedimentation on aquatic ecosystems from the clearance of riparian vegetation. Impacts from erosion and sedimentation are further described in the *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d).
11.1	(h) Identify sensitive receiving environments (which may include marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments;	Section 3.3 describes the approach applied to determining sensitive receiving environments (SREs) within the study area. Section 4.8 identifies the SREs and section 9 describes the recommended mitigation strategy that aim to avoid impacts to SREs.

1.4 Structure of this report

The structure of the report is outlined below.

- Section 1 – provides an introduction to the report and outlines relevant SEARs to be addressed.
- Section 2 – provides an overview of relevant legislation, policies and guidelines applicable to this assessment.
- Section 3 – describes the methodology and approach for the assessment.
- Section 4 – describes the existing environment with respect to catchments, watercourses, water quality, as well as threatened aquatic species and ecological communities found within the study area. This section also describes watercourses that have been identified as SREs.
- Section 5 – provides an assessment of the impacts to aquatic ecology from the construction of the proposal.
- Section 6 – provides an assessment of the impacts to aquatic ecology from the operation of the proposal.
- Section 7 – provides an assessment of the potential impacts on sensitive environments.
- Section 8 – provides an assessment of cumulative impacts.
- Section 9 – provides recommended mitigation and management measures.
- Section 10 – concludes the key findings and recommendations from the investigation.

2. Legislative and policy context

This section provides assessment requirements and a review of the legislation and environmental planning instruments that are applicable to the assessment of the proposal's potential impacts on aquatic ecosystems.

2.1 Legislative requirements

2.1.1 Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act protects Matters of National Environmental Significance (MNES). Under the EPBC Act, an action would require approval from the Minister for the Environment if the action has, will have, or is likely to have, a significant impact on MNES. MNES are defined in the EPBC Act and include the following biodiversity-related matters:

- Commonwealth marine areas
- Great Barrier Reef Marine Park
- listed migratory species
- listed threatened species and ecological communities
- Ramsar-listed wetlands.

The significance of impacts is determined in accordance with the *Significant impact guidelines 1.1 – Matters of National Environmental Significance* (DoE, 2013). The guidelines have been developed to assist proponents in deciding if a referral to the Department of Agriculture, Water and the Environment (DAWE) would be required. An assessment of significance was undertaken for aquatic species that were identified as threatened under the EPBC Act. See Appendix B.

Where a project is likely to have a significant impact on a Protected Matter, the project is referred to the Minister for the Environment. The referral process involves a decision on whether or not the project is a 'controlled action'. When a project is declared a controlled action, approval from the Minister is required.

The proposal was declared a controlled action on 05 November 2018 (EPBC reference 2018/8259).

2.1.2 NSW legislation

Environmental Planning and Assessment Act 1979

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 (the Regulation) provide the framework for development assessment in NSW. The EP&A Act and the Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction.

The proposal is declared State significant infrastructure (SSI) and an EIS has been prepared under Division 5.2 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to aquatic species, communities and their habitat. An impact assessment has been carried out for threatened species, endangered populations and ecological communities listed under the *Fisheries Management Act 1994* (FM Act) and EPBC Act.

Under section 5.23 of the EP&A Act, the requirement for specified authorisations and specified provisions of legislation that may prohibit a State Significant Infrastructure project, do not apply. Of relevance to this report is that the requirement for permits under sections 201, 205 or 219 of the FM Act do not apply.

Fisheries Management Act 1994

The FM Act provides for the conservation, protection and management of fisheries, aquatic systems and habitats in NSW. The FM Act is administered by the Department of Planning, Industry and Environment (DPIE) (Regions, Industry, Agriculture and Resources) and establishes mechanisms for:

- the listing of threatened species, populations and ecological communities or key threatening processes (KTPs)
- the declaration of critical habitat
- consideration and assessment of threatened species impacts in the development assessment process.

Part 7A, Division 12 of the FM Act relates to the environmental assessment of a development under Part 5 of the EP&A Act. Section 4.7.2 of this report identified threatened species, populations and ecological communities listed under Schedule 4, 4A and 5 of the FM Act which are predicted to occur in the study area. Appendix B of this report assesses likely impacts of the proposal on these listed species in accordance with sections 221ZV and 221ZX of the FM Act.

With regard to this proposal, construction works associated with some watercourse crossing structures would require 'dredging' (excavation of water land or removal of material from water land) or 'reclamation' (using material to fill/reclaim or depositing material to construct anything other than water land) as defined under section 198A of the FM Act. In addition, construction and operation of the proposal would result in the 'temporary or permanent blockage of fish passage within watercourses' as defined under section 219 of the FM Act. Section 4.8 of this report describes aquatic habitats where works are proposed.

Part 7 of the FM Act relates to the protection of aquatic habitats, including providing management of dredging and reclamation works within permanently or intermittently flowing watercourses, as well as the temporary or permanent blockage of fish passage within a watercourse. However, by force of section 5.23 of the EP&A Act, the requirement to receive permits for these activities (listed under sections 201, 205 or 219 of the *Fisheries Management Act 1994*) do not apply.

Despite the exemption, any construction of watercourse structures and/or crossings would consider fish habitat class as defined in *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013), as well as the use of appropriately designed water crossing structures that do not obstruct fish passage (as recommended in *Why do Fish need to Cross the Road? Fish Passage Requirements for Watercourse Crossings (*Fairfull and Witheridge, 2003)).

Further, Part 7A of the FM Act states that a threatening process is eligible to be listed as a "key threatening process" if, in the opinion of the Fisheries Scientific Committee –

- "it adversely affects threatened species or ecological communities, or
- it could cause species or ecological communities that are not threatened to become threatened".

Schedule 6 of the FM Act outlines the KTPs related to aquatic species and ecological communities. Of the KTPs listed, the proposal is expected to involve the following:

- degradation of native riparian vegetation along NSW water courses
- installation and operation of instream structure and other mechanisms that alter natural flow regimes of rivers and streams
- removal of large woody debris from NSW rivers and streams.

Impacts due to KTPs are discussed further in section 7.1.

Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* (BC Act) provides legal status for biota of conservation significance in NSW. The BC Act aims to, amongst other things, 'maintain a healthy, productive and resilient environment for the greatest well-being of the community, now and into the future, consistent with the principles of ecologically sustainable development'. It provides for the listing of threatened species and communities, establishes a framework to avoid, minimise and offset the impacts of proposed development (the Biodiversity Offsets Scheme), and establishes a scientific method for assessing the likely impacts on biodiversity values and calculating measures to offset those impacts (the Biodiversity Assessment Method, BAM).

Of relevance to this assessment, aquatic groundwater dependent ecosystems (GDEs) that are protected under the BC Act have been identified within the study area of the proposal and therefore have been assessed as required. Refer to section 4.8.2 for detail.

2.2 Guidelines and policies

2.2.1 Policy and Guidelines for Fish Habitat Conservation and Management

The *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) is the guideline applicable to all planning and development proposals and various activities that affect freshwater ecosystems in NSW. The aims of this guideline is to maintain and enhance fish habitat for the benefit of native fish species, including threatened species in freshwater environments. First published in 1999, the 2013 updated document assists developers, their consultants and government and non-government organisations to ensure their actions comply with legislation, as well as policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed and offset. The guidelines outlined in this document are taken into account when DPIE (Regions, Industry, Agriculture and Resources) assesses proposals for developments and other activities that affect fish habitats. The document contains:

- background information on aquatic habitats and fisheries resources in NSW
- an outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitat in NSW
- general policies and classification schemes for the protection and management of fish habitats and an outline of the information that DPIE (Regions, Industry, Agriculture and Resources) requires to be included in development proposals that affect habitat
- specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers

- specific policies and guidelines for foreshore works and waterfront developments
- specific policies and guidelines for the management of other activities that affect watercourses.

DPIE (Regions, Industry, Agriculture and Resources) is responsible for the application of the FM Act, Fisheries Management (General) Regulation 2019 and the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) on KFH, ensuring mitigation and compensation measures are in place to redress any adverse environmental impacts to aquatic systems. The guideline states that *"to ensure "no net loss" of aquatic habitats, NSW DPI requires that proponents should, as a first priority, aim to avoid impacts upon KFH. Where avoidance is impossible or impractical, proponents should then aim to minimise impacts. Any remaining impacts should then be offset with compensatory works".*

It is suggested that mitigation may include re-establishing habitat that has been removed or otherwise damaged, re-instating fish passage along waterways (removing barriers or building fishways) and improving water quality.

ARTC met with DPIE (Regions, Industry, Agriculture and Resources) on 14 August 2020 to discuss the requirement of an aquatic biodiversity offset strategy for impacts to watercourses which have been identified as KFH. It was confirmed that, with the implementation of the proposed design and alignment, construction methodology, mitigation measures, rehabilitation strategy and operational monitoring and management, no areas of KFH would be permanently lost or disrupted therefore no offsets would be required. This is further discussed in section 7.2.2.

2.2.2 Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings

The DPI guideline *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003*)* provides practical guidelines for the planning, design, construction and maintenance of watercourse crossings aimed at minimising impacts of fish passage and aquatic ecology in general. It should be used in conjunction with the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) by outlining potential impacts of instream structures and design specifications/recommendations for crossings to avoid erecting barriers to fish passage.

Water crossing structures which are proposed to be built across watercourses have been designed in accordance with minimum crossing requirements outlined in *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003*)*. Aquatic habitat assessment has also taken into account requirements of these guidelines. Section 4.8 summarises SREs in the study area based on desktop and field assessment. Further detail of the aquatic habitat assessment at survey sites is available in Appendix A.

2.2.3 Aquatic Ecology in Environmental Impact Assessment – EIA Guideline

DPIE's *Aquatic Ecology in Environmental Impact Assessment - EIA guideline* (NSW Department of Planning, 2003) (the EIA guideline) provides a framework to assist proponents of projects and their consultants, the community and decision-makers in the identification, prediction and assessment of impacts and suggest approaches to the management of impacts that have been predicted or observed through monitoring. The guidelines also aim to facilitate improvement of the environmental impact process in general by:

- Encouraging a standardised, rigorous approach to aquatic investigations in environmental impact assessment.
- Providing information which can be used to understand and manage changes to the aquatic environment in NSW.

The guidelines apply to the assessment of impacts on aquatic habitats including coastal waters, estuaries, rivers and streams, natural and artificial lakes and reservoirs, and permanent and ephemeral wetlands. The guidelines may be applied whenever aquatic ecological assessment is required under the EP&A Act. The guidelines provide reference for:

- The extent to which the existing environment needs to be described.
- The extent to which a proposal is likely to affect aquatic ecology.
- The minimal acceptable standard for assessment of potential impacts on aquatic ecology.
- Predicting cumulative impacts within a body of water.
- When monitoring should be done and what components of aquatic ecology (biotic and abiotic) should be monitored.
- Requirements for adequate information to manage potential impacts and initiate feedback from monitoring to management.

The existing environment, assessment and sampling methodology, potential impacts, as well as recommendations for mitigation measures and monitoring programs which are outlined in this report have taken into consideration the EIA guidelines.

2.2.4 NSW Biodiversity Offsets Policy for Major Projects

The *NSW Biodiversity Offsets Policy for Major Projects* (OEH, 2014) clarifies and standardises biodiversity impact assessment and offsetting for major project approvals in NSW. Biodiversity offsets provide benefits to biodiversity to compensate for adverse impacts of a proposed action. They assist in achieving long-term conservation outcomes while providing development proponents with the ability to undertake actions that have unavoidable impacts on biodiversity.

Under the policy, the default position is that impacts must be offset in a like-for-like manner. This means that aquatic habitat that is impacted must be offset with the same aquatic habitat. Where like-for-like is not available (provided reasonable steps have been taken to locate an appropriate measure at that level), variation rules can be applied to allow for aquatic habitat to be offset in similar or more threatened habitat within the same catchment.

Unlike for terrestrial biodiversity offsets, aquatic habitat offsets are not undertaken through biodiversity stewardship agreements, as a method for quantifying aquatic biodiversity using tradable credits is yet to be developed. Aquatic offsets instead use mechanisms outlined in the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013).

The Biodiversity Offset Policy states that *"to meet aquatic biodiversity offset requirements, the Fisheries NSW policy and guidelines (DPI, 2013) will classify the habitat types being offset. It will then apply a ratio and dollar value to determine the total dollar value of the offset required to be implemented by the proponent via on-ground protection or rehabilitation works, or placed into the aquatic biodiversity offset fund. The proponent will have the opportunity to reduce this cost through direct negotiation with Fisheries NSW, subject to meeting the minimum overall offset ratio requirements".*

ARTC met with DPIE (Regions, Industry, Agriculture and Resources) on 14 August 2020 to discuss the requirement of an aquatic biodiversity offset strategy for impacts to watercourses which have been identified as KFH. It was agreed that, with the implementation of the proposed design and alignment, construction methodology, mitigation measures, rehabilitation strategy and operational monitoring and management, no areas of KFH would be permanently lost or disrupted therefore no offsets would be required. This is further discussed in section 7.2.2.

2.2.5 Guideline for controlled activities on waterfront land

Controlled activities carried out in, on or under waterfront land are regulated by the *Water Management Act 2000* (WM Act). This Act defines waterfront land to include the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river lake or estuary.

Under section 5.23 of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the WM Act 2000 is not required for SSI. The former NSW Department of Primary Industries, Office of Water prepared guidelines for controlled activities which provide information on the design and construction of a controlled activity, and other ways to protect waterfront land. Despite the exemption, the design and construction of the proposal would take into account the NSW DPI (2018) guidelines for controlled activities on waterfront land.

3. Assessment approach

3.1 Study area

The study area for the aquatic ecology assessment is the area either directly or indirectly affected by the proposal. For the purposes of this aquatic ecology assessment, the study area is identified as the proposal site as shown in Figure 1.2 and comprises the construction and operational footprints and a 500 metre buffer around the alignment (refer Figure 3.1).

3.2 Background research

A desktop review of previous literature and reports relevant to the proposal has been undertaken. The following public database searches were performed for all watercourses along the proposed alignment:

- *Directory of important wetlands* (DAWE, 2020) (accessed April 2020)
- *Freshwater threatened species distribution maps* (DPI, 2016) (accessed April 2020)
- *Key Fish Habitat Maps* (DPI, 2007a) (accessed April 2020)
- Mapping of State Forests and National Parks (NPWS, 2020) (accessed April 2020)
- BioNet - the Atlas of NSW Wildlife *Threatened Species Profile Database* (Environment, Energy and Science Group (EESG), 2020) (accessed April 2020)
- Protected Matters Search Tool (DAWE, 2020) (accessed April 2020)
- Bureau of Meteorology (BOM) *Groundwater Dependent Ecosystems Atlas* (BOM, 2020) (accessed April 2020)
- *Atlas of Living Australia* (ALA) (ALA, 2020) (accessed April 2020).

Other relevant literature reviewed included:

- ANZECC/ARMCANZ, 2000 *National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.
- ANZG, 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Governments and Australian state and territory governments. Canberra ACT, Au.stralia. Available at www.waterquality.gov.au/anz-guidelines. Accessed February 2020
- Copeland, C., Schooneveldt-Reid, E. and Neller, S., 2003, *Fish Everywhere - an oral history of fish and their habitats in the Gwydir River*, NSW Fisheries.
- Frawley, J Nichols, S, Goodall. H. and Baker, E., 2011, *Namoi: Talking Fish – making connections with the rivers of the Murray-Darling Basin*, Murray Darling Basin Authority, Canberra.
- Green D., Petrovic J., Moss P., Burrell M., 2011, *Water resources and management overview: Namoi catchment*, NSW Office of Water, Sydney.
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- Lintermans, M., 2007, *Fishes of the Murray Darling Basin: An introductory guide*. MDBC Publication No., Accessed August 2019.

- Murray–Darling Basin Authority, 2012, *Sustainable Rivers Audit 2: The ecological health of rivers in the Murray–Darling Basin at the end of the Millennium Drought (2008–2010)*.
- Murray-Darling Basin Commission, 2003, *Native Fish Strategy for the Murray-Darling Basin* 2003-2013, May 2003.
- NSW Department of Planning, 2003, *Aquatic Ecology in Environmental Impact Assessment*, EIA Guideline Series.
- NSW Department of Primary Industries, 2006, *Reducing the Impact of Weirs on Aquatic Habitat - NSW Detailed Weir Review*. Border Rivers / GwydirCMA region. Report to the NSW Environmental Trust.
- NSW Department of Primary Industries, 2013, *Policy and guidelines for fish habitat conservation and management*, Department of Trade and Investment, Regional Infrastructure and Services.
- NSW Department of Primary Industry, 2015, *Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray-Darling Basin – Valley Scale Report,* Final report prepared for the Murray-Darling Basin Authority. NSW Department of Primary Industries, Tamworth.
- Transport for NSW, 2017, *Sustainable Design Guidelines*, Version 4.0.
- Umwelt Australia Pty Limited, 2014, *Melbourne Brisbane Inland Railway Parkes to Narromine and Narrabri to North Star – Ecological Investigations*, on behalf of ARTC.

Additionally, literature related to potentially impacted threatened species was also reviewed during research. Literature included:

- Cadwallader, P.L., & Eden, A.K., 1979, “Observations of the food of the Macquarie Perch *Macquaria australasica* (Pices: Percichthyidae), during the initial filling phase of Lake Dartmouth, Victoria”, *Australian Journal of Marine and Freshwater Research*, vol. 37, pp. 7 – 657.
- Fisheries Scientific Committee, 2008, *The Tandanus tandanus – Eel Tailed Catfish in the Murray-Darling Basin as an endangered population*, Established under Part 7 of the NSW Fisheries Management Act 1994.
- Kalatzis, A. & Baker, L., 2010, *Murray Cod (Maccullochella peelii peelii) Fact Sheet,* Recreational Fishers’ Education Project – NSW Industry & Investment and Southern Cross University.
- National Murray Cod Recovery Team, 2010, *National Recovery Plan for the Murray Cod Maccullochella peelii peelii*, Department of Sustainability and Environment, Melbourne.
- NSW Department of Primary Industries, 2007a, *Primefact: Endangered ecological communities in NSW*: *Lowland Darling River aquatic ecological community*, September 2007, Primefact 173 Second Edition, Fisheries Conservation and Aquaculture Branch, Port Stephens Fisheries Institute.
- NSW Department of Primary Industries, 2014, *Primefact: Flathead Galaxias (Galaxias rostratus)*, December 2014, Primefact 880, First Edition, Aquatic Ecosystems Unit, Port Stephens Fisheries Institute.
- NSW Department of Primary Industries, 2017a, *Primefact: Trout Cod (Maccullochella macquariensis)*, February 2017, Primefact 185, Third Edition, Threatened Species Unit, Port Stephens Fisheries Institute.

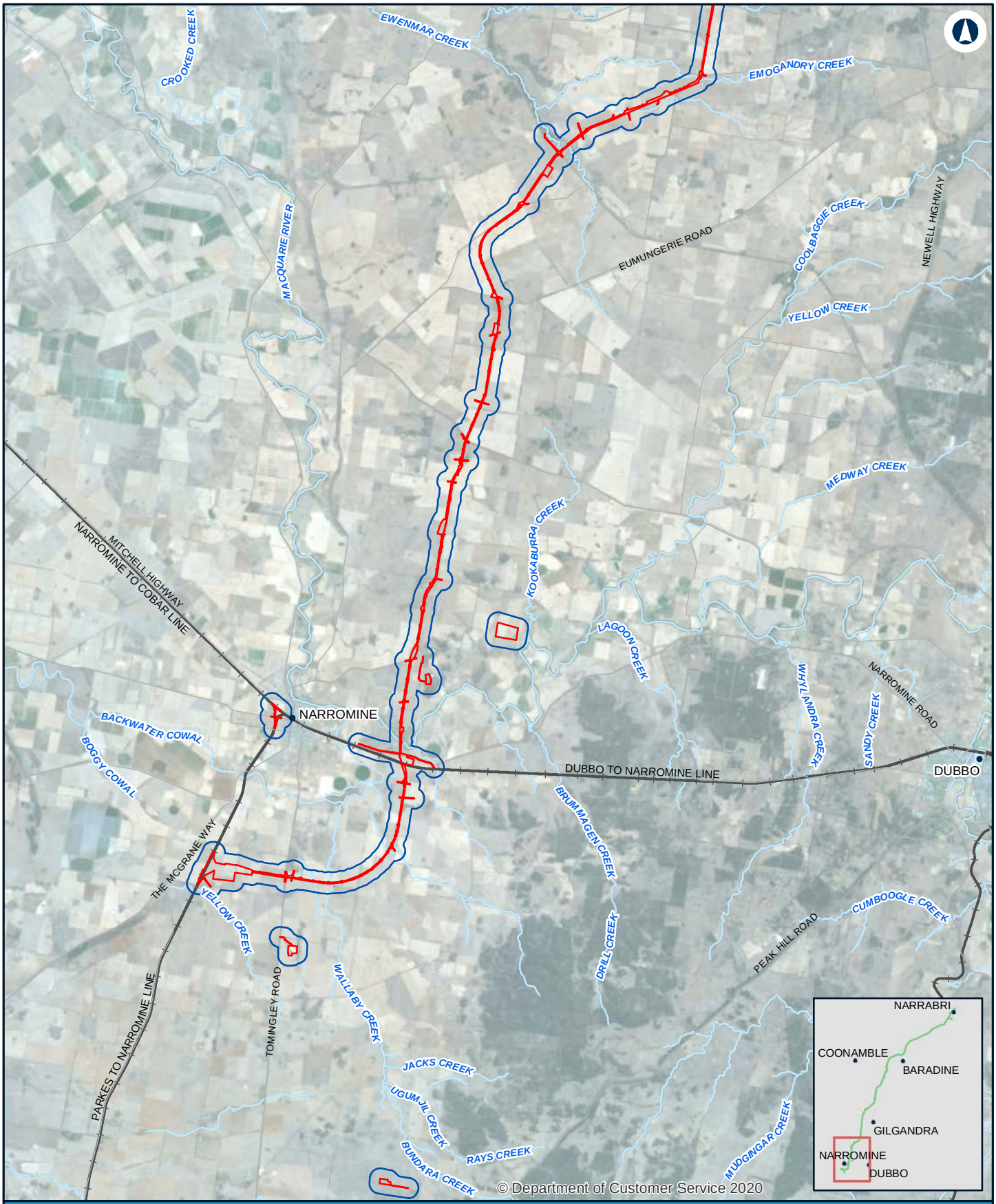
- NSW Department of Primary Industries, 2017b, *Primefact: Southern Purple Spotted Gudgeon (Mogurnda adspersa)*, July 2017, Primefact 1275, Second Edition, Threatened Species Unit, Port Stephens Fisheries Institute.
- NSW Department of Primary Industries, 2017c, *Primefact: Silver Perch (Bidyanus bidyanus)*, July 2017 Primefact 8, Third Edition, Threatened Species Unit, Port Stephens Fisheries Institute.

3.3 Classification of sensitive receiving environments

SREs are environments that have a high conservation or community value or support ecosystem/human uses of water that are particularly sensitive to pollution or degradation of water quality. SREs were identified upstream and downstream of the proposal based on the following conditions:

- waterway classification (Fairfull and Witheridge, 2003)
- key fish habitat mapping (DPI, 2007a)
- aquatic habitat field assessment which was completed in accordance with the requirements of DPI (2013)
- presence of threatened aquatic species listed under FM Act and EPBC Act based on threatened species distribution mapping (DPI, 2016), and database searches including the Protected Matters Search Tool (DAWE, 2020), Bionet Atlas records (EESG, 2020) and ALA records (ALA, 2020)
- groundwater and surface water dependent vegetation and fauna communities listed under the BC Act and EPBC Act
- proximity to a drinking water catchment
- areas that contribute to aquaculture and commercial fishing.

SREs are identified in section 4.8. Further details of aquatic habitat assessment at survey sites can be found in Appendix A.



NARROMINE TO NARRABRI Study area Figure 3.1a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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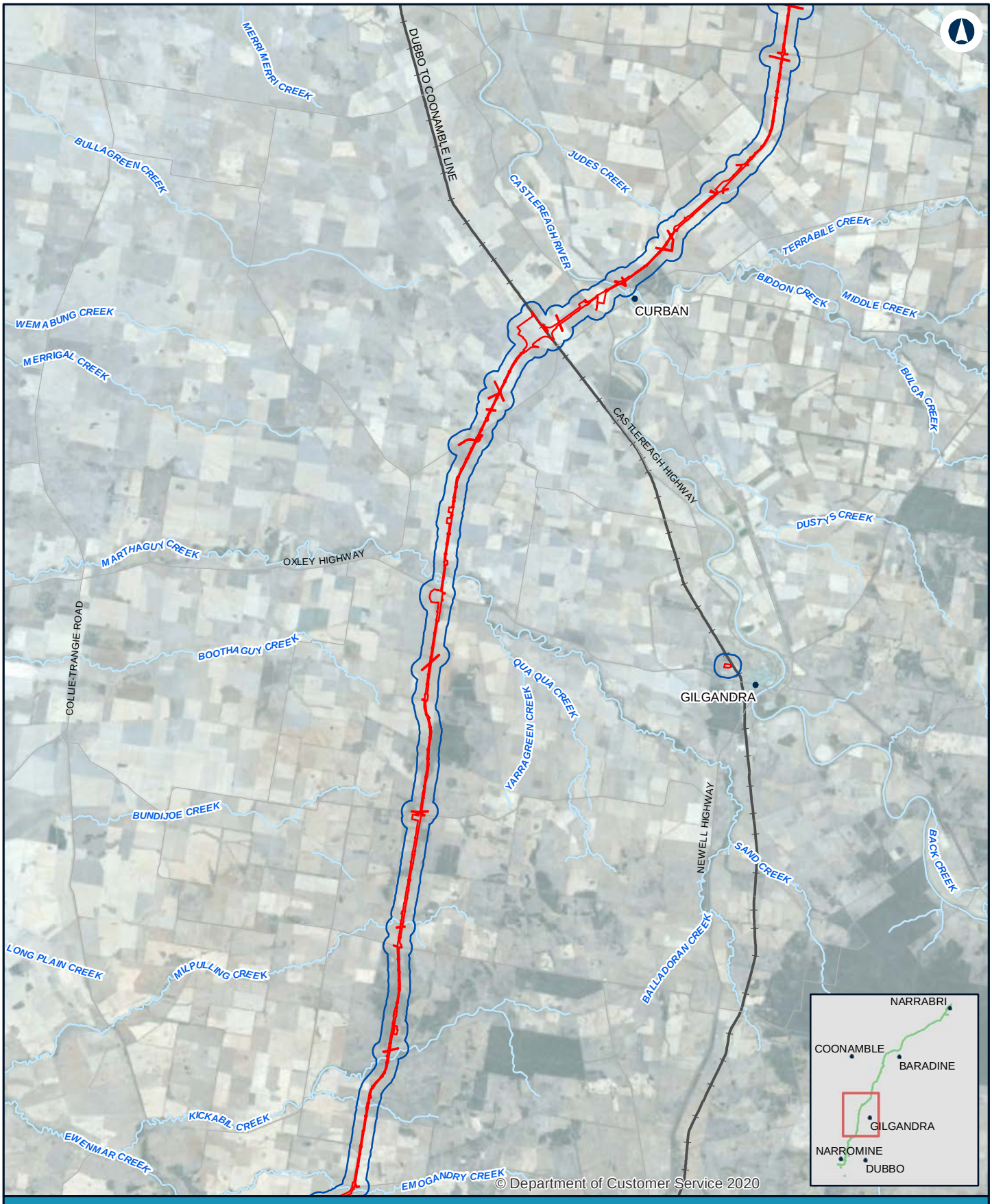

NARROMINE TO NARRABRI Study area Figure 3.1b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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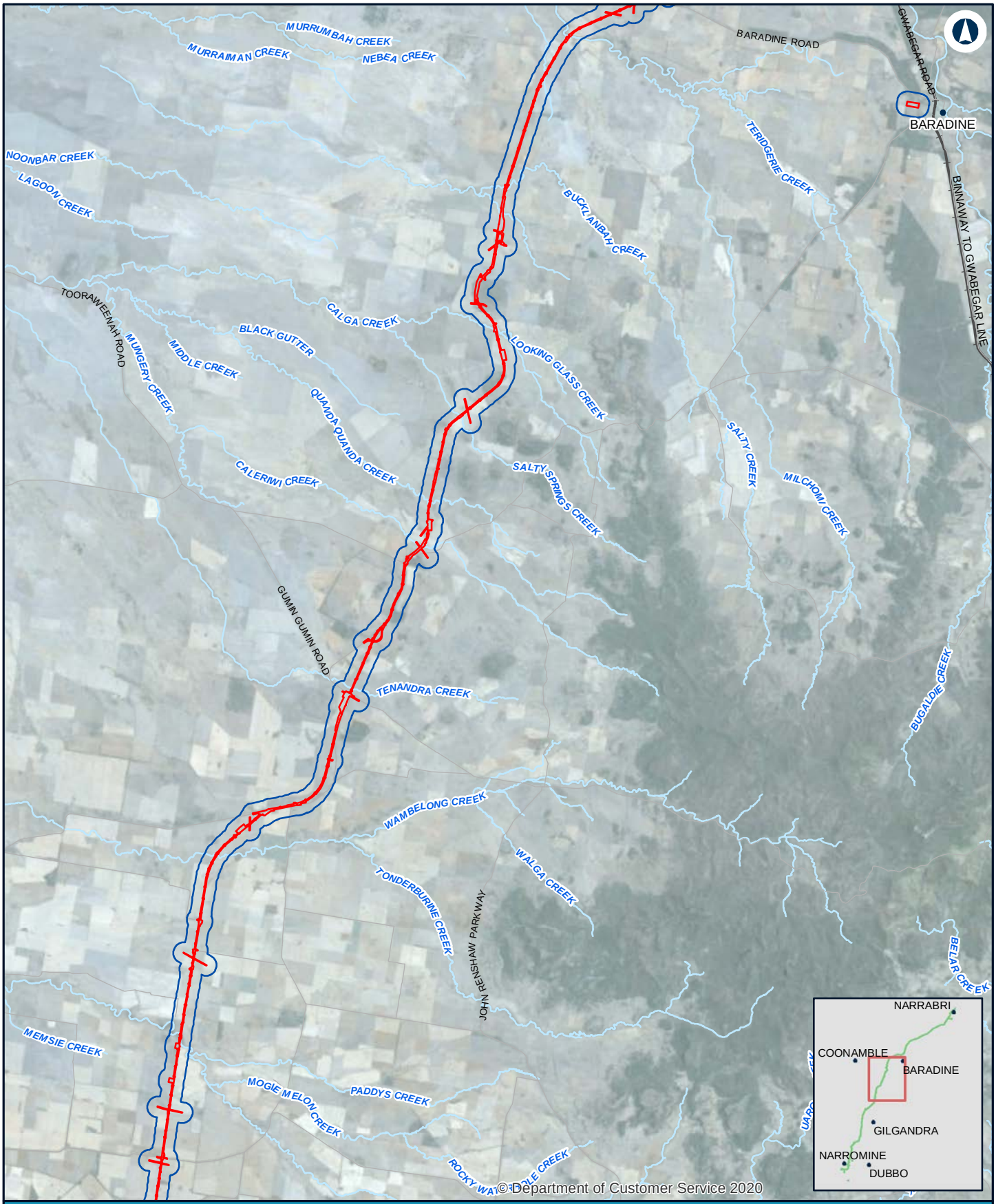

NARROMINE TO NARRABRI Study area Figure 3.1c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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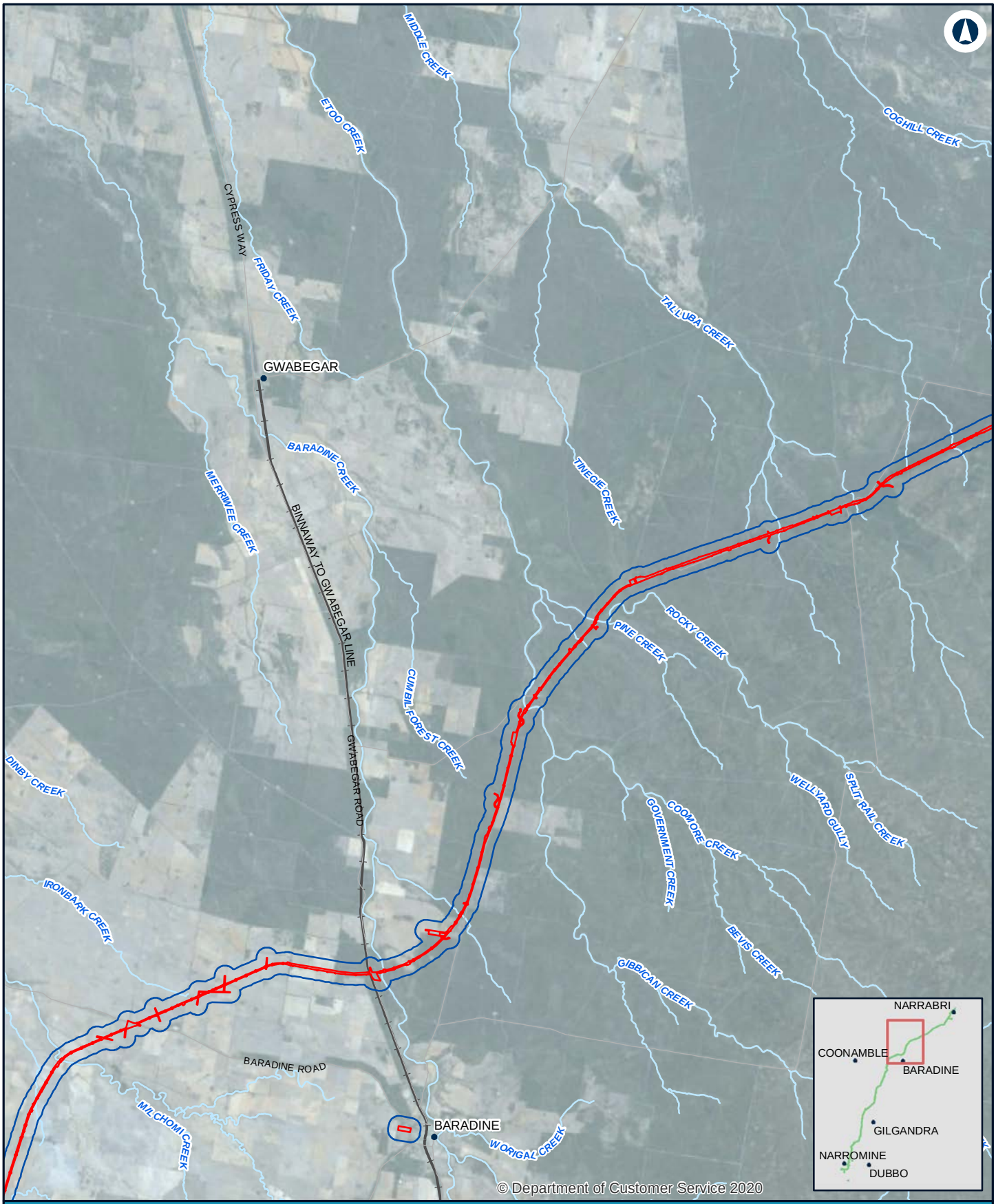

NARROMINE TO NARRABRI Study area Figure 3.1d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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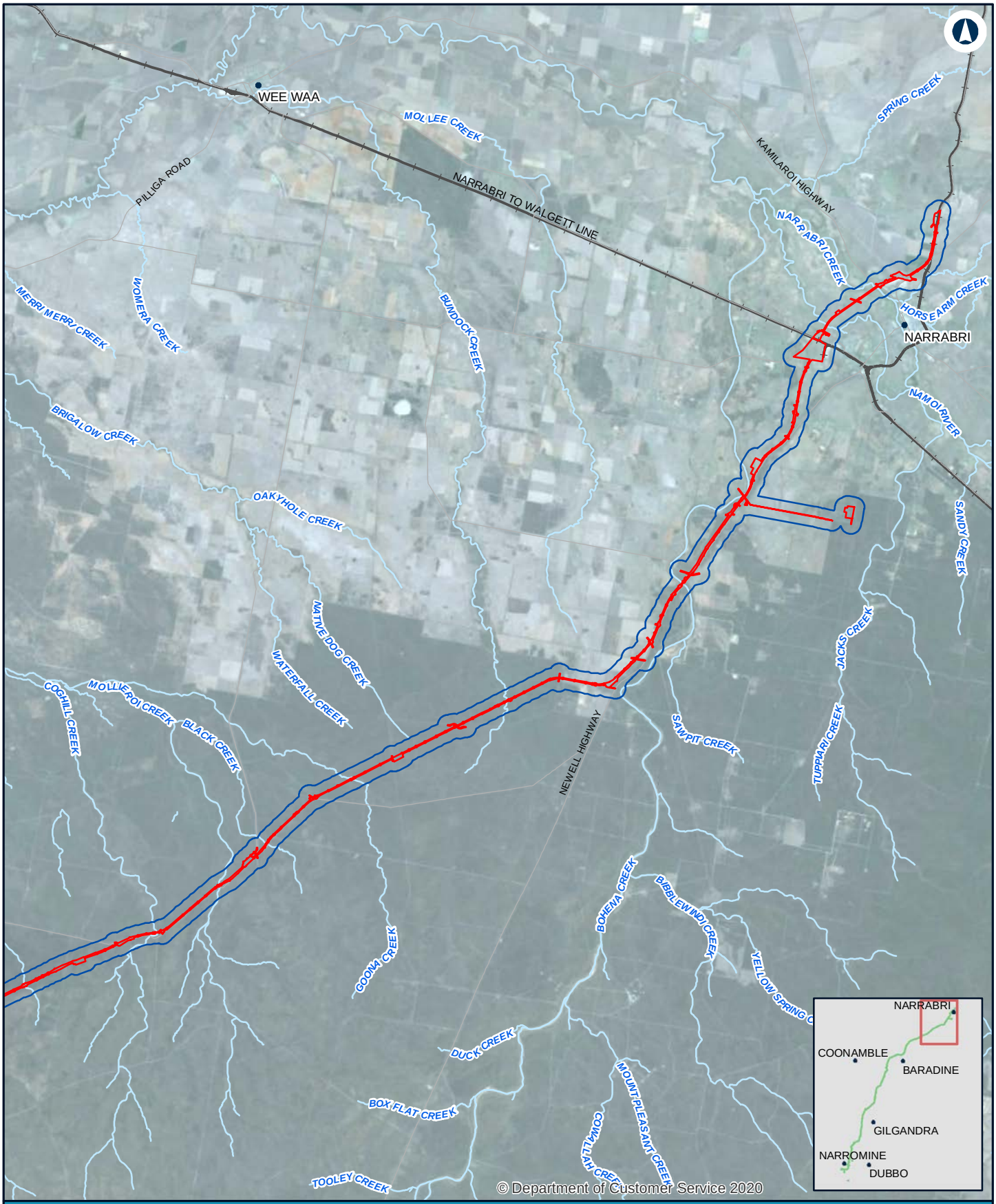

NARROMINE TO NARRABRI Study area Figure 3.1e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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3.4 Stream order mapping

In characterising the watercourses in the area, consideration has been given to the Strahler ordering system (Strahler, 1952). The Strahler ordering system is a hierarchical numbering system based on the degree of branching within a watercourse and provides an indication of the complexity of the creek system. In summary, the methodology used is as follows:

- At its origins, a watercourse is numbered as first order. The watercourse remains first order until it joins another watercourse.
- If the watercourse joins another first order watercourse, downstream of the confluence is deemed second order. The confluence of two watercourses with a similar order results in the order increasing by one, so that two second order streams joining would result in a third order stream, and so on, moving downstream.
- Where a watercourse of a higher order joins with a lower order watercourse, downstream of the confluence remains at the higher order.

The stream ordering system is additionally used to indicate likelihood of a stream containing fish or fish habitat based on its numerical order within the catchment. Within NSW, a stream which is classified as third order or above is recognised as likely to contain valuable fish habitat and support fish populations. Therefore, barriers that may prevent fish passage in third order streams and above should be considered for remediation (DPI, 2013). Each watercourse within the study area has been assessed against the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) and the stream order value has been identified through GIS mapping datasets to determine potentially sensitive receiving environments.

3.5 Watercourse classification

3.5.1 Key fish habitat mapping

In 2007, the then Department of Primary Industries – Fisheries (DPI) published maps of NSW which defined and identified KFH across the state. A policy definition for the term was developed to guide the compilation of the maps. Of relevance to this proposal, KFH was defined to include the following:

- permanently flowing rivers and creeks including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified
- intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified
- billabongs, lakes, lagoons, wetlands associated with other permanent fish habitats (eg permanent rivers and creeks, estuaries etc)
- flood channels or flood runners that may normally be dry but would be used by fish to move/migrate across or along floodplains between habitats during high flow events
- any waterbody, regardless of whether or not it may be listed under the heading 'What is not included?' below, if it is known to support or could be confidently expected (based on predictive modelling) to support threatened species, threatened populations or threatened communities listed under the provisions of Part 7A of the FM Act.

Watercourses that are were excluded from the KFH mapping were:

- unmapped gullies and first and second order streams (based on the Strahler method of stream ordering) as determined from the largest scale topographic map produced for the area concerned (ie use 1:25,000 rather than 1:50:000 and use 1:50:000 rather than 1:100,000 and include all depicted streams)
- farm dams constructed on unmapped gullies and first and second order streams
- purpose built irrigation and other water supply channels and off-stream storages
- irrigation, agricultural or urban drains
- sections of streams that have been concrete lined or piped (but not including where an otherwise natural stream passes through culverts)
- intermittent lagoons or wetlands filled from localised runoff and not otherwise hydrologically connected to other permanent habitats such as rivers, creeks, estuaries and ocean.

Due to the liberal definition of KFHs, the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) provides a framework to classify key fish habitat types based on their aquatic habitat features. This is described in section 3.5.2.

3.5.2 Watercourse classification and KFH sensitivity analysis

Table 3.1 defines the habitat types and sensitivity classes of KFH by application of the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013). These descriptions have formed the basis for:

- classifying watercourses with respect to KFH
- the methodology for aquatic habitat assessment at nominated survey sites (to be considered in the determination of SREs)
- for consideration in determining the offset strategy.

Table 3.1 Key fish habitat types and descriptions (adapted from the DPI, 2013 guidelines)

Habitat type	Description
TYPE 1 – Highly sensitive key fish habitat	• Classified as watercourses that contain any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act • Native aquatic plants • Ramsar, JAMBA, CAMBA, ROKAMBA listed sites • SEPP protected wetlands • Watercourses that contain in-stream gravel beds or rocks greater than 500 mm in two dimensions • Instream woody debris greater than 3 m length or 300 mm in diameter or mound springs
TYPE 2 – Moderately sensitive key fish habitat	• Watercourses that can be defined as freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in TYPE 1 • Weir pools and dams up to full supply level where the weir or dam is across a natural watercourse
TYPE 3 – Minimally sensitive key fish habitat	• Watercourses that contain ephemeral aquatic habitat not supporting native aquatic or wetland vegetation • Unstable or unvegetated sand or mud substrate

Habitat type	Description
Not fish habitat	• First and second order streams on gaining streams (based on the Strahler method of stream ordering) • Farm dams on first and second order streams or unmapped gullies; • Agricultural and urban drains • Urban or other artificial ponds (eg evaporation basins, aquaculture ponds) • Sections of stream that have been concrete-lined or piped (not including a watercourse crossing)

In addition to the habitat type – 'Watercourse class', as outlined in *Why do Fish need to Cross the Road? Fish Passage Requirements for Watercourse Crossings (*Fairfull and Witheridge, 2003*)*, has also been identified to assess functionality of a watercourse, and determine the minimum crossing type requirements to maintain long term fish passage. The criteria by which the watercourse class is derived are defined in Table 3.2**.**

Table 3.2 Classification of watercourses for fish passage (Fairfull and Witheridge, 2003)

Class type	Description	Minimum [1] Recommended Crossing Type
CLASS 1: Major key fish habitat	Characteristics include permanently flowing or flooded freshwater watercourses such as major rivers or major creeks; habitat of a threatened or protected fish species or 'critical habitat'.	Bridge, arch structure or tunnel.
CLASS 2: Moderate key fish habitat	An intermittently flowing stream, creek or watercourse which is generally named, with clearly defined bed and banks and semi-permanent to permanent pools or connected wetland areas; freshwater aquatic vegetation or TYPE 1 and 2 habitats is present.	Bridge, arch structure tunnel, culvert [2] or ford.
CLASS 3: Minimal key fish habitat	A named or unnamed watercourse with intermittent flow and sporadic refuge, breeding or feeding areas for aquatic fauna such as fish or yabbies. Contains semi-permanent pools within the watercourse or adjacent wetlands after a rain event. Otherwise, any minor watercourse that interconnects with wetlands or other CLASS 1-3 fish habitats.	Culvert [3] or ford
CLASS: 4 Unlikely key fish habitat	A generally unnamed watercourse with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or freestanding water or pools are present post rain events. No aquatic flora is present. Examples include dry gullies or shallow floodplain depressions.	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 outlined in *Why do Fish need to Cross the Road? Fish Passage Requirements for Watercourse Crossings (*Fairfull and Witheridge, 2003*).*

[3] Minimum culvert design using the "Low Flow Design" outlined in *Why do Fish need to Cross the Road? Fish Passage Requirements for Watercourse Crossings (*Fairfull and Witheridge, 2003*);* however, "High Flow Design" and "Medium Flow Design" should be given priority where affordable.

3.6 Determination of survey sites

Based on hydroline mapping of the region, the proposal is expected to traverse 102 mapped watercourses and/or waterbodies (including drainage lines and farm dams). Thirty-six of these watercourses are identified as KFH, however only three are permanently flowing (perennial) (Narrabri Creek, Namoi River, and Macquarie River). The remaining 33 watercourses mapped as KFH, and all other named and unnamed watercourses that are not KFH, are ephemeral, meaning they only flow during and after significant rainfall. As such, given the mostly dry climate (refer section 4.3.4), these watercourses are usually dry.

Watercourses chosen for field assessment were prioritised based upon the predicted presence of threatened aquatic species, stream order and the presence of KFH. Watercourses were categorised into three categories - high, moderate and low priority watercourses (see Table 3.3).

Table 3.3 Watercourse priority

Priority Categorisation	Consideration	Watercourses
High	• Threatened fish species predicted to occur based on DPI mapping (DPI, 2016) • Key Fish Habitat (DPI, 2007a)	• Narrabri Creek* • Namoi River* • Tributary of Namoi River • Bohena Creek • Bundock Creek • Goona Creek • Mollieroi Creek • Coghill Creek • Rocky Creek • Etoo Creek • Baradine Creek • Bucklanbah Creek • Salty Springs Creek • Quanda Quanda Creek • Caleriwi Creek • Baronne Creek • Gulargambone Creek • Castlereagh River • Macquarie River* • Backwater Cowal

Priority Categorisation	Consideration	Watercourses
Moderate	• Key Fish Habitat (DPI, 2007a)	• Coolangla Creek • Black Creek • Talluba Creek • Stockyard Creek • Teridgerie Creek • Tributary of Bucklanbah Creek • Calga Creek • Tenandra Creek • Marthaguy Creek • Millpulling Creek • Kickabil Creek • Native Dog Creek • Emogandry Creek • Goulburn Creek • Ewenmar Creek • Wallaby Creek
Low	• No threatened fish species based on DPI mapping (DPI, 2016) • Not Key Fish Habitat (DPI, 2007a)	• Tinegie Creek • Cumbil Forest Creek • Small Creek • Black Gutter Creek • Mungery Creek • Judes Creek • Bundijoe Creek • Pint Pot Gully Creek • All other unnamed tributaries.

* - Permanently flowing watercourse (perennial).

A number of high and moderate priority watercourses were chosen for field assessment. Based on ease of access, a number of low priority watercourses were also chosen to be included in the survey in order to ground-truth the assessment methodology (refer to Table 3.4 and Table 3.5).

Table 3.4 Proposed watercourse monitoring sites

Watercourse	Threatened fish likely to occur (DPI, 2016 or DAWE, 2020)	KFH	Strahler Stream Order
Narrabri Creek	Eel Tailed catfish, Flathead Galaxias, Purple Spotted Gudgeon, Olive Perchlet	Yes	9
Namoi River	Olive Perchlet, Flathead Galaxias, Eel Tailed Catfish, Purple Spotted Gudgeon, Silver Perch, Murray Cod	Yes	9
Tributary of Namoi River	Purple Spotted Gudgeon, Silver Perch	Yes	1
Bohena Creek	Purple Spotted Gudgeon, Eel Tailed Catfish	Yes	6
Bohena Creek	Purple Spotted Gudgeon	Yes	6
Bundock Creek	Purple Spotted Gudgeon	Yes	2

Watercourse	Threatened fish likely to occur (DPI, 2016 or DAWE, 2020)	KFH	Strahler Stream Order
Goona Creek	Purple Spotted Gudgeon	Yes	3
Black Creek	No	Yes	3
Tributary of Black Creek	No	No	2
Mollieroi Creek	Purple Spotted Gudgeon	Yes	4
Coghill Creek	Purple Spotted Gudgeon	Yes	4
Tributary of Talluba Creek	No	Yes	3
Talluba Creek	No	Yes	3
Rocky Creek/Pine Creek	Eel Tailed Catfish	Yes	4
Stockyard Creek	No	Yes	3
Etoo Creek	Eel Tailed Catfish	Yes	5
Coolangla Creek	No	Yes	3
Baradine Creek	Eel Tailed Catfish, Purple Spotted Gudgeon	Yes	6
Teridgerie Creek	No	Yes	5
Bucklanbah Creek	Purple Spotted Gudgeon	Yes	5
Tributary of Bucklanbah Creek	No	Yes	3
Salty Springs Creek	Purple Spotted Gudgeon	Yes	4
Quanda Quanda Creek	Purple Spotted Gudgeon	Yes	5
Caleriwi Creek	Purple Spotted Gudgeon	Yes	4
Tenandra Creek	No	Yes	4
Barronne Creek	Eel Tailed Catfish, Olive Perchlet	Yes	6
Gulargambone Creek	Purple Spotted Gudgeon, Eel Tailed Catfish	Yes	5
Castlereagh River	Eel Tailed Catfish	Yes	7
Boothaguy Creek	No	Yes	2
Bundijoe Creek	No	No	3
Kickabil/Native Dog Creek/Pint Pot Creek	No	Yes	4
Ewenmar Creek	No	Yes	4
Macquarie River	Eel Tailed Catfish, Trout Cod, Silver Perch, Murray Cod	Yes	9
Backwater Cowal/ Boggy Cowal	Flathead Galaxias, Eel Tailed Catfish	Yes	5
Emogandry Creek	No	Yes	4
Wallaby Creek	No	Yes	5

3.7 Field assessment

3.7.1 Survey site inspections

Initial site inspections were undertaken at assessment locations for high and moderate priority watercourses (where accessible) between 13 and 16 November 2018, and between 19 and 22 March 2019. A follow up assessment at accessible sites was also undertaken between 8 and 12 October 2019. Fifty-five millimeters of rain was recorded at Baradine Forestry Weather Station (monitoring station no. 053002) (BOM, 2019) within five days of the March 2019 site inspection. Rainfall was not recorded prior of any of the other site inspections.

Water quality monitoring was carried out in conjunction with aquatic habitat assessments and began in Narrabri and concluded in Narromine. The purpose of the site inspections was to undertake water quality monitoring and determine presence of habitat features at watercourses that would be crossed by the proposal. Due to access constraints, only 25 of the 32 proposed watercourse monitoring sites were visited during the sampling events. Five high priority watercourses were unable to be visited (Bucklanbah Creek Salty Springs Creek, Quanda Quanda Creek, Caleriwi Creek and Baronne Creek). For the purpose of this assessment, all high priority watercourses, including those that were not visited, have been identified as SREs and have therefore been considered for fish-friendly crossings.

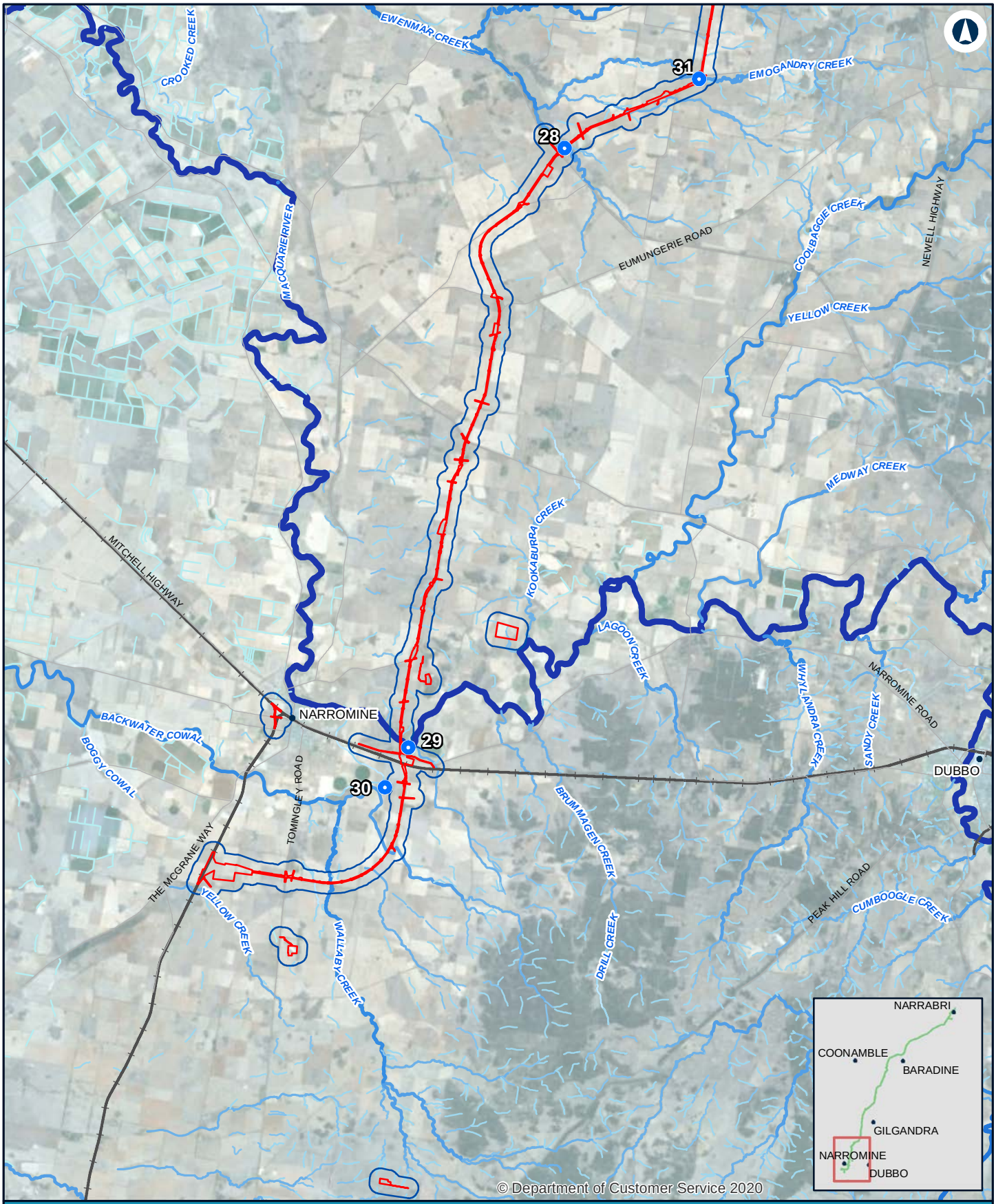
Assessment sites are listed in Table 3.5 and shown in Figure 3.2. Site numbers are based on order they were visited.

Table 3.5 Watercourse monitoring sites

Site Number	Watercourse Name	Date(s) Visited	Priority Categorisation
1	Narrabri Creek	13/11/2018	High
2	Namoi River	13/11/2018 20/03/2019 11/10/2019	High
3a	Bohena Creek	13/11/2018 11/10/2019	High
3b	Bohena Creek	13/11/2018 11/10/2019	High
4	Bundock Creek	19/03/2019	High
6	Goona Creek	19/03/2019	High
7	Black Creek	19/03/2019	Moderate
8	Tributary of Black Creek	19/03/2019	Low
10	Mollieroi Creek	19/03/2019	High
11	Coghill Creek	19/03/2019 11/10/2019	High
14	Talluba Creek	19/03/2019 11/10/2019	Moderate
15	Tinegie Creek	19/03/2019	Low
16	Rocky Creek	19/03/2019 11/10/2019	High
17	Stockyard Creek	19/03/2019	Moderate

Site Number	Watercourse Name	Date(s) Visited	Priority Categorisation
18	Etoo Creek	20/03/2019 11/10/2019	High
19	Cumbil Forest Creek	20/03/2019 11/10/2019	Low
20	Coolangla Creek	20/03/2019	Moderate
21	Baradine Creek	20/03/2019	High
22	Tenandra Creek	14/11/2018 10/10/2019	Moderate
23	Gulargambone Creek	14/11/2018 10/10/2019	High
24	Castlereagh River	14/11/2018 10/10/2019	High
27	Kickabil Creek	20/03/2019 09/10/2019	Moderate
28	Ewenmar Creek	15/11/2018 09/10/2019	Moderate
29	Macquarie River	15/11/2018 24/03/2019 09/10/2019	High
30	Backwater Cowal	15/11/2018 09/10/2019	High
31	Emogandry Creek	22/03/2019 09/10/2019	Moderate

Outcomes of the survey site inspection and determination of SREs is outlined in section 4.8. Description of aquatic habitat at survey sites is further detailed in Appendix A.



NARROMINE TO NARRABRI Waterways and aquatic habitat assessment locations in the study area Figure 3.2a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site

Strahler stream order

0 1 2 3 4 5 6 7 9

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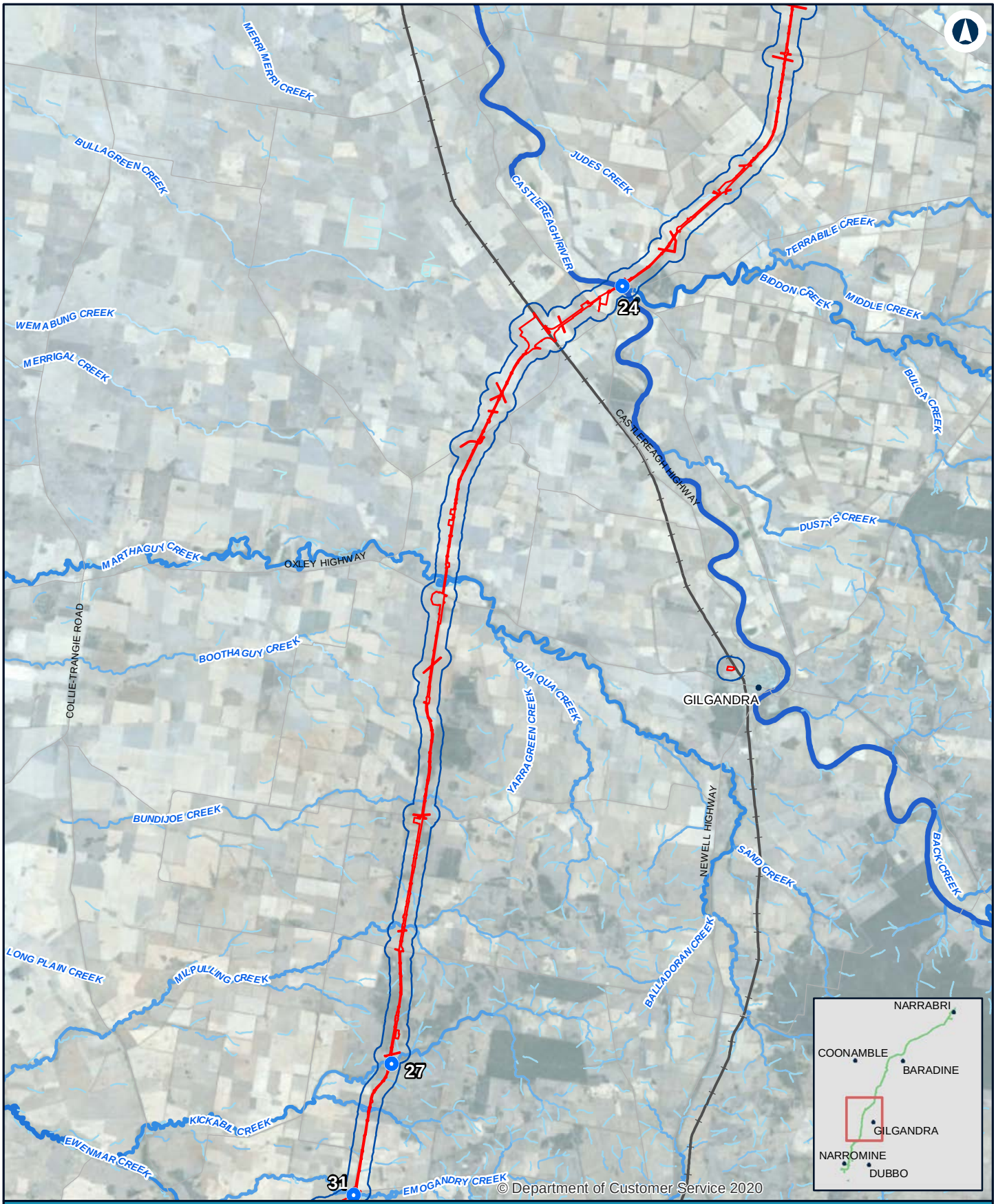

NARROMINE TO NARRABRI Waterways and aquatic habitat assessment locations in the study area Figure 3.2b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site

Strahler stream order

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

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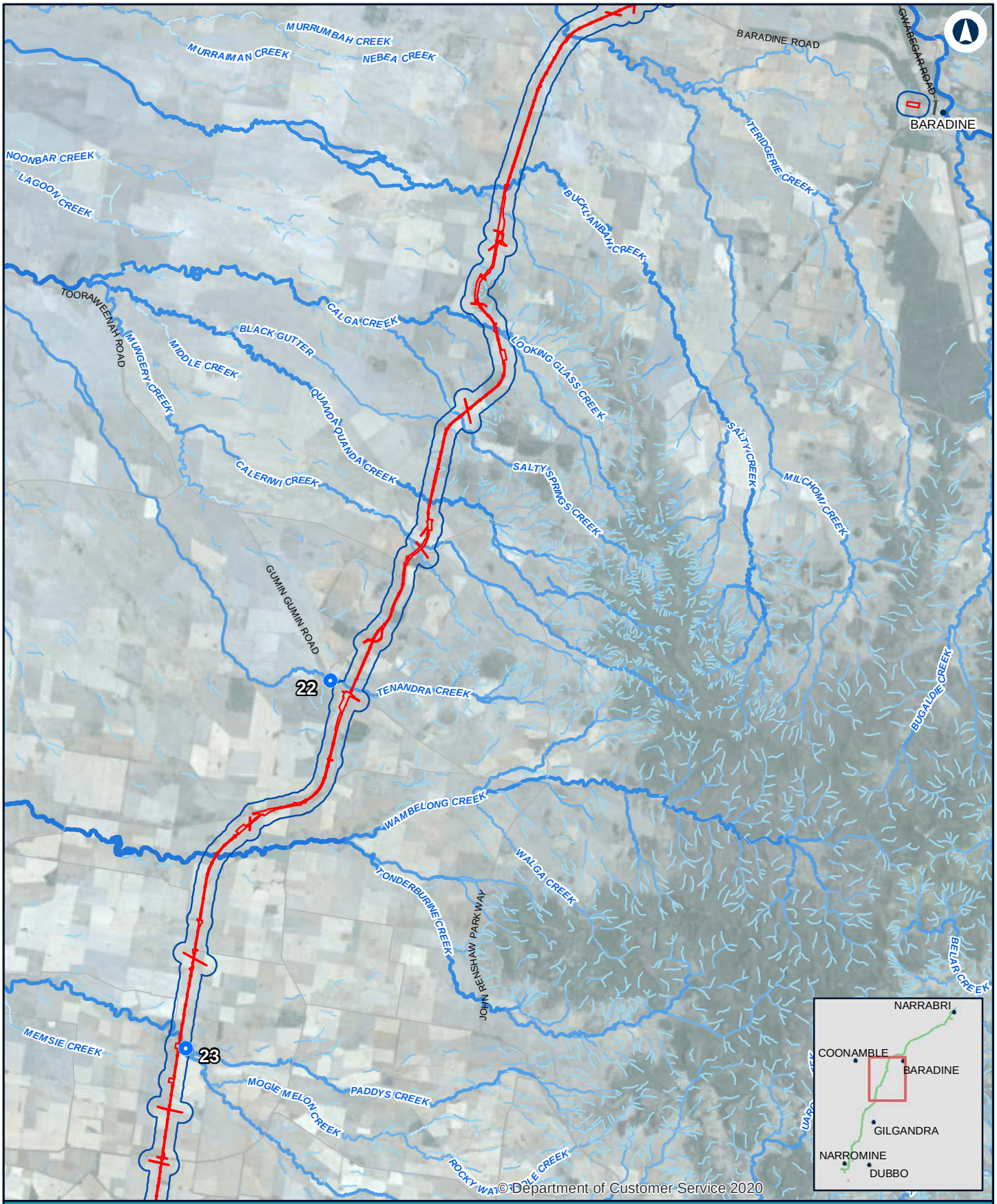

NARROMINE TO NARRABRI Waterways and aquatic habitat assessment locations in the study area Figure 3.2c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site

Strahler stream order

0 1 2 3 4 5 6

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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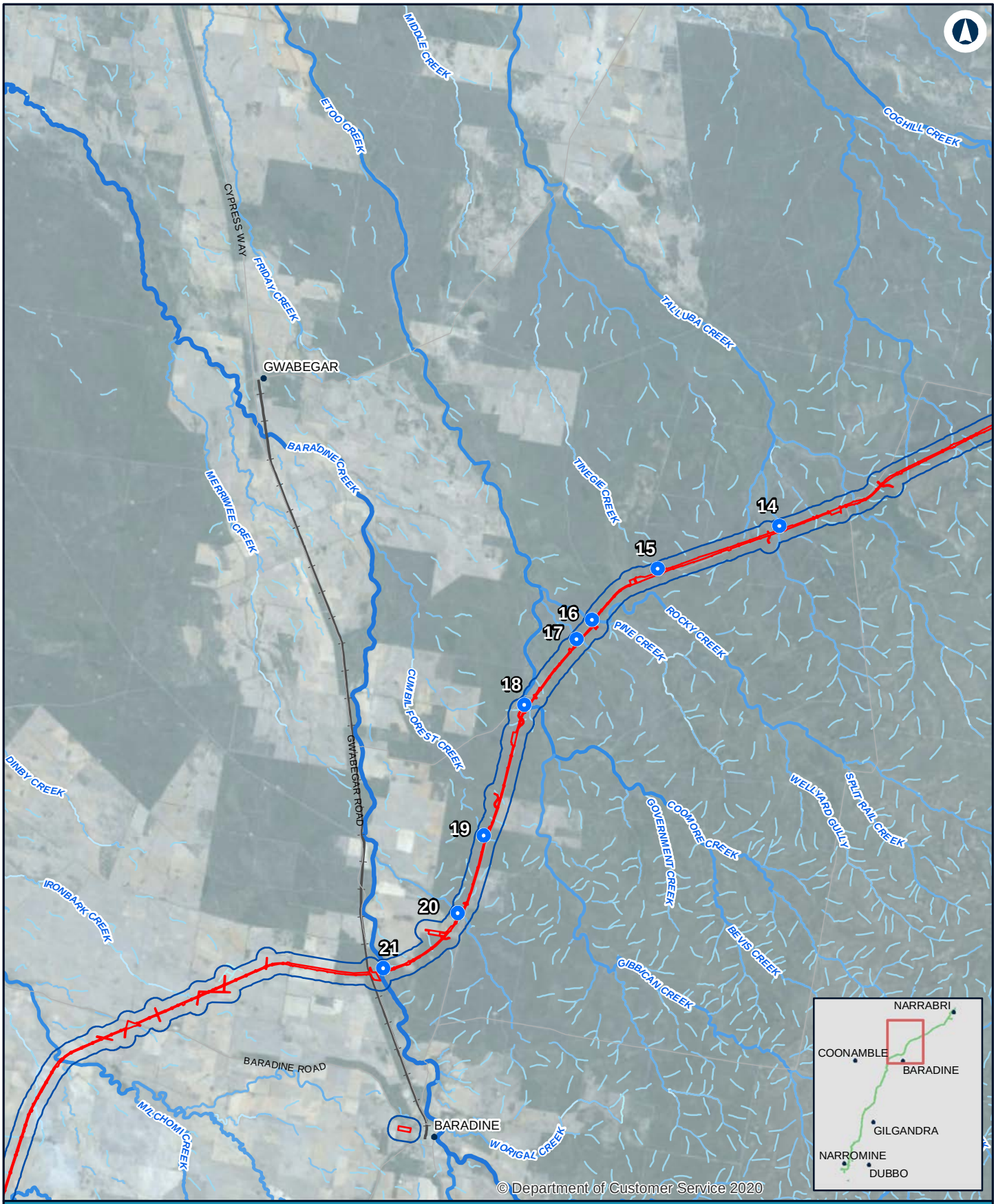

NARROMINE TO NARRABRI Waterways and aquatic habitat assessment locations in the study area Figure 3.2d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site

Strahler stream order

- 0
- 1
- 2
- 3
- 4
- 5
- 6

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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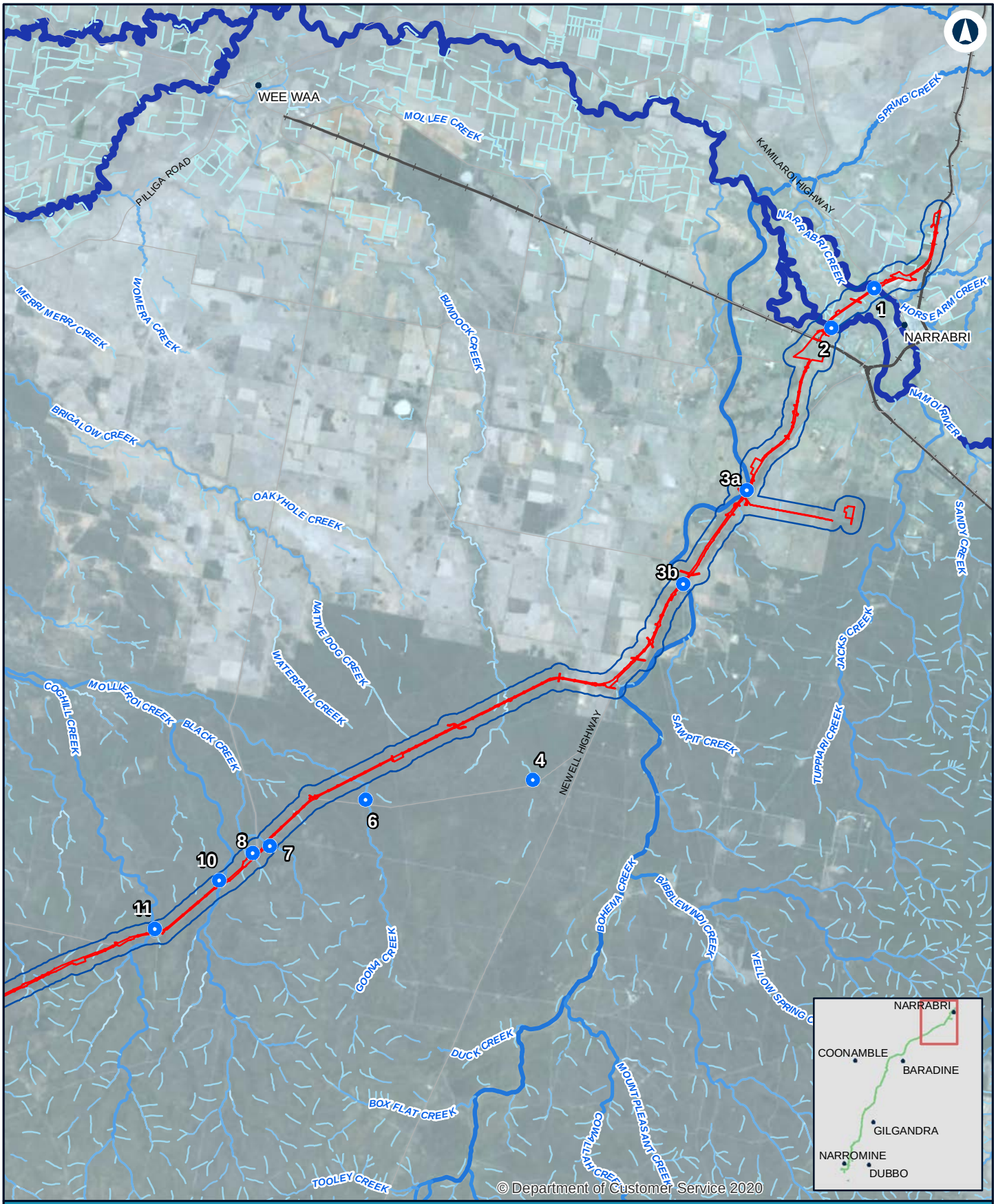

NARROMINE TO NARRABRI Waterways and aquatic habitat assessment locations in the study area Figure 3.2e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site

Strahler stream order

0 1 2 3 4 5 6 9

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3.7.2 Riparian vegetation survey and mapping

Riparian vegetation was surveyed as part of the terrestrial biodiversity surveys. Rapid ground-truthing of regional vegetation mapping and mapping from other local projects was conducted in September 2018, with plant community types (PCTs) identified based on dominant stratum species. Detailed flora surveys were conducted in November 2018, March 2019, September 2019 and October 2019, and included refinement of PCT mapping and assessment of vegetation integrity in accordance with the Biodiversity Assessment Method (OEH, 2017).

Function, composition and structure of vegetation was assessed within a 50 metre by 20 metre plot. All flora species within a 20 metre by 20 metre plot nested within the 50 metre by 20 metre plot were identified. Analysis of soil type, landscape position and landuse maps in conjunction with existing regional vegetation mapping was used to determine potential PCT classification in areas where no access at all was possible.

Plot surveys were conducted in River Red Gum vegetation at various waterways including the Macquarie River, Ewenmar Creek, Gulargambone Creek, the Castlereagh River, Etoo Creek, Pine Creek, Talluba Creek, Mollieroi Creek, Bohena Creek, and Narrabri River, among others.

Further details are provided in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).

4. Existing environment

4.1 Local government areas

The proposal area is located within the Narromine, Dubbo Regional, Gilgandra, Coonamble, Warrumbungle and Narrabri local government areas.

4.2 Landscape features

The study area between Narrabri and Narromine spans a total distance of 306 kilometres and crosses landscapes dominated by floodplains with highly variable rainfall. The Namoi River catchment at the northern extent of the alignment is semi-arid and flows through extensive riverine plains which occasionally flood the townships north of the Pilliga Forests. Mildly undulating and heavily vegetated landscapes occur within the mid to northern section of the study area which encompass the Pilliga Forests. The Pilliga Forests consist of approximately 3,000 square kilometres of semi-arid woodland forest and are sectioned into areas of National Park, State Forest, Nature Reserve or State Conservation Area. Near Gulargambone, mountain ranges with peaks of approximately 1300 metres occur to the east of the alignment, known as the Warrumbungle ranges. The southern reaches of the study area from Narromine to Gulargambone are situated on low-lying alluvial plains. Narromine and surrounding grazing areas are prone to flooding from the Macquarie River during wet seasons.

Since European settlement, natural river flows have been highly altered throughout the region to assist in agricultural production through water extraction (MDBA, 2018). Minor unaltered watercourses occur in the Pilliga National Park and protected areas.

4.3 Catchments

4.3.1 Namoi River catchment

The upland catchment of the Namoi River is boarded by the Great Dividing Range, approximately 1500 metres above sea level and receives 640 mm of rainfall per annum. A diverse range of agricultural practices within the catchment rely heavily on groundwater and surface water supplies from the Namoi River System. Cattle and sheep grazing is the dominant land use, followed by grain crops including cotton farming. The system also supports the Billabong Wetlands downstream of Narrabri and the Pilliga State Forest (MDBA, 2018).

Tamworth is the largest regional centre within the catchment with a population of 42,000 people. Other smaller towns include, Narrabri and Gunnedah. Major water storage dams within the catchment include Lake Keepit on the Namoi River which also serves as flood mitigation for the area. Several weirs are also constructed on the Namoi River to regulate flows. Smaller dams include Split Rock Dam on the Manilla River and Chaffey Dam on the Peel River, which was augmented in 2015 to increase the permanent storage capacity from 62,000 ML to 100,000 ML (MDBA, 2018 and WaterNSW, 2015).

The Namoi River is the major river that traverses the catchment flowing over undulating topography. Downstream of Narrabri, the landscape is low lying and generally flat, approximately 100 metres above sea level and receives approximately 400 millimetres of rainfall per annum. High yield aquifers are present along the Namoi and Peel Rivers which are important suppliers to farmland and domestic use. The lower part of the catchment, west of Narrabri, is less reliant on the river system due to direct access to the Great Artesian Basin. Generally, around 60 per cent of the water supply is extracted from surface waters. However, in dryer years groundwater may account for up to 75 per cent of the water supply (MDBA, 2018).

4.3.2 Castlereagh River catchment

The Castlereagh River catchment forms part of the Murray-Darling Basin and spans an area of 17,400 square kilometres. The catchment is located between the Namoi and Macquarie-Bogan catchments and contains predominantly agricultural grazing land as well as state forests, the Warrumbungle National Park and Goonoo State Conservation Area, south east of Gilgandra (DPI, 2018).

The watercourses within the catchment generally originate at high altitudes where rainfall is above 600 mm and discharge through topographically low-lying landscapes. The Castlereagh River headwaters are located within the Warrumbungle Ranges and flows east to Coonabarabran and then in a southerly direction until it meets the confluence of the lower Macquarie River (DPI, 2018).

The major townships within the catchment include Coonabarabran, Coonamble and Gilgandra. There are no major water storages within the Castlereagh River resulting in highly variable flows and often dry stream beds (DPI, 2018).

4.3.3 Macquarie-Bogan catchment

The Macquarie-Bogan catchment in central-west NSW spans an area of approximately 74,800 square kilometres. Variable elevations occur across the catchment ranging from 1,300 metres in the mountains south of Bathurst, to less than 100 metres on the western floodplains. The catchment encompasses the regional centres of Dubbo, Bathurst and Orange as well as the Macquarie and Bogan Rivers which flow north-west to the Barwon River. Both rivers are the major source of town and agricultural water and supports the Ramsar listed Macquarie Marshes located in the western reaches of the catchment between Dubbo and Brewarrina.

The Macquarie River discharges from the Great Dividing Range flowing through Bathurst and Dubbo before traversing the lower plains. The catchment contains a number of small dams constructed along tributaries of the main river in order to supply town water. Burrendong Dam near Wellington is the main source of water storage within the catchment (MDBA, 2018).

The Bogan River originates in the Harvey Ranges and flows north west through Nyngan before discharging to the Barwon River (MDBA, 2018). Agriculture is the primary land use within the catchment which is largely dominated by livestock grazing (DPI, 2018).

4.3.4 Climate and current drought conditions

The Castlereagh and Macquarie-Bogan Catchments have a dry semi-arid climate. Average annual rainfall in the catchment ranges from about 1200 millimetres in the south east to 300 millimetres in the north west. The average annual rainfall within the proposal area is approximately 500 millimetres per year. Generally, the highest rainfall is recorded over summer, and the driest conditions over autumn (DPI, 2015).

Climate change predictions for the Namoi catchment include a warmer and drier climate. This change in climate would also see increased evaporation and an increase in the number of days the catchment experiences extreme heat and increased winds and fire risk. Despite the drier climate, there is also likely to be increased extreme wet weather events (CSIRO, 2006).

Climate change for the Castlereagh and Macquarie-Bogan catchments is predicted to result in a decrease in spring rainfall but an increase in autumn rainfall. Summer rainfall is also expected to decrease. Temperature records show that the average temperatures in this region have been increasing since the 1970s and are expected to continue to increase, the greatest change in the maximum temperatures in spring and summer (DPI, 2015). Changes in predicted precipitation (rainfall) from current are provided in Table 4.1. These changes were calculated for the time periods 2020-2039 and 2060-2079 using the NSW and Regional Climate Model (NARCLiM).

Table 4.1 Predicted changes in rainfall (NARCLiM)

Parameter	Projected change (%) to 2020-2039	Projected change (%) to 2060-2079
Annual mean rainfall change	+ 0.5	+ 0.5
Summer rainfall	- 6.76	+ 10.66
Autumn rainfall	+ 22.3	+ 15.65%
Winter rainfall	- 7.42	+ 14.1
Spring rainfall	- 0.66	- 6.07

As of 23 February 2020, NSW, and particularly inland areas located west of the Great Dividing Range, have been experiencing 'drought' to 'intense drought' conditions (DPI, 2020). Whilst it is acknowledged that there has been rainfall in the subsequent months to June 2020, the magnitude of rainfall has not alleviated these areas from drought conditions and is unlikely to have resulted in any change to the results of the field investigations.

4.4 Watercourses

The proposal would cross numerous waterbodies, including major rivers and creeks, ephemeral (intermittently flowing) streams, farm dams and drainage lines. There are 48 named watercourses. All watercourses are shown in Figure 3.1.

4.4.1 Major river and basin systems

The proposal is located within the major water catchments of the Macquarie Bogan River Basin, Castlereagh River Basin and the Namoi River Basin as shown in Figure 4.1.

4.4.2 Watercourses crossed by the proposal

Namoi River Catchment

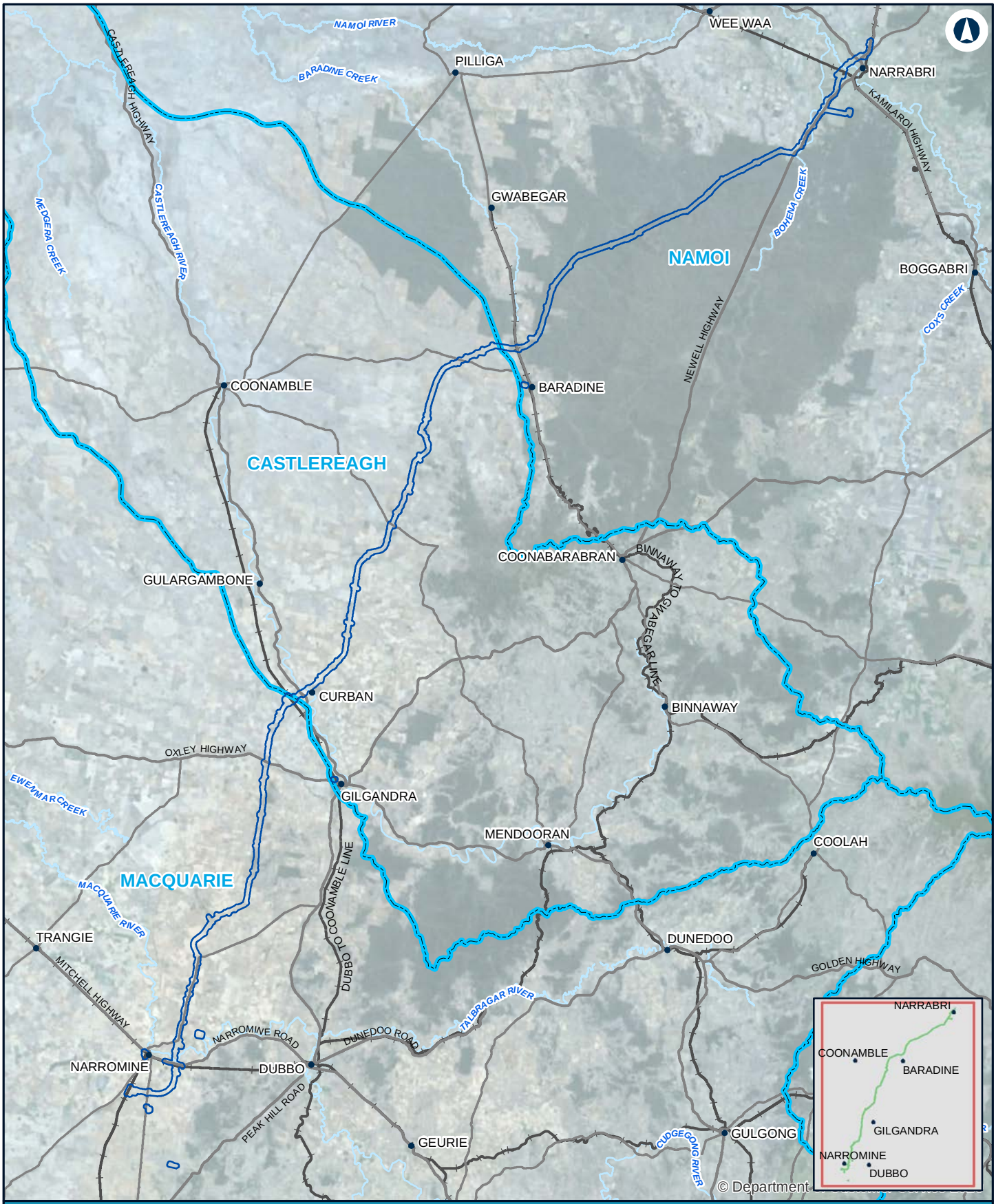
Named watercourses within the Namoi River catchment and traversed by the proposal heading from south to north include Baradine Creek, Coolangla Creek, Cumbil Forest Creek, Etoo Creek, Stockyard Creek, Rocky Creek, Tinegie Creek, Coghill Creek, Mollieroi Creek, Black Creek, Goona Creek, Bundock Creek, Bohena Creek, Namoi River and Narrabri Creek. There are also several unnamed tributaries traversed by the proposal.

Castlereagh River Catchment

Named watercourses within the Castlereagh River catchment and traversed by the proposal heading from south to north include Castlereagh River, Judes Creek, Gulargambone Creek, Baronne Creek, Tenandra Creek, Mungery Creek, Caleriwi Creek, Quanda Quanda Creek, Black Gutter, Salty Springs Creek, Calga Creek, Noonbar Creek, Bucklanbah Creek, Small Creek, Teridgerie Creek and Ironbark Creek. There are also several unnamed tributaries traversed by the proposal.

Macquarie-Bogan River Catchment

Named watercourses within the Macquarie-Bogan River catchment and traversed by the proposal heading from south to north include Wallaby Creek, Macquarie River, Ewenmar Creek, Goulburn Creek, Emogandry Creek, Native Dog Creek, Pint Pot Gully, Kickabil Creek, Milpulling Creek, Bundijoe Creek and Marthaguy Creek. There are also several unnamed tributaries traversed by the proposal.



NARROMINE TO NARRABRI Major water catchments Figure 4.1

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- Study area
- Catchment boundaries
- Watercourse

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers, catchments: NSWSS; Study area: GHDJACOBS

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4.5 Geomorphology

The geomorphology of the watercourses traversed by the proposal was assessed via desktop to classify the river styles and the geomorphic condition and fragility of the watercourse. This information is provided in detail in the *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment* (JacobsGHD, 2020c) and briefly summarised in Table 4.2. The condition of named watercourses was divided into three broad categories:

- Good (natural and intact)
- Moderate (noticeably impacted by human disturbance)
- Poor (degraded).

The stream fragility refers to the sensitivity or susceptibility of a stream to changes or alterations in its geomorphic category when exposed to disturbances such as degradation (Outhet et al, 2004). Streams with higher fragility have a lower threshold to threatening processes and would show more geomorphic and physical change than streams that are less fragile or susceptible.

Table 4.2 Condition and fragility of watercourses traversed by the proposal

Chainage (km)	Watercourse	Condition	Fragility
Macquarie Catchment			
6.9	Wallaby Creek	Poor	Moderate
16	Macquarie River	Good	Moderate
48.4	Ewenmar Creek	Good	High
52	Goulburn Creek	Poor	Moderate
55.9	Emogandry Creek	Moderate	High
60.2	Native Dog Creek	Poor	High
62	Pint Pot Creek	Poor	Moderate
62.8	Kickabil Creek	Moderate	High
69.7	Milpulling Creek	Poor	Moderate
76.2	Bundijoe Creek	Moderate	High
87.5	Marthaguy Creek	Moderate	High
Castlereagh Catchment			
105.2	Castlereagh River	Moderate	High
112.1	Judes Creek	Moderate	High
125.9	Gulargambone Creek	Moderate	High
135.5	Baronne Creek	Moderate	Moderate
147.1	Tenandra Creek	Moderate	High
153.5	Mungery Creek	Moderate	High
155.2	Caleriwi Creek	Poor	High
157.8	Quanda Quanda Creek	Poor	High
161.65	Black Gutter	Moderate	High
162.4	Salty Springs Creek	Poor	High
167.7	Calga Creek	Moderate	Moderate
175.4	Bucklanbah Creek	Moderate	Moderate

Chainage (km)	Watercourse	Condition	Fragility
181.3	Small Creek	Moderate	High
183.65	Teridgerie Creek	Moderate	High
Namoi Catchment			
200.95	Baradine Creek	Moderate	High
205.9	Coolangla Creek	Moderate	Moderate
209.95	Cumbil Forest Creek	Moderate	Moderate
216.8	Etoo Creek	Moderate	High
222.35	Rocky Creek	Moderate	Moderate
226.7	Tinegie Creek	Good	High
232.8	Talluba Creek	Moderate	Moderate
242.55	Rocky Creek	Moderate	Moderate
249.8	Coghill Creek	Moderate	Moderate
253.65	Mollieroi Creek	Moderate	Moderate
262.3	Goona Creek	Moderate	High
270.9	Bundock Creek	Moderate	High
282.6	Bohena Creek	Moderate	High
297.6	Namoi River	Poor	Moderate
300.75	Narrabri Creek	Poor	Moderate

4.6 Water quality

This section provides a brief summary of existing surface water quality within the three main catchments (Namoi River Catchment, Castlereagh River Catchment and Macquarie River Catchment) where water quality data was available. Available water quality data was analysed and compared to default trigger values for protection of water quality in aquatic ecosystems outlined in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Governments (ANZG, 2018) (referred to herein as the ANZG water quality guidelines). Detailed results of water quality analysis are provided in *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d).

4.6.1 Namoi River catchment

Narrabri Creek at Narrabri is a regulated creek draining a catchment area of 25,120 square kilometres. Historically, the creek has had fluctuating levels of electrical conductivity, with higher conductivities being recorded during periods of low flow or following first flush rainfall events. Continuous monitoring of conductivity every 15 minutes between 2002 and 2007 recorded median conductivity of approximately 500 µS/cm (Mawhinney, 2011).

The state of the environment reporting in 2015 assessed the health of watercourses in the Namoi River catchment as poor. With respect to water quality, the Namoi River generally had low conductivity (mean ~463 µs/cm) and elevated nutrients. Between 2009 and 2011, both total nitrogen and phosphorus concentrations exceeded the recommended trigger values more than 75 per cent of the time (NOW, 2011).

Most current water quality reporting for the Namoi River at Mollee, and Narrabri Creek at Narrabri revealed nutrient concentrations exceeded the recommended limit 100 per cent of the time. Turbidity levels varied, with Narrabri Creek having slightly better turbidity with less than 25 per cent of the samples exceeding the guidelines compared to almost 50 per cent exceeding the guideline in the Namoi River. Macroinvertebrate condition across the Namoi Region is generally poor (DECCW, 2011). The 2015 State of the Environment report also states that water quality is poor due to elevated total nitrogen and phosphorus, however compliance for TN in the Namoi River had improved slightly since the previous reporting period of 2007-2011 inferring lower concentrations have been recorded over recent times.

4.6.2 Castlereagh River catchment

Water quality monitoring within the Castlereagh River catchment is limited, with sufficient water quality data only available for one site in the catchment, the Castlereagh River. The Castlereagh River catchment has been monitored at one site consistently and results reported between 2007 and 2012 indicate that only turbidity and pH levels are considered good, with median levels within recommended guidelines. Total nitrogen, total phosphorus and salinity concentrations were all elevated and considered poor to very poor (DSEWPaC, 2011). Median salinity was 821 µs/cm (n=58) and notably higher than the recommended guideline of 30-350 µS/cm, Median total nitrogen concentrations were 310 µg/L (n=31) and total phosphorus was 68.5 µg/L (n=56), both notably higher than the guidelines of 250 µg/L for TN and 20 µg/L for TP (DSEWPaC, 2011). Dissolved oxygen levels were lower than the recommended limit of 90 per cent saturation with median levels of 75 per cent saturation.

4.6.3 Macquarie-Bogan catchment

The water quality in the Macquarie-Bogan catchment is generally poor, with elevated total phosphorus and nitrogen resulting in frequent exceedance of guidelines. Salinity concentrations which were often elevated were also considered poor (DSEWPaC, 2011). The Macquarie River has been monitored at numerous locations within the catchment with total nitrogen and total phosphorus were consistently poor between the monitoring locations. Total nitrogen levels were elevated at all sites with concentrations generally two to four times the recommended limit of 250 µg/L. Total phosphorus concentrations were also elevated exceeding the recommended guidelines by up to five times. Median electrical conductivity, dissolved oxygen and turbidity were classified as poor to fair between the sites due to low dissolved oxygen levels and elevated conductivity and turbidity. pH levels were consistently within the recommended guidelines along the Macquarie River.

The Bogan River generally exhibited poor water quality due to low dissolved oxygen concentrations (median 75.9 per cent) and elevated total nitrogen (median 845 µg/L) and total phosphorus (median 85 µg/L), Turbidity was also elevated and exceeded the limit of 25 NTU. pH and conductivity complied with the ANZECC/ARMCANZ (2000) guidelines for upland rivers.

Marthaguy Creek, which flows into the Macquarie River, was monitored between 2008 and 2012 and could be considered to have poor water quality. Dissolved oxygen and pH were the only indicators to comply with the relevant guidelines. Median conductivity of 421 µs/cm exceeded the upper limit of 350 µS/cm and total nitrogen and total phosphorus were more than five and 10 times the recommended limit respectively, for protection of aquatic ecosystems. Additionally, unlike other sites in the catchment Marthaguy Creek recorded very high median turbidity (120 NTU) which exceeded the guideline limit of 25 NTU.

The poor water quality in the Macquarie-Bogan and Castlereagh catchments as described at the abovementioned sites is mostly due to the alteration to natural flow regime and changes in land use (DPI, 2017).

4.7 Aquatic ecology

4.7.1 Regional aquatic biodiversity

The Macquarie-Bogan, Castlereagh and Namoi River catchments contain a variety of aquatic environments including major and minor rivers and streams, wetlands, semi-arid floodplains, inland billabongs and freshwater lakes. These systems are known or predicted to support several native aquatic species including nationally and state listed threatened fish species (DAWE, 2020; EESG, 2020, ALA, 2020 and DPI, 2016). It is suggested, however, that native aquatic populations are extremely low due to poor water quality and presence of high numbers of exotic fish species within the watercourses, particularly Common Carp (*Cyrinus carpio*), Eastern Gambusia (*Gambusia holbrooki*), Redfin Perch (*Perca fluviatilis*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) (Bioregional Assessments, 2018). Macro invertebrate diversity is also reported to be poor in these catchments (Bioregional Assessments, 2018). Other native and exotic fauna which are known to rely on watercourses within the catchments for at least some of their lifecycle include several species of snail, frogs, turtles, reptiles and waterbirds. A detailed list of aquatic flora and fauna species that are predicted within the study area is provided in *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).

4.7.2 Threatened aquatic species and populations

Six threatened fish and two endangered fish populations are listed as potentially occurring within the study area based on DPI threatened species distribution mapping (DPI, 2016) and database searches undertaken in April 2020 (DAWE, 2020, EESG, 2020, ALA, 2020). The two endangered populations are the Western population of the Olive Perchlet (*Ambassis agassizi*i), and the Murray-Darling Basin population of the Eel Tailed Catfish (*Tandanus tandanus).* The predicted threatened species are Silver Perch (*Bidyanus bidyanus*), Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*), Flathead Galaxias (*Galaxias rostratus*) and Purple Spotted Gudgeon (*Mogurnda adspersa*). The mapped distributions of these species and populations (DPI, 2016) are shown in Figure 4.2(a – f). In addition, Macquarie Perch (*Macquaria australasica*), was listed as potentially occurring within the region (DAWE, 2020), however based on DPI distribution modelling, the species is not predicted to occur within the study area (DPI, 2016).

No targeted surveys were undertaken as it was determined that there was sufficient evidence available in publicly accessible databases (EESG, 2020; ALA, 2020) to support species presence in the study area. In addition, the majority of watercourses crossed by the alignment are ephemeral and dry most of the time (except for Macquarie River, Namoi River and Narrabri Creek) therefore did not require survey effort. Regardless of presence of water, a precautionary approach has been applied and species have been presumed to be present in watercourses (when water is available) based on DPI distribution modelling (2016) and recorded sightings. The likelihood of occurrence for all predicted threatened species is described in Table 4.3.

Table 4.3 Threatened aquatic species and populations likelihood of occurrence within study area

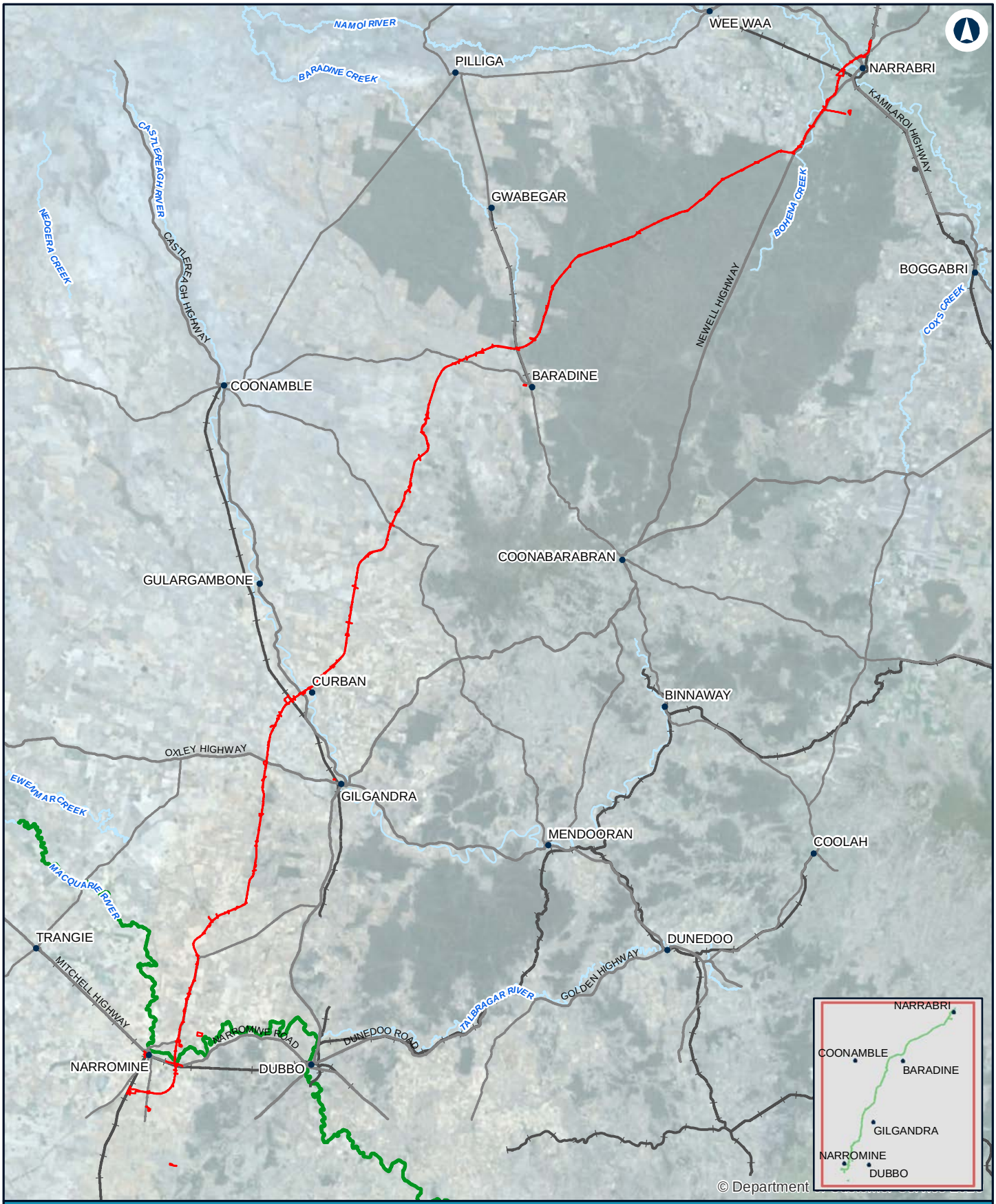
Scientific name	Common name	FM Act	EPBC Act	Distribution and habitat	Likelihood of occurrence
Ambassis agassizii	Olive Perchlet (Western Population), Glass perchlet, Agassiz's glassfish, Western chanda perch (Western Population)	EP	-	The Olive Perchlet is associated with instream woody debris and prefers vegetated bank edges of lakes, swamps, creeks, wetlands and rivers. Particularly in backwaters where there is little to no flowing water. In NSW, the species was formally widespread in the Darling, lower Murrumbidgee, lower Murray and Lachlan Rivers. However, is now known in few localities which include Darling drainage and upstream of Bourke (Lintermans, 2007).	Likely to occur within proposal area in perennial watercourses of Namoi River, Narrabri Creek, Macquarie River, and in the ephemeral watercourse Barrone Creek, when water is present (DPI, 2016). However, no recorded sightings within the study area (EESG, 2020; ALA, 2020). The most recent sighting was recorded in 1991, near Nyngan, approximately 120 km away (ALA, 2020).
Bidyanus bidyanus	Silver Perch, Bidyan, Black bream, Silver bream	CE	CE	The Silver Perch was once widespread with a distribution range including most of the Murray Darling Basin and extending through drainage lines within western NSW. The species has experienced dramatic decline throughout the region however, is still patchily abundant within the central Murray. The species prefers turbid and slow flowing waters similar habitats to the Murray cod and is commonly artificially stocked into farms and reservoirs.	Likely to occur within proposal area in perennial watercourses of Macquarie River and Namoi River, according to DPI threatened species distribution maps (2016). No sightings have been recorded within the study area (EESG, 2020; ALA, 2020). Most recent sighting was recorded in 2004, near Cryon, approximately 120 km away (ALA, 2020).
Macquaria australasica	Macquarie Perch, Mountain perch, Black bream, White eye	E	E	The Macquarie Perch is a riverine species, typically found in the cool upper reaches of the Murray Darling river system. The fish prefers clear water and deep, rocky holes with abundant cover such as aquatic vegetation, large boulders, debris and overhanging banks. In NSW, natural inland populations are isolated to the upper reaches of the Lachlan, Goulbourn and Murrumbidgee Rivers. Translocated populations in NSW are found in the Mongarlowe River, Queanbeyan River upstream of the Googong Reservoir and in Cataract Dam (Lintermans, 2007).	Unlikely – no recordings within the study area (EESG, 2020; ALA, 2020) and not mapped as occurring within the area by DPI distribution maps (2016). No further assessment required.

Scientific name	Common name	FM Act	EPBC Act	Distribution and habitat	Likelihood of occurrence
Maccullochella macquariensis	Trout Cod, Blue nose cod	E	E	Often confused with the Murray cod and only formally recognised as a separate species in 1972, the Trout Cod is endemic to the southern Murray-Darling system including the Murrumbidgee, Murray and Macquarie Rivers. The species also prefers similar habitat to the Murray cod such as deep pools and instream cover such as large boulders, fallen trees and woody debris. There are only three known self-sustaining populations left in the wild. The largest is in the Murray River below Yarrawonga and small translocated populations in Cataract Dam and upper reaches of Sevens Creek (Lintermans, 2007).	Moderate likelihood of occurrence in Macquarie River based on DPI threatened species distribution maps (2016). No recent sightings recorded (EESG, 2020; ALA, 2020), however, this may be due to historical misidentification with Murray Cod.
Maccullochella peelii	Murray Cod, Cod, Goodoo	-	V	The Murray Cod occurs naturally in the watercourses of the Murray-Darling Basin (ACT, SA, NSW and Vic) and is known to live in a wide range of habitats that range from clear, rocky streams to slow flowing turbid rivers and billabongs. The species prefers habitats with good instream cover such as overhanging branches, fallen trees, undercut banks and deep holes. Formally widespread in lower and mid altitudes of the Murray Daring Basin the species now has patchy distribution. Some translocated populations exist outside the species' natural distribution in impoundments and watercourses in NSW and Vic which are maintained by the release of hatchery bred fish (Lintermans, 2007).	Likely to occur within the perennial watercourses of Macquarie River, Namoi River and Narrabri Creek (DPI, 2016). Also recorded in these watercourses by the Murray Darling Basin Commission (Lintermans, 2007) and online databases (EESG, 2020; ALA, 2020).

Scientific name	Common name	FM Act	EPBC Act	Distribution and habitat	Likelihood of occurrence
Mogurnda adspersa	Purple Spotted Gudgeon	E	E	The Purple Spotted Gudgeon is a benthic species associated with good habitat coverage such as cobbles and aquatic vegetation. It is found in slow moving or still deep waters such as wetlands, billabongs or slow flowing rivers and creeks. The species has experienced significant decline in the Murray Darlin Basin and is patchily distributed throughout NSW. However, a new population was more recently discovered in in the Macquarie catchment NSW (Lintermans, 2007).	Likely to occur within proposal area in ephemeral watercourses (when water is present) including Gulargambone Creek, Caleriwi Creek, Quanda Quanda Creek¸ Salty Springs Creek¸ Bucklanbah Creek¸ Baradine Creek¸ Coghill Creek¸ Mollieroi Creek¸ Goona Creek¸ Bundock Creek and Bohena Creek. Also predicted to occur in perennial waterways of Namoi River, tributaries of Namoi River, Narrabri Creek and around 6 km upstream of the proposed Macquarie River crossing (DPI, 2016). No recent sighting recorded within the study area (EESG, 2020; ALA, 2020).
Galaxias rostratus	Flathead Galaxias, Beaked minnow, Flat-headed Galaxias, Flat-headed jollytail, Flat-headed minnow	CE	CE	The Flathead Galaxias was historically collected form habitats including billabongs, swamps, lakes and rivers usually in still or slow flowing waters. Originally known from the Southern Murray Darling Basin including the Macquarie, Lachlan, Murrumbidgee and Murray Rivers with patchy recordings. The species is affected by cold water pollution and altered flow regimes with a significant decline in numbers across its range (Lintermans, 2007).	Likely to occur within proposal area in Narrabri Creek, Namoi River and Backwater Cowal (when water is present), according to DPI threatened species distribution maps (2016). No recent sightings recorded within the study area (EESG, 2020; ALA, 2020).

Scientific name	Common name	FM Act	EPBC Act	Distribution and habitat	Likelihood of occurrence
Tandanus tandanus	Eel Tailed Catfish, Jewfish, Freshwater catfish (Murray Darling Basin population)	EP	-	The Eel Tailed Catfish is a benthic species preferring low and slow moving streams, rivers and lakes. Most riverine populations have significantly declined and are no longer common in areas where it was formally abundant however, the distribution range is generally widespread across the Murray Darling Basin. The species has been restocked into some farm dams and lakes to establish breeding populations. Changes to natural flow and elevated salinity levels are suspected causes of declining local populations (Lintermans, 2007).	Likely to occur within in proposal area in ephemeral watercourses (when water is present) of Backwater Cowal, Gulargambone Creek, Baronne Creek, Castlereagh River, Baradine Creek, Etoo Creek, Rocky Creek/Pine Creek and Bohena Creek when water is present. Also predicted to occur in perennial watercourses of Macquarie River, Namoi River and Narrabri Creek, according to DPI threatened species distribution maps (2016). Sightings have been recorded within the study area, most recently in 2006 (ALA, 2020). A sighting was recorded in 2017 in Macquarie River, approximately 55 km upstream of the proposal area (ALA, 2020).

*Species listings; CE (Critically Endangered), E (Endangered), V (Vulnerable), EP (Endangered Population)



NARROMINE TO NARRABRI Threatened species, populations and ecological communities - Trout Cod Figure 4.2a

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 10/08/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

LEGEND

The proposal site
Watercourse

Threatened species and endangered population

Trout Cod *(Maccullochella macquariensis)*

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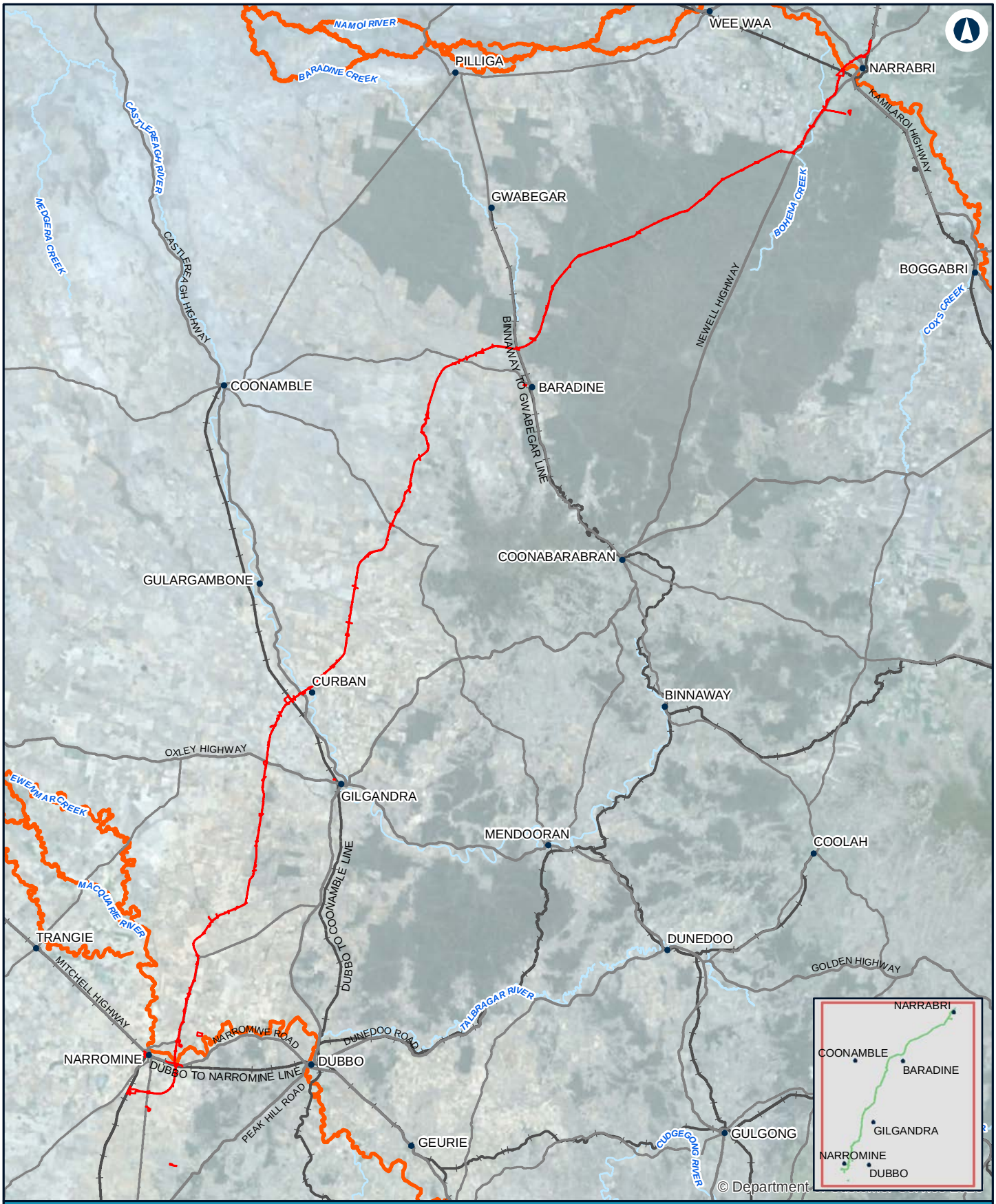

NARROMINE TO NARRABRI Threatened species, populations and ecological communities - Silver Perch Figure 4.2b

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

The proposal site **Threatened species and endangered population**

Watercourse Silver Perch *(Bidyanus bidyanus)*

Date: 10/08/2020 Paper: A4

Author: JacobsGHD Scale: 1:1,100,000

Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

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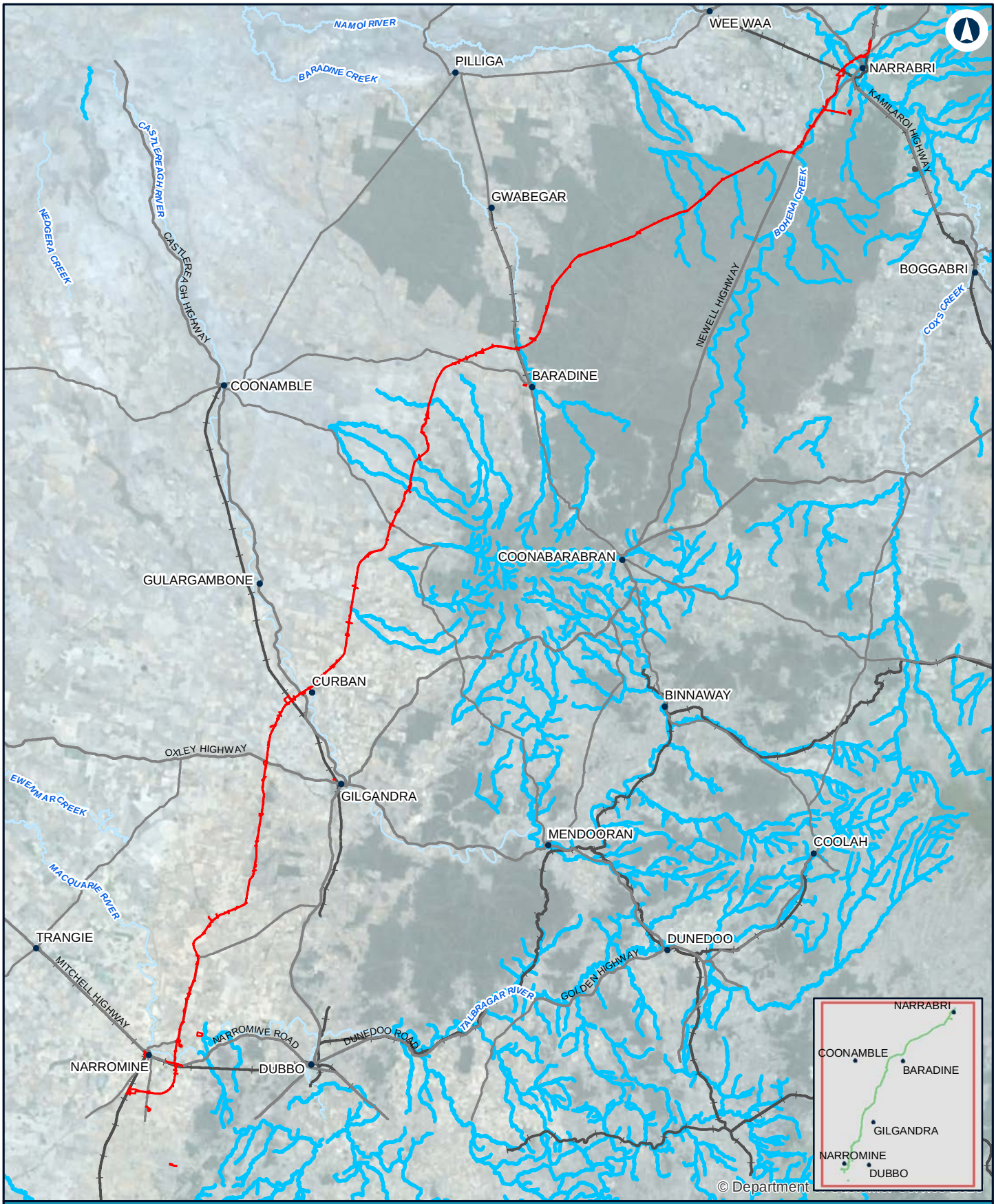

NARROMINE TO NARRABRI Threatened species, populations and ecological communities - Purple Spotted Gudgeon Figure 4.2c

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Coordinate System: GDA 1994 MGA Zone 55

Date: 10/08/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

LEGEND

The proposal site **Threatened species and endangered population**
Watercourse
Purple Spotted Gudgeon *(Mogurnda adspersa)*

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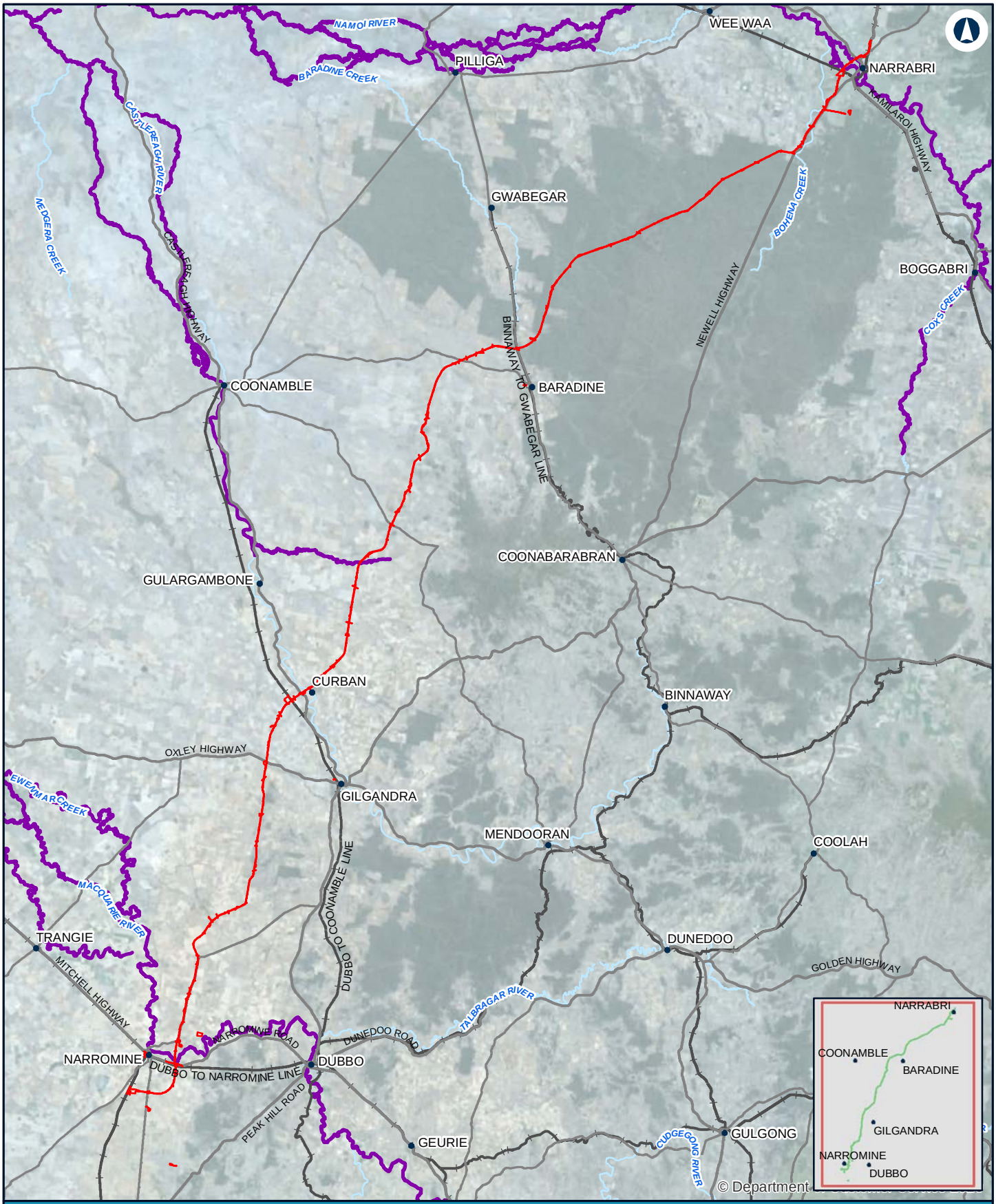

NARROMINE TO NARRABRI

Threatened species, populations and ecological communities - Western population of the Olive Perchlet

Figure 4.2d

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Watercourse
- **Threatened species and endangered population**
- Western population of the Olive Perchlet *(Ambassis agassizii)*

Date: 10/08/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

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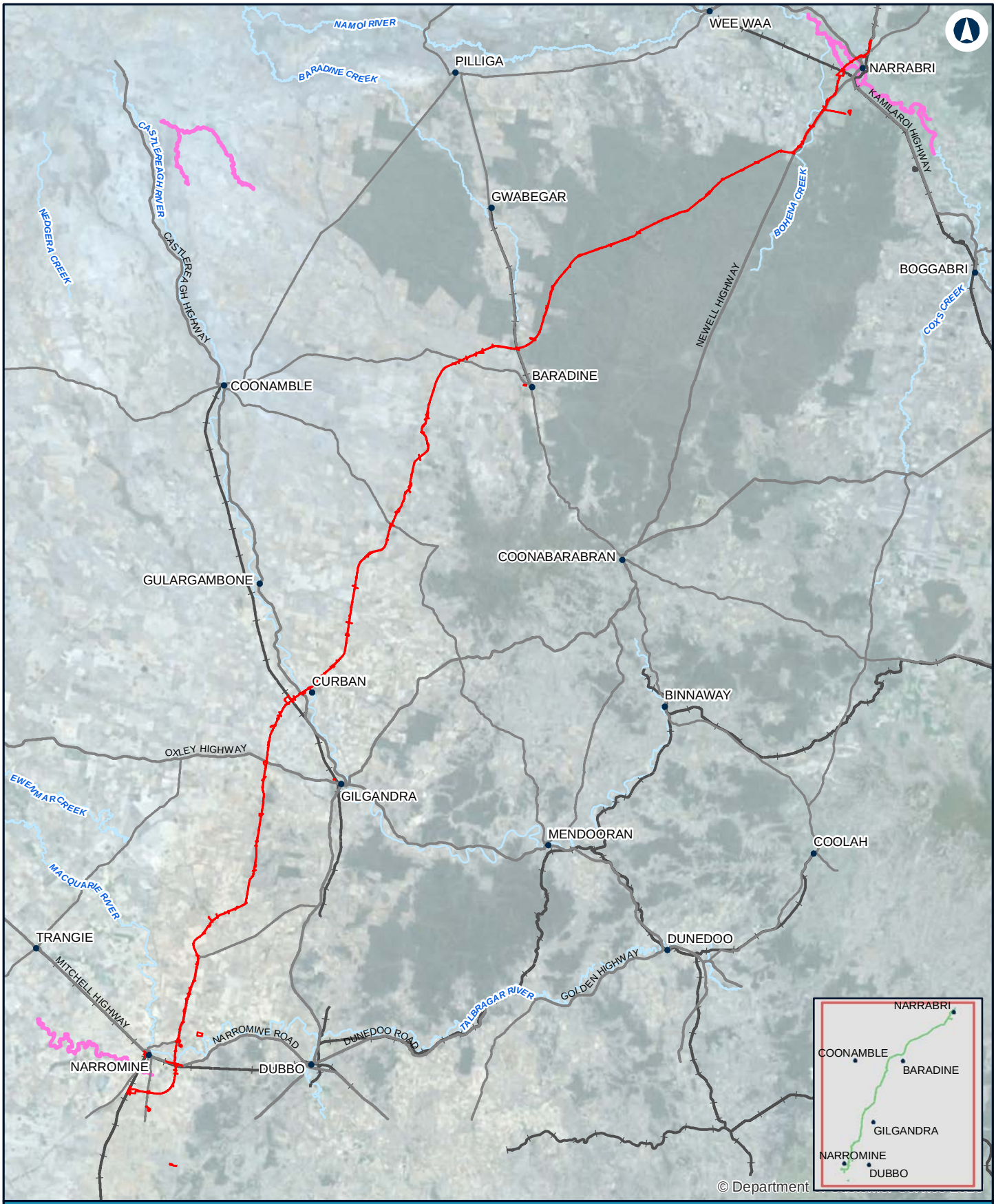

NARROMINE TO NARRABRI Threatened species, populations and ecological communities - Flathead Galaxias Figure 4.2e

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

The proposal site **Threatened species and endangered population**

Watercourse

Flathead Galaxias *(Galaxias rostratus)*

Date: 10/08/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

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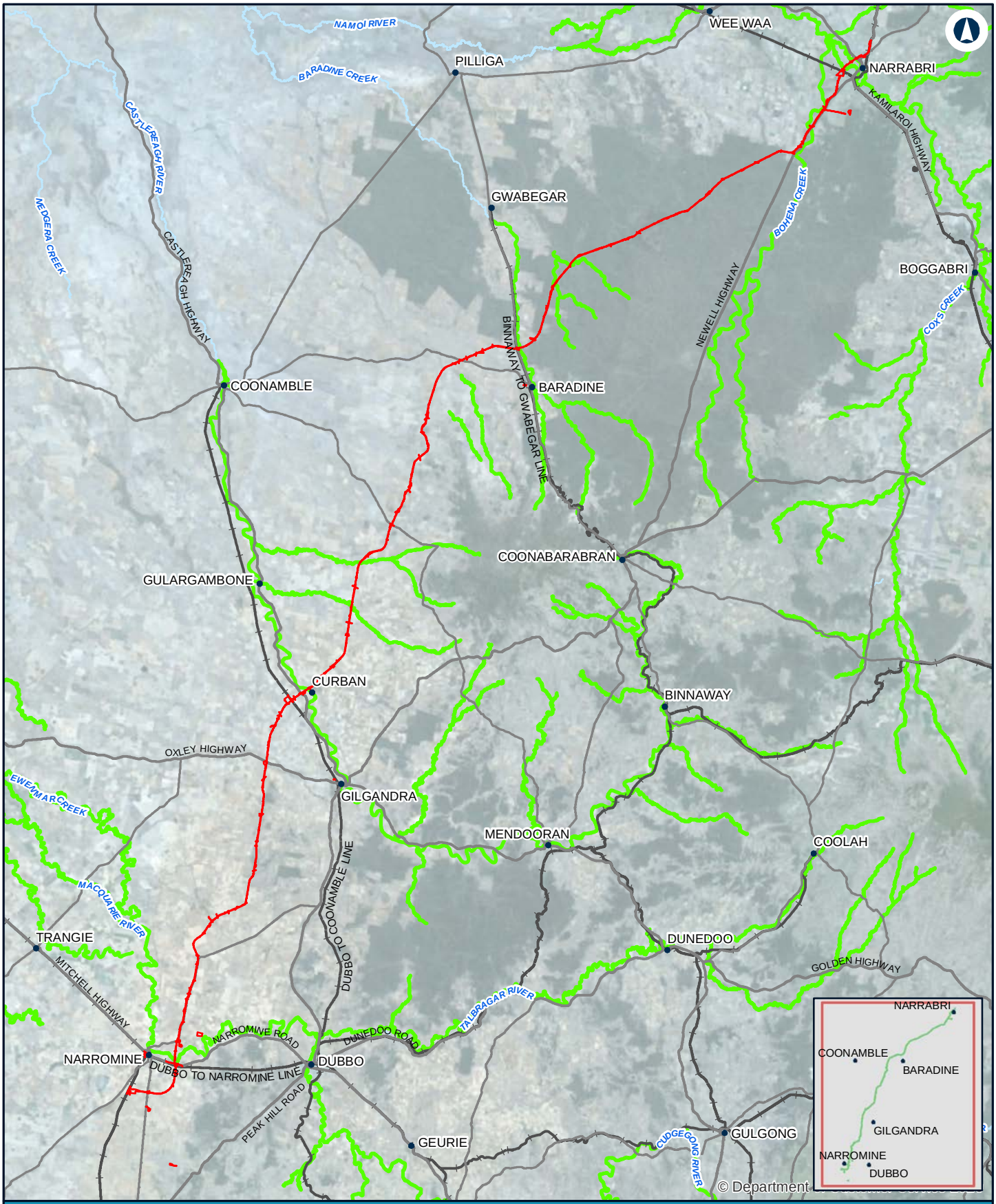

NARROMINE TO NARRABRI Threatened species, populations and ecological communities - Murray Darling Basin Population of the Eel Tailed Catfish Figure 4.2f

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 10/08/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS; EECs: DPI; Study area: GHDJACOBS

LEGEND

The proposal site
Watercourse

Threatened species and endangered population

Murray Darling Basin Population of the Eel Tailed Catfish *(Tandanus tandanus)*

INLAND RAIL ARTC

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4.7.3 Threatened ecological communities

The proposal lies wholly within the endangered ecological community (EEC) known as '*the natural drainage system of the lowland catchment of the Darling River*' (Darling River EEC). The Darling River EEC encompasses a large area of inland NSW including the Macquarie, Namoi and Castlereagh Rivers (DPI, 2007b) (refer to Figure 4.3). This aquatic EEC comprises all native fish and aquatic invertebrates within all natural creeks, rivers, streams and associated lagoons, billabongs, lakes, anabranches, flow diversions to anabranches and floodplains of the Darling River within NSW. Artificial canals, water distribution and drainage works, farm dams and off-stream reservoirs are excluded from this aquatic EEC.

The Darling River EEC system is characterised by highly variable flows and unpredictable patterns which has led to reliance of many native aquatic species on seasonal flows to trigger spawning events (DPI, 2007b). Since European settlement, the Darling River EEC has experienced significant modification due to anthropogenic-related activities of land clearing, agriculture, water pollution and introduction of invasive species. These activities have caused a significant amount of the aquatic habitat to become heavily degraded and as a result, many of the native species have greatly declined in both their distributions and abundance.

As such, the Darling River EEC has been protected under the FM Act. In accordance with the EP&A Act, legal penalties apply to unapproved activities which may harm a feature of this EEC. Potential impacts of the proposal on the Darling River EEC have been considered in this assessment and are documented in an 'assessment of significance' for the Darling River EEC in Appendix B of this report.

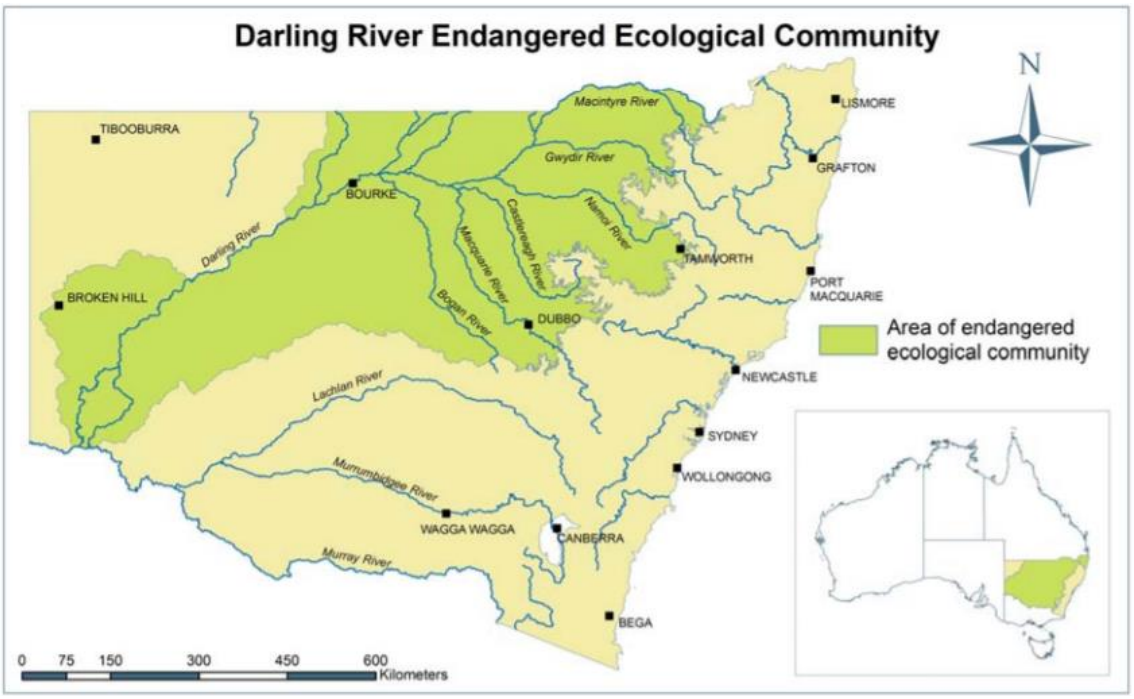


Figure 4.3 Darling River Endangered Ecological Community (DPI, 2007b)

4.7.4 Ramsar listed wetlands

The Macquarie Marshes Ramsar listed wetlands occur approximately 100 kilometres downstream of the study area along the Macquarie River and approximately 80 kilometres to the west of Gilgandra. The Macquarie Marshes are a large diverse wetland system in the lower Macquarie River. The site was listed on the Ramsar List of Wetlands of International Importance in 1986. It is significant because of the diversity of wetland types, its highly abundant and diverse waterbird populations and its support for colonial nesting and nationally threatened species. The critical processes and components that support the site's ecological character are its hydrology, aquatic ecosystems, and the diversity of wetlands that support waterbird breeding and nationally threatened species (Bioregional Assessments, 2018). The site supports permanent populations of threatened aquatic fauna including Silver Perch and Murray Cod (DAWE, 2020).

The proposal is not expected to result in a change in the hydrological regime of any of the watercourses that flow toward the Macquarie Marshes, notably the Macquarie River, therefore there would be no impact on the hydrology of the wetlands. Furthermore, any water quality impacts during construction are expected to be localised and managed at the site such that there is unlikely to be any measurable change in water quality in any inflowing watercourses, including the Macquarie River, that would impact on the wetland.

4.8 Sensitive receiving environments

SREs were identified based on considerations outlined in section 3.3. Prior to undertaking any field survey, it was determined that all ‘high priority’ watercourses were SREs because they are predicted to support state and nationally listed aquatic species (DPI, 2016). All but five of the high priority watercourses were visited in the field to support and enhance the findings of the desktop analysis, confirm presence of aquatic habitat features and refine the understanding of potential issues. The high priority watercourses that could not be visited were Bucklanbah Creek, Salty Springs Creek, Quanda Quanda Creek, Caleriwi Creek and Baronne Creek. Other watercourses that were not identified as ‘high priority’ were visited in the field to determine whether they were SREs, based on presence of aquatic habitat features.

Based on both desktop assessment and aquatic habitat assessment in the field, the SREs within the study area are Narrabri Creek, Namoi River, tributary of Namoi River, Bohena Creek, Bundock Creek, Goona Creek, Mollieroi Creek, Coghill Creek, Rocky Creek, Stockyard Creek, Etoo Creek, Baradine Creek, Bucklanbah Creek, tributary of Bucklanbah Creek, Salty Springs Creek, Quanda Quanda Creek, Caleriwi Creek, Tenandra Creek, Baronne Creek, Gulargambone Creek, Castlereagh River, Kickabil Creek, Ewenmar Creek, Backwater Cowal, Emogandry Creek and Macquarie River.

4.8.1 Aquatic habitat assessment

As discussed in section 3.5.2, watercourses nominated for field assessment were to be categorised into KFH habitat types/sensitivity (DPI, 2013), and watercourse classifications (Fairfull and Witheridge, 2003) based on identified aquatic features in the field. This assessment is summarised in Table 4.4 and the watercourses which were identified as SREs based on field assessment are mapped on Figure 4.4. Full detail of the aquatic habitat assessment at survey sites can be found in Appendix A.

Most watercourses which were visited are ephemeral in nature and were mostly dry (some sites had presence of isolated pools) at the time of inspection, with exception to the Macquarie River, Namoi River and Narrabri Creek, which are perennial. Despite the lack of water, aquatic habitat characteristics were present at most of the watercourses that were visited. Key aquatic habitat characteristics were large woody debris and uprooted trees within and along the banks of the watercourses. Many streams were deep and narrow with undercutting occurring at meander bends.

Most watercourses that were visited had some vegetation in the riparian zones. A tall forest or woodland dominated by River Red Gum (*Eucalyptus camaldulensis* subsp. *camaldulensis*) lines major watercourses including Macquarie River and Castlereagh River. A sparse shrublayer and groundlayer is also present. Rushes and ferns are present in some locations. In the Narrabri area, riparian vegetation often comprises tall open forest or woodland composed of River Red Gum often with Rough-barked Apple (*Angophora floribunda*), Yellow Box (*Eucalyptus melliodora*) or River Oak *(Casuarina cunninghamiana)*. Ground cover is often dense and is composed of a mixture of forbs, graminoids and sedges, while shrub layer is sparse. Willows (*Salix* spp) are present at some of the major waterway. Riparian vegetation in the Pilliga forests generally comprises woodland dominated by Blakely's Red Gum (*Eucalyptus blakelyi)* along the watercourse with Rough-barked Apple *(Angophora floribunda),* White Cypress Pine *(Callitris glaucophylla),* and Buloke *(Allocasuarina luehmannii)* growing on the adjoining sandy valley flats. The shrub layer is sparse. Much of the ground cover in the watercourses in these forests are bare of vegetation and covered with sand with patches of shrubs, sedges, water plants and rushes (JacobsGHD, 2020a).

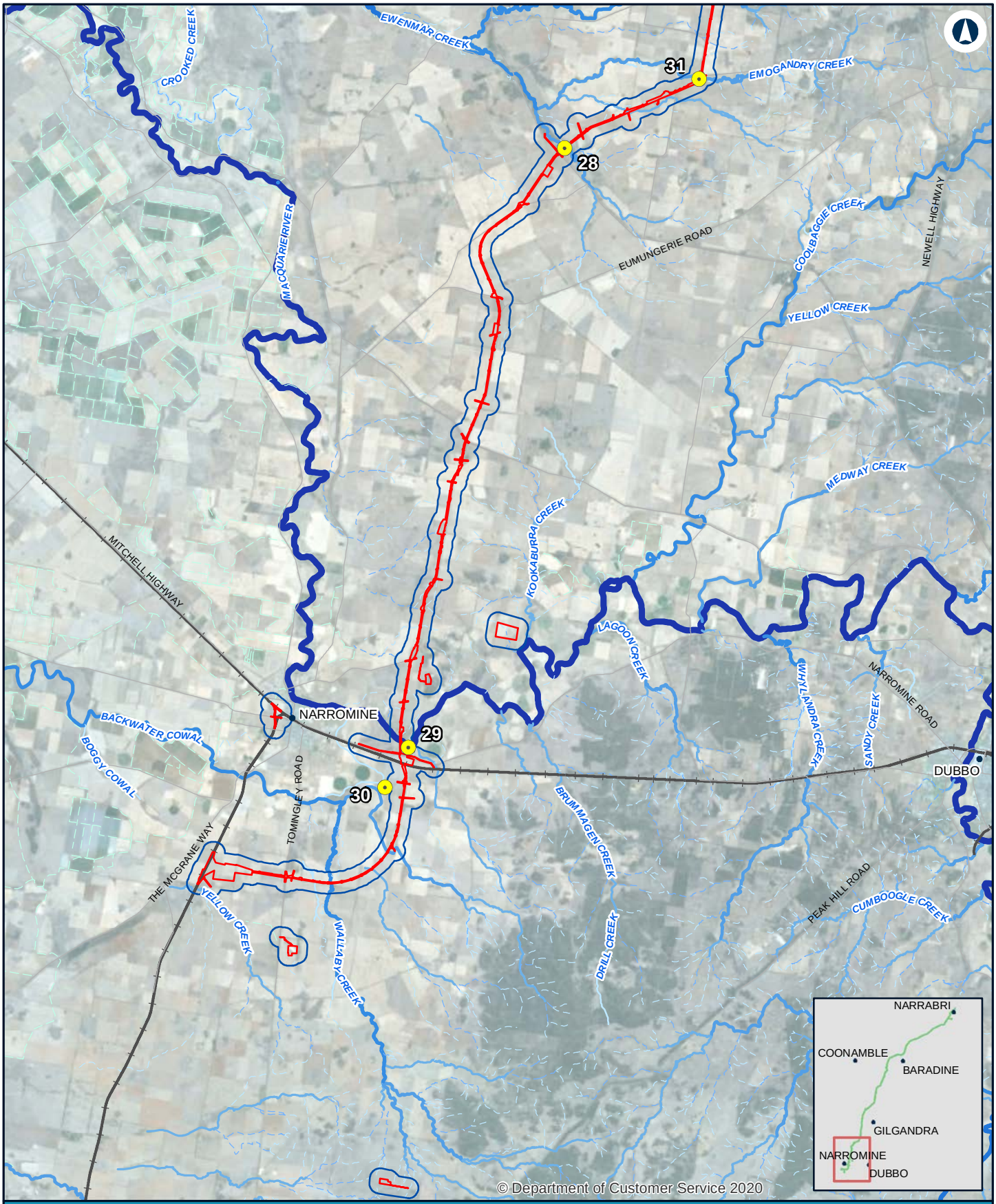
Occasional macrophyte growth was present in the form of senescing or dry foliage within major watercourses. It was not possible to identify water flow or the likelihood of pools and riffles at watercourses that were dry. Macquarie River and Narrabri Creek retained low to moderate water levels at the time of the site inspections and there appeared to be little to no water flow at both watercourses. Gravel beds and boulders were uncommon unless artificially placed at remediated sites.

Table 4.4 Aquatic habitat assessment results

Catchment	Name of watercourse	Water present at the time of inspection	Strahler Stream Order (Strahler, 1952)	Likely to contain threatened fish species (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Watercourse classification (Fairfull and Witheridge, 2003)	Sensitive receiving environment – should be considered for fish-friendly crossings
Namoi River	Narrabri Creek	Yes	9	Yes	Type 1	Class 1	Yes
	Namoi River	No – however some residual pools were present at the site and some areas had a slightly wet streambed.	9	Yes	Type 1	Class 2	Yes
	Bohena Creek	No	6	Yes	Type 1	Class 2	Yes
	Bundock Creek	No	2	No	Type 3	Class 3	No
	Goona Creek	No – however some residual pools were present at the site and some areas had a slightly wet streambed.	3	Yes	Type 1	Class 2	Yes
	Tributary of Black Creek	No	2	No	Type 3	Class 3	No
	Black Creek	No	3	No	Type 3	Class 3	No
	Mollieroi Creek	No	4	Yes	Type 1	Class 2	Yes
	Coghill Creek	No	4	Yes	Type 1	Class 2	Yes
	Talluba Creek	No	3	No	Type 3	Class 3	No
	Tinegie Creek	No	1	No	Type 3	Class 3	No.
	Rocky Creek	No	4	Yes	Type 1	Class 2	Yes
	Stockyard Creek	No	3	No	Type 1	Class 2	Yes

Catchment	Name of watercourse	Water present at the time of inspection	Strahler Stream Order (Strahler, 1952)	Likely to contain threatened fish species (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Watercourse classification (Fairfull and Witheridge, 2003)	Sensitive receiving environment – should be considered for fish-friendly crossings
	Etoo Creek	No, however there were some areas which exhibited a slightly wet streambed.	4	Yes	Type 1	Class 2	Yes
	Cumbil Forest Creek	No – however there were some residual pools.	1	No	Type 3	Class 3	No.
	Coolangla Creek	No	3	No	Type 3	Class 3	No.
	Baradine Creek	No, however there was evidence of recently evaporated residual pools.	6	Yes	Type 1	Class 2	Yes
Castlereagh River	Tenandra Creek	No	4	No	Type 3	Class 3	No
	Gulargambone Creek	No	5	Yes	Type 1	Class 2	Yes
	Castlereagh River	No	7	Yes	Type 1	Class 1	Yes
Macquarie-Bogan River	Kickabil Creek	No, however the creek exhibited a slightly wet streambed in some areas.	4	No	Type 1	Class 2	Yes
	Emogandry Creek	No	4	No	Type 1	Class 2	Yes
	Ewenmar Creek	No	4	No	Type 1	Class 2	Yes
	Macquarie River	Yes	9	Yes	Type 1	Class 1	Yes

Catchment	Name of watercourse	Water present at the time of inspection	Strahler Stream Order (Strahler, 1952)	Likely to contain threatened fish species (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Watercourse classification (Fairfull and Witheridge, 2003)	Sensitive receiving environment – should be considered for fish-friendly crossings
	Backwater Cowal	No, however some residual pools present.	Wetland depression on the floodplain	Yes	Type 1	Class 2	Yes
Macquarie Marshes Ramsar listed wetland	Macquarie Marshes Ramsar listed wetland	Not visited	-	Yes	Type 1	Class 1	Yes – however due to significant distance from the study area, the wetland is unlikely to affected by proposal activities.



NARROMINE TO NARRABRI Aquatic habitat assessment - sensitive receiving environments Figure 4.4a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 7 9

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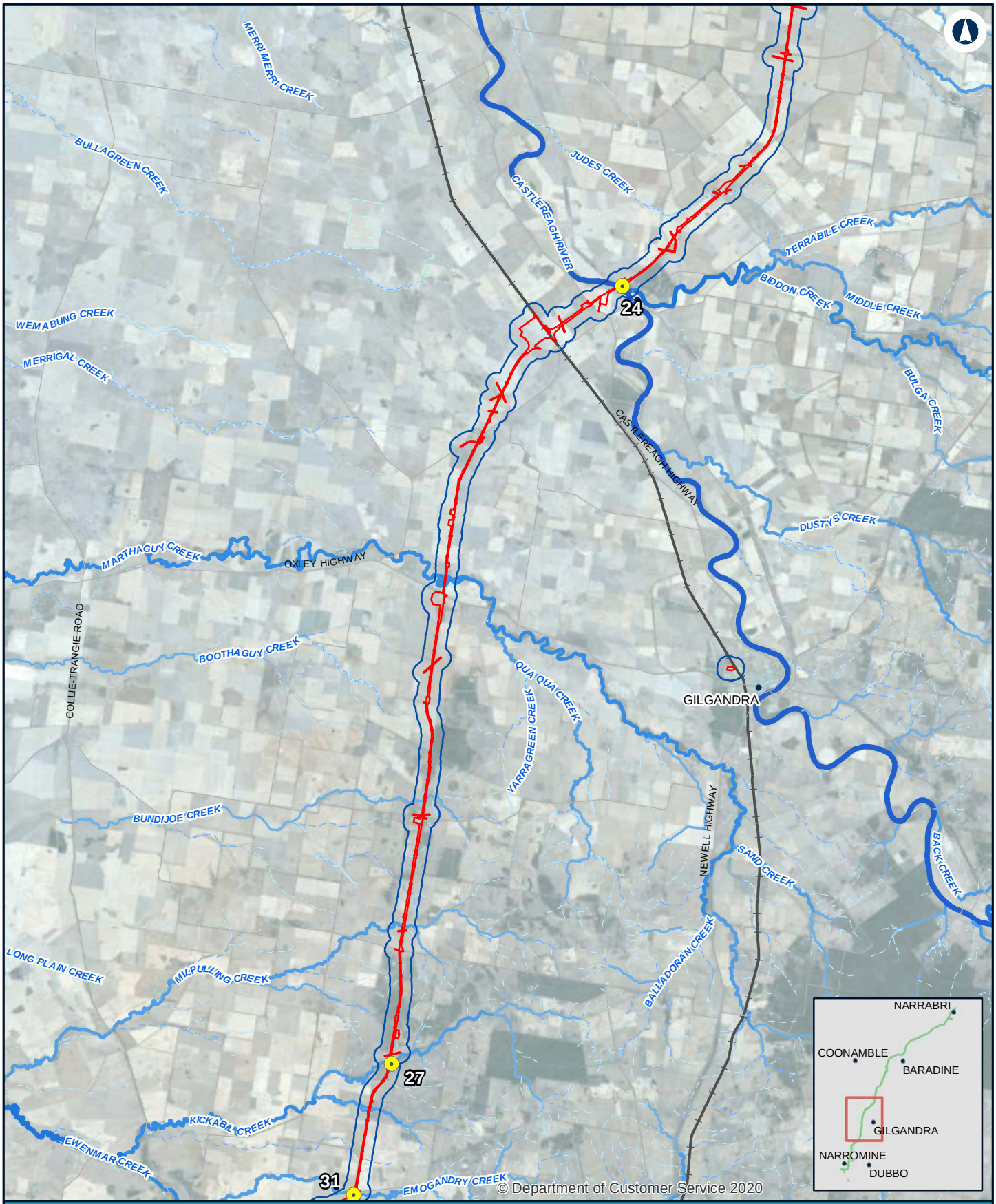

NARROMINE TO NARRABRI Aquatic habitat assessment - sensitive receiving environments Figure 4.4b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 7

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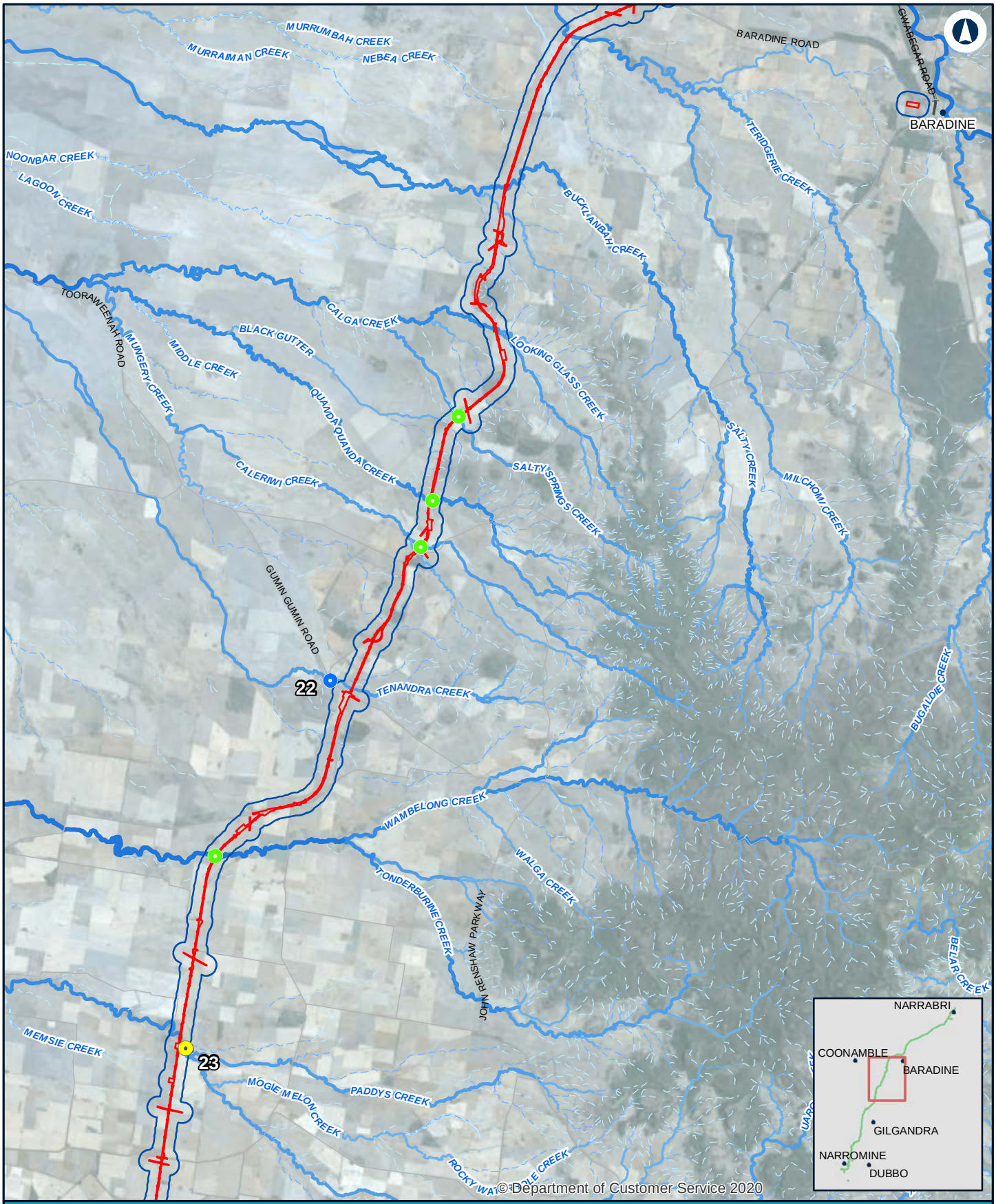

NARROMINE TO NARRABRI Aquatic habitat assessment - sensitive receiving environments Figure 4.4c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)
- Not visited (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6

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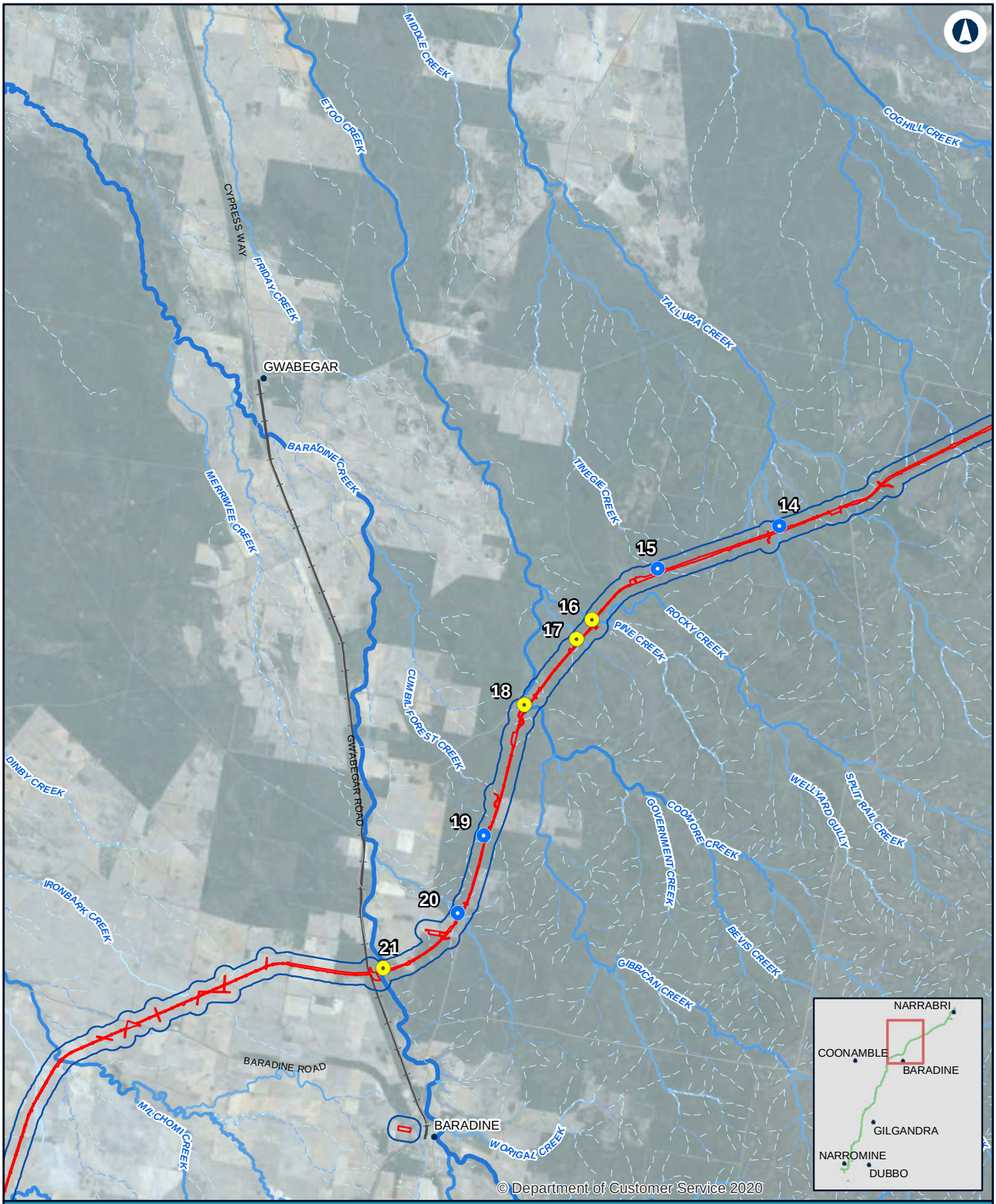

NARROMINE TO NARRABRI Aquatic habitat assessment - sensitive receiving environments Figure 4.4d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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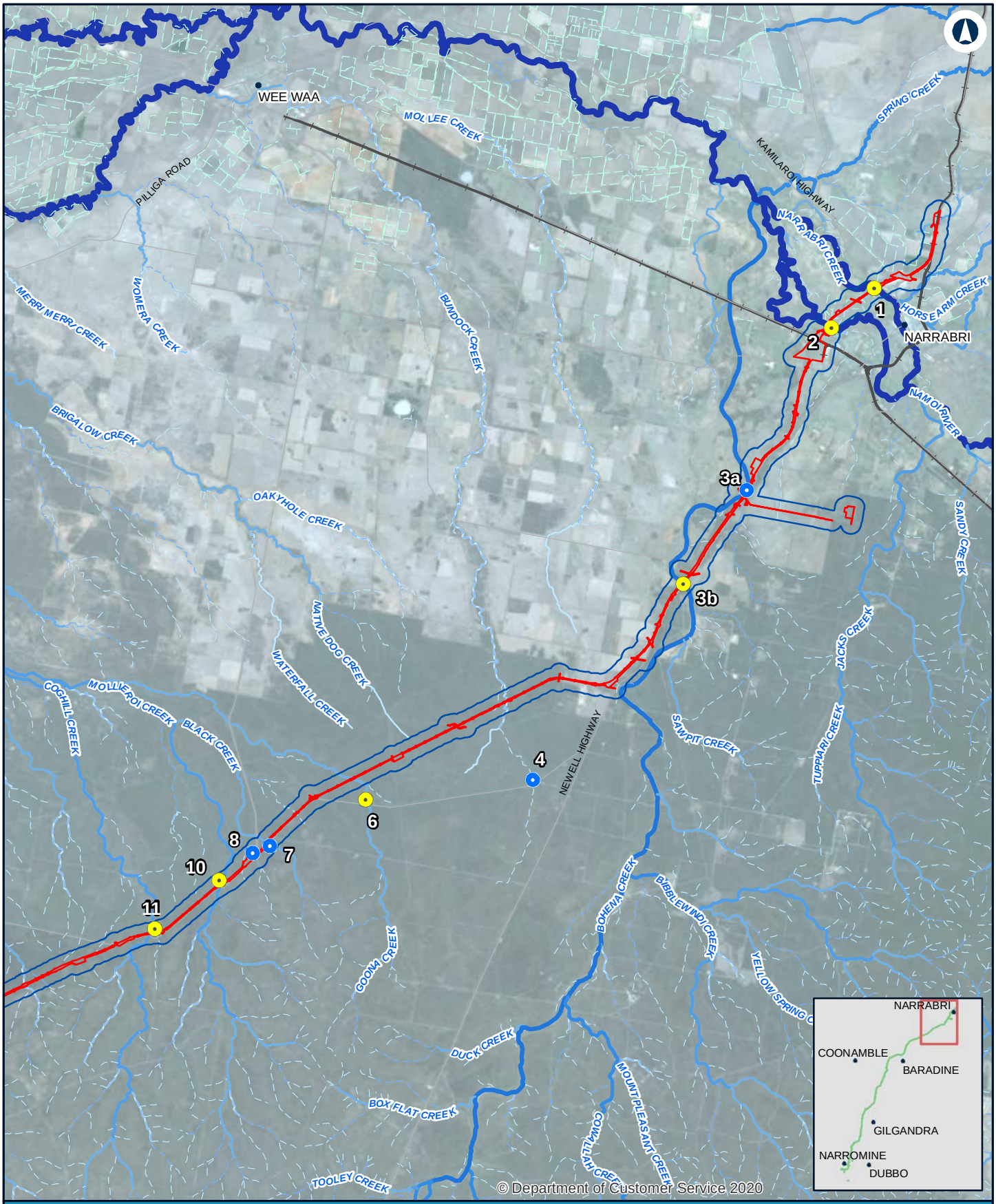

NARROMINE TO NARRABRI Aquatic habitat assessment - sensitive receiving environments Figure 4.4e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/06/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal site
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 9

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4.8.2 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are ecological communities that are dependent, either entirely or in part, on the presence of groundwater for their health or survival. The DPI *Water Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Serov et al., 2012) adopts the definition of a GDE as:

"*Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater*".

GDEs might rely on groundwater for the maintenance of some or all of their ecological functions, and that dependence can be variable, ranging from partial and infrequent dependence, ie seasonal or episodic, to total continual dependence. Aquatic GDEs include floodplains, wetlands, riparian areas and springs. These ecosystems provide important environmental services including habitat for fish, invertebrates and aquatic and terrestrial flora and fauna.

High priority GDEs

The groundwater Water Sharing Plans (WSPs) covering the proposal site identify areas of high priority GDE vegetation within the groundwater study area. High priority GDE vegetation as mapped by the WSPs is shown in Figure 4.5. The mapped high priority GDE vegetation areas are crossed by the proposal's alignment at the following locations:

- Macquarie River
- Castlereagh River
- Gulargambone Creek
- Baradine Creek
- Etoo Creek
- Rocky Creek
- Goona Creek
- Bohena Creek
- Small unnamed tributary of Bohena Creek, located close (less than 200 metres) to Bohena Creek
- Namoi River
- Narrabri Creek.

In addition, review of the WSPs relevant to the proposal indicates there are 10 mapped high priority GDE springs within the project study area. The closest is located about 10 kilometres from the alignment and all of the springs reside in the areas covered by the WSPs for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020 and the Lachlan Fold Belt Murray-Darling Basin Groundwater Source. For completeness, high priority GDE springs within proximity to the proposal are shown in Figure 4.5 but are not discussed further as impacts due to the proposal are highly unlikely because of the large separation distance.

GDE Atlas

The Bureau of Meteorology's GDE Atlas (BOM, 2020) was reviewed to investigate the potential for GDEs to exist within the broader region of the proposal. The atlas mapping outlined four main broad areas of mapped potential terrestrial GDEs and 14 potential aquatic GDEs which the proposal dissects. Terrestrial GDEs are discussed in detail in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).

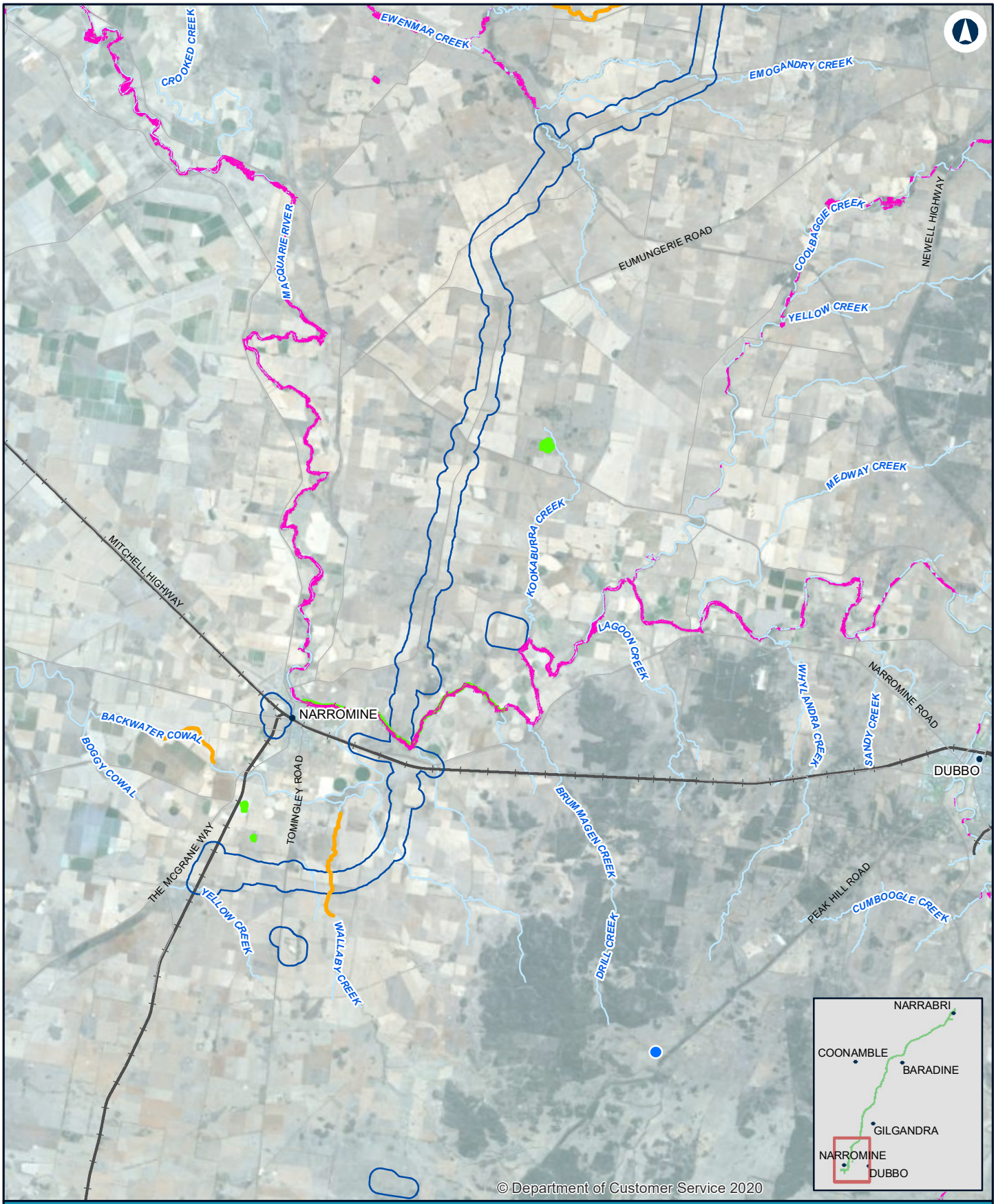
Aquatic GDE mapping

The proposal crosses 14 individual watercourses (Bohena Creek is crossed twice) which are mapped in BOM's GDE atlas as either low or moderate potential GDEs. These watercourses are shown in Figure 4.5 and documented in Table 4.5.

Table 4.5 BOM (2018) aquatic GDE potential mapping summary

Watercourse	Aquatic GDE potential
Wallaby Creek	Moderate
Macquarie River	Low
Kickabil Creek	Moderate
Marthaguy Creek	Moderate
Castlereagh River, Curban	Low
Baronne Creek, south of Mount Tenandra	Moderate
Caleriwi Creek, north of Gulargambone Baradine Road	Moderate
Teridgerie Creek, south of Coonamble Road	Moderate
Baradine Creek, east of Gwabegar Road	Moderate
Etoo Creek, south of Aloes Road	Moderate
Coghill Creek	Moderate
Mollieroi Creek, near intersection of Jack Scott Road and Pilliga Forest Way Road	Moderate
Bohena Creek (crosses alignment twice)	Moderate
Namoi River	Low

Further detail regarding GDEs is available in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020b).



NARROMINE TO NARRABRI

Potential GDE Mapping (BOM, 2018) and High Priority GDE mapping (NSW Gov WSPs)

Figure 4.5a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 20/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; GDE: BOM, DPI; Proposal: GHDJACOBS

LEGEND

- Study area
- Watercourse
- High Priority GDE (spring) (WSP for the NSW MDB Fractured Rock Groundwater Sources 2020)
- High priority GDE vegetation (NSW Gov WSPs)

Aquatic GDE

- Low potential GDE
- Moderate potential GDE

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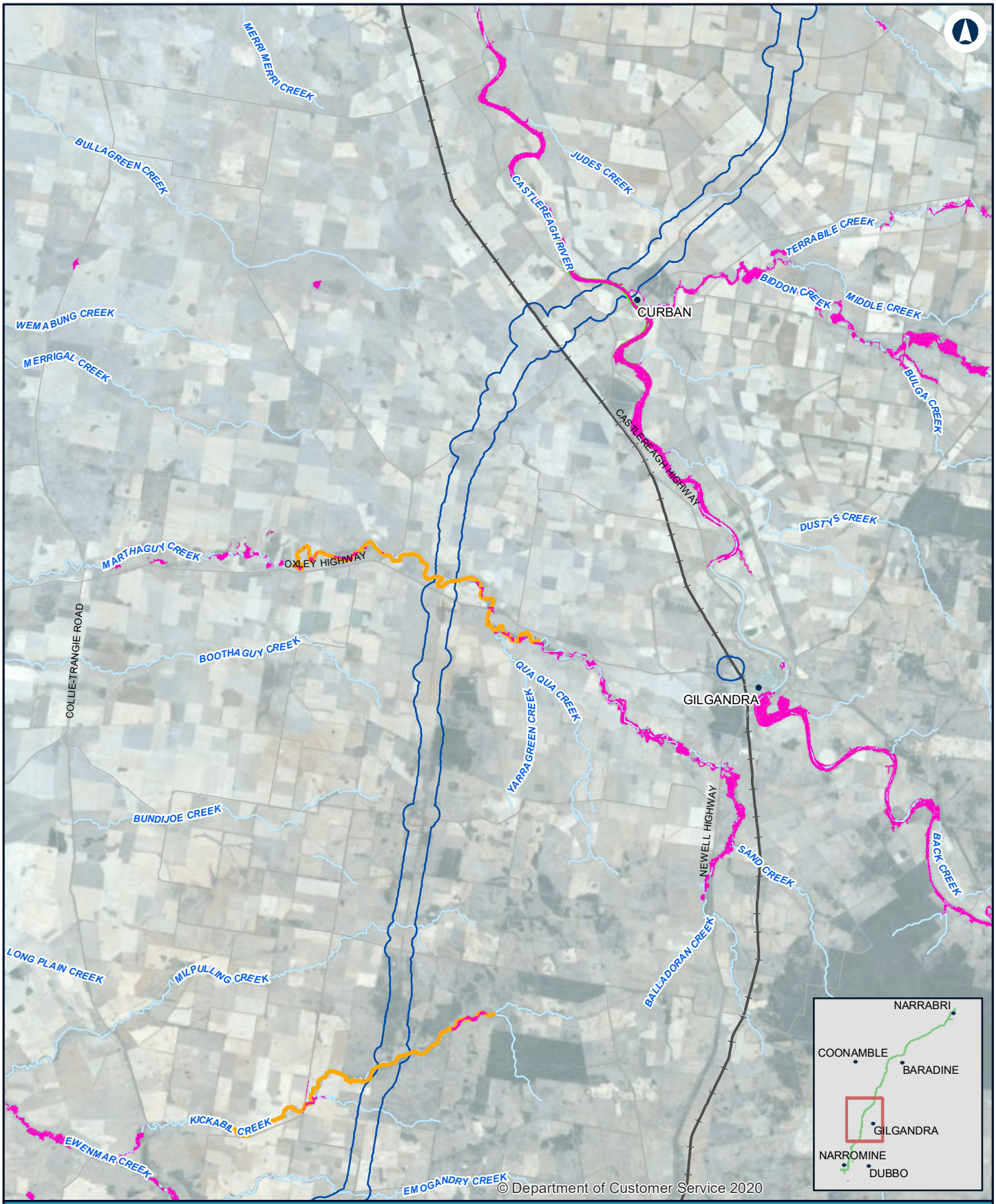

NARROMINE TO NARRABRI Potential GDE Mapping (BOM, 2018) and High Priority GDE mapping (NSW Gov WSPs) Figure 4.5b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- Study area
- Watercourse
- High priority GDE vegetation (NSW Gov WSPs)

Aquatic GDE

- Low potential GDE
- Moderate potential GDE

Date: 20/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; GDE: BOM, DPI; Proposal: GHDJACOBS

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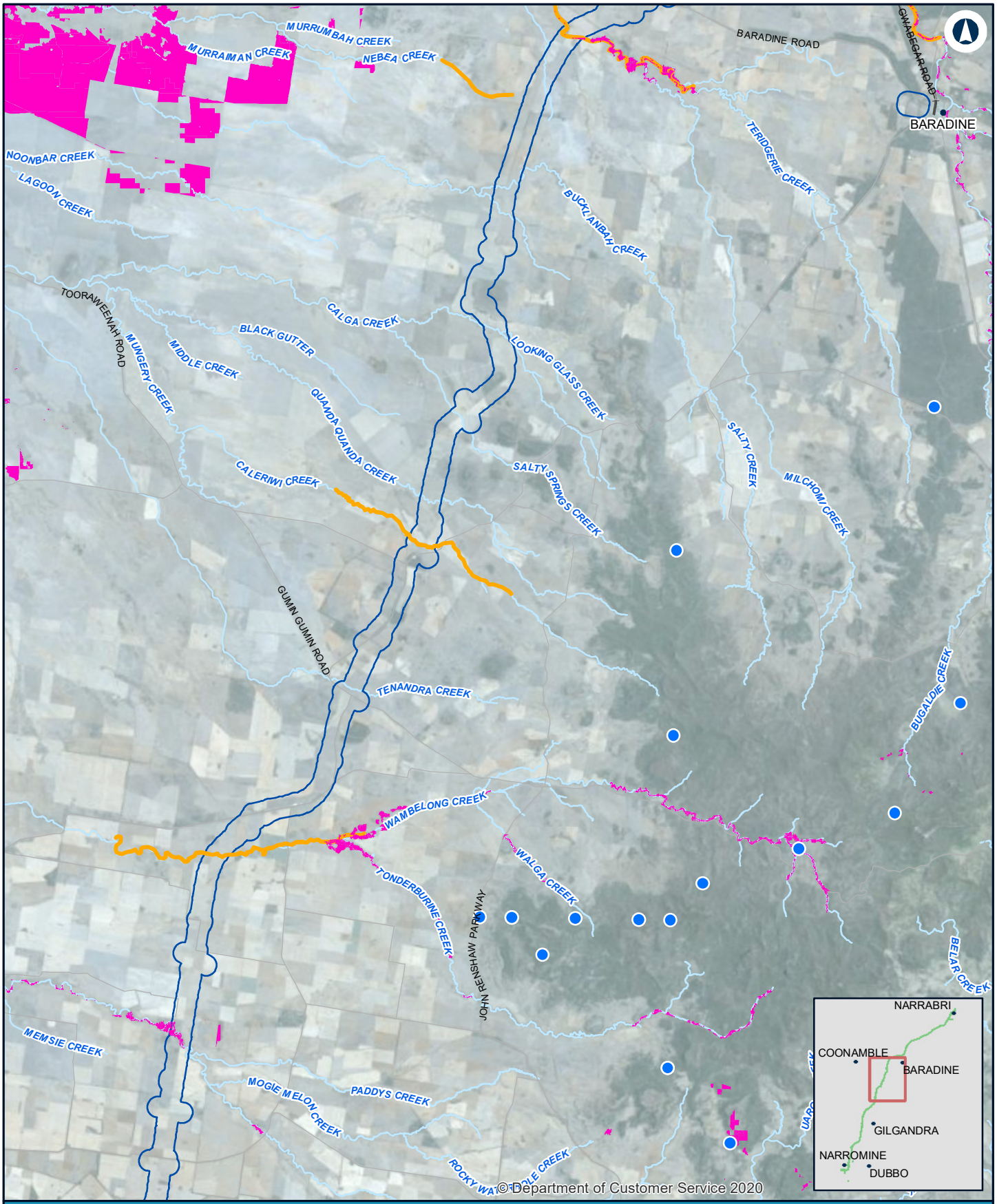

NARROMINE TO NARRABRI Potential GDE Mapping (BOM, 2018) and High Priority GDE mapping (NSW Gov WSPs) Figure 4.5c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 20/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; GDE: BOM, DPI; Proposal: GHDJACOBS

LEGEND

- Study area
- Watercourse
- High Priority GDE (spring) (WSP for the NSW MDB Fractured Rock Groundwater Sources 2020)
- High priority GDE vegetation (NSW Gov WSPs)

Aquatic GDE

- Low potential GDE
- Moderate potential GDE

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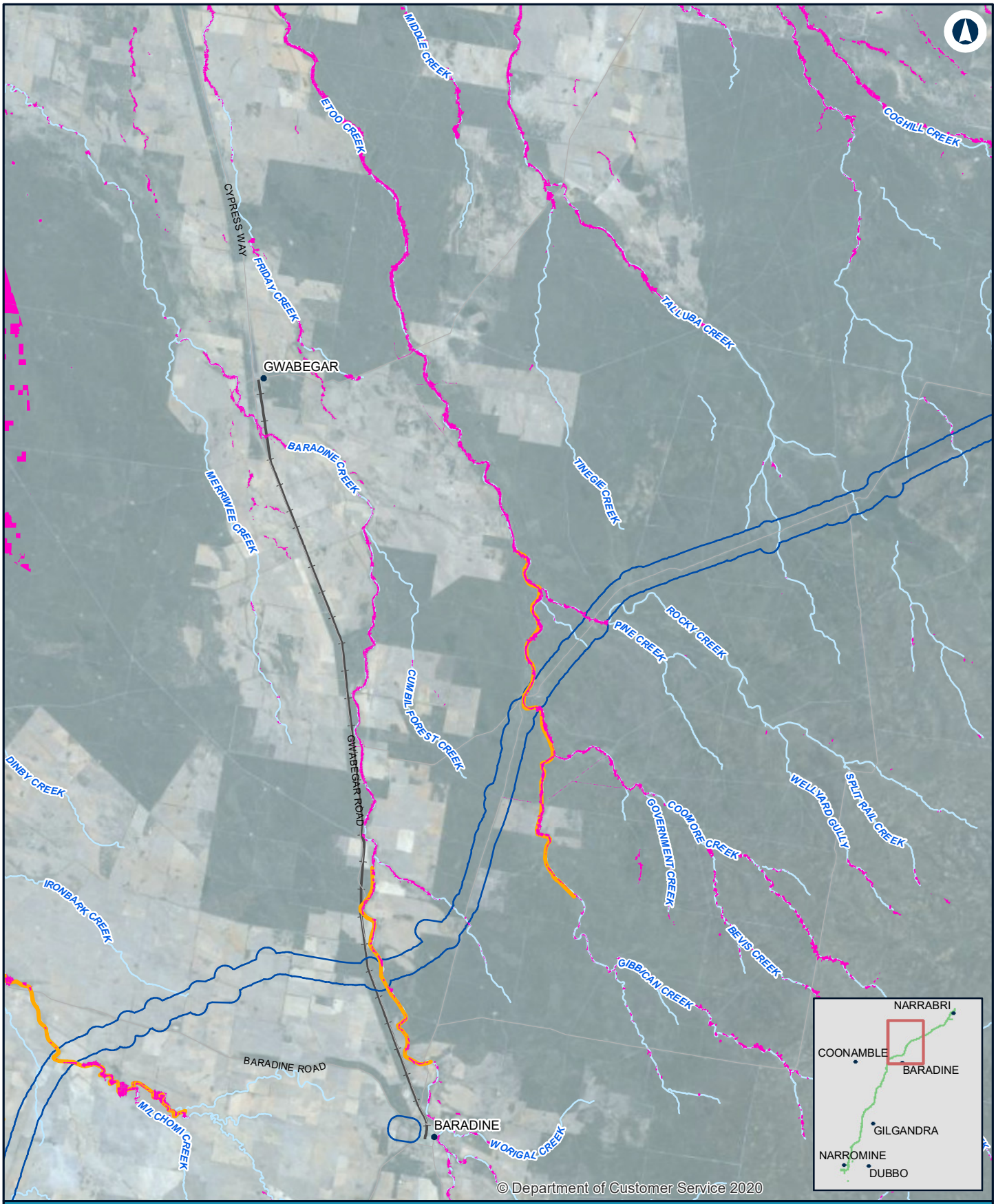

NARROMINE TO NARRABRI

Potential GDE Mapping (BOM, 2018) and High Priority GDE mapping (NSW Gov WSPs)

Figure 4.5d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- Study area
- Watercourse
- High priority GDE vegetation (NSW Gov WSPs)

Aquatic GDE

- Low potential GDE
- Moderate potential GDE

Date: 20/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; GDE: BOM, DPI; Proposal: GHDJACOBS

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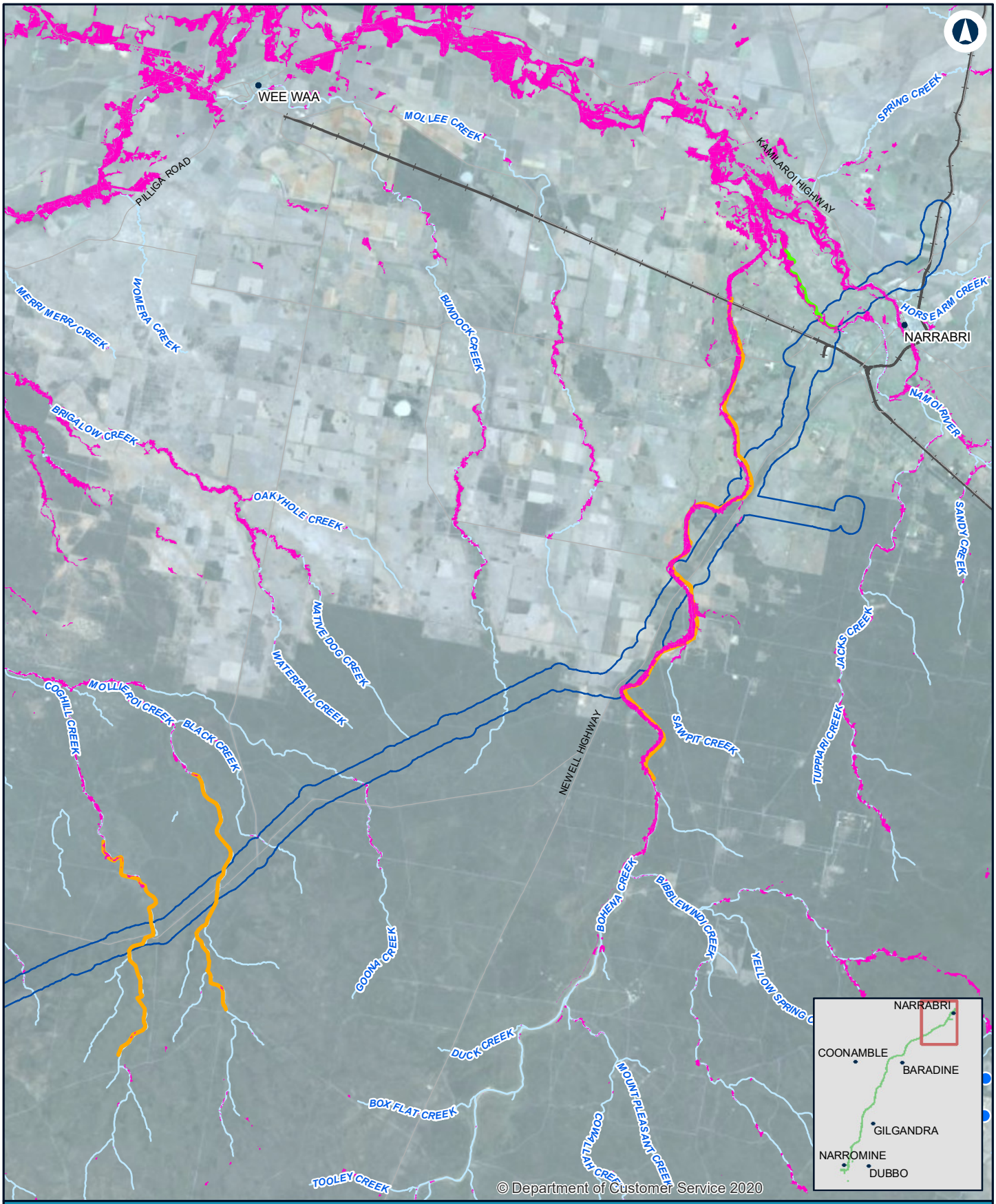

NARROMINE TO NARRABRI Potential GDE Mapping (BOM, 2018) and High Priority GDE mapping (NSW Gov WSPs) Figure 4.5e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 20/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; GDE: BOM, DPI; Proposal: GHDJACOBS

LEGEND

- Study area
- Watercourse
- High Priority GDE (spring) (WSP for the NSW MDB Fractured Rock Groundwater Sources 2020)
- High priority GDE vegetation (NSW Gov WSPs)

Aquatic GDE

- Low potential GDE
- Moderate potential GDE

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5. Impact assessment – construction

For the purposes of this assessment, the proposal has been spilt into three components, rail infrastructure, road infrastructure and key construction infrastructure. The proposal alignment is shown in Figure 1.1 and the location of all watercourse bridge crossings are shown in Figure 1.2

The *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d) and *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment* (JacobsGHD, 2020c) have identified the potential impacts and associated management and mitigation measures with respect to anticipated surface water, hydrological and flooding impacts. This aquatic ecology assessment has considered the impacts identified in these assessments as relevant to aquatic ecology.

5.1 Rail infrastructure

Construction of the various proposal elements would involve a range of activities that present a potential risk to aquatic ecology both directly and indirectly if management measures are not implemented, monitored and maintained throughout the construction phase. A summary of construction activities relevant to the aquatic ecology impact assessment is below:

The key construction work associated with the rail infrastructure are:

- Main line track – construction of 306 kilometres of new single track gauge railway that would consist of track formation earthworks, railway ballast, concrete sleepers and track.
- Crossing loops – seven crossing loops of up to 2.2 kilometres in length would be constructed parallel to the new rail corridor. Each crossing loop would contain a maintenance siding with back up power supply.
- Bridges and Culverts – where the proposal is required to cross existing roads, existing rail line and watercourses.
- Narromine West connection – a new junction that provides connectivity between the Parkes to Narromine Line and Parkes to Cobar Line.
- Connections with other rail lines - the proposal connects with existing rail lines that are part of the ARTC and Country Regional Network rail networks. These include connections with Parkes to Narromine Line, Dubbo to Coonamble Line, Narrabri to Walgett Line and Narrabri to North Star.
- Turnouts – Turnouts would be located at all connections with existing rail lines and at the end of each crossing loop.
- Level crossings – would be located throughout the proposal to provide vehicular access across the rail line.
- Embankments and cuttings – the new railway is being constructed in a predominately greenfield environment and therefore a number of cuttings and embankments would be required.
- Temporary ancillary infrastructure to support construction – including sedimentation basins and haul roads during construction that are all located within the rail corridor.

Without the implementation of appropriate erosion and sediment controls and mitigation measures throughout the construction phase, potential direct impacts to aquatic ecosystems would be related to construction works undertaken in the riparian zone, along the riverbanks and within the channel, and particularly where water crossing structures are proposed to be built. Indirect impacts would be related to uncontrolled stormwater runoff from construction areas resulting in the mobilisation of sediments and other contaminants and their deposition in receiving watercourses. A summary of potential impacts is provided in Table 5.1, however further detail is provided in section 5.4 regarding the likelihood of these impacts to be realised.

5.2 Road infrastructure

The key construction work associated with the road infrastructure include road realignments and closures at various locations, including realignment of Pilliga Forest Way for a distance of 6.7 kilometres.

Without the implementation of appropriate erosion and sediment controls and mitigation measures throughout the construction phase, the activities associated with the construction of road infrastructure present a risk to aquatic ecology if poor quality construction runoff is allowed to mobilise to nearby receiving environments. A summary of potential impacts related to construction activities is provided in Table 5.2 however further detail is provided in section 5.4 regarding the likelihood of these impacts to be realised.

Table 5.1 Potential construction impacts on aquatic ecology – Rail infrastructure

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses / likelihood of impacts
Main line rail track Crossing loops and turnouts Level crossings Connections with other rail lines Ancillary Infrastructure	• Cut and fill earthworks • Movement and use of heavy vehicles across exposed earth • Stockpiling • Vegetation clearing and mulching • Construction of railway ballast and track • Disturbance of potentially contaminated land • Relocation of utilities • Concrete works including building concrete sleepers • Establishment of water quality controls (sedimentation basins) • Vehicle movements to and from sites • Modifications to surface roads (within the rail corridor)	Construction of rail infrastructure has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes may be: • transportation of dust, litter and other pollutants associated with construction and demolition • transportation of soils, exposed sediments and contaminants associated with earthworks and vegetation clearing • transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment • transportation of concrete dust, concrete slurries or washout water associated with concrete works. As a result, the following potential impacts may occur • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	The watercourses which are at greatest risk of being impacted due to changes in water quality are the perennial watercourses in proximity to construction works, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses / likelihood of impacts
Embankments and cuttings	• Excavation • Earthworks, cuttings and stockpiling • Transport of materials	Construction of embankments and cuttings has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes may be: • transport of sediment-laden runoff from areas of excavation and excess spoil storage • transportation of dust generated from stockpiles • transportation of sediment movement from embankment slopes following rainfall. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	The watercourses which are at greatest risk of being impacted are the perennial watercourses in proximity to construction works, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses / likelihood of impacts
Bridges and culverts	• Instream works, including temporary barriers to fish-passage • Clearing of riparian vegetation and habitat features • Temporary diversion of water if present at time of construction • Construction of watercourse crossings and installation of drainage structures and culverts • Concrete works	Construction of watercourse crossing structures have the potential to directly impact on aquatic species, riparian zones, river banks and channels. Indirect impacts can also occur from the mobilisation of sediments and toxicants via wind or stormwater runoff. Potential causes may be: • temporary instream works including stream bed levelling, concreting and piling • removal of aquatic habitat features such as large woody debris, overhanging or trailing vegetation, instream macrophytes and gravel streambeds • removal of vegetation along river banks and in the riparian zone • alterations of creek flow velocity due to temporary instream barriers which could potentially cause scour, as well as streambed and bank destabilisation • transportation of sediments and pollutants due to construction activities within or near watercourses • transportation of soils, exposed sediments and contaminants associated with earthworks and vegetation clearing • transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment • transportation of concrete dust, concrete slurries or washout water associated with concrete works. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality	The watercourses which are at greatest risk of being impacted are the perennial watercourses in proximity to construction works, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses / likelihood of impacts
		• smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills • temporary instream barriers may impede fish passage and alter flow velocity in watercourses. This has the potential to reduce the suitability of the aquatic habitat for native species and impact on ecological processes of recruitment, spawning and migration, as well as access to food supply • aquatic species that may be present in the enclosed instream construction area may be injured or killed from interaction with equipment and machinery during construction activities (ie piling) • removal of aquatic habitat features can impact on the suitability of aquatic habitat for native species and subsequently impact on ecological processes of recruitment, spawning and migration, as well as access to food supply • clearing riparian vegetation can cause increased erosion and sedimentation of watercourses from mobilisation of exposed soils and bank destabilisation which can lead to a decline in aquatic ecosystem function as discussed above. Further detail regarding impacts from the construction of water crossing structures is provided in section 5.4.	

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses / likelihood of impacts
Dewatering	• Discharge of sedimentation basins • Decommissioning farm dams containing water	Discharge from sedimentation basins has the potential to impact water quality of receiving watercourses if not properly treated prior to discharge. Decommissioning farm dams could additionally cause potential release of exotic species to downstream receiving environments. Potential causes may be: • transport of sediment-laden water to downstream watercourses • transport of contaminated water that contains elevated toxicant concentrations of heavy metals, hydrocarbons and pesticides • release of aquatic fauna, including pest species such as Common Carp (*Cyprinus carpio*) and Eastern gambusia (*Gambusia holbrooki*). As a result, the following impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills • pest species can alter the natural environment, including stirring up sediments, increasing nutrient levels and contributing to erosion, feed on or destroying native plants, preying on invertebrates, native fish, and their eggs, as well as competing with native species for food, habitat or spawning grounds.	The watercourses which are at greatest risk of being impacted are the perennial watercourses in proximity to sedimentation basins, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

5.3 Key construction infrastructure

This impact assessment of the construction infrastructure relates to both the establishment of the construction infrastructure and the usage of construction infrastructure for four years.

Construction infrastructure for the proposal would include:

- Borrow pits – four borrow pits are required to provide general and structural fill for the proposal.
- Access tracks – constructed outside of the rail construction corridor and utilised throughout construction to facilitate movement of borrow material.
- Workforce accommodation – temporary camps for up to 500 people would provide accommodation to the construction workforce. At the Narromine North and 'Baradine temporary workforce accommodation facilities wastewater would be treated and potentially irrigated onsite, through the provision of wastewater treatment plants (WWTP). These WWTPs are expected to have membrane biological reactor technology, which produces high quality reclaimed water suitable for various beneficial reuses including recycling and irrigation. At the three remaining camps wastewater is proposed to be disposed of through connections to the towns' existing wastewater network.
- Multi-function compounds – three multi-function compounds are proposed at Narromine South, Curban and Narrabri West to support a range of construction activities, including facilities such as office and amenities, laydown areas, material storage, topsoil storage, fuel and hazardous storage areas, maintenance areas, temporary workforce accommodation, welding yard, concrete precast yard and groundwater extraction bores.
- Compounds – numerous smaller compounds are required within the construction footprint to support construction.
- Concrete batch plants – fixed or mobile concrete batching plants would be established at the Curban multi-function compound, structure compounds at the Macquarie River, Castlereagh River and Narrabri Creek/Namoi River and general compound sites, to supply concrete during construction.

The establishment and use of the construction infrastructure presents a potential risk to aquatic ecosystems if poor quality runoff is able to mobilise to watercourses. Potential impacts are summarised in Table 5.3, however further detail is provided in section 5.4 regarding the likelihood of these impacts to be realised.

Table 5.2 Potential construction impacts on aquatic ecology – Road infrastructure

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses
Road closures or realignments	• Earthworks, including ground levelling and vehicle movements across exposed earth • Vegetation removal and topsoil stripping • Relocation of utilities • Demolition works • Concrete works • Activities associated with construction for permanent works	Construction of road infrastructure has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • transportation of dust, litter and other pollutants associated with construction and demolition • transportation of soils, exposed sediments and contaminants associated with earthworks and vegetation clearing • transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment • transportation of concrete dust, concrete slurries or washout water associated with concrete works. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	The watercourses which are at greatest risk of being impacted due to changes in water quality are the perennial watercourses within 500 metres of proposed road alignments, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Table 5.3 Potential construction impacts on aquatic ecology – Construction infrastructure

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses
Borrow pits and associated access tracks	• Site clearance, including stripping of topsoil, vegetation removal • Earthworks, as well as movement and use of heavy vehicles across exposed earth • Crushing and blasting • Transport of blasted and crushed rock • Establishment of borrow pit access tracks	The establishment and use of the borrow pits (and their associated access tracks) has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • transportation of loose sediment associated with earthworks and vegetation removal • transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment • transportation of contaminated sediments which may have elevated concentrations of heavy metals, hydrocarbons and pesticides • transportation of dust, litter and other pollutants associated with construction; particularly, blasting and crushing which may produce a fine dust • compaction of soil at access tracks, reducing infiltration of runoff and increased risk of contaminated water entering watercourses • pollution, including accidental litter dispersion and accidental spills/material released during transportation of construction waste to and from site. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation	The closest watercourses to the borrow pits and associated access tracks are as follows: • Borrow pit A – Nearest watercourse (unnamed) is >2 km from borrow pit. • Access track for Borrow pit A is >1 km away from nearest watercourse (unnamed). • Borrow pit B – nearest watercourse (Wallaby Creek) is >2 km from borrow pit. • Access track for Borrow pit B crosses Wallaby Creek. • Borrow pit C is ~1 km from Macquarie River. • Access track to Borrow pit C is >1 km from Macquarie River. • Borrow pit D – nearest watercourse >2 km. • Beginning of the access track to Borrow pit D is 60 m away from Bohena Creek at its nearest point, however the Newell Highway and main construction corridor are located between the access track and the channel therefore runoff from the access track is unlikely to reach the watercourse.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses
		• deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	The construction methodology, erosion and sediment controls and mitigation strategy would be implemented to further minimise any impacts to these watercourses. As such, the likelihood of impacts is considered low. This is further discussed in section 5.4.
Compounds Concrete batching plants	• Site clearance • Establishment of site boundaries • Earthworks, as well as movement and use of heavy vehicles across exposed earth • Transport of spoil material from stockpiles sites • Concrete works • Welding works • Concrete batching	The establishment and use of the construction compounds has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • transportation of dust, litter and other pollutants associated with establishment and use of construction compounds • transportation of loose sediment associated with earthworks, including vehicle movement across exposed earth, and transport of material from stockpile sites • transportation of soils and exposed sediments from vegetation clearing • transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment • transportation of stormwater runoff contaminated with by-products of activities occurring on sites, such as welding, concreting and material laydown • transportation of cement dust, concrete slurries or washout water • transportation of contaminated sediments which may have elevated concentrations of heavy metals, hydrocarbons and pesticides. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality	Watercourses that are at greatest risk of being impacted are the perennial watercourses in proximity to compounds and batching plants, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the works are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses
		• potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	
Workforce accommodation	• Site clearance. • Earthworks, as well as movement and use of heavy vehicles across exposed earth during site establishment. • Usage of the site by workers.	The establishment and use of the workforce accommodation has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • potential for litter and debris to be transported off area by stormwater runoff, floods or wind • potential for wastewater effluent to be transported off site due to leaks or spills from the on site WWTPs at the Narromine North and Baradine facilities, or from recycling or irrigation, leading to runoff to surface water • transportation of loose sediment associated with vehicle movement across exposed earth • transportation of soils and exposed sediments from vegetation clearing • transportation of pollutants from accidental spills or leaks from vehicles or machinery. As a result, the following potential impacts may occur: • fish kills due to clogging fish gills • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality	All watercourses within the study are have the potential to be impacted. At greatest risk are the perennial watercourses in proximity to the workforce accommodation sites, these are: • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the workforce accommodation sites are unlikely to be impacted due to the lack of water within the watercourses. In addition, the proposed construction methodology, erosion and sediment controls and the proposed mitigation strategy would aim to minimise any impacts to watercourses within proximity to the construction works. This is further discussed in section 5.4.

Construction activity / source of pollutants	Construction works	Potential impacts to aquatic ecology	Receiving watercourses
		• potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality • smothering of aquatic vegetation • deposition of sediment within aquatic habitat such as deep, rocky holes • a decrease in trophic interactions due to decreased visibility • reduced light penetration which can limit the growth of aquatic vegetation • algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	

5.4 Construction impacts

The following subsections describe potential impacts and the likelihood of direct and indirect impacts to aquatic ecosystems associated with construction activities.

The likelihood of the potential impacts that have been identified differs with respect to the type/sensitivity of the watercourse that may be impacted, the size and type of the water crossing structure proposed (ie bridge or culvert), as well as the proposed construction methodology, erosion and sediment controls, and mitigation measures.

5.4.1 Runoff from construction activities

Runoff from construction activities can result in sediment and pollutants mobilising into downstream watercourses, which can directly or indirectly impact aquatic species. Sedimentation may impact aquatic ecosystems by increasing the turbidity of water, increasing algal productivity, clogging fish gills, smothering aquatic vegetation and causing sediment to settle into habitat features such as rocky pools. Pollutants and toxicants from construction runoff may also degrade the water quality, which can be harmful to aquatic life that may be sensitive to changes in water quality. Activities that may result in impacts to aquatic ecology include:

- Vegetation removal – vegetation removal would expose soils to weathering processes, thereby increasing the risk of erosion and sedimentation. Removal of vegetation in the riparian zone has the potential to destabilise banks leading to bank erosion, sedimentation of watercourses and potentially geomorphic impacts downstream which may alter habitat quality and structure for aquatic flora and fauna.
- Construction of railway line, access and haulage roads – during the construction of these features, movement of heavy machinery across exposed earth may disturb soils and make it more susceptible to erosion. Toxicants, including heavy metals may also be mobilised by stormwater runoff during the construction of these features. Sedimentation and polluted runoff may affect fish species that may be sensitive to changes in water quality.
- Stockpiling – some excavation material would require stockpiling prior to being transferred and reused on the proposal. Stockpiles that are not adequately stabilised can result in material eroding away during windy or high rainfall events which could result in sedimentation of aquatic ecosystems.
- Cut and fill earthworks – cut and fill earthworks are located along the majority of the alignment which would disturb soils and affect the topography and geology in the area. This may result in increased sedimentation of watercourses and subsequently impacts to aquatic species:
  - In areas of cut, the earthworks have the potential to destabilise the landform. To reduce this risk, the design of cuts has been considered to avoid and/or minimise potential destabilisation.
  - In areas of fill, soils and landform have the potential to be eroded during rainfall events by runoff. This can result in sedimentation of downstream watercourses through mass movement of soils.
- Use of construction plant equipment and construction compounds – Pollutants from concrete works, accidental spills or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment, and litter and wastewater from construction compounds or temporary workforce accommodation facilities have the potential to mobilise to watercourses in stormwater runoff. This may result in increased nutrient or toxicant concentrations in the water which could impact aquatic ecosystems. Further discussion regarding the potential for surface water impacts associated with WWTPs at the Narromine North and Baradine temporary workforce accommodation facilities is provided in the *ARTC*

Inland Rail Narromine to Narrabri Surface Water Quality Assessment (JacobsGHD, 2020d).

- Dewatering – Runoff that is captured in sedimentation basins would be discharged to downstream receiving environments which has the potential to result in sedimentation and pollution of watercourses, however, it is expected that water collected in sedimentation basins would be appropriately treated in accordance with ANZG (2018) water quality guidelines prior to discharge. Water pumped out during decommissioning of farm dams would similarly be treated and discharged in accordance with ANZG (2018) water quality guidelines. In addition, to avoid any dispersal of aquatic pest species during the decommissioning of farm dams, Fauna salvage would be undertaken prior to water being pumped out. If any aquatic pest species are present, the appropriate management procedures would be undertaken in accordance with the FM Act.

Watercourses which are at greatest risk of being impacted by poor water quality are those that are perennial (Macquarie River and Namoi River/Narrabri Creek). However, impacts to these aquatic environments are considered unlikely provided adequate erosion and sediment controls are employed at construction sites which would divert all construction runoff to sedimentation basins for appropriate treatment prior to discharge into watercourses. Sedimentation basins would allow construction runoff to settle and would only be discharged to downstream environments in accordance with ANZG (2018) water quality guidelines.

Impacts to watercourses that are usually dry (ephemeral) are considered unlikely as construction would only be undertaken during dry conditions. Erosion and sedimentation control measures would ensure no untreated construction runoff would be able to mobilise to downstream watercourses. The risk of mobilisation of poor-quality runoff due to a rainfall event is minimal as construction within the watercourses is expected to only take about one to two days, particularly with the use of precast structures, and the climate of the region is such that, in most cases, there would be sufficient notice of rainfall to allow construction activities to cease prior to the rainfall. In the unlikely event that unexpected rainfall were to occur during construction, a contingency plan would be developed as part of the Construction Environment Management Plan (CEMP) to ensure sediment is captured prior to mobilisation into available water.

5.4.2 Removal of instream vegetation and habitat features

Clearance of instream aquatic vegetation and habitat features has the potential to impact aquatic species that depend on these habitat features for food supply, shelter, spawning and recruitment processes. Aquatic habitat features are often used as breeding habitat and provide protection for juveniles. Removal of habitat features therefore has the potential to result in reduced reproductivity or direct mortality of larvae and young-of-year native species.

It is expected, however, that impacts to the aquatic habitat features due to the proposal would be temporary and minimal because habitat features that are able to be relocated (ie large woody debris) would be moved from the proposal site to areas upstream or downstream in consultation with a qualified ecologist. Aquatic habitat features would then be reinstated in the construction footprint area following construction. Further, to minimise any impact of construction on the breeding processes of species, construction of the bridge crossings in ephemeral streams where threatened species are predicted, would only be undertaken during the breeding season if the watercourse streambed is dry. For those structures which will be constructed in perennial watercourses, namely the bridges over Macquarie River and Namoi Creek/Narrabri River, bridge construction would be via barges only, to minimise the potential disturbance of habitat features and the streambed. Where possible, these works in perennial watercourses should be undertaken outside of the breeding season (spring and summer) of threatened native fish species that may utilise these features for spawning.

5.4.3 Removal of riparian vegetation

The proposed construction of the water-crossing structures is anticipated to require removal of approximately 85 hectares of riparian vegetation along the length of the construction footprint.

Removal of riparian vegetation can indirectly impact on aquatic species as it can affect water quality if runoff is able to mobilise exposed soils into a watercourse. Water quality impacts could subsequently result in a breach of a range of chemical and physio-chemical parameters that support healthy aquatic communities. The ecological effects can range from direct fatality to organisms, to alteration of the ecosystem structure through changes in the abundance, composition and diversity of communities and habitats. Changes to nutrient loads mobilising to a watercourse and increased turbidity can lead to reduced visibility for fish and algal blooms. Increased turbidity and algal blooms can also lead to clogging fish gills, smothering of aquatic vegetation, or may cause a reduction of light penetration which can limit the growth of macrophytes.

The removal of riparian vegetation can also reduce channel stability which could result in increased bank erosion and subsequent sediment deposition downstream of the works. Sedimentation and erosion can impact the geomorphology of a stream through deposition of sediment and changes to flow rate, thus altering habitat structure.

Degradation of water quality and geomorphic changes as a result of sedimentation from vegetation clearing is considered a risk for perennial watercourses where major bridge crossings are proposed (Macquarie River and Namoi River / Narrabri Creek). However, it is expected that any exposed sediment generated from vegetation clearing would not mobilise into watercourses as it would be sufficiently captured through appropriate sediment and erosion control measures. Erosion and sediment controls would be outlined in a soil and water management plan prepared as part of the CEMP. In addition, it is expected that only a minimal amount of clearance would be required at these locations as the alignment is situated in areas that have been cleared of vegetation or have relatively sparse vegetation.

Water crossing structures proposed to be built across ephemeral streams and drainage lines are mostly situated on relatively flat properties that have been cleared for agricultural purposes. Vegetation clearing at these sites is therefore expected to be minimal and would only span the width of the corridor. Further to this, the construction of culverts would take place when watercourse channels are dry, and erosion and sediment controls would also be established at all construction sites. As such, removal of vegetation is unlikely to result in mobilisation of sediments into the watercourse.

The risk of mobilisation of sediment due to a rainfall event is also minimal as construction of culverts and bridges is expected to only take about one to two days due to the use of precast structures, and the climate of the region is such that, in most cases, there would be sufficient notice of rainfall to allow instream activities to cease prior to the rainfall. In the unlikely event that unexpected rainfall was to occur during construction, a contingency plan would be developed as part of the CEMP to ensure sediment is captured prior to mobilisation into available water.

5.4.4 Temporary barriers to fish passage

The installation of temporary structures has the potential to hinder and possibly prevent movement of fish. The works associated with the Macquarie River and Namoi River/Narrabri Creek major bridge structures have the greatest potential to impact fish passage as they are the only perennial watercourses. Potential barriers may be caused by the following:

- Silt curtains – recommended to be erected around piling locations for major bridge structures proposed to be constructed across perennial watercourses (Macquarie River and Namoi River/Narrabri Creek).
- Barge platform – proposed to be used as an instream platform for building the major bridge structures proposed to be constructed across perennial watercourses (Macquarie River and Namoi River/Narrabri Creek).

The potential for floating silt curtains to obstruct fish passage would depend on how complete the barrier was. The floating silt curtains would be located around the piling activities and designed so that no damming or weir effect is created. As such, the majority of the watercourse would be unobstructed, and fish would be able to move upstream and downstream.

Barges are proposed to be used in the construction of major bridge structures on perennial watercourses (Macquarie River and Namoi River/Narrabri Creek). A barge is a floating platform, therefore no physical barriers to fish passage is anticipated.

In addition, the use of instreams structures would be temporary and would be installed/removed from watercourses as construction of the alignment progresses. As such, any barriers to fish passage due to use of temporary instream structures would be short term.

5.4.5 Riverbank disturbance and instream works

Instream works are required for building the water crossing structures, including piling activities for bridge structures across perennial watercourses (Macquarie River and Namoi River/ Narrabri Creek), and stream bed levelling for building culverts on ephemeral watercourses. Additionally, river banks would be disturbed during construction of the watercourse crossings which could potentially destabilise the banks. These activities have the potential to increase the risk of exposed sediment being mobilised downstream which could result in water quality impacts that effect aquatic species.

Piling activities also have the potential to directly impact aquatic fauna that may be present in the works area. If the area is enclosed and fauna salvage not undertaken, then aquatic fauna that may be present within the construction area may have the potential to be harmed by equipment or machinery.

The impacts due to piling are considered unlikely as floating silt curtains would be placed around piling works which would contain the disturbed sediment. Piling would additionally be undertaken from barges which would not disturb the streambed. No other instream construction works would be required as all other bridge elements would be craned into place from the river bank. Fauna salvage within the enclosed works area would also be undertaken prior to commencement of piling works.

For the construction of culverts, the only area of channel disturbance would be for streambed levelling at the base. Levelling is expected to take less than one day and would immediately be filled with concrete, which would be sufficiently dry (such that concrete would not be mobilised by rainfall) within one day. Precast structures would then be put in place via cranes to further minimise the need for disturbance within the watercourses.

All water crossing structures proposed to be built across ephemeral watercourses would be constructed when the streambeds are dry and cease prior to any expected rainfall, as described in section 5.4.1. As such, any risk of sedimentation and erosion due to works on riverbanks and within stream beds would be adequately managed through employment of erosion and sediment control measures that would be developed and detailed in the soil and water management plan. Therefore, mobilisation of sediment due to these activities is unlikely. To further minimise the potential for impacts, works on banks and within streambeds would be minimised, with cranes and other equipment being located outside of this area, wherever possible.

5.4.6 Concrete works

Concrete works, particularly in-situ pouring of concrete, is required for building all water crossing structures. Concrete works can result in concrete dust, concrete slurries or washout water entering downstream waters. Concrete by-products are alkaline, with a pH of around 12, and therefore have the potential to alter the pH of downstream watercourses which can be harmful to aquatic life that are sensitive to changes in water quality. Additionally, concrete washout water contains high levels of chromium that can accumulate in the gills and intestines of fish.

For major bridge structures on perennial watercourses (Macquarie River, and Namoi River/ Narrabri Creek), impacts to water quality due to concrete are considered unlikely as appropriate containment measures such as an encapsulation structure above the watercourse would be utilised to avoid ingress of concrete waste into the watercourses.

All in-situ pouring of concrete for culverts across ephemeral watercourses would be undertaken when the streambeds are dry and cease during wet weather or when the watercourse is flowing, therefore mobilisation of concrete waste is unlikely.

6. Impact assessment – operation

During the operational phase of the proposal, the railway line would be complete, cleared areas would be landscaped and stabilised as required. Scour protection would be installed. An operational access and maintenance road along the length of the proposal would also be retained and stabilised for standard ARTC maintenance activities. Areas with high risk of soil erodibility would be stabilised and therefore there would be little or no risk of soil erosion and subsequent transport of sediment into nearby watercourses. Risks to aquatic ecosystems during the operation would instead be associated with permanent in-stream structures, operation of the railway, maintenance activities and accidental spills or leaks that could potentially mobilise contaminants.

For the purposes of this assessment, the proposal has been spilt into two components, rail infrastructure and road infrastructure. Construction infrastructure is not considered at the operational stage as it would be rehabilitated prior to operation of the proposal. As detailed in section 5, this assessment has considered the surface water quality, and hydrology and flooding impacts identified in the *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d) and *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment (*JacobsGHD, 2020c), as relevant to aquatic ecology.

6.1 Rail infrastructure

The key operational components associated with the rail infrastructure are:

- use of rail line features including main line track, crossing loops, turnouts and interactions with other rail lines
- permanent water crossing structures, including bridges and culverts.

The new rail infrastructure has the potential to directly and indirectly impact aquatic ecology if not properly designed and managed. A summary of potential impacts associated with operational activities are provided in Table 6.1, however further detail is provided in section 6.3.3 regarding the likelihood of these impacts to be realised.

Table 6.1 Potential operational impacts on aquatic ecology – Rail infrastructure

Proposal element	Key operational activities	Potential aquatic ecology impacts	Receiving watercourses
Rail line features including main line track, crossing loops, turnouts and interactions with other rail lines	• Train operations • Maintenance activities • Track drainage	The operation of the rail line infrastructure has the potential to impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • Transportation of dust, litter and other pollutants associated with train operations. • Transportation of pollution and sediments due to increased volume of runoff from less permeable surfaces. The runoff may contain sediments and gross pollutants from the rail formation, cuttings and from trackside drainage systems. • Transportation of pollutants from accidental spills or leaks from loaded trains. • Transportation of pollutants from major incidents such as a train derailment. • Transportation of pollutants during maintenance activities such as routine vegetation clearing and weed control. As a result, the following potential impacts may occur: • Fish kills due to clogging fish gills. • Fish kills due to changes in water quality. • Loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality. • Potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality. • Smothering of aquatic vegetation. • Deposition of sediment within aquatic habitat such as deep, rocky holes. • A decrease in trophic interactions due to decreased visibility. • Reduced light penetration which can limit the growth of aquatic vegetation. • Algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills.	The watercourses which are at greatest risk of being impacted due to changes in water quality are the perennial watercourses in proximity to construction works, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the proposal are unlikely to be impacted due to the lack of water within the watercourses. This is further discussed in section 6.3.3.

Proposal element	Key operational activities	Potential aquatic ecology impacts	Receiving watercourses
Water crossing structures	• Instream structures, including pylons and culverts	The permanent water crossing structures have the potential create to permanent instream barriers and interfere with natural flow regimes. Indirect impacts can also occur from the mobilisation of sediments and toxicants via wind or stormwater runoff. Potential causes may be: • Permanent instream structures of pylons and culverts causing potential barriers to fish passage. • Permanent instream structures of pylons and culverts causing interference with natural flow regimes, including alterations of creek flow velocity which could potentially cause scour as well as streambed and bank destabilisation. • Transportation of pollution and sediments due to increased volume of runoff from less permeable surfaces. The runoff may contain sediments and gross pollutants from the rail formation, cuttings and from trackside drainage systems. As a result, the following potential impacts may occur: • Permanent instream structures can, to some extent, physically obstruct the movement of fish. This has the potential to reduce the suitability of the aquatic habitat for native species and impact on ecological processes of recruitment, spawning and migration, as well as access to food supply. • Permanent structures can also cause obstruction to fish passage due to potential increase in flow velocity. • Changes in flow velocity can lead to scouring which may increase the amount of sediment being transported downstream. Increased sedimentation can result in geomorphic impacts and smothering of aquatic fauna. Increased sedimentation can also result in increased turbidity and blockage of sunlight, leading to a decrease in oxygen concentrations in the water and potentially limiting growth of aquatic vegetation. • Long culverts that are built have the potential to block sunlight which can create potential barriers to fish passage, particularly for species that are sensitive to temperature fluctuations. This has the potential to reduce the suitability of the aquatic habitat for native species and impact on ecological processes of recruitment, spawning and migration, as well as access to food supply. • Polluted runoff can result in increased toxicant loads and alter pH. This could lead to a reduction in biodiversity due to fish kills, loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality. • In some areas, there may be a reduction in abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality.	The watercourses which are at greatest risk of being impacted due to changes in water quality are the perennial watercourses in proximity to construction works, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the proposal are unlikely to be impacted due to the lack of water within the watercourses. This is further discussed in section 6.3.3.

6.2 Road infrastructure

A summary of impacts related to operation of road infrastructure is provided in Table 6.2 however further detail is provided in section 6.3.3 regarding the likelihood of these impacts to be realised.

6.3 Operational impacts

The following subsections describes potential impacts and the likelihood of direct and indirect impacts to aquatic ecology associated with operational activities.

6.3.1 Erosion and sedimentation

Following the completion of construction, there is a period of time where recently disturbed soils are susceptible to scour and erosion from stormwater runoff. In general, direct impacts of sedimentation include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, algal blooms, altered stream geomorphology, smothering of benthic organisms and reduced visibility for fish.

It is expected that the risk of erosion would be minimised through progressive rehabilitation efforts of the construction footprint throughout the construction phase and post-construction. Disturbed construction areas would not be left exposed for extended periods of time after use, therefore the risk of impacts due to mobilisation of disturbed soils is negligible.

6.3.2 Accidental spills

The release of potentially harmful chemicals and other substances in the environment may occur accidentally during operation from leaks of vehicle oils, lubricants and hydraulic fluids and other accidental spills from transportation of cargo material by train carriages. Spills and leaks could potentially be transported to downstream watercourses and could result in increased toxicant concentrations which may be toxic to aquatic species.

It is anticipated, however, that train operations would be carried out in accordance with ARTC protocols and standards that would ensure appropriate maintenance and usage of the rail. Accidental pollution due to train operations would therefore be negligible and is unlikely to impact watercourses. Additionally, the likelihood of an accidental spill from a train derailment is very low as the rail track would be maintained in accordance with ARTC protocols and standard control measures would be in place to avoid such an event.

Table 6.2 Potential operational impacts on aquatic ecology – Road infrastructure

Proposal element	Key operational activities	Potential aquatic ecology impacts	Receiving watercourses
Road realignments	• Use of road vehicles on new road sections	Road use can potentially impact water quality due to the mobilisation of sediments and other contaminants via wind or stormwater runoff. Potential causes of impacts may be: • Transportation of dust, litter and other pollutants associated with road use. • Transportation of pollution and sediments due to increased volume of runoff from less permeable surfaces. The runoff may contain sediments and gross pollutants from the road and associated drainage systems. • Transportation of pollutants from accidental spills or leaks from vehicles. • Transportation of pollutants from major incidents such as a car or truck crashes. As a result, the following potential impacts may occur: • fish kills due to changes in water quality • loss of habitat or reduced suitability of habitat for native fauna that are sensitive to water quality • potential reduction in the abundance or distribution of native fauna species and increase in pest species which may be able to tolerate poorer water quality.	The watercourses which are at greatest risk of being impacted due to changes in water quality are the perennial watercourses within 500 metres of proposed road realignments, these are: • Narrabri Creek • Namoi River • Macquarie River. Other watercourses (ephemeral) in proximity to the proposal are unlikely to be impacted due to the lack of water within the watercourses. This is further discussed in section 6.3.3.

6.3.3 Stormwater runoff

Increased impervious surfaces from the rail track features and maintenance access tracks along the rail corridor may cause an increase in the volume of runoff that is able to mobilise to a downstream receiving environment. Contaminated runoff from both railway and road infrastructure could result in:

- Increased turbidity and silting of watercourses. This, in turn, can impact water quality, reduce light penetration through the water column, and/or lead to algal blooms which can impact on aquatic species.
- Increased levels of heavy metals and hydrocarbons either directly or attached to sediments which are toxic to aquatic biota.
- Excessive hydrocarbons and reduction of metals leading to depletion of dissolved oxygen in the water. This may cause the death of aquatic organisms.

The overall increase in impervious area would be very small relative to the total area of the catchments. The overall impact to the volume of runoff would therefore be minimal. Runoff from the proposal is expected to be low and not change export of annual pollutant loads to downstream watercourses. As a result, it would be unlikely to degrade the water quality and thus, not likely to impact on aquatic ecosystems.

Further, rail maintenance would be carried out in accordance with ARTC protocols and standards which would additionally ensure the rail track and drainage system are kept in suitable condition. Appropriately designed drainage would be installed within the rail corridor to capture surface flows and direct the intercepted flows to points where it would be discharged to the nearest watercourse or drainage line. Water captured by these drainage structures would be designed to discharge via overland flow. For drains that exceed the velocities of one metre per second, rock check dams or other flow dissipating devices would be used (subject to detailed design). This would reduce the impact of sediment during high rainfall events entering watercourse as a result of scouring.

6.3.4 Water crossing structures

If not properly designed, the instream components of the water crossings (pylons and culverts) and the edges of rail embankments, may impact aquatic ecosystems due to physical and behavioural barriers to fish-passage.

Instream structures would be required for all water crossings except for where plank bridges are proposed. Permanent instream structures have the potential to impact aquatic species largely due to barriers to fish-passage which can be caused due to the following factors:

- Physical obstruction within the watercourse – It is expected that pylons and culverts would, to some extent, become a physical barrier to fish moving downstream.
- Insufficient water depth or increased water velocity – Faster flow velocities at watercourse crossings, including at pylons or edges of rail embankments, could lead to potential scouring of river beds and downstream river banks. Scour leads to an increase in sedimentation which can result in water quality impacts and subsequently impacts to aquatic species and habitat.
- Behavioural barriers where conditions elicit an avoidance response that deters or slows fish movement – Long culverts which block sunlight can create a potential barrier to fish passage, particularly for species that are sensitive to temperature fluctuations.

- Changes in flow direction – Instream structures also have the potential to cause a change in the direction of water flow which can result in geomorphic changes of a watercourse through increased erosion and scour. This can subsequently lead to impacts to aquatic ecology and habitat. The watercourse crossing proposed for Gulargambone Creek is at highest risk for this to occur due to the proposed design of the bridge.

To avoid physical barriers, water crossing structures have been designed to provide for the maintenance of fish passage and natural flow velocities in accordance with the *Policy and guidelines for fish habitat conservation and management* (DPI, 2013) and *Why do fish need to cross the road? Fish passage requirements for watercourse crossings* (Fairfull and Witheridge, 2003). Appropriate scour protection and drainage structures have also been incorporated into the design at the edge of rail embankment.

Culverts have been designed to minimise shading to creeks as much as practicable, so that water temperature is not impacted. Fish-friendly bridge crossings, rather than culverts, are proposed to be built at most watercourses that are identified as KFH as well as at most other named watercourses crossed by the alignment, therefore shading is unlikely to cause a significant impact. Culverts are proposed at unnamed first and second order, ephemeral tributaries and at three watercourses that have been identified as KFH, although the KFH at these locations as been determined to be “Type 3, Class 3” due to the ephemeral nature of the streams, no threatened species predicted when water is available and minimal aquatic habitat features present at these sites, therefore culverts at these locations is in accordance with relevant crossing type requirements (Fairfull and Witheridge, 2003).

There is some potential for the proposed water crossing structure on Gulargambone Creek to cause changes to flow direction due to the proposed positioning of the bridge structure, however since the watercourse is not permanently flowing (and flow velocity is not expected to be high when there is flow) the water crossing structure proposed is unlikely to significantly alter the geomorphology downstream. As such, potential impacts to aquatic ecology is considered to be negligible at this site.

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7. Potential impacts on sensitive environments

The following sub-section outlines the potential impacts of the proposal upon:

- KTPs
- environmentally sensitive lands and processes
- threatened species and ecological communities
- GDEs.

7.1 Key threatening processes

Schedule 6 of the FM Act outlines the KTPs related to aquatic species and ecological communities. The proposal is expected to involve the KTPs outlined in Table 7.1.

Table 7.1 Summary of key threatening processes

KTP	Proposal impact
Degradation of native riparian vegetation along NSW water courses	The construction and operation of the proposal is anticipated to require removal of approximately 85 hectares of riparian vegetation along the width of the construction footprint corridor. This could result in indirect impacts on aquatic ecosystems as it can affect water quality and result in sedimentation of the watercourses if construction runoff is allowed to mobilise exposed soils to a watercourse. Sedimentation may cause increased turbidity which can clog fish gills or limit growth of aquatic flora due to blocking sunlight. Mobilised sediments may contain elevated concentrations of nutrients which can cause algal blooms and subsequently result in the creation of areas with little to no oxygen where aquatic life cannot survive. Sediments may also contain tannins which can reduce the water quality and result in fish kills. Sediments may settle into refuge pools that are used by species during times of low flow. Removal of riparian vegetation can result in destabilisation of the riverbanks and subsequent erosion. Sedimentation and bank erosion can subsequently cause changes to stream geomorphology which may impact flow velocities or changes to aquatic habitat features downstream. Clearance of riparian vegetation would be avoided as much as practicable and following completion of construction at a site, riparian vegetation would be progressively re-established in areas not used during operation. Furthermore, construction at most watercourses would be undertaken when the streambed is dry, therefore mobilisation of poor water quality is considered unlikely. Further detail on mitigation measures is discussed in section 9.

KTP	Proposal impact
Installation and operation of instream structure and other mechanisms that alter natural flow regimes of rivers and streams	The new water crossing structures along the proposed corridor present the biggest risk to aquatic ecology in both the construction and operation stages of the proposal. The level of impact expected differs with respect to the size and type of the water crossing structure proposed (ie bridge or culvert) and the type/sensitivity of the watercourse that the structure would be built across. Impacts related to installation and operation of temporary and permanent instream structures are: • Increased risk of streambed disturbance and sedimentation which can result in geomorphic changes. Changes to geomorphology may impact flow velocities and aquatic habitat features downstream of the project footprint. • Temporary or permanent structures may result in changes to flow velocities and subsequent barriers to fish passage due to instream physical barriers or behavioural barriers where flow conditions elicit an avoidance response that deters or slows fish movement. Installation and operation of the watercourse crossings would involve the following activities that may result in altering natural flow regimes: • temporary in-stream obstructions such barges and floating silt curtains • permanent in-stream pylons for supporting bridges • permanent culverts. The proposal is expected to cross 102 watercourses (including major and minor watercourses, drainage lines and farm dams), of which only three are permanently flowing (perennial). Bridge structures would be built at all of the perennial watercourses in accordance with the appropriate crossing type outlined in *Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge, 2003). Bridge structures are also proposed at most other named watercourses. Bridge structures are also proposed at most other named watercourses which are ephemeral. Culverts would be built at the remaining watercourses that have not been identified as SREs or KFH. Water crossings and scour protection have also been designed to ensure retention of natural watercourse functions including flow velocities, as much as practicable.
Removal of large woody debris from NSW rivers and streams.	Removal of instream aquatic vegetation and habitat features including large woody debris, large rocks, boulders, and gravel beds, have the potential to impact aquatic species that depend on these habitat features for food supply, shelter and spawning. Removal of habitat features has the potential to result in reduced reproductivity or direct mortality. Any aquatic vegetation and/or instream habitat features such as large woody debris that is situated within the construction footprint would be cleared as required however would be relocated upstream or downstream in consultation with an appropriate qualified ecologist. Further, it is anticipated that aquatic habitat features would then be reinstated, to the extent possible, once construction is completed.

7.2 Impact on environmentally sensitive land and processes

7.2.1 Protected areas managed by NPWS of DPIE and/or DPIE (Regions, Industry, Agriculture & Resources)

Under the *National Parks and Wildlife Act 1974* and the *Marine Estate Management Act 2014*, the protected areas managed by DPIE (Regions, Industry Agriculture and Resources) include NSW marine parks and aquatic reserves. The National Parks and Wildlife Service (NPWS) of DPIE is responsible for management of NSW National Parks and other conservation reserves.

The proposal would not impact on any protected area managed by NPWS of DPIE or DPIE (Regions, Industry, Agriculture & Resources) because:

- The proposal is not located in the coastal region of NSW and therefore would not impact any marine parks.
- No aquatic reserves are located within the proposal footprint or study area.
- The proposal does not traverse any national parks or conservation areas. The closest national park, the Warrumbungle National Park, is located approximately 15 kilometres east of the proposal at its nearest point.

Forestry Corporation of NSW is responsible for managing State Forests which are located within the proposal study area. The proposal footprint traverses the Pilliga East State Forest, Merriwindi State Forest, Baradine State Forest, Cumbil State Forest and Euligal State Forest.

Proposal activities related to the aquatic environments within the State Forests include:

- riparian vegetation clearing
- instream works
- earthworks, including cuttings and embankments and movement/use of vehicles across exposed soil
- road realignments, including realignment of the Pilliga Forest Way for a distance of 6.7 kilometres
- construction and use of new access roads.

Where the proposal is expected to impact the State Forests, appropriate mitigation and management measures would be adopted. Refer to the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a) for further details of mitigation measures.

7.2.2 Key fish habitat

As described in section 3.6, water crossing structures are proposed at 36 watercourses which have been identified as KFH, although only three of these are permanently flowing (perennial). Impacts to KFH in perennial and ephemeral watercourses are as follows:

Perennial watercourses

- During bridge construction at perennial watercourses, it is expected that some temporary loss of instream habitat and riparian vegetation would be required for the construction footprint and instream works (barge platforms and piling locations), however the proposed construction methodology, design and mitigation measures have aimed to minimise any clearance of instream habitat and riparian vegetation as far as practicable.
- Permanent loss of instream habitat in perennial watercourses is anticipated to be negligible as the only instream features proposed are bridge pylons which have been designed to ensure fish-passage is not obstructed and habitat functionality is maintained.

- Riparian vegetation within the operational footprint area would require permanent clearance, however this is also expected to be minimal and would be managed through the biodiversity offset strategy for the proposal. Refer to the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a) for details about the biodiversity offset strategy. Riparian vegetation would also be re-established where practicable within the riparian zone which are not within in the operational corridor.
- No direct impacts to aquatic habitat due to sedimentation or changes in water quality is expected at perennial watercourses as sediment and erosion controls would be established prior to construction.

Ephemeral watercourses

- Permanent built structures within KFH areas in ephemeral streams are expected to be negligible as most of the water crossing structures proposed are bridges, and depending on the size of the bridge, instream pylons may or may not be required. Where required, the proposal design and location, construction methodology and mitigation strategy has aimed to minimise disturbance of habitat features as far as practicable.
- A small amount of permanent clearance of riparian vegetation may be required on the banks of ephemeral watercourses however most of the water crossing structures would be situated on relatively flat properties that have been cleared for agricultural purposes. Therefore, clearance would be minimal and would be managed through the biodiversity offset strategy for the proposal. Riparian vegetation would also be re-established where practicable within the riparian zone which are not within in the operational corridor.
- No direct impacts to aquatic habitat due to sedimentation or changes in water quality is expected as all water crossing structures across ephemeral watercourses would be built when the streambed is dry, and erosion and sediment controls would be established prior to any construction activities.
- A small amount of streambed area would be occupied by culvert structures; however, culverts are only proposed across three watercourses that have been identified as KFH and the structures have been designed to ensure fish passage and habitat functionality is maintained. The KFH at these sites has been classified as “Type 3, Class 3” based on the ephemeral nature of the watercourses, no threatened species predicted when water is present and lack of aquatic habitat features available, therefore this design is in accordance with minimum requirements outlined in *Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge, 2003).

ARTC met with DPIE (Regions, Industry, Agriculture and Resources) on 14 August 2020 to discuss requirements of an aquatic biodiversity offset strategy for the proposal. It was agreed that, with the implementation of the proposed design and alignment, construction methodology, mitigation measures, rehabilitation strategy and operational monitoring and management, no areas of KFH would be permanently lost or disrupted therefore aquatic biodiversity offsets would not be required.

7.2.3 Waterfront lands

The construction and operation of the proposal would involve works on the bed and bank of watercourses and all land in the construction zone which is within 40 metres of the river banks. Activities that are expected to impact waterfront land include:

- riparian vegetation clearing
- instream works

- earthworks, including cuttings and embankments and movement/use of vehicles across exposed soil
- construction compounds and associated activities.

Where possible, the construction footprint would be minimised to reduce clearing in the riparian corridor and practises would be implemented to minimise disturbance of the banks. Bank stabilisation processes would also be undertaken after installation of water crossing structures.

7.2.4 Lands or waters identified as critical habitat under the FM Act

There are no areas identified as 'critical habitat' within the proposal footprint during construction or operation. Watercourses within the proposal footprint that have been deemed SREs have been considered in this assessment and are described in section 4.8 and Appendix A.

A '7-part test' has been carried out for the populations of endangered and critically endangered aquatic species which are predicted to occur in the study area (DPI, 2016). A summary of these assessments in outlined in section 7.3 and detailed in Appendix B.

7.3 Threatened species and ecological communities impact summary

As discussed in section 5 and section 6, aquatic species, populations and ecological communities including those that are listed as threatened under the FM Act and EPBC Act (refer to Table 4.3) are anticipated to be directly or indirectly impacted by the proposal because of the following activities:

- riparian vegetation removal
- removal of aquatic habitat features (large woody debris, aquatic vegetation, gravel beds, rocks and boulders)
- streambed disturbance
- instream construction works
- permanent instream structures blocking fish passage
- accidental spills and pollution
- erosion and sedimentation due to other construction and operation activities.

Significance tests in accordance with the Commonwealth and state legislation have been carried out for all threatened species, populations and endangered ecological communities listed in Table 4.3. Table 7.2 provides a summary of the significance tests. The Murray Cod, which is a nationally listed species, was assessed against the significant impact criteria for species listed as vulnerable under the EPBC Act (DoE, 2013). All other species have been assessed against the '7-part test' of significance in accordance with the FM Act. Appendix B presents the significance tests in further detail.

No assessment was undertaken for the Macquarie Perch, which was listed as potentially occurring within the region by the Protected Matters Search Tool (DAWE, 2020) but was not predicted to occur within the study area based on DPI distribution modelling (2016).

The following abbreviations are used in Table 7.2:

- EEC – Endangered ecological community
- EP – Endangered population
- CE – Critically endangered.

Table 7.2 Summary of significance impact assessment for threatened aquatic species

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Lowland Darling River Aquatic Ecological Community	Darling River EEC	EEC	-	• The construction of the proposal would require clearing of instream vegetation and aquatic habitat features such as woody debris and instream macrophytes during construction. Some permanent vegetation clearing would be necessary in the alignment easement and in the locations of the water crossing structures, however this would be minimal. As most of the vegetation and aquatic features would be reinstated, the proposal is unlikely to fragment or isolate the long-term survival of the ecological community in the locality. • Fish friendly crossings would be constructed where the proposal alignment intersects watercourses that have been predicted to support threatened aquatic species. Water crossings have been designed with the aim to minimise disturbance to aquatic habitat structure and ensure there are no potential barriers to fish-passage. As such, the proposal is unlikely to have an adverse effect on the extent of the EEC or adversely modify the composition of the ecological community such that its local occurrence is likely to be place at risk of extinction. • The proposal would incorporate recovery and conservation actions that would aim to: – Conserve and restore habitat at watercourse crossings by protecting aquatic and riparian vegetation, and habitat features such as large woody debris. Adequate erosion and sediment control measures during construction would be implemented. Drainage and scour protection would be included at water crossing structure to minimise potential for erosion and sedimentation downstream. – Where practicable, aquatic habitat features such as large woody debris, instream macrophytes and boulders would be reinstated within the construction footprint area after construction. – The water crossing structures would be designed to ensure fish passage remains available. Fish passage has been designed in accordance with relevant guidelines (Fairfull and Witheridge, 2003).	Proposal is not likely to significantly impact on the Darling River EEC.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Ambassis agassizii	Olive Perchlet (Western Population), Glass Perchlet, Agassiz's gGassfish, Western Chanda Perch (Western Population)	EP	-	• The works associated with the construction of water crossing structures may impact on some areas of breeding habitat through direct disturbance of rocky substrate on streambeds, clearance of vegetation instream and on the banks, blockage of fish passage or by pollution from construction runoff. Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. Watercourse structures would be designed to maintain flows and avoid barriers to fish passage. – In perennial watercourses where the Olive Perchlet is predicted, construction would be undertaken outside of the breeding season (Spring/Summer). In ephemeral watercourses where the Olive Perchlet is predicted, water crossing structures would be built when the streambed is dry. • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats. • The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on the Western population of the Olive Perchlet.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Bidyanus bidyanus	Silver Perch, Bidyan, Black Bream, Silver Bream	CE	CE	• The works associated with the construction of bridges and culverts may impact on areas of potential habitat through sedimentation, temporary barriers to fish passage or by potential pollution from construction runoff. Increased sedimentation may be caused by clearing of instream and riparian vegetation, displacement of woody debris, or direct disturbance of the streambed leading to changes in water quality. Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats. • The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on Silver Perch.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Maccullochella macquariensis	Trout Cod, Blue Nose Cod	E	E	• The works associated with the construction of bridges and culverts may impact on areas of potential breeding habitat through sedimentation, temporary barriers to fish passage or by potential pollution from construction runoff. Increased sedimentation may be caused by clearing of instream and riparian vegetation, displacement of woody debris, or direct disturbance of the streambed leading to changes in water quality. • Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. – In Macquarie River, where the Trout Cod is predicted to occur, construction would be undertaken outside of the breeding season (Spring/Summer). • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats. • The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on Trout Cod in the locality.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Maccullochella peelii	Murray Cod, Cod, Goodoo	-	V	• The works associated with the construction of bridges and culverts may impact on areas of potential habitat through sedimentation, temporary barriers to fish passage or by potential pollution from construction runoff. Increased sedimentation may be caused by clearing of instream and riparian vegetation, displacement of woody debris, or direct disturbance of the streambed leading to changes in water quality. • Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. – Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. • With implementation of appropriate mitigation measures, a long-term decrease in the size of the population would not occur as a result of the proposal. • Disruption of the preferred habitat instream in the main channels of Namoi River would be limited to the construction footprint where the water crossing structure is proposed to be built. Disruption is also limited to the construction phase as appropriate design of water crossing structures would ensure there was no obstruction fish movement or reduce the occupancy of the population. It is anticipated that an appropriate amount of flow would be available during construction to ensure fish passage is not fully blocked. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats.	Proposal is not likely to significantly impact on Murray Cod in the locality.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
				• The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	
Mogurnda adspersa	Purple Spotted Gudgeon	E	E	• The works associated with the construction of bridges and culverts may impact on areas of potential habitat through sedimentation, temporary blockage to fish passage or by potential pollution from construction runoff. Increased sedimentation may be caused by clearing of instream and riparian vegetation, displacement of woody debris, or direct disturbance of the streambed leading to changes in water quality. • Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats. • The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on Purple Spotted Gudgeon in the locality.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Galaxias rostratus	Flathead Galaxias, Beaked Minnow, Flat-headed Galaxias, Flat-headed Jollytail, Flat-headed Minnow	CE	CE	• The works associated with the construction of bridges and culverts may impact on areas of potential habitat through sedimentation, temporary blockage to fish passage or by potential pollution from construction runoff. Increased sedimentation may be caused by clearing of instream and riparian vegetation, displacement of woody debris, or direct disturbance of the streambed leading to changes in water quality. • Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works and reinstating aquatic habitat features including woody debris and aquatic vegetation after construction. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. This would include silt curtains around piling activities in perennial streams. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects therefore there should be no fragmentation or isolation of habitats. • The proposal would be accordance with relevant guidelines for constructing water crossings (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on Flathead Galaxias in the locality.

Scientific name	Common name	FM Act	EPBC Act	Considerations	Determination of significance
Tandanus tandanus	Eel Tailed Catfish, Jewfish, Freshwater Catfish (Murray Darling Basin population)	EP	-	• The works associated with the construction of water crossing structures may impact on some small areas of breeding habitat through direct disturbance of the bottom substrate, alteration of natural flows, clearance of vegetation or through barriers to fish passage. • Practices which would be undertaken to avoid impacts are: – Relocation of woody debris upstream and downstream of the proposal footprint prior to commencement of the works. – Adequate erosion and sediment controls would be implemented to manage and minimise further sedimentation. – Sedimentation basins and drainage design would ensure no polluted runoff would be transported to watercourses during construction. Discharge of sedimentation basins would be in accordance with ANZG (2018) water quality guidelines. – Watercourse structures would be designed to maintain flows and avoid blockage to fish passage. – In perennial watercourses where the Eel Tailed Catfish is predicted, construction would be undertaken outside of the breeding season (Spring/Summer). In ephemeral watercourses where the Eel Tailed Catfish is predicted, water crossing structures would be built when the streambed is dry. • As such, there would be no significant impact on the lifecycle of the species and the proposal is unlikely to impact on the survival of the species in the locality. Standard practices would minimise adverse effects relating to the fragmentation or isolation of habitats. • The design of water crossing structures would be accordance with relevant guidelines (Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Proposal is not likely to significantly impact on the Murray Darling Basin population of the Eel Tailed Catfish.

7.4 Aquatic groundwater dependent ecosystem impact summary

Due to the mostly dry climate, prevailing drought conditions and ephemeral nature of most of the watercourses, there is limited water available in the proposal area. No direct water extraction from any creek is proposed during construction of the proposal, however water is proposed to be sourced from deep aquifer bores during construction. The total estimated volume of water to be used is 4,600 mega litres, this is further detailed in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020b).

Water sourcing comprises of both non-potable (estimated to be 1400 mega litres per year), which would be sourced from groundwater bores, and potable water (estimated to be 118 mega litres per year), which would be supplied by either town water supply or groundwater bores. Without appropriate mitigation measures, pumping of the deep aquifers has the potential to reduce creek and river baseflows which could result in reduced environmental water availability and flows to aquatic GDEs.

7.4.1 Rail infrastructure and road infrastructure:

Activities required for the construction and operation of the rail and road infrastructure are not expected to result in groundwater level drawdown as the water table is not expected to be intercepted. As such, potential impacts to GDEs due to drawdown are not anticipated. Furthermore, potential minor water level changes associated with ground consolidation for the infrastructure are not anticipated to impact potential GDEs.

While there would be no changes to flows or water levels, clearance of riparian vegetation for proposed construction works would occur within the proposal construction corridor which may impact nearby aquatic GDEs due to potential increased erosion and sedimentation or contamination of waterways by tannin leachate. These changes may subsequently result in temporary impacts to aquatic ecosystem function because of degradation of aquatic habitat features such as smothering aquatic macrophytes or infilling deep rocky holes which are often used as refuge and breeding habitat, and can provide protection for juveniles and some adult aquatic species.

7.4.2 Borrow pits

Borrow pits are not anticipated to intercept the water table except for borrow pit A which may intercept the water table by about three metres. BOM (2018a) does not map potential GDEs in the region of borrow pit A and there are no high priority GDEs mapped within the vicinity of the borrow pit. As such, potential to impacts to aquatic GDEs from the excavation of borrow pit A is low.

7.4.3 Bore fields

Bore field pumping is not anticipated to impact GDEs due to groundwater level drawdown as only minor water level changes (maximum 0.39 metres) are expected and the level of drawdown is within the bounds of natural variability due to climate and recharge processes. Furthermore, there are no high priority aquatic GDEs mapped near potential bore fields.

7.4.4 Narromine North and Baradine temporary workforce accommodation facilities

Pumping groundwater bores for potable water at the Narromine North and Baradine temporary workforce accommodation facilities could lead to changes in groundwater quality and groundwater levels in the vicinity of pumped bores which may result in reduced water availability and water quality for aquatic GDEs. These changes may subsequently result in temporary impacts to aquatic ecosystem function because of the following factors:

- barriers to fish passage due to insufficient water depth or reduction of extent of ephemeral pools within the watercourses
- degradation of aquatic environments and habitat features such as aquatic macrophytes which are often used as breeding habitat and provide protection for juveniles and some adult aquatic species.

Barriers to fish passage, as well as water quality and habitat degradation have the potential to result in reduced reproductivity or direct mortality of native aquatic species at every stage of their lifecycle (larvae, young-of-year or adult). This is particularly important for several threatened species that are predicted to occur within the watercourses which may be sensitive to water quality. However, due to the minor and temporary nature of the changes expected, it is unlikely that the proposal would significantly compromise the functionality, long-term connectivity or viability of habitats, or ecological processes within assemblages of aquatic species. In addition (as specified in section 4.8.2), most high potential and high priority aquatic GDEs are located a significant distance from the proposal site and therefore are not expected to be impacted from water extraction activities.

Impacts to GDEs, both terrestrial and aquatic, are further detailed in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020b).

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8. Cumulative impacts

8.1 Review of relevant projects

For an EIS, cumulative impacts can be defined as the successive, incremental, and combined effect of multiple impacts, which may in themselves be minor, but could become significant when considered together. The methodology and projects considered for the cumulative impact assessment are provided in detail in the EIS (Part D chapter D1). The study area for the cumulative aquatic ecology assessment is watercourses crossed by the proposal and a 500 metre buffer around these watercourses. Seven major projects were identified as having a cumulative impact and sufficient information to undertake a cumulative impact assessment. The following projects have been considered:

- APA - Western Slopes Pipeline
- Inland Rail – Narrabri to North Star
- Inland Rail – Parkes to Narromine
- Narrabri Gas Project
- Silverleaf Solar Farm, Narrabri
- Gilgandra Solar Farm
- Narromine Solar Farm.

The locations of these projects are shown in Figure 8.1.

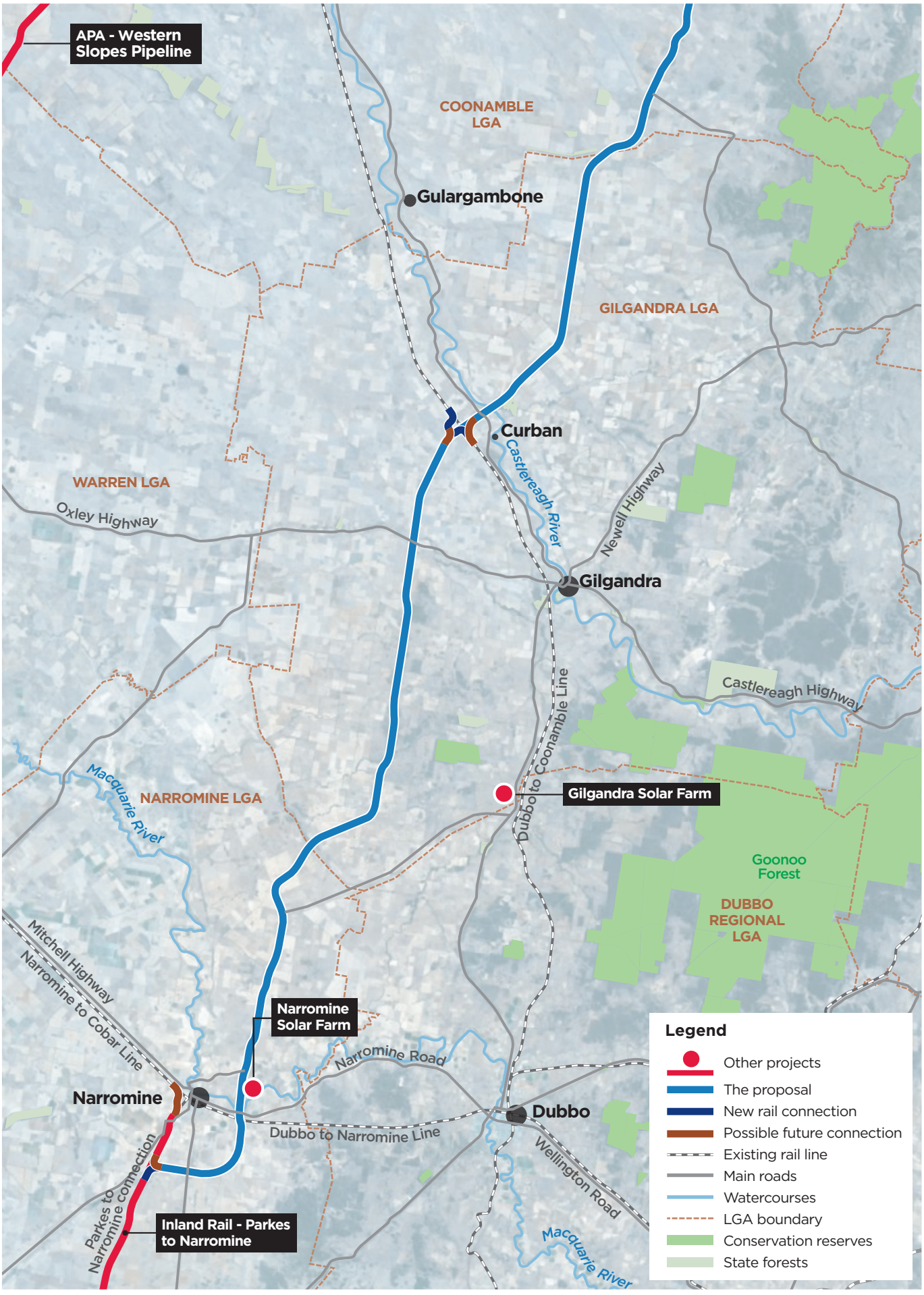

Figure 8.1a **Projects with the potential for cumulative impacts**

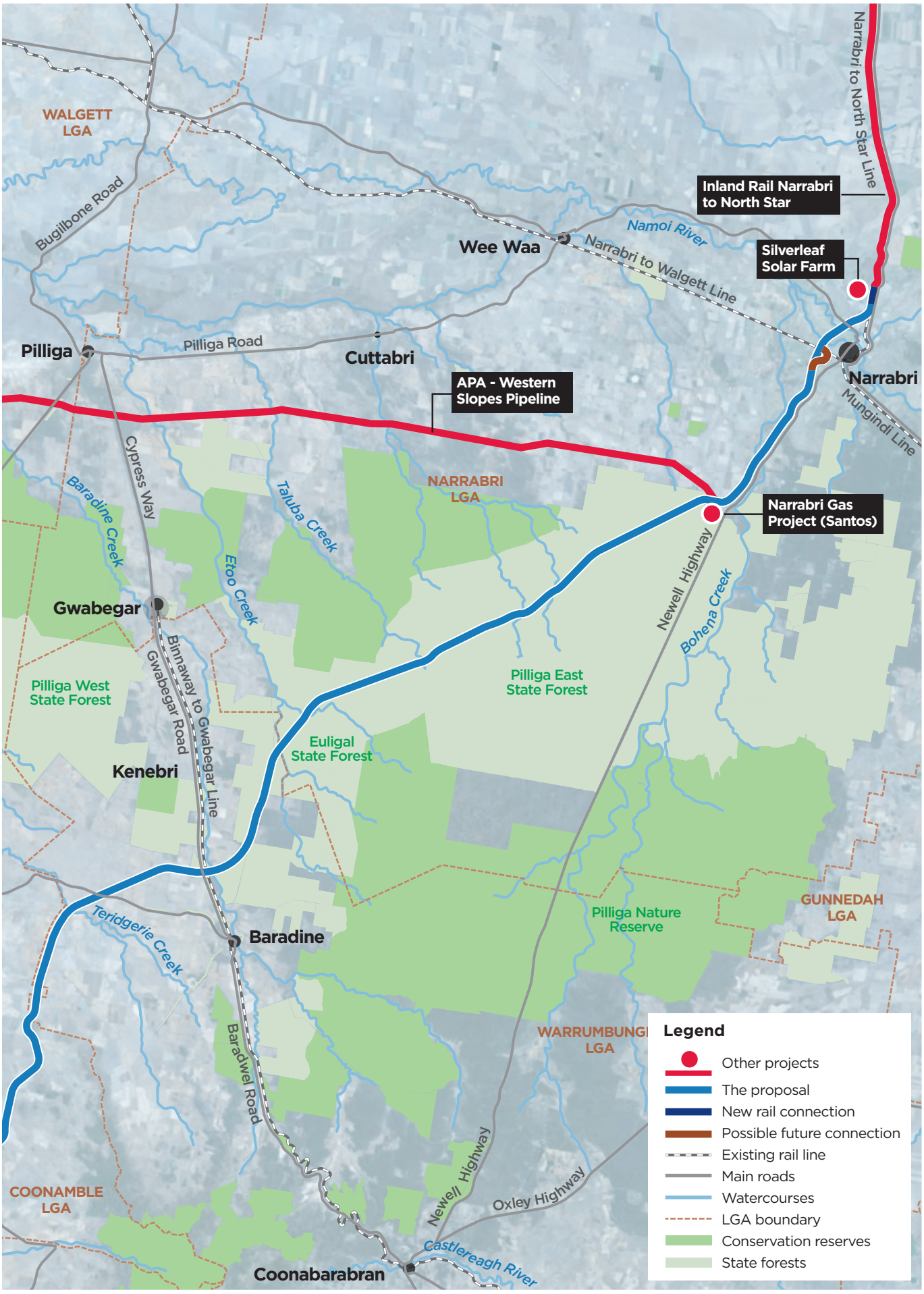

Figure 8.1b **Projects with the potential for cumulative impacts**

Table 8.1 Summary of potential cumulative impacts

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
APA - Western Slopes Pipeline					
Macquarie River, Castlereagh River, and Namoi River.	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Staging of works. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life.	• Staging of works. • Drainage design. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Inland Rail - Narrabri to North Star					
Namoi River and Narrabri Creek	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Stockpile management. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes. Cumulative groundwater drawdown, leading to impacts on Namoi River and Narrabri Creek.	• Drainage upgrades. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	• Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible. • Impacts to the base flow of Namoi River and Narrabri Creek are unlikely to occur as a consequence of groundwater drawdown that occurs due to project construction. Contributions by the project to the cumulative groundwater drawdown and baseflow impacts would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Inland Rail – Parkes to Narromine					
Backwater Cowal	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Stockpile management. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes.	• Drainage design. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Narrabri Gas Project (Santos)					
Goona Creek, Bundock Creek, and Bohena Creek	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes.	• Drainage design • Flood mitigation measures • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Silver Leaf Solar Farm (Narrabri)					
Namoi River and Narrabri Creek	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Stockpile management. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures. • Construction of water treatment plant.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes.	• Drainage upgrades. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Gilgandra Solar Farm					
Emogandry Creek	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Stockpile management. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes.	• Drainage design. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

Common receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Narromine Solar Farm					
Macquarie River	Increased water quality pollutants, sediment loads and litter into watercourses which could subsequently cause direct impacts to aquatic flora and fauna by smothering or clogging fish gills, or by limiting aquatic plant growth. Poor water quality and sedimentation may also indirectly impact aquatic ecosystems by altering the suitability of aquatic habitat due to degradation of habitat features.	• Erosion and sediment control measures in accordance with the Blue Book. • Staging of works. • Stockpile management. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the construction footprint to check adequacy of mitigation measures.	• Increased water quality pollutants and litter into watercourses which could subsequently indirectly impact on aquatic life. • Impacts on drainage infrastructure which may result in flooding and subsequently impact on aquatic species due to changes in flow regimes. • Flood impacts due to redirection of overland flows which may subsequently impact on aquatic species due to changes in flow regimes.	• Drainage upgrades. • Flood mitigation measures. • Water quality and aquatic habitat monitoring at water crossing structures and in upstream and downstream locations of the operational footprint to check adequacy of mitigation measures.	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be negligible.

8.2 Summary of findings

The major projects considered relevant for potential cumulative impacts to aquatic ecosystems is where there is a relative interface during construction and/or operation with the proposal. Other projects occurring in the broader locality would likely have a negligible impact on:

- water quality, which could in turn result in direct or indirect impacts to aquatic flora, fauna or cause degradation of aquatic ecosystems;
- drawdown of groundwater, which may impact on water availability in watercourses and therefore impact availability of aquatic habitat; or
- drainage and flooding which may impact aquatic ecosystems by altering flow regime.

Combined with the distance to downstream watercourses and standard management controls, the cumulative impact is expected to be negligible.

Overall, the proposal, along with other ongoing and planned developments in the area, would have minor cumulative impact on aquatic ecosystems associated with the construction and minor cumulative impacts associated with operation. Where any minor impacts occur, they are likely to be either highly localised, temporary and/or readily assimilated into the existing watercourses.

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9. Recommended mitigation measures

The proposal has been designed to avoid and minimise potential impacts to watercourses and aquatic ecology. The strategies that have been, and would continue to be implemented include the following:

- bridge piers have been located outside of watercourse channels where practicable to preserve fauna passage
- works in the majority of watercourses would only be undertaken in dry weather conditions when watercourses are dry
- pre-cast culvert structures would be used, thereby minimising works in watercourses
- flow discharge points (culverts and longitudinal drainage) would include scour protection measures such as rock protection, to minimise the risk of erosion as surface water enters and exists the structure
- bridge piers in flowing watercourses would be constructed using driven piles from barges.

Where impacts could not be avoided, mitigation measures to minimise or manage impacts to aquatic ecology are detailed in Table 9.1, Table 9.2 and Table 9.3. Additionally, Table 9.4 includes management measures which should be included in the biodiversity management plan to manage impacts during construction.

As discussed in sections 5 and 6, impacts to aquatic ecology are largely related to mobilisation of poor-quality runoff and erosion/sedimentation to watercourses. The mitigation measures detailed in *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020d) and *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment (*JacobsGHD, 2020c) are therefore also relevant to aquatic ecology.

Table 9.1 Measures for detailed design/pre-construction

Issue	Recommended mitigation measure – Detailed design/pre-construction
Direct impacts on biodiversity	Detailed design and construction planning would minimise the construction and operational footprints and avoid direct impacts on riparian vegetation as far as practicable.
Riparian vegetation	Vegetation clearing would be limited to the minimum necessary to construct the proposal and allow for its effective operation. Micro-siting of infrastructure would be undertaken during detailed design to further minimise or avoid impacts on riparian vegetation where practicable.
Fish passage	Watercourse crossing structures would meet Inland Rail design standards and be designed in accordance with the guideline *Why do fish need to cross the road? Fish passage requirements for watercourse crossings* (Fairfull and Witheridge, 2003).

Issue	Recommended mitigation measure – Detailed design/pre-construction
Rehabilitation strategy	A rehabilitation strategy would be prepared to guide the approach to rehabilitation of disturbed areas following the completion of construction. The strategy would include: • clear objectives and timeframes for rehabilitation works (including the biodiversity outcomes to be achieved and clear objectives for the rehabilitation of riparian vegetation in temporary disturbance areas) • details of the actions and responsibilities to progressively rehabilitate, regenerate, and/or revegetate areas • identification of flora species and sources • procedures for monitoring the success of rehabilitation • corrective actions should the outcomes of rehabilitation not conform to the objectives adopted.

Table 9.2 Measures for construction

Issue	Recommended mitigation measures – Construction
General biodiversity impacts	A biodiversity management plan would be prepared prior to construction and implemented as part of the CEMP. It would include measures to manage biodiversity and minimise the potential for impacts to aquatic ecology during construction. The plan would be prepared in accordance with relevant legislation, guidelines and standards. The plan would include, but not be limited to: • locations and requirements for pre-clearing surveys • management measures to manage impacts to aquatic ecology as per those provided in Table 9.4 and measures to reduce the risk of aquatic fauna mortality/injury • measures to manage weeds, pests and invasive species, including the management of priority weeds and weeds of national significance.
Riparian vegetation	Exclusion areas would be established and maintained around riparian vegetation, particularly areas of biodiversity value adjoining the proposal site and areas of riparian vegetation to be retained that are located in close proximity to work areas. Compounds and stockpile sites would be located at an appropriate distance from riparian habitat to avoid indirect impacts on aquatic habitat. This includes, where practicable, a minimum of 100 metres for Type 1, Class 1 watercourses, 50 metres for Type 2, Class 2 and 3 watercourses, and 10 to 50 metres for Type 3, Class 2 to 4 watercourses. Direct impacts on in-stream vegetation and native vegetation on the banks of watercourses would be avoided as far as practicable.
Avoidance of impacts – aquatic biodiversity	Pre-clearing surveys would be undertaken prior to construction by a spotter catcher, where appropriate, or a suitably qualified practitioner, in accordance with the biodiversity management plan. Specific surveys would include fauna salvage in watercourses or residual pools within 50 metres of the construction footprint, and in areas that would be enclosed by silt curtains (eg piling locations).

Issue	Recommended mitigation measures – Construction
Avoidance of impacts – aquatic biodiversity from farm dam dewatering	A dam dewatering protocol would be developed as part of the soil and water management plan. It would consider: • options for reuse of water in the dam • licensing and approval requirements, where relevant • the quality and quantity of the water to be released, if relevant • strategies to minimise impacts to native, threatened or protected species • strategies to minimise spread of nuisance flora and fauna species.
Rehabilitation	Rehabilitation of disturbed areas would be undertaken progressively and in accordance with the rehabilitation strategy.

Table 9.3 Measures for operation

Issue	Recommended mitigation measures – Operation
Fish passage	Culverts that provide for the flow of watercourses would be inspected and maintained during routine track inspections to address any issues that may contribute to the blockage of fish passage.
Weed management	Weed inspections would be undertaken and weed management would occur in accordance with ARTC's standard operating procedures to meet its obligations under the *Biosecurity Act 2015.*

Example management measures that would be included in the biodiversity management plan are listed in Table 9.4.

Table 9.4 Management measures

Aspect	Environmental management measures
Instream aquatic vegetation and habitat features	Removal and displacement of habitat features would be avoided as far as practicable. Woody debris that is removed would be placed upstream and downstream of the construction footprint, in consultation with a qualified ecologist. Large rocks and boulders that are removed would be placed upstream and downstream of the construction footprint, in consultation with a qualified ecologist. In watercourses which have been identified as potential habitat for native fish species that require habitat features for spawning, construction would not take place within the watercourse during the breeding season (spring and summer). This would only apply to watercourses that have available water. After completion of the construction phase, aquatic habitat features such as woody debris, instream aquatic macrophytes, rocks and boulders, would be reinstated within watercourses in the construction footprint area.

Aspect	Environmental management measures
Instream structures	As far as practicable, concrete usage would be minimal in locations within 100 metres of watercourses that have been identified as SREs. Where concrete works would be required over perennial watercourses, appropriate containment measures such as an encapsulation structure above the watercourse would be utilised to avoid ingress of concrete waste in the watercourses. Culverts and bridges on ephemeral watercourses would be installed when the watercourse is dry and construction activities would cease prior to any rainfall. In the unlikely event that unexpected rainfall were to occur during construction, a contingency plan would be developed as part of the CEMP to ensure concrete waste is captured prior to mobilisation into the water. At perennial watercourses where two of the major bridge structures are proposed to be built (Macquarie River and Namoi River/Narrabri Creek), silt curtains would be placed around piling sites to ensure no sediment or polluted water can mobilise downstream. In enclosed areas, fauna salvage would be undertaken in consultation with a qualified ecologist. Any individuals collected would be released in suitable downstream habitats that are identified by an ecologist. If pest species would be managed in accordance with the biodiversity management if caught during fauna salvage. At barge sites that would be located on Macquarie River, Namoi River or Narrabri Creek, appropriate bunding would be included around the perimeter of the barge to prevent construction materials or spills from drilling equipment impacting the watercourse. Where possible, access to watercourses by construction plant would be minimised.

10. Conclusion

The aquatic ecological assessment for the construction and operation of the ARTC Inland Rail infrastructure between Narromine and Narrabri has been prepared based on a review of available aerial photography, topography, databases, literature, policies and guidelines, as well as results of field investigation. The key findings of report are as follows:

Existing aquatic environment

- Desktop assessment revealed that the proposed alignment would cross 102 mapped watercourses and/or waterbodies, including drainage lines, farm dams, minor ephemeral streams and major perennial waterways. Thirty-six of these watercourses are identified as KFH, however only three are permanently flowing (perennial) (Narrabri Creek, Namoi River, and Macquarie River). The remaining 33 watercourses mapped as KFH, and all other named and unnamed watercourses that are not KFH, only flow during and after significant rainfall (ephemeral).
- Aquatic habitat assessment in the field found that most sites exhibited habitat features, although water was not present in most of the watercourses. Key habitat characteristics that were common along the watercourses were large fallen logs, uprooted trees and aquatic macrophytes. First and second order tributaries that were visited, however, usually had minimal native riparian or aquatic vegetation and were significantly modified by agricultural land practices.

Threatened species, populations and EECs

- Seven threatened species and two endangered populations, listed under the EPBC Act and/or FM Act, have been recorded or predicted to occur in watercourses within the proposal construction footprint (DAWE, 2020; EESG, 2020; ALA, 2020; DPI, 2016). Populations and species predicted are:
  - the Western population of the Olive Perchlet (*Ambassis agassizi*i)
  - the Murray Darling Basin population of the Eel Tailed Catfish (*Tandanus tandanus)*
  - Silver Perch (Bidyanus bidyanus)
  - Murray Cod (Maccullochella peelii)
  - Trout Cod (Maccullochella macquariensis)
  - Flathead Galaxias (*Galaxias rostratus*)
  - Purple Spotted Gudgeon (*Mogurnda adspersa*)
  - All watercourses within the proposal area are also considered features of the Darling River EEC, which is listed under the FM Act.
- In accordance with the FM Act and EPBC Act, a test of significance was undertaken for the Darling River EEC, as well as for all threatened species, and endangered populations predicted in the region. The assessments determined that construction and operation of the proposal would not result in any lasting impacts due to the design, construction methodology and management measures, mitigation measures, and rehabilitation strategy proposed. Any temporary impacts during construction are expected to be minor and/or manageable through standard practices. Further, temporary impacts to species during construction are only considered to be a risk at perennial watercourses. All other ephemeral watercourses would be dry when construction takes place, therefore species would not be present and are not at risk of being impacted.

Aquatic GDEs

- Aquatic GDEs in the proposal area are associated with the riparian vegetation along watercourses. The proposal is expected to cross 11 high priority GDE vegetation areas at Macquarie River, Castlereagh River, Gulargambone Creek, Baradine Creek, Etoo Creek, Rocky Creek, Goona Creek, Bohena Creek, a small unnamed tributary of Bohena Creek, Namoi River and Narrabri Creek. Fourteen individual watercourses were also mapped as either low or moderate potential for GDEs (BOM, 2020) including Wallaby Creek, Kickabil Creek, Marthaguy Creek, Baronne Creek, Caleriwi Creek, Teridgerie Creek, Baradine Creek, Etoo Creek, Coghill Creek, Mollieroi Creek and Bohena Creek which been identified as having moderate GDE potential, and Macquarie River and Castlereagh River which have been identified as having low GDE potential. In addition, there are 10 mapped high priority GDE springs within the region however the closest is located about 10 kilometres from the proposal alignment. As such, all high priority GDE springs (DPI, 2017), as well as high potential (BOM, 2020) GDEs, are located a significant distance away from the proposal area and are therefore not expected to be impacted by the proposal.
- Due to the predominantly dry climate, prevailing drought conditions and ephemeral nature of most of the watercourses, there is limited water available in the proposal area. No direct water extraction from any creek is proposed during construction of the proposal, however water is proposed to be sourced from deep aquifer bores during construction. Due to the minor and temporary nature of the changes expected during construction and operation, it is unlikely that the proposal would significantly compromise the long-term ecological processes within aquatic GDEs crossed by the proposal. In addition, all high potential and high priority aquatic GDEs are not expected to be impacted from water extraction activities due to their distance from the proposal.

Impact assessment - Construction

- For the construction phase, potential direct impacts to aquatic ecosystems would be related to construction works undertaken in the riparian zone, along the riverbanks and within the channel, and particularly where water crossing structures are proposed to be built.
- Direct impacts include temporary barriers to fish-passage, potential mortality of fish due to interaction with equipment and machinery, or from poor water quality.
- Indirect impacts to aquatic ecology would be related to the mobilisation of poor-quality stormwater runoff from construction activities including vegetation removal, earthworks, establishment and use of construction compounds as well as riverbank and streambed disturbance that would result in sedimentation and pollution downstream.
- Potential impacts during construction are only considered to be a risk at perennial watercourses. All other ephemeral watercourses would be dry when construction takes place, therefore water and aquatic species would not be present and are not at risk of being impacted.
- It is expected that the potential for construction impacts would be substantially reduced through implementation of the following activities:
  - Undertaking relocation of aquatic habitat features from the instream construction footprint to downstream locations in the same reach prior to construction.
  - In watercourses (where water is available) that are potential breeding habitat for threatened species, instream construction works should be avoided during the breeding season (spring and summer).
  - Undertaking fauna salvage in enclosed areas for piling activities where required.

- Adoption of comprehensive erosion and sediment controls to capture stormwater and construction runoff.
- Establishment of construction drainage to direct flows to sedimentation basins,
- Discharge of sedimentation basins in accordance with national water quality guidelines (ANZG, 2018).

Impact assessment - Operation

- For the operational phase, the risks are related to permanent barriers to fish-passage due to the water crossing structures, potential downstream pollution due to mobilisation of stormwater runoff from new impervious surfaces, as well as from possible leaks or spills from maintenance vehicles on the permanent access tracks or from cargo in train carriages. Maintenance works required during the life of the proposal could also result in dispersion of sediment, pollutants and pesticides from weed control and minor vegetation clearing. These potential risks were determined to be unlikely due to the following reasons:
  - Water crossing structures have been designed to be fish-friendly in accordance with recommended crossing types outlined in relevant guidelines (Fairfull and Witheridge, 2003).
  - The overall increase in impervious area would very small relative to the total area of the catchments, therefore overall impact to the volume of runoff would be minimal.
  - Runoff from the proposal is expected to be low and not change export of annual pollutant loads to downstream watercourses.
  - The rail track and trains would be maintained in accordance with ARTC standards and protocols, therefore risk of spills would be unlikely.
- During operation, it is expected that potential impacts would be substantially reduced through implementation of the following:
  - Adopting appropriately designed fish-friendly crossing structures, drainage and scour protection at all watercourse crossing structures.
  - Re-establishment of riparian vegetation and aquatic habitat features within and on the banks of watercourses.
  - On-going monitoring and maintenance to ensure that watercourse crossing structures and associated aquatic habitats in the proposal operational footprint are preserved.

Impacts to key fish habitat

- The only areas where structures would permanently occupy instream area will be where pylons are situated instream and across three ephemeral watercourses where culverts would be built. These instream structures are in accordance with relevant design guidelines for water crossing structures and are therefore not expected to impact fish-passage or disrupt habitat functionality in anyway.
- There would additionally be some permanent clearing of riparian vegetation in the operational corridor at the water crossing locations, although this would also be minimal as the majority of water-crossing locations do not have extensively vegetated riparian zones on the riverbanks and any vegetation loss will be managed through the Biodiversity Offset Strategy for the proposal.
- In consultation with DPIE (Regions, Industry, Agriculture and Resources), it was agreed that KFH at water crossing locations would not be permanently lost or disrupted provided the proposal will implement the proposed design and alignment, construction methodology, mitigation measures, rehabilitation strategy and operational monitoring and management. As such, no aquatic biodiversity offset strategy is required.

On the basis of the assessment of the existing aquatic environment, the description of the proposal and construction methodology, and assuming that mitigation measures that have been described in this report (and in other assessment undertaken by other specialists) are implemented, the aquatic ecology assessment concludes that the impacts would not significantly compromise the functionality, long-term connectivity or viability of habitats, or ecological processes within assemblages of biota. The majority of potential impacts are associated with the construction phase and would therefore be temporary and manageable through the adoption of procedures and controls which have been described and would be further developed in the CEMP. Any potential operational impacts would be sufficiently managed through appropriate design, rehabilitation efforts, and on-going maintenance and management of the operational footprint. Given successful implementation of these management controls, residual impacts to aquatic ecology would be negligible.

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Appendices

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TECHNICAL REPORT

2

Aquatic ecology assessment

Appendix A Aquatic habitat assessment

Appendix A – Aquatic Habitat Assessment

Appendix A provides the full assessment of aquatic habitat undertaken at the survey sites (Appendix A1). The assessment was undertaken to determine SREs. Survey sites within the study area have been assessed against the *Policy and Guidelines for Fish Habitat Conservation and Management* (2013) and *Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003*)*

Appendix A1 Aquatic Habitat Assessment

Site	Photos		Description
1 – Narrabri Creek	 Narrabri Creek facing *upstream* (photo taken on 13/11/2018)	 Narrabri Creek facing *downstream* (photo taken on 13/11/2018)	Narrabri Creek is a major river (Strahler 9th order). Water levels were low at the time of inspection, and there appeared to be no flow at the time of inspection. The substrate consisted of sandy loam with evidence of active erosion along the right bank. The riparian habitat is largely cleared for grazing however, instream aquatic habitat such as emergent macrophytes beds (*Phragmites australis),* large woody debris and overhanging Willows (*Salix sp*) were observed. Small mats of floating Duckweed (*Lemna minor*) were gathered at the at both bank edges. Threatened fish including; Eel Tailed Catfish (*Tandanus tandanus)*, Flathead Galaxias (*Galaxias rostratus)*, Purple Spotted Gudgeon (*Mogurnda adspersa)* and Olive Perchlet (*Ambassis agassizii*) are likely to occur (DPI, 2016). Murray Cod (*Maccullochella peelii)* are also recorded within Narrabri Creek (Lintermans, 2007; ALA, 2020). Habitat appeared to be suitable for all species listed above. As Narrabri Creek is 9th order watercourse containing several threatened species, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). The Creek is identified as “Class 1 – Major fish habitat” (Fairfull and Witheridge, 2003). Narrabri Creek is identified as a sensitive receiving environment which should be considered for fish friendly crossings

Site	Photos		Description
2 – Namoi River	 Namoi River facing *upstream* (photo taken on 11/10/2019)	 Namoi River facing *downstream* (photo taken on 11/10/2019)	Upstream Namoi River is a major watercourse (Strahler 9th order) which was mostly dry at the time of inspection with some residual pools and a damp streambed. The riparian zone is densely vegetated by native trees along its entirety. Large macrophytes beds (*Phragmites australis*) occur at the site. Several threatened fish are likely to occur when water is present, including Olive Perchlet (*Ambassis agassizii)*, Flathead Galaxias (*Galaxias rostratus)*, Eel Tailed Catfish (*Tandanus tandanus)*, Purple Spotted Gudgeon (*Mogurnda adspersa)*, Silver Perch (*Bidyanus bidyanus*) (DPI, 2016) and Murray Cod, (*Maccullochella peelii peelii)* (Lintermans, 2007). Habitat appeared to be suitable for all species listed above. Namoi River has been classified “Type 1 – Highly sensitive key fish habitat” as several threatened fish are predicted to occur (DPI, 2013). With respect to fish passage, it is classified “Class 2 – Moderate fish habitat” due the ephemeral nature of the creek (Fairfull and Witheridge, 2003). Namoi River has been identified as a sensitive receiving environment which should be considered for fish friendly crossings.

Site	Photos		Description
3a - Bohena Creek	 Bohena Creek facing *upstream* (photo taken on 11/10/2019)	 Bohena Creek facing *downstream* (photo taken on 11/10/2019)	Bohena Creek is a sixth Strahler stream which was completely dry at the time of inspection. The creek runs adjacent to the proposed alignment overlapping for approximately 100 m also crossing the proposed alignment approximately 5.5 km upstream. Channel definition was only apparent on the right bank. The substrate was a very dry, silt loam with a heavily vegetated riparian zone. Significant large woody debris dominated the watercourse, however no aquatic macrophytes were visible. Threatened fish including Eel Tailed Catfish (*Tandanus tandanus)* and Purple Spotted Gudgeon (*Mogurnda adspersa)* are predicted to occur when water is present (DPI, 2016). Although the site was dry, some suitable habitat features appeared to be present for the species listed above. As the watercourse is likely to contain threatened fish habitat, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Bohena Creek is identified as a sensitive receiving environment which should be considered for fish friendly crossings.

Site	Photos		Description
3b – Bohena Creek	 Bohena Creek facing *upstream* (photo taken on 11/10/2019)	 Bohena Creek facing *downstream* (photo taken on 11/10/2019)	Bohena Creek is a sixth order Strahler stream which was completely dry at the time of inspection. The creek dissects the Newell Highway under a concrete bridge. The creek had limited channel definition however, abundant macrophytes in poor condition were present below the bridge construction. Aquatic habitat including large woody debris and apparent man-made gravel beds were present under the bridge. Threatened fish including Purple Spotted Gudgeon (*Mogurnda adspersa)* and Eel Tailed Catfish (*Tandanus tandanus)* are predicted to occur when water is present (DPI, 2016). Although the site was dry, suitable habitat features appeared to be present for the species listed above. As the watercourse is likely to contain threatened fish habitat, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 2 – Moderate key fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Bohena Creek is identified as a sensitive receiving environment which should be considered for fish friendly crossings.

Site	Photos	Description
4 – Bundock Creek	 Bundock Creek facing *upstream* (photo taken on 19/03/2019)  Bundock Creek facing *downstream* (photo taken on 19/03/2019)	Bundock Creek is an ephemeral, second order Strahler stream which was dry at the time of inspection. The creek is situated in a broad valley/floodplain environment with limited channel definition. There was no evidence of active erosion present, however the substrate is predominantly highly erodible, mobile sand. The stream is mapped as key fish habitat (DPI, 2007a) however no aquatic habitat was present at the time of inspection. Some riparian vegetation was present on the banks although no macrophytes were present. Threatened species are not predicted to occur at this site along Bundock Creek, however the Purple Spotted Gudgeon (*Mogurnda adspersa)* is predicted upstream (DPI, 2016). No suitable habitat features for the Purple Spotted Gudgeon appeared to be present at the site. Due to the lack of suitable aquatic habitat and no predicted threatened species, Bundock Creek has been classified as a “Type 3 – Minimally sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 3 – Minimal fish habitat’ (Fairfull and Witheridge, 2003) due to its ephemeral nature. Bundock Creek has not been identified as a sensitive receiving environment.

Site	Photos		Description
6 – Goona Creek	 Goona Creek facing *upstream* (photo taken on 19/03/2019)	 Goona Creek facing *downstream* (photo taken on 19/03/2019)	Goona Creek is an ephemeral, third order Strahler Stream which was mostly dry at the time of inspection, however some small residual pools were present at site and some areas exhibited a slightly wet stream bed. Channel definition is only apparent on the right bank where there is a steep slope and some evidence of active erosion including undercutting. The left bank exhibits a gradual slope. The substrate was predominantly rock, with some sand and gravel constituents. The riparian zone was sparsely vegetated. Some large woody snags were present within the channel, however there was no aquatic macrophytes present within the streambed or along the banks. The stream is mapped as key fish habitat (DPI, 2007a), with the threatened Purple Spotted Gudgeon (*Mogurnda adspersa)* predicted to occur when water is present (DPI, 2016). Some suitable habitat features for the Purple Spotted Gudgeon appeared to be present at the site. As the watercourse contains significant aquatic habitat features and threatened fish species are likely to occur, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate key fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Goona Creek is identified as a sensitive receiving environment which should be considered for fish friendly crossings.

Site	Photos	Description
7 – Black Creek	 Black Creek facing *upstream* (photo taken on 19/03/2019)  k Creek facing *downstream* (photo taken on 19/03/2019)	Black Creek is an ephemeral, third order Strahler stream which was dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The channel substrate was predominantly sand with some gravel constituents. The stream is mapped as key fish habitat (DPI, 2007a) however, no aquatic habitat was present at the time of inspection and threatened fish are not predicted to occur (DPI, 2016). Due to the lack of suitable aquatic habitat and no predicted threatened species, Black Creek has been classified as a “Type 3 – Minimally sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 3 – Minimal key fish habitat” (Fairfull and Witheridge, 2003) due to its ephemeral nature. Black Creek has not been identified as a sensitive receiving environment.

Site	Photos		Description
10 – Mollieroi Creek	 Mollieroi Creek facing *upstream* (photo taken on 19/03/2019)	 Mollieroi Creek facing *downstream* (photo taken on 19/03/2019)	Mollieroi Creek is an ephemeral, fourth Order Strahler stream which was mostly dry with some residual pools at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. No evidence of active erosion was present; however, the substrate is predominantly highly erodible, mobile sand. The riparian zone was heavily vegetated and some large woody snags were present within the channel. The stream is mapped as key fish habitat (DPI, 2007a) with the threatened Purple Spotted Gudgeon (*Mogurnda adspersa)* predicted to occur when water is present (DPI, 2016). Some suitable habitat features for the Purple Spotted Gudgeon appeared to be present at the site. As the watercourse contains some significant aquatic habitat features and threatened fish species are likely to occur, it is classified “Type 1 – Highly sensitive key fish habitat’ (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate key fish habitat’ due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Mollieroi Creek is identified as a sensitive receiving environment which should be considered for fish friendly crossings.

Site	Photos		Description
11 – Coghill Creek	 Coghill Creek facing *upstream* (photo taken on 11/10/2019)	 Coghill Creek facing *downstream* (photo taken on 11/10/2019)	Coghill Creek is an ephemeral fourth order Strahler stream which was dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand with some gravel. The riparian zone was heavily vegetated, and no evidence of active erosion was present. The stream is mapped as key fish habitat (DPI, 2007a) with the threatened Purple Spotted Gudgeon (*Mogurnda adspersa)* predicted to occur when water is present (DPI, 2016). As the watercourse contains some significant aquatic habitat features and threatened fish species are likely to occur, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Coghill Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
14 – Talluba Creek	 Talluba Creek facing *upstream* (photo taken on 11/10/2019)	 Talluba Creek facing *downstream* (photo taken on 11/10/2019)	Talluba Creek is an ephemeral, third order Strahler stream which was completed dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand. No evidence of active erosion was present. The riparian zone was heavily vegetated with large trees and shrubs. Some macrophytes in good condition were present along the banks and some small woody snags were present within the streambed. The stream is mapped as key fish habitat (DPI, 2007a) however, threatened fish are not predicted to occur (DPI, 2016). Due to the lack of suitable fish habitat features, Talluba Creek has been classified as a “Type 3 – Minimally sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 3 – Minimal fish habitat” (Fairfull and Witheridge, 2003) due to its ephemeral nature. Talluba Creek has not been identified as a sensitive receiving environment due to its ephemeral nature and it being classified as Type 3 key fish habitat.

Site	Photos	Description
15 – Tinegie Creek	 Tinegie Creek facing *upstream* (photo taken on 19/03/2019)	Tinegie Creek is an ephemeral, first order Strahler stream which was dry at the time of inspection. The creek is characterised as a minor drainage line and is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand. No evidence of active erosion was present at the time of inspection. The riparian zone was sparsely vegetated. No macrophytes were present within the streambed however several large woody snags were present at the site. Threatened fish are not predicted to occur (DPI, 2016) in Tinegie Creek and there was minimal aquatic habitat present at the site therefore it has been classified as a “Type 3 – Minimally sensitive key fish habitat” (DPI, 2013). With respect to fish passage, Tinegie Creek is classified “Class 3 – Minimal key fish habitat” (Fairfull and Witheridge, 2003) due to its ephemeral nature. Tinegie Creek has not been identified as a sensitive receiving environment due to its ephemeral nature and it being classified as Type 3 key fish habitat.

Site	Photos		Description
16 – Rocky Creek	 Rocky Creek facing *upstream* (photo taken on 11/10/2019)	 Rocky Creek facing *downstream* (photo taken on 11/10/2019)	Rocky Creek is an ephemeral, fourth order Strahler stream which was mostly dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand. No evidence of erosion was present. The riparian zone was heavily vegetated with large trees and several large woody snags were present within the channel. Pebble beds were present in the channel. The stream is mapped as key fish habitat (DPI, 2007a) with the threatened Eel Tailed Catfish (*Tandanus tandanus)* predicted to occur when water is present (DPI, 2016). Some suitable habitat features for the Eel Tailed Catfish appeared to be present at the site. As the watercourse may contain threatened fish habitat, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Rocky Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
17 – Stockyard Creek	 Stockyard Creek facing *upstream* (photo taken on 19/03/2019)	 Stockyard Creek facing *downstream* (photo taken on 19/03/2019)	Stockyard Creek is a third order Strahler stream which was dry at the time of inspection. The creek is situated in a broad valley landscape. Channel definition was only apparent on the left bank which exhibited a moderate slope. No evidence of active erosion was present however the streambed had sand bar formations and a highly erodible, mobile sand substrate. The riparian zone was heavily vegetated, although no macrophytes were present within the streambed. Some overhanging trees and large woody snags were present along the banks. The stream is mapped as key fish habitat (DPI, 2007a) however no threatened species are predicted to occur (DPI, 2016). Due to the several aquatic habitat features at the site, it has been classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate key fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Stockyard Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
18 – Etoo Creek	 Etoo Creek facing *upstream* (photo taken on 11/10/2019)	 Etoo Creek facing *downstream* (photo taken on 11/10/2019)	Etoo Creek is an ephemeral, fifth order Strahler stream which was mostly dry with some areas exhibiting a slightly wet stream bed at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand. No evidence of active erosion was present. The riparian zone was heavily vegetated with large trees. Some macrophytes in poor condition were present at the site and some woody snags were present within the streambed. Some large boulders were present in the channel. The stream is mapped as key fish habitat (DPI, 2013) with the threatened Eel Tailed Catfish (*Tandanus tandanus)* predicted to occur when water is present (DPI, 2013). Some suitable habitat features for the Eel Tailed Catfish appeared to be present at the site. As the watercourse is likely to contain threatened fish habitat, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Etoo Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
19 – Cumbil Forest Creek	 Cumbil Forest Creek facing *upstream* (photo taken on 11/10/2019)	 Cumbil Forest Creek facing *downstream* (photo taken on 11/10/2019)	Cumbil Forest Creek is an ephemeral first order Strahler stream which was mostly dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand with some large boulders and gravel beds. No evidence of active erosion was present at the time of inspection. The riparian zone was sparsely vegetated and some macrophytes in poor condition were present within the streambed. Several large woody snags were present at the site. Threatened fish are not predicted to occur (DPI, 2016). Cumbil Forest Creek has been classified as a "Type 3 – Minimally sensitive key fish habitat" (DPI, 2013). With respect to fish passage, it is classified "Class 3 – Minimal fish habitat" (Fairfull and Witheridge, 2003) due to its ephemeral nature. Cumbil Forest Creek has not been identified as a sensitive receiving environment due to its ephemeral nature and it being classified as Type 3 minimally sensitive key fish habitat.

Site	Photos		Description
20 – Coolangla Creek	 Coolangla Creek facing *downstream* (photo taken on 20/03/2019)	 Coolangla Creek facing *downstream* (photo taken on 20/03/2019)	Coolangla Creek is an ephemeral, third order Strahler stream which was dry at the time of inspection. The creek is situated in a broad valley landscape with limited channel definition. The substrate is predominantly sand. No evidence of erosion was present. The riparian zone was heavily vegetated and macrophytes in poor condition were present within the streambed and along the banks. The stream is mapped as key fish habitat (DPI, 2007a) however, threatened fish species are not predicted to occur (DPI, 2016). Coolangla Creek has been classified as a “Type 3 – Minimally sensitive key fish habitat” (DPI, 2013) due to the high level of suitable habitat features. With respect to fish passage, it is classified “Class 3 - Minimal fish habitat” (Fairfull and Witheridge, 2003) due to its ephemeral nature. Coolangla Creek has not been identified as a sensitive receiving environment as it is Type 3 key fish habitat.

Site	Photos		Description
21 – Baradine Creek	 Baradine Creek facing *upstream* (photo taken on 20/03/2019)	 Baradine Creek facing *upstream* (photo taken on 20/03/2019)	Baradine Creek is a sixth order Strahler stream which was mostly dry with recently evaporated residual pools. Channel definition is only apparent on the right bank which is gradually sloped, and the substrate is predominantly sand with some gravel. The riparian zone was heavily vegetated with several over-hanging trees at the time of inspection. Some aquatic macrophytes in poor condition were present along the bank edges, and some significant large woody debris was present within the channel. Threatened fish including Eel Tailed Catfish (*Tandanus tandanus)* and Purple Spotted Gudgeon (*Mogurnda adspersa)* are predicted to occur when water is present (DPI, 2016). Some suitable habitat features appeared to be present at the site for the species listed above. As the watercourse is likely to contain threatened fish habitat, it is classified “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Baradine Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
22 – Tenandra Creek	 Tenandra Creek facing *upstream* (photo taken on 10/10/2019)	 Tenandra Creek facing *downstream* (photo taken on 10/10/2019)	Tenandra Creek is an ephemeral, fourth order stream which was dry at the time of inspection. The stream is mapped as key fish habitat (DPI, 2007a) however, minimal aquatic habitat was present at the time of inspection. The stream is highly modified, and vegetation has been cleared from the banks. The road presents a barrier to flow with significant undercutting and infilling occurring along the banks suggesting a high potential for erosion at this site. Threatened fish are not predicted to occur (DPI, 2016). Tenandra Creek has been classified as a "Type 3 – Minimally sensitive key fish habitat" (DPI, 2013). With respect to fish passage, it is classified "Class 3 – Minimal fish habitat" (Fairfull and Witheridge, 2003) due to its ephemeral nature. Tenandra Creek has not been identified as a sensitive receiving environment as it is Type 3 key fish habitat.

Site	Photos		Description
23 – Gulargam-bone Creek	 Gulargambone Creek facing *upstream* (photo taken on 10/10/2018)	 Gulargambone Creek facing *downstream* (photo taken on 10/10/2018)	Gulargambone Creek is a fifth order stream, which was completely dry at the time of inspection. The creek is narrow, approximately 3 m in width and had a silty loam substrate. Active erosion and undercutting occur along the banks was present and appeared to be causing protruding tree roots. Native trees line the creek and abundant large woody debris was throughout the creek. There was a small mesh fence across the channel. No apparent instream aquatic macrophytes were present during site inspection. There were some large woody debris within the channel. When water is present, two threatened fish are predicted to occur; Purple Spotted Gudgeon (*Mogurnda adspersa*) and Eel Tailed Catfish (*Tandanus tandanus*) (DPI, 2016). Some suitable habitat features appeared to be present at the site for the species listed above. Gulargambone Creek has been classified as a "Type 1 – Highly sensitive key fish habitat" as it is a 5th order watercourse, containing threatened fish habitat and large woody debris (DPI, 2013). With respect to fish passage, it is classified "Class 2 – Moderate fish habitat" due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Gulargambone Creek has been identified as a sensitive receiving environment and should be considered for fish friendly crossings.

Site	Photos		Description
24 – Castlereagh River	 Castlereagh River facing *upstream* (photo taken on 10/10/2019)	 Castlereagh River facing *downstream* (photo taken on 10/10/2019)	Castlereagh River is seventh order major watercourse which was dry at the time of inspection. The channel is characterised by gradually sloping banks and a predominantly sandy channel bed. Other significant channel features included instream sand bars. Significant aquatic habitat was present at the site. There was instream large woody debris, abundant macrophytes beds, and overhanging vegetation along the banks. The riparian zone was also heavily vegetated and no evidence of erosion was present at the site. Since the river is mapped as key fish habitat (DPI, 2007a), exhibits significant habitat features and the threatened Eel Tailed Catfish (*Tandanus tandanus)* is predicted as 'likely to occur' (DPI, 2016), it has been classified "Type 1 – Highly sensitive key fish habitat" (DPI, 2013). The river has also been identified as "Class 1 – Major fish habitat" (Fairfull and Witheridge, 2003). Some suitable habitat features for the Eel Tailed Catfish appeared to be present at the site. Castlereagh River is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
27 - Kickabil Creek	 Kickabil Creek facing *upstream* (photo taken on 09/10/2019)	 Kickabil Creek facing *downstream* (photo taken on 09/10/2019)	Kickabil Creek is an ephemeral, fourth order Strahler stream which was dry at the time of inspection. The channel is characterised by steep sloping banks, and the substrate was predominantly sand with some gravel beds. Other channel features include sand bars and evidence of erosion which has been stabilised by macrophytes. The creek intersects Kickabil Road under a concrete bridge. Significant aquatic habitat was present at the site. Abundant macrophytes were present within the streambed and along the bank, and large woody debris was present within the channel. The riparian zone was heavily vegetated and there was some over-hanging vegetation. The stream is mapped as key fish habitat (DPI, 2007a) however, threatened fish species are not predicted to occur (DPI, 2016). Due to the creek exhibiting significant aquatic habitat features, it has been classified as “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Kickabil Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

Site	Photos		Description
28 – Ewenmar Creek	 Ewenmar Creek facing *upstream* (photo taken on 09/10/2019)	 Ewenmar Creek facing *downstream* (photo taken on 09/10/2019)	Ewenmar Creek is an ephemeral fourth order stream. The creek had moderate water depth at the time of inspection. Water was highly turbid and there was no flow. The creek is positioned within a gully surrounded by cleared farm land. Aquatic habitat including abundant woody debris greater than three meters, overhanging vegetation with exposed tree roots were present throughout the watercourse. Native flood dependent trees line the banks. The creek is mapped as key fish habitat (DPI, 2007a) however, threatened fish are not predicted to occur (DPI, 2016). Ewenmar Creek is comprised of silt loam substrate with active erosion and undercutting along the bank. This suggests a moderate potential for erosion, particularly if the riparian vegetation is removed. Ewenmar Creek has been classified as “Type 2 – Moderately sensitive key fish habitat” as it is a fourth order watercourse, containing aquatic habitat including large woody debris (DPI, 2013). With respect to fish passage, it is classified “Class 2 – Moderate fish habitat” (Fairfull and Witheridge, 2003). Ewenmar Creek has been identified as a sensitive receiving environment and should be considered for fish friendly crossings.

Site	Photos	Description
29 – Macquarie River	 Macquarie River facing *upstream* (photo taken on 15/11/2018)  Macquarie River facing *downstream* (photo taken on 15/11/2018)  Macquarie River facing *upstream* (photo taken on 10/10/2019)  Macquarie River facing *upstream* (photo taken on 10/10/2019)	Macquarie River is a permanently flowing (perennial) watercourse (Strahler 9th order) which contained moderate water levels at the initial site inspection. The river contained a variety of aquatic habitat including large fallen trees (instream woody debris) overhanging vegetation and emergent native macrophytes. The river is densely lined with large flood dependent trees. Significant undercutting occurs at the left bank and consists of a silt substrate. Several threatened fish are likely to occur including; Eel Tailed Catfish (*Tandanus tandanus)*, Silver Perch (*Bidyanus bidyanus)*, Trout Cod (*Maccullochella macquariensis)*, Olive Perchlet (*Ambassis agassizii* (DPI, 2016) and Murray Cod (*Maccullochella peelii)*.) (Lintermans, 2007; ALA, 2020) Suitable habitat features were present at the site for the species listed above. As the watercourse contains significant aquatic habitat and several threatened fish are predicted to occur, it is identified as “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 1 – Major key fish habitat” (Fairfull and Witheridge, 2003). Watercourse condition appeared to have deteriorated from the initial site visit in November 2018 to the final site visit in October 2019. In October 2019, the watercourse depth was significantly lower and there was algae growing on a significant portion of the water surface. There was some large woody debris present at the site. Macquarie River considered a highly sensitive receiving environment and should be considered for fish friendly crossings.

Site	Photos		Description
30 - Backwater Cowal	 Backwater Cowal facing *upstream* (photo taken on 09/10/2019)	 Backwater Cowal facing *downstream* (photo taken on 09/10/2019)	Backwater Cowal (also known as Boggy Cowal) is a wetland depression on the floodplain which discharges from Macquarie River. The wetland then forms a north west flowing watercourse 'Boggy Cowal'. The wetland was predominantly dry at the time of inspection with two residual pools remaining. Native trees line the edges and few woody snags were observed. Aquatic habitat included minor undercut banks along the refuge island and a small patch of instream macrophytes (*Phragmites australis*). Threatened fish including Flathead Galaxias (*Galaxias rostratus*) are mapped in Backwater Cowal when water is present (DPI, 2016). Suitable habitat features for the Flathead Galaxias did not appear to be present at the site. As the watercourse contains native aquatic macrophytes and threatened fish are predicted to occur, Backwater Cowal have been identified as "Type 1 – Highly sensitive key fish habitat" (DPI, 2013). With respect to fish passage, it is classified "Class 2 – Moderate fish habitat" (Fairfull and Witheridge, 2003) due to the ephemeral nature of the wetland. The waterbody is considered a sensitive receiving environment and should be considered for fish friendly crossings.

Site	Photos		Description
31 – Emogandry Creek	 Emogandry Creek facing *upstream* (photo taken on 09/10/2019)	 Emogandry Creek facing *downstream* (photo taken on 09/10/2019)	Emogandry Creek is an ephemeral, fourth order stream which was dry at the time of inspection. The channel exhibits steep sloping banks and substrate which is predominantly sand with some gravel beds. Other channel features include large sand bars and evidence of erosion including undercutting on the outer bends of the channel. The creek dissects Old Mill Road under a concrete culvert. Significant aquatic habitat was present at the site. Macrophytes in poor condition were present within the streambed and along the banks, and large woody debris was present within the channel. The riparian zone was vegetated and there was some over-hanging vegetation. The stream is mapped as key fish habitat (DPI, 2007a) however, threatened fish species are not predicted to occur (DPI, 2016). Due to the creek exhibiting significant aquatic habitat features, it has been classified as “Type 1 – Highly sensitive key fish habitat” (DPI, 2013). With respect to fish passage, it is classified “Class 2 – Moderate fish habitat” due to the ephemeral nature of the watercourse (Fairfull and Witheridge, 2003). Emogandry Creek is identified as a sensitive receiving environment which should considered for fish friendly crossings.

TECHNICAL REPORT

2

Aquatic ecology assessment

Appendix B Threatened species and ecological communities impact assessment

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

FM Act Seven-part test of significance

The results of this assessment identified five threatened fish species, two endangered fish populations and one endangered ecological community listed under the Fisheries Management Act 1994. A seven part test in accordance with the Environmental Planning and Assessment Act 1979 has been carried out for each in Tables B.1 to B.4.

Appendix B1 Seven-part test of significance for Lowland Darling River Aquatic Ecological Community (Darling River EEC)

Seven part test questions	Assessment
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.	Not applicable
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.	No applicable
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *I. is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or* *II. is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*	The project lies within the natural drainage system of the lowland catchment of the Darling River (Darling River EEC) which includes the Macquarie River, Castlereagh River and Namoi River. Extents of the Lower Darling EEC within these catchments include; the Gwydir River from Copeton Dam downstream; the Namoi River from the junction of the Manilla River at Manilla (including Mehi River channel west of Moree) downstream; the Manilla River from Split Rock Dam downstream; the Peel River from Chaffey Dam downstream; the Macquarie River from Burrendong Dam downstream; the Cudgegong River from Windamere Dam downstream; the Castlereagh River from below Binnaway downstream; and the Bogan River from below Peak Hill downstream. All watercourses crossings within the project alignment fall within the Darling River Endangered Ecological Community. Excluded from this community are the manmade/artificial canals, water distribution and drainage works, farm dams and off-stream reservoirs. Other watercourses above 500 m not specifically named above are also excluded (DPI, 2007a) Fish friendly crossings would be constructed where the project alignment intersects watercourses that have been identified as SREs. Water crossings have been designed with the aim to minimise disturbance to aquatic habitat structure and ensure there are no potential barriers to fish-passage. Additionally, aquatic habitat features such as large woody debris would be reinstated into watercourses within the construction footprint area.

Seven part test questions	Assessment
	The project is therefore unlikely to: I. have an adverse effect on the extent of the ecological community or place the community at risk of extinction II. substantially or adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction
d) in relation to the habitat of a threatened species, population or ecological community: *I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and* *II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*	I. The extent of riparian habitat that is likely to be removed during construction is ~85 hectares. Riparian vegetation within private lands is predominantly cleared and heavily modified with large native trees remaining. Watercourses within state forests are heavily vegetated and would require localised clearing within the construction footprint and in watercourses at watercourse crossing locations. During operation, vegetation clearing would be limited to the operational footprint. Other areas are proposed to be cleared during construction, ie construction compounds would be rehabilitated. II. As many of the watercourses contain threatened fish and have been assessed as “Type 1, highly sensitive key fish habitat”, crossings require fish friendly passage including bridge structures and rehabilitation of habitat structure that may be disturbed during construction. Disturbance such as the temporary removal of vegetation and woody debris may occur during the construction phase of the project. However, as they would be reinstated the project is unlikely to fragment or isolate the long-term survival of the species, population or ecological community in the locality.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No critical habitat near watercourses has been identified with the proposal area.

Seven part test questions	Assessment
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	Recovery and conservation actions for the EEC which are associated with project activities would include: • Conserving and restoring habitat at watercourse crossings by protecting aquatic and riparian vegetation and, using effective erosion control measures both during and after construction; • Reinstating large woody debris and rocks, where appropriate; • Providing fish passage by avoiding barriers or installing fishways in consultation with stakeholders; Recovery actions would be made in accordance with national guidelines *Why do fish cross the road? Fish passage requirements for waterways crossings* (Fairfull and Witheridge, 2003)
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	Threatening processes which may occur during the construction of watercourse crossings may include; • Temporary removal of large woody debris. • Alteration of natural flow regimes through the installation of instream structures. • Removal of riparian vegetation and associated erosion of stream banks. By incorporating erosion and sediment control measures, rehabilitating habitat structure and designing fish friendly crossings, the KTPs as mentioned above would be minimised. This is further detailed in section 7.1.

Appendix B2 Seven-part test of significance for endangered populations listed under the FM Act

Murray Darling Basin population of Eel Tailed Catfish *(Tandanus tandanus)*	Western population of Olive Perchlet *(Ambassis agassizii)*
a) *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*	
Not applicable.	Not applicable.
b) *in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction*	
The Eel Tailed Catfish is a relatively sedentary species, with adults typically only moving within a 5 km range (Lintermans, 2007). The species live, feed and breed near the bottom of a waterbody, in a wide range of habitats including rivers, creeks, lakes, billabongs and lagoons, and although it inhabits flowing streams, its preferred habitat is clear, sluggish or still waters (Fisheries Scientific Committee, 2008). They spawn in spring/summer when water temperatures range between 20 to 24˚C and eggs are laid in a nest of pebbles and gravel. The male guards the nest and eggs hatch after 7 days. The lifecycle is threatened by loss of habitat and spawning sites through siltation, reduced spawning success through alterations to flow patterns and flooding regimes, and loss of spawning cues due to cold water pollution. It is noted that the Eel Tailed Catfish has been recorded in a number of watercourse where the proposal alignment is expected to cross (DPI, 2016). Watercourses that have well defined channels with pools evident in or immediately upstream or downstream of the proposal site included Narrabri Creek, Castlereagh River, and Macquarie River. Other watercourses that were dry at the time of inspection but are expected to have residual pools upstream and downstream of the proposal site included Namoi River, Bohena Creek, Rocky Creek (also known as Pine Creek), Etoo Creek, Baradine Creek and Gulargambone Creek. Additionally, an expected preferred habitat for the Eel Tailed Catfish was identified at Backwater Cowal (also known as Boggy Cowal) which is a turbid, relatively deep (however was almost dry at the time of inspection), low velocity environment where the proposal intersects. The works associated with the construction of bridges and culverts may impact on some small areas of breeding habitat through direct disturbance of	The Olive Perchlet's preferred habitat is the vegetated edges of lakes, creeks, swamps, wetlands and rivers, where it is often associated with woody habitat and aquatic vegetation in areas with little or no flow, particularly backwaters (Lintermans, 2007). They spawn in spring/summer when water temperatures reach between 22 – 23˚C. The eggs are small, adhesive and attach to aquatic plants and rocks on the streambed. Hatching occurs in 5-7 days at 22˚C. The lifecycle is threatened by loss of aquatic habitat and spawning sites through siltation and vegetation removal, reduced spawning success and preferred habitat through alterations to flow patterns and flooding regimes, and loss of spawning cues due to cold water pollution. It is noted that the Olive Perchlet has been recorded in a number of watercourses where the proposal alignment is expected to cross (DPI, 2016). Mapped potential habitat of the Olive Perchlet within the study area includes Namoi River, Narrabri Creek, Macquarie River and Barrone Creek. The works associated with the construction of bridges and culverts may impact on areas of breeding habitat through direct disturbance of rocky substrate on streambeds, clearance of vegetation within the streambed and on the banks, increased sedimentation caused by construction activities, blockage of fish passage or by cold water pollution from overland flows or construction activities. Standard measures during construction and operation would be undertaken to avoid impacts. Woody debris would be relocated upstream and downstream of the works. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation. To minimise impact on spawning success, watercourse crossing structures should be built outside of the breeding

Murray Darling Basin population of Eel Tailed Catfish *(Tandanus tandanus)*	Western population of Olive Perchlet *(Ambassis agassizii)*
the bottom substrate, through alteration of natural flows, clearance of vegetation or through blocking of fish passage. Standard measures during construction and operation would be undertaken to avoid impacts. Woody debris would be relocated upstream and downstream of the works. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation. To minimise impact on spawning success, watercourse crossing structures should be built outside of the breeding season (Spring / Summer) in watercourses where the Eel Tailed Catfish is predicted to occur (where water is present). These standard practices would minimise adverse effects on the life cycle of the population.	season (Spring / Summer) in watercourses where the Olive Perchlet is predicted to occur (where water is present). These standard practices would minimise adverse effects on the life cycle of the population.
c) *in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*	
Not applicable.	Not applicable.
d) *in relation to the habitat of a threatened species, population or ecological community: i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*	
The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and would include clearance of adjoining riparian vegetation. Disturbance would be limited to 50 m upstream and downstream of the watercourse, and riparian vegetation would be reinstated in cleared areas post-construction. In relation to the proposal, the Macquarie catchment upstream of Warren and the Castlereagh catchment upstream of Mendooran are considered to support a moderate remnant population of the Eel Tailed Catfish (Fisheries Scientific Committee, 2008). Accordingly, Macquarie River, Castlereagh River and associated tributaries of both watercourses are likely to be considered important for the survival of the species. Where the alignment is expected to cross the alignment at sensitive watercourses, culverts and bridges have been designed to avoid blockage of	The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and may include clearance of adjoining riparian vegetation. Disturbance would be limited to 50 m upstream and downstream of the watercourse. The western population of the Olive Perchlet is reported to have significantly declined in recent years (DPI, 2015). However, in relation to the proposal, populations of Olive Perchlet have been mapped in a semi-permanent wetland known as Gulligal Lagoon which is connected to the Namoi River. Whilst Gulligal Lagoon is not within the proposal study area, its connection to the Namoi River means that there is potential for the species to be located within Namoi River. Accordingly, Namoi River is considered to be important for the survival of the western population of the Olive Perchlet.

Murray Darling Basin population of Eel Tailed Catfish *(Tandanus tandanus)*	**Western population of Olive Perchlet *(Ambassis agassizii)***
fish passage and minimise disturbance of remnant vegetation upstream and downstream of the work area. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. These standard practices would minimise adverse effects relating to the fragmentation or isolation of habitats.	The watercourse structures would be designed to avoid blockage of fish passage at Namoi River and minimise disturbance of remnant vegetation upstream and downstream of the work area. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. These standard practices would minimise adverse effects relating to the fragmentation or isolation of habitats.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	
No critical habitat has been identified in the proposal area.	No critical habitat has been identified in the proposal area.
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	
Priority action statements for the Eel Tailed Catfish include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations • review regulatory and voluntary incentive based mechanisms to enhance habitat protection • pest eradication and control • stocking/translocation • habitat rehabilitation including: management of environmental flows; improved fish passage at major regulating structures; protection and rehabilitation of aquatic habitat and riparian vegetation; and mitigate impacts of cold-water pollution. The proposal would involve constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway*	Priority action statements for the Olive Perchlet include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations • review regulatory and voluntary incentive based mechanisms to enhance habitat protection • pest eradication and control • stocking/translocation • conduct targeted surveys to determine the current distribution and abundance of the Olive Perchlet and collect data on the presence/absence of Olive Perchlet during incidental surveys. The proposal would involve constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.

Murray Darling Basin population of Eel Tailed Catfish *(Tandanus tandanus)*	Western population of Olive Perchlet *(Ambassis agassizii)*
*crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	
The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris. The proposal may require removal of large woody debris in the proposal site. Any large woody debris in the proposal site would be relocated upstream or downstream in consultation with an appropriate qualified ecologist. Instream vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Through appropriate design of the watercourse crossing structures and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.	The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris. The proposal may require removal of large woody debris and riparian vegetation in the proposal area. Any large woody debris in the proposal area would be relocated upstream or downstream in consultation with an appropriate qualified ecologist. Instream vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Through appropriate design of the watercourse crossing structure and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.

Appendix B3 Seven part test of significance for threatened species listed under the FM Act (continued)

Flathead Galaxias (*Galaxias rostratus*)	Trout Cod (*Maccullochella macquariensis*)
a) *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*	
The Flathead Galaxias is generally found mid-water in still and gently moving waters of small streams, lakes, lagoons, billabongs and backwaters. Its preferred habitat consists of course sand or mud substrate and aquatic vegetation (DPI, 2014). Spawning occurs in spring when water temperatures are above 10.5˚C. The eggs are small, adhesive and attach to aquatic plants and rocks on the streambed. Hatching occurs after 9 days at temperatures between 9 – 14˚C (DPI, 2014). The lifecycle is threatened by: • spawning or recruitment failure due to water regulation and cold-water releases; • loss of or altered connectivity between rivers and floodplains; • loss of or degradation of habitats in lakes, wetlands and billabongs such as the loss of aquatic vegetation; • predatory and competitive interactions with introduced species such as Carp (*Cyprinus carpio*), Redfin Perch (*Perca fluviatilis)*, and Gambusia (*Gambusia holibrooki)*; • construction of barriers to migration and re-colonisation such as weirs and dams without fish ways; • habitat modification as a result of agricultural practices including siltation and loss of riparian vegetation; and, • pollution from domestic, agricultural and industrial sources (DPI, 2014). It is noted that the Flathead Galaxias has been recorded as ‘likely to occur’ in a number of watercourses where the proposal alignment is expected to cross (DPI, 2016). Mapped potential habitat of the Flathead Galaxias within the study area includes Narrabri Creek, Namoi River, Barrone Creek and Backwater/Boggy Cowal. The works associated with the construction of bridges and culverts may impact on areas of breeding habitat through direct disturbance of streambeds, clearance of vegetation within the streambed and on the banks, increased sedimentation caused by construction activities, blockage of fish	The Trout Cods preferred habitat is areas that have lots of large in-stream woody debris or ‘snags’, which provide complex habitats for each stage of the species’ life cycle. The species would form pairs and spawn during spring and early summer when water temperature is around 15˚C. Females will attach their eggs to hard substrates and larvae would hatch after 5 – 10 day (DPI, 2017a). The species is threatened by: • modification of natural river flows and temperatures as a result of river regulation which has led to spawning failures, reduced fish dispersal, and reduced habitat quality; • habitat degradation through the removal of snags, water quality impacts associated with agriculture and other land uses, and sedimentation caused by land clearing activities; and, • competition from, or interactions with, introduced fish species such as Brown Trout (*Salmo trutta*), Redfin Perch (*Perca fluviatilis)* and common Carp (*Cyprinus carpio)*. It is noted that the Trout Cod has been mapped has having potential to be within in the Macquarie River, a watercourse where the proposal alignment is expected to cross (DPI, 2016). The works associated with the construction of bridges and culverts may impact on areas of habitat through direct disturbance/removal of woody debris within the watercourse, through clearance of vegetation within the streambed and on the banks, through sedimentation caused by construction activities, blockage of fish passage or by cold water pollution from overland flows. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to

Flathead Galaxias (*Galaxias rostratus*)	Trout Cod (*Maccullochella macquariensis*)
passage or by cold water pollution from overland flows. Aquatic vegetation would be inspected for fish eggs and larvae prior to removal. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Woody debris would be relocated upstream and downstream of the works. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation and cold-water pollution from runoff. To minimise impact on spawning success, watercourse crossing structures should be built outside of the breeding season (Spring / Summer) in watercourses where the Flathead Galaxias is predicted to occur (where water is present). Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.	manage and minimise further siltation and cold-water pollution from runoff. To minimise impact on spawning success, watercourse crossing structures should be built outside of the breeding season (Spring / Summer) in watercourses where the Trout Cod is predicted to occur (where water is present). Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction	
Not applicable.	Not applicable.
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	
Not applicable.	Not applicable.
d) in relation to the habitat of a threatened species, population or ecological community: i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	
The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and would include clearance of adjoining riparian vegetation. Disturbance would be limited to 50m upstream and downstream of the watercourse.	The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and would include clearance of adjoining riparian vegetation. Disturbance would be limited to 50 m upstream and downstream of the watercourse.

Flathead Galaxias (*Galaxias rostratus*)	Trout Cod (*Maccullochella macquariensis*)
Records have revealed a significant reduction in the distribution of the Flathead Galaxias since 1990, with the majority of sightings post 1990 mainly occurring in catchments south of the study area in Goulburn, Loddon and Murray catchments (Lintermans, 2007). However, since the Flathead Galaxias is categorised as critically endangered under NSW legislation, all areas that are considered preferential habitat for the species are considered important for the survival of the population. In relation to the proposal, distribution of the Flathead Galaxias has been mapped in the Macquarie River Catchment prior to 1990, therefore Narrabri Creek, Namoi River, Barrone Creek and Backwater/Boggy Cowal are considered to be important habitat for the survival of the population.	Historically, Trout Cod were present throughout the upper reaches of the Macquarie River Catchment but the species was thought to have become extinct in the area by 1984 (Trueman, 2011). Hundreds of thousands of Trout cod fingerlings were subsequently restocked in the Macquarie River upstream and downstream of the Burrendong Dam between 1991 and 2004. No consistent monitoring has been undertaken to understand whether the population has managed to become self-sustaining however opportunistic scientific data and reports from recreational fishers indicate that trout cod have survived in the upper and lower reaches of the river since this restock effort has taken place. Accordingly, in relation to the proposal, Macquarie River is considered to be important habitat for the survival of the population.
The watercourse structures would be designed to avoid blockage of fish passage and minimise disturbance of remnant vegetation upstream and downstream of the work area. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation and cold-water pollution due to runoff. These standard practices would minimise adverse effects relating to the fragmentation or isolation of habitats.	The watercourse structures would be designed to avoid blockage of fish passage and minimise disturbance of remnant vegetation and woody debris upstream and downstream of the work area. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation and cold-water pollution due to runoff. These standard practices would minimise adverse effects relating to the fragmentation or isolation of habitats.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	
No critical habitat has been identified in the proposal area.	No critical habitat has been identified in the proposal area.
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	
Priority action statements for the Flathead Galaxias include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations at identified important sites • review regulatory and voluntary incentive-based mechanisms to enhance habitat protection and minimise adverse impacts on threatened species • pest eradication and control • stocking/translocation	Priority action statements for the Trout Cod include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations including national recovery plan to minimise adverse impact on the species • habitat rehabilitation including: providing increased protection and rehabilitation for key area of Trout Cod aquatic habitat and riparian vegetation.

Flathead Galaxias (*Galaxias rostratus)*	Trout Cod (*Maccullochella macquariensis)*
• habitat protection and rehabilitation including: potential artificial refuge area for the protection of Flathead Galaxias, management of environmental flows; improved fish passage at major regulating structures; protection and rehabilitation of aquatic habitat and riparian vegetation; and mitigate impacts of cold-water pollution. The proposal would be constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	The proposal would be constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	
The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris. The proposal may require removal of large woody debris in the proposal site. Any large woody debris in the proposal site would be relocated upstream or downstream in consultation with an appropriate qualified ecologist. Through appropriate design of the watercourse crossing structure and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.	The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris. The proposal may require removal of large woody debris in the proposal site. Any large woody debris in the proposal site would be relocated upstream or downstream in consultation with an appropriate qualified ecologist. Through appropriate design of the watercourse crossing structure and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.

Appendix B4 Seven part test of significance for threatened species listed under the FM Act (continued)

Purple Spotted Gudgeon (*Mogurnda adspersa*)	Silver Perch (*Bidyanus bidyanus)*
a) *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*	
Purple Spotted Gudgeon are a benthic species and occur in a variety of habitats including rivers, creeks and billabongs with slow-moving or still waters, or streams with low turbidity. Microhabitats such as aquatic vegetation, overhanging vegetation from river banks, leaf litter, rocks or woody debris are important for this species (DPI, 2017b). Spawning occurs overs summer and females deposit their eggs in clusters on solid objects such as rocks, wood or broad-leafed plants. Hatching occurs within 3 – 8 days (DPI, 2017b). The lifecycle is threatened by: • Loss of favourable habitat, particularly aquatic plants. • Fluctuations in water levels and flow as a result of river regulation. This has a significant impact on the inundation habitats important for the Southern Purple Spotted Gudgeon reproduction and recruitment. • Thermal pollution • Increased turbidity and damage of streambanks • Decrease water quality due to agricultural runoff and siltation • Predation and being out-competed by introduced species such as Eastern Gambusia (*Gambuisa holbrooki),* Redfin Perch (*Perca fluviatilis)* and common Carp (*Cyprinus carpio).* It is noted that the Purple Spotted Gudgeon has been recorded in many of the watercourses where the proposal alignment is expected to cross (DPI, 2016). Mapped potential habitat of the Purple Spotted Gudgeon within the study area includes Narrabri Creek, Namoi River, Bohena Creek, Bundock Creek, Goona Creek, Mollieroi Creek, CoghilL Creek, Baradine Creek, Tributary of Bucklanbah Creek, Salt Spring Creek, Quanda Quanda Creek, Caleriwi Creek, Barrone Creek and Backwater/Boggy Cowal. The works associated with the construction of bridges and culverts may impact on the habitat of the species and areas of breeding through direct disturbance of streambeds causing increased turbidity, clearance of vegetation and woody debris within the streambed and on the banks, increased sedimentation caused	Silver Perch can be found in a range of habitats and climates across the Murray-Darling Basin. The species generally prefers faster-flowing water including rapids and more open sections of river (DPI, 2017c). Adult Silver perch can travel large distances, often associated with spawning activity in spring and summer. Juveniles disperse over large distances and are often seen at fishways travelling upstream in large schools. Females can lay up to 300,000 eggs which passively drift with the river current for a number of days before hatching. The lifecycle is threatened by: • Changes in water quality associated with agriculture and forestry, for example siltation (as a result of clearing) can destroy deep rock pools used by adults as well as smothering spawning areas • Modification of natural river flows and temperatures as a result of construction of dams and weirs lead to disrupted cues for migration and spawning and reduce opportunities for dispersal and availability of food. • Loss of riparian (river bank) vegetation by deliberate removal result in sedimentation, increased salinity and declines in water quality subsequently degrading instream habitats important to Silver Perch. • Loss of submerged macrophytes which are important nursery areas for juvenile Silver Perch and important sites for feeding. • Competition from introduced species such as Car, Redfin Perch and Gambusia (DPI, 2017c). It is noted that the Silver Perch has been recorded in a number of the watercourses where the proposal alignment is expected to cross (DPI, 2016). Mapped potential habitat of the Silver Perch within the study area includes Namoi River and Macquarie River. Namoi River has also recently been subject to a conservation stocking program where hundreds of Silver Perch were released into the river in April 2017. The works associated with the construction of bridges and culverts may impact on areas of potential habitat through direct disturbance of streambeds causing increase turbidity, clearance of vegetation and woody debris within the streambed and on the banks, increased sedimentation caused by construction

Purple Spotted Gudgeon (*Mogurnda adspersa*)	Silver Perch (*Bidyanus bidyanus)*
by construction activities, blockage of fish passage or by thermal pollution caused by overland flows and cold-water releases during construction. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation and cold-water pollution from runoff. To minimise impact on spawning success, watercourse crossing structures should be built outside of the breeding season (Spring / Summer) in watercourses where the Purple Spotted Gudgeon is predicted to occur (where water is present). Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.	activities, blockage of fish passage or by cold water pollution from overland flows and cold-water releases during construction. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation and cold-water pollution from runoff. Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.
b) *in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction*	
Viable populations of the Purple Spotted Gudgeon are present within watercourses in the footprint area (DPI, 2017b). The western population is reported to be confined to small remnant populations in the Macquarie, Gwydir and Border River catchments, and a self-sustaining population created from captive-bred fish in the Castlereagh catchment. Despite this, the population is widespread across the footprint and therefore it is unlikely that the local population would be placed at risk of extinction.	Not applicable.
c) *in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*	
Not applicable.	Not applicable.

Purple Spotted Gudgeon (*Mogurnda adspersa*)	Silver Perch (*Bidyanus bidyanus)*
d) in relation to the habitat of a threatened species, population or ecological community: i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	
The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and may include clearance of adjoining riparian vegetation. Disturbance would be limited to 50m upstream and downstream of the watercourse. It is known that the Purple Spotted Gudgeon population in the western region of NSW is expected to be confined to the small remnant populations in Macquarie, Gwydir and Border River and Castlereagh catchments. In relation to the proposal, populations of Flathead Galaxias have been mapped as having suitable habitat in the Narrabri Creek, Namoi River, Bohena Creek, Bundock Creek, Goona Creek, Mollieroi Creek, CoghilL Creek, Baradine Creek, Tributary of Bucklanbah Creek, Salt Spring Creek, Quanda Quanda Creek, Caleriwi Creek, Barrone Creek and Backwater/Boggy Cowal, therefore these watercourses are considered to be important habitat for the survival of the western population. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation and cold-water pollution from runoff. Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.	The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and may include clearance of adjoining riparian vegetation. Disturbance would be limited to 50m upstream and downstream of the watercourse. It is known that a population of Silver Perch population is in Namoi River and Macquarie River, therefore these watercourses are considered to be important habitat for the survival of the local population. Standard measures during construction and operation would be undertaken to avoid impacts. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with sediment and erosion controls to manage and minimise further siltation and cold-water pollution from runoff. Shading from bridge and culvert structures would be minimised as far as practicable. These standard practices would minimise adverse effects on the life cycle of the population.

Purple Spotted Gudgeon (*Mogurnda adspersa*)	Silver Perch (*Bidyanus bidyanus)*
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	
No critical habitat has been identified in the proposal area as the population is expected to occur throughout the region.	No critical habitat has been identified in the proposal area as the population is expected to occur throughout the Murray-Darling Basin.
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	
Priority action statements for the Purple Spotted Gudgeon include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations at identified important sites and communicating with aquarium enthusiasts about the ban on collecting the Purple Spotted Gudgeon • implement and enforce relevant fishing regulations including national recovery plan to minimise adverse impact on the species • pest eradication and control • stocking/translocation • habitat protection and rehabilitation including management of environmental flows and water quality from expanding development; improved fish passage at major regulating structures; protection and rehabilitation of aquatic habitat and riparian vegetation; and mitigate impacts of cold-water pollution. The proposal would be constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.	Priority action statements for the Silver Perch include the following recovery actions: • provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution • community and stakeholder liaison, awareness and education • implement and enforce relevant fishing regulations in priority Silver Perch areas, • implement and enforce relevant fishing regulations including national recovery plan to minimise adverse impact on the species • stocking/translocation • habitat protection and rehabilitation including management of environmental flows and water quality; improved fish passage at major regulating structures; protection and rehabilitation of aquatic habitat and riparian vegetation; and mitigate impacts of cold-water pollution. The proposal would be constructing watercourse structures designed and constructed in accordance with the national guidelines *Why do fish need to cross the road? Fish passage requirements for waterway crossings (*Fairfull and Witheridge, 2003). This is in keeping with recovery actions.
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	
The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris.	The proposal may contribute to the following KTPs: • installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams • degradation of native riparian vegetation • removal of large woody debris.

Purple Spotted Gudgeon (*Mogurnda adspersa*)	Silver Perch (*Bidyanus bidyanus)*
The proposal may require removal of large woody debris in the proposal site. Any large woody debris in the proposal site would be relocated upstream or downstream in consultation with an appropriate qualified ecologist.	The proposal may require removal of large woody debris in the proposal site. Any large woody debris in the proposal site would be relocated upstream or downstream in consultation with an appropriate qualified ecologist.
Through appropriate design of the watercourse crossing structure and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.	Through appropriate design of the watercourse crossing structure and avoiding/minimising disturbance of riparian vegetation, the proposal would minimise the above threatening processes.

EPBC Act Assessment of significance

Under the EPBC Act, the approval of the Commonwealth Minister for the Environment is required for any action that may have a significant impact on matters of national environmental significance (MNES). One aquatic species (Murray Cod) was identified as likely to occur within the proposal area and is assessed against the test of significance in Table B.5.

Appendix B5 Test of significance for the EPBC listed 'Vulnerable' species Murray Cod *(Maccullochella peelii)*

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
a) lead to a long-term decrease in the size of an important population of the species	Murray Cod can be found in a range of freshwater habitats including rivers and creeks in the Murray-Darling Basin. Reports suggest that an important population of Murray Cod is present in the Namoi River from Peel River junction downstream of Wee Waa, including most major tributaries except upper Mooki River (National Murray Cod Recovery Team, 2010). The works associated with the construction of bridges and culverts may impact on areas of potential habitat through direct disturbance of streambeds, clearance of vegetation and woody debris within the streambed and on the banks, sedimentation caused by construction activities, blockage of fish passage or by cold water pollution from overland flows and cold-water releases during construction. Watercourse structures would be designed to maintain flows and avoid blockage of fish passage. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Provided these standard practices are maintained through the construction and operation of the proposal, it is unlikely that a long-term decrease in the size of the population would occur.
b) Reduce the area of occupancy of an important population	Disruption of preferred habitat instream in the main channels of the Namoi River would be limited to the construction footprint where the water crossing structure is proposed to be built. Disruption is also limited to the construction period as appropriate design of structures would not obstruct movement of fish or reduce the area of occupancy of the population. It is anticipated that an appropriate amount of flow would be available during construction to ensure fish passage is not fully blocked. The works would not reduce the area of highest records of the important species from Peel River junction to downstream of Wee Waa.
c) fragment an existing population into two or more populations	The distribution of the population is not within the footprint area where a water crossing structure is proposed for Namoi River. Appropriate design of the structure ensures that fish passage is not obstructed and activities would not fragment the population upstream or downstream of the corridor.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
d) adversely affect habitat critical to the survival of a species	The proposal would require localised disturbance of watercourses to construct watercourse crossing structures and also include clearance of adjoining riparian vegetation. Disturbance would be limited to the footprint area, and 50 m upstream and downstream of the watercourse. Instream works during construction may disturb submerged large woody debris in the relatively small areas affected by construction. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation, rocks and woody debris would subsequently be reinstated in the construction footprint area after construction. Instream works and subsequent permanent structures may also disrupt flow and block fish passage downstream. However, water crossings and scour protection have been designed to ensure retention of natural watercourse functions including flow velocities, as much as practicable.
e) disrupt the breeding cycle of a population	Murray Cod have an annual reproductive cycle, with spawning occurring from spring to summer. Eggs are deposited on clay beds, rocks and logs in shallow and warm warmer. Larvae hatch after 5-13 days and drift downstream to find food and mature. High water levels enhance the survival of eggs, larvae and juveniles by providing better water quality and more food (Kalatzis and Baker, 2010). Recruitment success is except to be linked to higher river flows. Construction may disrupt the breeding cycle of individuals in the river. However, the population of Murray Cod is not expected to occur within the proposal footprint therefore these impacts are not likely to disrupt the breeding cycle of the important population.
f) introduce disease that may cause the species to decline, or	Little is known of the impact of diseases on Murray Cod (National Murray Cod Recovery Team, 2010). Naturally occurring pathogens may be a problem for injured fish. The proposal would not introduce any alien species that may act as a source of disease.
g) interfere with the recovery of the species.	The proposal is not expected to interfere with recovery actions for the species as set out in the national recovery plan (National Murray Cod Recovery Team, 2010). In particular, design of the water crossing structures and management control measures would be designed to maintain flow and avoid blockage to fish passage. Any large woody debris that is removed from the footprint area would be relocated upstream and downstream.

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