Australian Government

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ARTC InlandRail

Inland Rail Programme
Narrabri to North Star Project

Environmental Impact Statement

Technical Report 6: **Hydrology and Flooding Assessment**

Technical Report 7: **Water Quality Assessment**

Image: Newell Highway north of Narrabri, NSW

Technical Report 7:
Water Quality Assessment

Image: Railway near Edgeroi, NSW

Australian Rail Track Corporation

Inland Rail - Narrabri to North Star
Water Quality Assessment

October 2017

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Abbreviations

Abbreviation	Explanation
AEP	Annual exceedance probability
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
ARR	Australian Rainfall and Runoff
ARTC	Australian Rail Track Corporation
BoM	Bureau of Meteorology
DPI	NSW Department of Primary Industries
EIS	Environmental Impact Statement
EMP	Environment Management Plan
EPA	Environmental Protection Agency
GHD	GHD Pty Ltd
LiDAR	Light Detection and Ranging
MDB	Murray Darling Basin
NARCLiM	NSW and ACT Regional Climate Model
NSW	New South Wales
NWQMS	National Water Quality Management Strategy
OEH	Office Environment and Heritage
RCBC	Reinforced Concrete Box Culvert
SEARs	Secretary's Environmental Assessment Requirements
SRTM	Shuttle Radar Topography Mission
WQO	Water Quality Objectives

Glossary

Term	Explanation
Afflux	A rise in flood level as a result of an obstruction to flow.
Alluvial plain	A large relatively flat area formed by deposition of sediment over an extended period.
Alluvial sediment	Loose sediments mobilised and deposited by non-marine water actions (e.g. floodplain soils).
Annual Exceedance Probability (AEP)	The change of a flood of a nominated size occurring in a particular year. The chance of the flood occurring is expressed as a percentage and, for large floods, is the reciprocal of the ARI. For example, the 1 per cent AEP flood event is equivalent to the 100 year ARI flood event.
Australian Height Datum (AHD)	National survey datum closely corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long term average number of year between the occurrence of a flood of a nominated size.
Ballast	Rock placed under the rail ties (sleepers) to provide stable support for a rail line.
Bidirectional	Allowing train travel in either direction according to the infrastructure and system of safe working in use.
Biological Oxygen Demand (BOD)	This is the amount of oxygen required by aerobic biological organism to break down organic material which is present in a given water sample, at a specific temperature, over a period of time.
Brownfield	Development areas that have been previously developed.
Calcic soil	A soil containing a relatively high concentration of secondary calcium carbonate.
Catchment	the catchment at a particular point is the area of land that drains to that point.
Cell	Culvert design termed meaning single opening.
Cess	Space between the outermost rail and the rail corridor boundary.
Chainage	A measure of distance along the rail corridor from Sydney. The nominated values are not exact distances as there are some local adjustments made to reflect progressive changes to the rail as works are progressively implemented to, for example, ease bends.
Channelized fill	Channelized fill systems are generally laterally, stable channels of low sinuosity incised within flat and featureless floodplains.
Chert	A hard, dark opaque rock composed of silica with a microscopically fine grained texture.
Design flood	A flood event, based on a design storm of a specific duration (critical duration) that creates the greatest volume of rainfall-runoff for a given probability of occurrence.
Design storm	A synthetic storm event used for modelling purposes, derived using the methods outlined in ARR.

Term	Explanation
Dispersive	A characteristic of soil indicating the potential for the breakdown of clay minerals into single clay particles in solution.
Embankment	An earth or stone bank, built to support a rail line or provide flood protection.
Ephemeral	Temporary, short-lived. An ephemeral watercourse is one that flows following periods of heavy rainfall.
Existing rail corridor	The area of land that is identified for the continued operation of the rail line between Narrabri to North Star.
Flood	Relatively high river, creek or water way flow which overtop the natural or artificial banks to inundate surrounding areas in an uncontrolled manner.
Flood depth	The depth of floodwater above ground level.
Flood plain	Land adjacent to a river, creek or waterway that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation be the probable maximum flood event.
Flood prone land	Land susceptible to inundation by the probable maximum flood.
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path natural or artificial that carries floodwater during a flood.
Formation	The earthen embankment that supports the ballast, ties and rail associated with a railway.
Hardsetting	A soil in which the topsoil sets hart when dry.
Hillslope	An area of land that flanks a valley and the margins of upslope steeper areas.
Historical flood	A flood that has occurred at some point in the past.
Hydraulic	The study of water flow in natural or artificial water ways.
Hydrograph	A graph showing water flow of a river, creek or water way over time.
Hydrology	The study or rainfall and runoff process.
Kaolin	A mineral within clay.
Chainage	A measure of distance along the rail corridor from Sydney. The nominated values are not exact distances as there are some local adjustments made to reflect progressive changes to the rail as works are progressively implemented to, for example, ease bends.
Lithosol	A group of soils that lack a defined soil structure.
Loam	A fertile soil comprising a mix of sand, silt and clay.
Local catchment	The area of land that lies upslope from a specified point.
Major under track structure	Has a design flow greater than 50 m^3/s – design for 1 per cent AEP event.
Minor structure	Has a design flow less than 50 m^3/s – design for 2 per cent AEP event.
Morphology	The form, shape and structure of a watercourse.
Mulitcell	Multiple number of openings within a structure.
Perennial	Lasting or enduring. A perennial watercourse has continuous flow all year round during years of normal rainfall.

Term	Explanation
Permeability	A measure of the ability of the soil to transmit water.
Pineena	The NSW Government water database.
Probable maximum flood	An extreme flood deemed to be the maximum flood likely to ever occur.
Proposal	The construction and operation of the Narrabri to North Star project.
Proposal site	The area that would be directly affected by construction works. The proposal site is considered to have a width of 30 metres, providing for a 15 metre buffer on each side of the alignment centreline. 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 storage areas/compounds sites that would be used to construct that infrastructure.
Rail overtopping	Flood waters rising above the level of the rail.
Regional flood frequency	A method of estimating flood flows for small ungauged basins.
Reinforced concrete box culvert	A drainage structure that has a rectangular cross sectional shape and is manufactured from concrete with steel reinforcing in the concrete walls.
River style	A classification of a watercourse based on character, behaviour, condition and recovery potential.
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Salinity	Refers to the amount of salt present in the soil solution.
Salting	The formation of a salt layer on the soil surface.
Sandstone	A sedimentary rock composed mainly of sand.
Siltstone	A sedimentary rock composed mainly of silt.
Sinuosity	Capacity to curve.
Sodic soil	Sodicity is a term that indicates the amount of sodium present in a soil.
Soffit	Underside of a bridge.
Stable channel	A watercourse that is not subject to significant changes in channel geometry.
Stage-storage	The relationship between water depth and storage volume within a dam or other water storage.
Stoniness	The tendency for presence of stones in soil.
Stream order	A measure of the relative size of a watercourse.
Structure	An underbridge or culvert under the rail line passing over a watercourse, pathway, floodway or some other similar feature.
Study area	The total area that may be impacted by construction and operation of the proposal.
Track	The combination of rails, rail connectors, sleepers, ballast, points, crossings and any substitute devices.
Subsoil	The layer of soil below the topsoil.
Topsoil	The upper or outermost soil layer. Typically 5 to 20 cm thick.
Underbridge	A bridge supporting the track and passing over a watercourse, roadway, pathway, floodplain or some other similar feature.

Term	Explanation
Unidirectional	Allowing train travel in a single direction according to the infrastructure and system of safe working in use.
Watercourse	A flow path that may operate during times of surface runoff. Generally, the flow path will have a defined cross sectional shape.
Waterlogging	A soil that contains the maximum practical amount of water.
Water take	The extraction of surface or groundwater interception.
Weir	A structure that partially retains water, regulating water levels upslope of the structure.
Valley fill	Unconsolidated deposits of sediment within a valley, typically eroded from the surrounding hillslopes.
Velocity	The speed at which the floodwaters are moving.

Executive summary

The proposal

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Narrabri to North Star section of Inland Rail (‘the proposal’).

The proposal would involve upgrading the existing rail line for a distance of 188 kilometres between Narrabri and North Star via Moree, including new crossing loops, track realignment and new sections of rail line, new river crossings, and new road over rail bridges at Jones Avenue and Newell Highway.

Ancillary work would include works to level crossings, signalling and communications, signage, fencing, and services and utilities.

This report

This report provides the results of the water quality impact assessment of the proposal. It includes an analysis of the existing and design condition hydrology, hydraulics/flooding and water quality conditions within the proposal site. This analysis forms supporting documentation for the Environmental Impact Statement for the proposal and addresses the requirements of the Secretary of the Department of Planning and Environment. This report builds on findings from the hydrology and hydraulic/flooding assessment, which are assessed in a separate report.

Water quality and sensitive receiving environments

The proposal site is located within the Namoi, Gwydir and a small portion of the Macintyre river catchments and crosses several named watercourses. The majority of the watercourses are ephemeral, with the exception of the Namoi, Gwydir and Mehi rivers, and there is a minimal amount of water quality data to describe the existing conditions along the corridor. Publically available information indicated water quality within the Namoi River and Gwydir River catchments typically exceed guideline values for turbidity, salinity, pH, total nitrogen and phosphorus. The poor quality is likely to reflect existing soil conditions and agricultural land use practices within the study area.

Available data would need to be supplemented by pre construction monitoring of perennial watercourses (Namoi, Gwydir and Mehi Rivers) to create a reliable understanding of baseline water quality. A water quality monitoring program is recommended to effectively identify the existing water quality conditions.

The receiving environments in the study area that are considered to be sensitive include the Lower Gwydir wetlands, The Morella, Pungbopugal and Boobera Lagoons, the Pilliga Scrub and Lake Goran, the nearest of which is about 25 kilometres southwest of the proposal site. These and other environmentally sensitive receiving environments are unlikely to be impacted by the proposal if appropriate water quality measures are implemented during the design and construction phases. Implementation of water quality measures would also minimise impacts to surface water quality within the study area.

Risk assessment and mitigation

A risk assessment of water quality impacts has been carried out, and measures are proposed to mitigate the risks and adverse impacts on water quality, as much as practical.

The implementation of the complete range of mitigation measures would protect the water quality of both surface waters and groundwater in accordance with the water quality objectives for the proposal.

Risks have been separately identified for the construction phase and the operational phase for the proposal. For the construction phase, the risks are primarily litter, sediments or nutrients being exported off site leading to downstream pollution of watercourse. In addition, spills of oils or grease could pollute the nearby soil, groundwater or surface water. Use of significant amounts of concrete could also lead to a short-term change in water pH during the first few runoff events.

For the operational phase, the risks have been identified as being the potential for failure of the formation leading to downstream pollution as well as wear of rolling stock potentially leading to metals on the track, possible spills of oil or grease from rolling stock or dust off carriages. Maintenance works required during the life of the proposal could also impact the environment through fragments of metals getting onto the soil the soil surface, minor spills of chemicals or soil disturbance resulting from access and minor earthworks.

Design phase

The following mitigation measures are proposed during the design phase:

- The proposed formation level and formation profile have been selected to achieve the targeted flood immunity while minimising adverse flooding, maximising the reuse of excavated material and reducing adverse water quality impacts resulting from the construction.
- The proposed culverts would be located under the rail line at locations generally consistent with the existing structure locations, and consistent with the existing watercourse invert level. This would maximise the potential fish passage and minimise excavation that could affect the water quality, and maintain existing ecological function.
- The proposed culvert form has been selected to facilitate as much offsite concrete work as possible while minimising the anticipated construction phase and water quality risks as well as minimising the water demand during the construction phase.
- The proposed provision of rock riprap immediately downstream of culverts would provide protection against erosion adjacent to the culvert aprons and in the watercourse through the downstream properties. While this measure has been detailed there is a predicted residual erosion risk in the area downstream of culverts, and risk would need to be considered for each site to achieve appropriate site specific designs.
- Existing pipes or culverts that are removed in a sound condition would be stored for potential future reuse.
- Precast culvert segments would be used, where practical, to minimise construction periods over watercourses that contain water at the time of construction.

The following mitigation measures are recommended during the construction phase:

- A Construction Environmental Management Plan (CEMP) would be prepared to address site management measures so that adverse water quality impacts are mitigated as much as practical. This plan would specifically address spill containment measures, culvert construction measures over water (as required) and waste minimisation measures to protect the water quality impacts as required by the water quality objectives.

- A Soil and Water Management Plan would be prepared to detail the erosion control measures to be implemented and maintained for the duration of the construction phase. The plan would be consistent with requirements in the *Managing Urban Stormwater: Soils and Construction Manual.* It would identify required implementation measures to protect water quality downstream and down gradient of the proposal.
- Activities which have the potential to impact water quality, including construction compounds, mobile concrete batching plants and vehicle washdown sites, would be located a minimum of 50 metres from any watercourse and any wastewater from these activities would be captured and discharge or disposed of in accordance with relevant requirements.

The following mitigation measures are recommended during the operational life of the project:

- Train speeds would be limited to the design value.
- Track inspections would be undertaken after significant flood events to identify any required repairs or maintenance prior to recommencing services.
- Appropriate environmental protection measures would be applied during maintenance works along the route of the proposal.

1. Introduction

1.1 Overview

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. The Inland Rail programme (Inland Rail) involves the design and construction of a new inland rail connection, about 1,700 kilometre long, between Melbourne and Brisbane. Inland Rail is a transformational rail infrastructure initiative that will enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Narrabri to North Star section of Inland Rail ('the proposal'), which consists of 188 kilometres of upgraded rail track and associated facilities.

The proposal requires approval from the NSW Minister for Planning under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also a controlled action under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment and Energy.

This report has been prepared by GHD Pty Ltd (GHD) as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to accompany the application for approval of the proposal, and addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs), issued on 8 November 2016.

1.2 The proposal

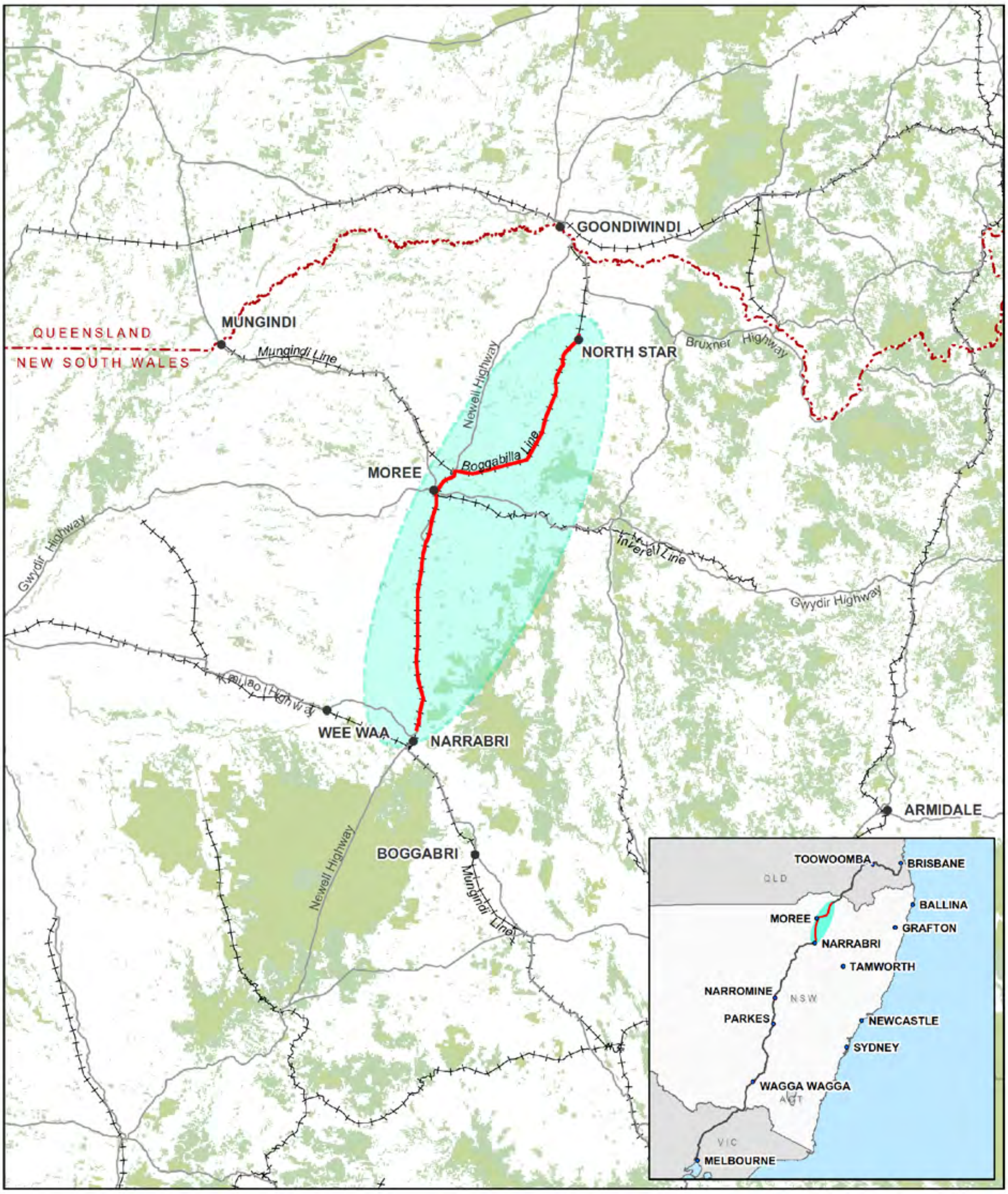
1.2.1 Location

The proposal is generally located in the existing rail corridor between the town of Narrabri and the village of North Star, via Moree. The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key features of the proposal involve:

- Upgrading the track, track formation, and culverts within the existing rail corridor for a distance of 188 kilometres between Narrabri and North Star
- Realigning the track where required within the existing rail corridor to conform with required platform clearances for Inland Rail trains
- Providing five new crossing loops within the existing rail corridor, at Bobbiwaa, Waterloo Creek, Tycannah Creek, Coolleearllee, and Murgo
- Providing a new section of rail line at Camurra, about 1.6 kilometres long, to bypass the existing hairpin curve ('the Camurra bypass')
- Removing the existing bridges and providing new rail bridges over the Mehi and Gwydir rivers and Croppa Creek



LEGEND

- Proposal site
- Proposal location
- Main road
- Railway
- State border

Paper Size A4

0 10 20 40 60

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Australian Rail Track Corporation
Inland Rail Track Alignment

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Location of the proposal

Figure 1-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\EIS\Specialist Reports\2217916_EIS001_NNS_Location_0.mxd

Data source: Commonwealth of Australia (Geoscience Australia), 250K Topographic Data Series 3, 2006. Created by: tmorton, kpsrcba

- Realigning about 1.5 kilometres of the Newell Highway near Bellata, and providing a new road bridge over the existing rail corridor ('the Newell Highway overbridge')
- Providing a new road bridge over the existing rail corridor at Jones Avenue in Moree ('the Jones Avenue overbridge')

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

Ancillary work would include works to level crossings, signalling and communications, signage and fencing, and services and utilities.

Further information on the proposal is provided in the EIS.

1.2.3 Timing

Subject to approval of the proposal, construction is planned to start in early to mid-2018, and is expected to take about 24 months. Existing train operations along the Narrabri to North Star line would continue prior to, during, and following construction. Inland Rail as a whole is expected to be operational in 2025.

1.2.4 Operation

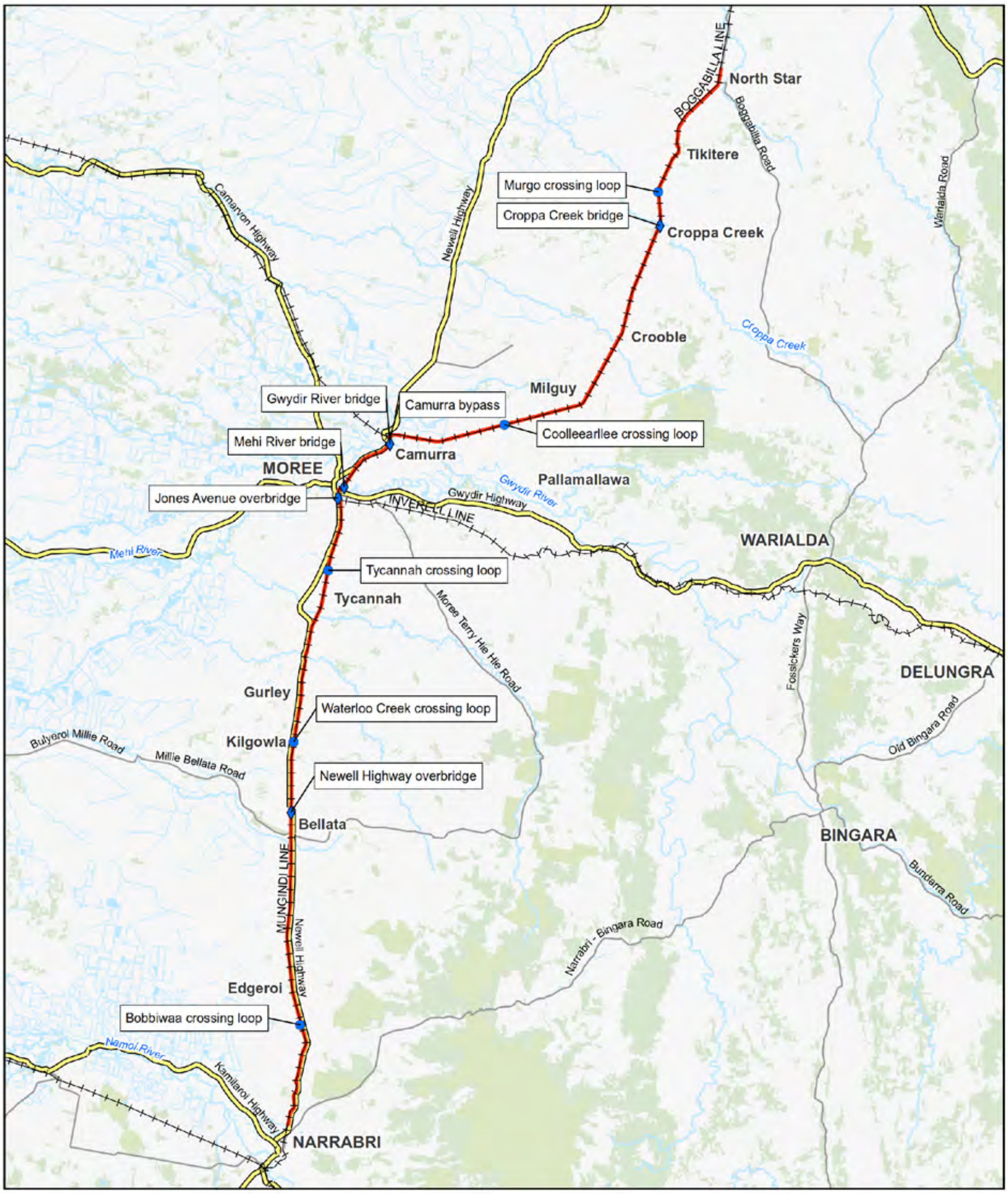
Prior to the opening of Inland Rail as a whole, the proposal would be used by existing rail traffic, which includes trains carrying passengers and grain at an average rate of about four trains per day. It is estimated that the operation of Inland Rail would involve an annual average of about 10 trains per day travelling north of Moree (between North Star and Moree) and 12 trains per day travelling south of Moree (between Moree and Narrabri) in 2025. This would increase to about 19 trains per day north of Moree (between North Star and Moree) and 21 trains per day south of Moree (between Moree and Narrabri) in 2040. The trains would be a mix of grain, intermodal (freight), and other general transport trains.

Once operational in 2020, the proposal would enable increased train running speeds in many areas that are currently the subject of restrictions due to local track conditions. Daily average train volumes are not expected to significantly change until Inland Rail through connection in 2025.

1.3 Purpose and scope of this report

This report provides the results of the water quality impact assessment of the proposal as required by the SEARS (Section 2.5.2). Specifically, this report:

- Provides a brief overview of the proposal.
- Provides a brief overview of the hydrologic and hydraulic impacts of the proposal. These are assessed in detail in the *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Hydrology and Flooding Assessment* (GHD 2017).
- Describes the existing environmental conditions.
- Establishes and documents the water quality impacts of the proposal, including consideration of the existing water quality regime and predicted impacts during the construction and operational life of the proposal.
- Identifies proposed ongoing monitoring programs for the verification of predicted water quality impacts.



LEGEND

♦	New bridge	┼┼┼	Railway
●	Crossing loop	═	Highway
▬	The proposal	―	Road

Paper Size A4
0 3 6 12 18 24
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Australian Rail Track Corportion
Inland Rail Track Alignment

Job Number | 22-17916
Revision | 0
Date | 01 Aug 2017

Key features of the proposal

Figure 1-2

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au
G:\22\17916\GIS\Maps\Deliverables\N2NS\EIS\Specialist Reports\2217916_EIS002_NNS_KeyFeatures_0.mxd

Data source: Commonwealth of Australia (Geoscience Australia), 250K Topographic Data Series 3, 2006. Created by: gmcdiarmid, tmorton, kpsroba

1.4 Structure of this report

The structure of the report is provided in Table 1.1.

Table 1.1 Report structure

Section	Details
1	Provides an introduction to the report
2	Describes the methodology for the assessment
3	Provides available data and a summary of the physical characteristics of the proposal site
4	Describes the existing water quality of the proposal site
5	Provides a water quality risk assessment
6	Provides an evaluation of the proposed impact mitigation measures and the residual risks
7	Describes the proposed monitoring program
8	Gives the conclusions from the investigation

2. Assessment approach and methodology

2.1 Definitions

2.1.1 Study area

The study area for the water quality investigation is considered as being the area that may be affected (directly or indirectly) by the proposal in a significant way. Additional areas, both upstream and downstream of the rail alignment, could potentially be impacted because of a regional flood in either the Namoi, Gwydir or Mehi River systems, as detailed in Section 4.1.2.

2.1.2 Terminology

Hydrology

The term 'hydrology' refers to the estimation of runoff generated from a catchment after rain hits the ground. For any given catchment, the relationship between rainfall and runoff can predict peak flow rates at a nominated discharge point through consideration of the catchment's characteristics. These characteristics include its terrain, soil type, shape, land use, vegetation coverage, areas of inundation and water storage.

Surface water flow paths within the study area are understood to mainly comprise ephemeral watercourses (i.e. watercourses which only flow following periods of intense or prolonged rainfall) and a small number of perennial major river systems that pass through the study area.

Flood event

The term 'flood event' can refer to either:

- A historical flood event, being an actual event that has occurred for which flood levels and rainfall data may have been gauged.
- A design flood event, which is generated based on a design storm of a specific duration (critical duration) that creates the greatest volume of rainfall-runoff for a given probability of occurrence.

Structure

The term 'structure' usually refers to a circular or rectangular culvert or underbridge that allows water to pass under an embankment (e.g. a rail embankment). Structures may be either single cell (generally one opening) or multi-cell (multiple openings).

2.2 Design objectives

The design objective of the proposal can be summarised as being an upgrade of the existing rail line from near Narrabri through to North Star to achieve an acceptable performance standard, while remaining cost effective for the forecast increased loadings considering both an anticipated increase in the train frequency and also an increase in the axle loading of carriages. Achieving these objectives would require:

- Reconstructing embankments
- Replacing structures
- Easing curves

The availability targets for the proposal (Parsons Brinkerhoff 2015) identified the need for:

- 98 per cent reliability for freight delivery as per agreed freight availability times
- 90 per cent of daily train throughout
- 90 per cent of heavy services arriving within 15 minutes of schedule

2.2.1 Design requirements

The design requirements, as related to hydraulics performance, are:

- The flood immunity is defined as the one per cent annual exceedance probability (AEP) flood, which is taken as being equivalent in magnitude to the 100 year average recurrence interval (ARI) event.
- The flood immunity and serviceability limit state AEP are taken as being the one per cent AEP at the shoulder corner of the formation capping.
- Key infrastructure should not be located within the one per cent AEP flood prone area, or, where this is not possible, to design for a flood immunity greater than one per cent AEP.

These requirements are applicable to local catchment flood events but not to regional flood events. A regional flood event is considered as being one in the Namoi, Gwydir or Mehi Rivers and areas where floods in these rivers spill onto the adjacent floodplains.

2.3 Design

2.3.1 Form

Engineering features of the proposal that would affect the hydrology and hydraulics and, thus, the water quality, would primarily be the raising of the existing rail embankment along the majority of the proposal site across the floodplains. The embankment and upgraded structures would be required to permit an appropriate flow to minimise adverse flooding impacts.

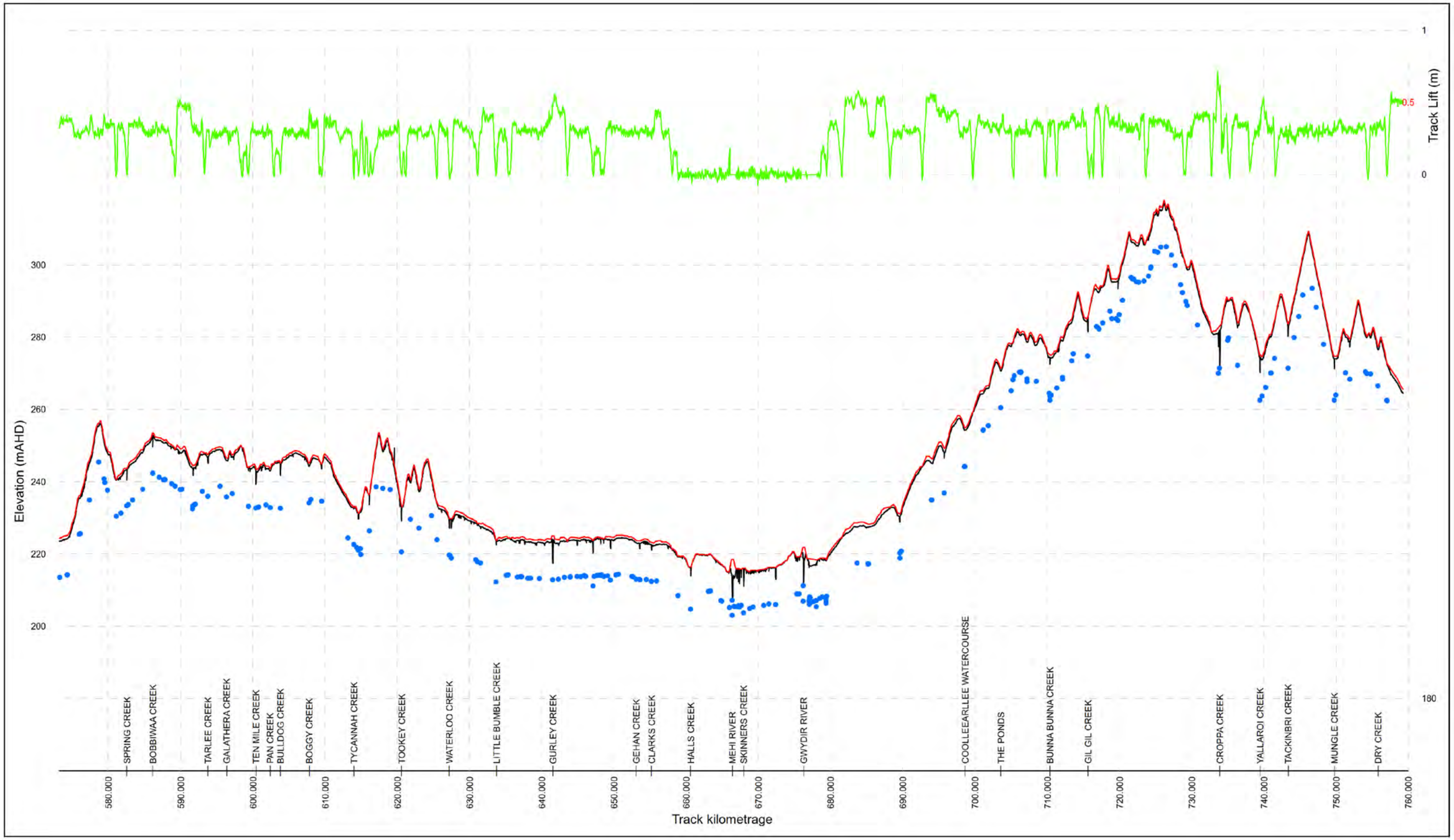
The upgraded structures are generally designed to pass flows up to the one per cent AEP magnitude and thus restrict the rail line from overtopping in all but extreme local catchment rainfall events. Regional flood events could overtop the rail line near the southern end near Narrabri and possibly immediately north of Moree through to Camura.

Changes to the hydrological and hydraulic regime could affect the water quality during both construction and operation of the proposal.

Details of the process used to select structure sizes for the proposal are described in accompanying *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Hydrology and Flooding Assessment* (GHD 2017).

Figure 2.1 shows the existing natural surface along the proposal site and the design track long section between Narrabri to North Star together with the location and quantities of lift between the existing track level and the design track level. No (or minimal) lift would be applied at existing level crossings, with a track lift for the majority of the proposal typically between about 0.3 and 0.5 metres.

The proposed locations of structures (culverts and underbridges) along the length of the proposal between Narrabri to North Star are shown in Figure 2.1. The structures are offset eight metres below the track level for clarity of presentation. A plan view of the proposed culvert locations for the same portion of track is shown in Figure 2.2.



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LEGEND
Design
Natural Surface
Track Lift
Culverts

Australian Rail Track Corporation
Inland Rail Route- Narrabri to North Star

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Date	02 Jun 2017

Design Track Alignment

Figure 2-1

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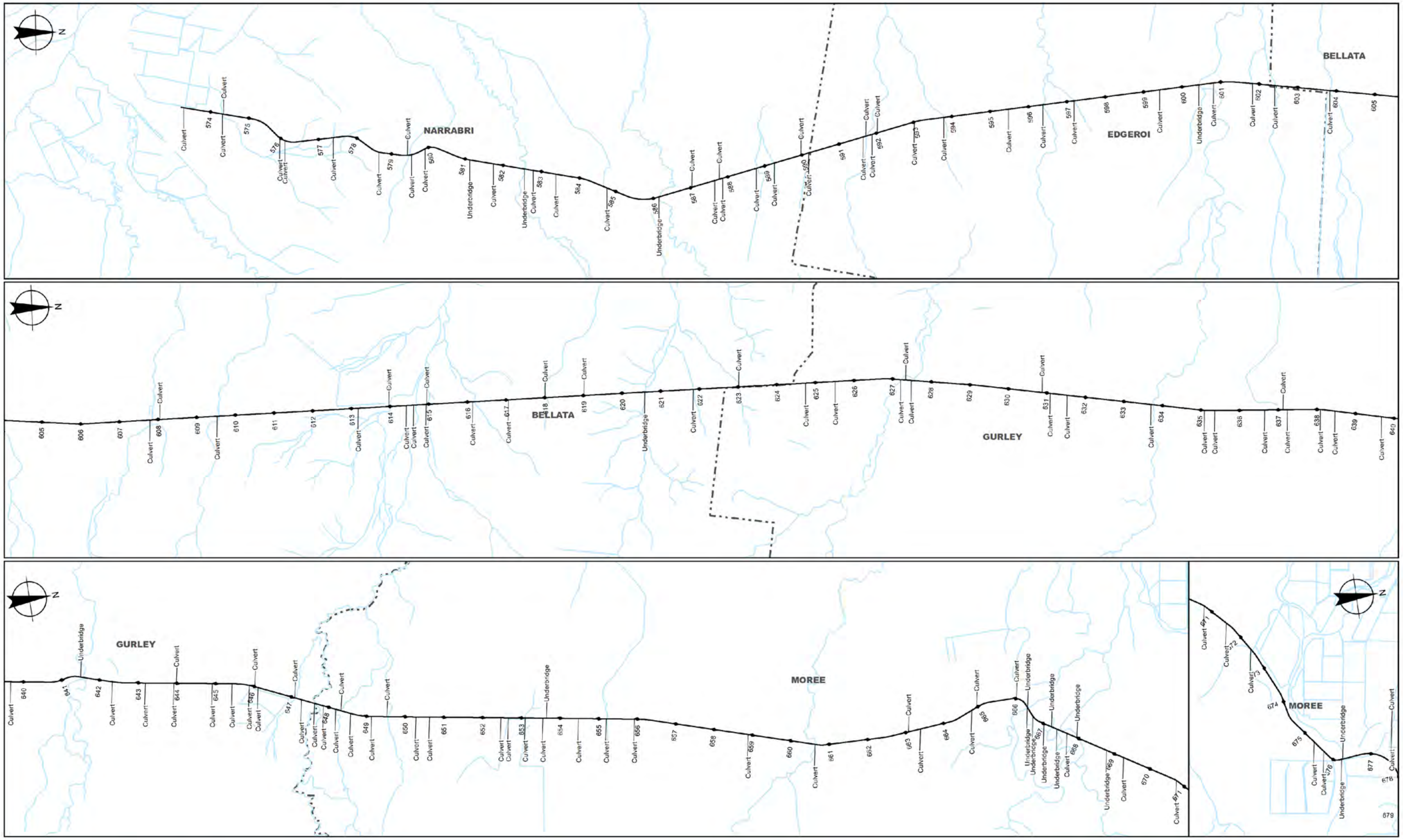
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: LPI: Watercourses, 2012. ARTC: Aerial lidar, 2015. Created by:kpsroba



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Rail Centreline
Watercourse
Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Proposed Culvert Locations- Sheet 1 Figure 2-2a

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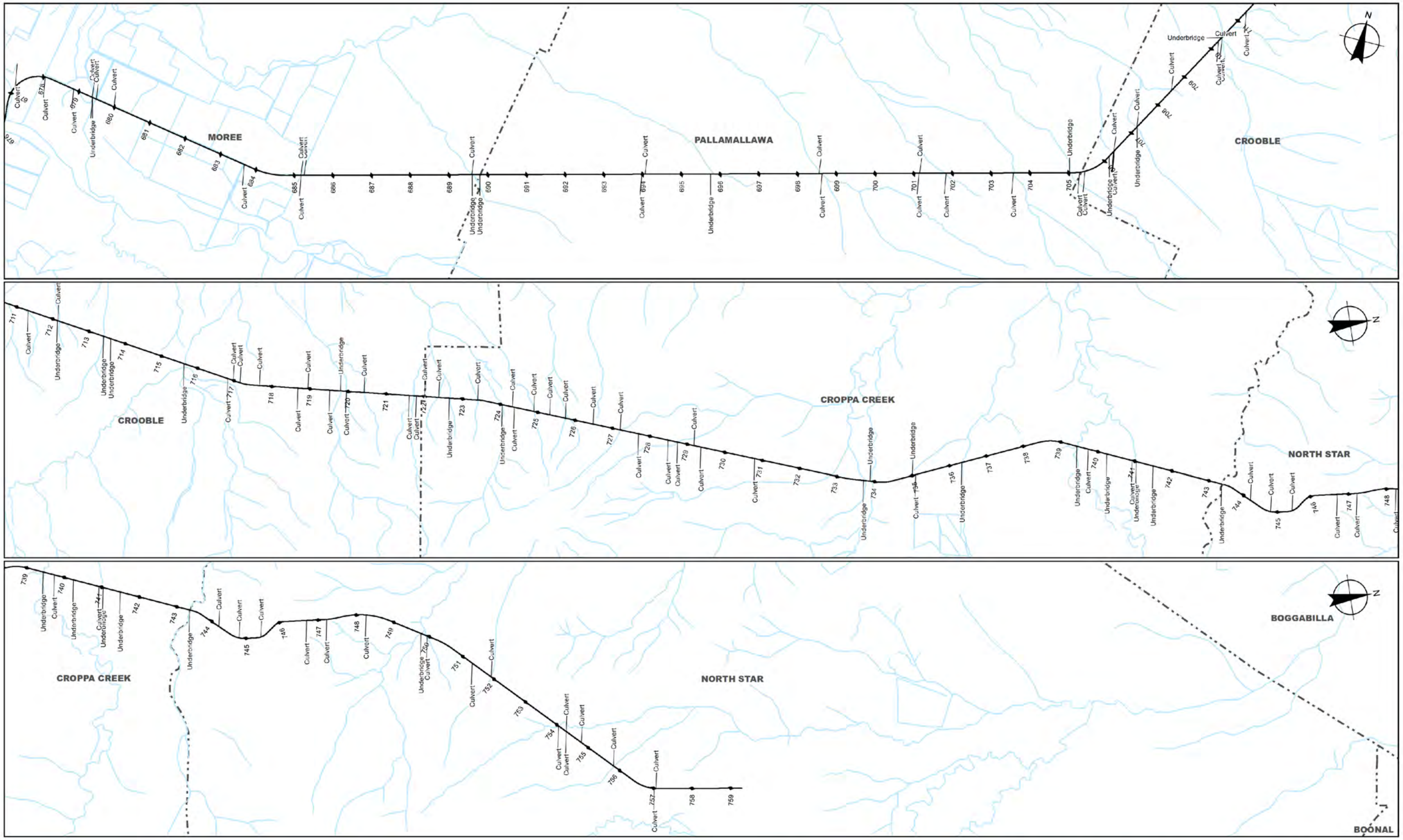
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Rail Centreline

Watercourse

Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to NorthStar

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Proposed Culvert Locations - Sheet 2 Figure 2-2b

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpacoba

2.3.2 Proposal end points

The local catchment flooding and water quality assessment extends from near Narrabri (Chainage 569.240) to near North Star (Chainage 758.571).

2.4 Hydrologic and hydraulic assessment

An assessment of the hydrologic and hydraulic impacts of the proposal are provided in the *ARTC Inland Rail – Narrabri to North Star Hydrologic and Flooding Report* (GHD 2017).

2.5 Water quality assessment

2.5.1 Methodology

The potential water quality impacts of the proposal were qualitatively assessed. Proposed impact mitigation strategies adopt recommendations from relevant guideline documents to mitigate known impacts. The assessment included:

- A review of existing literature, including the following reports:
  - Gwydir River Water Quality and River Flow Objectives (DECCW 2006a)
  - Namoi River Water Quality and River Flow Objectives (DECCW 2006b)
  - Border Rivers Water Quality and River Flow Objectives (DECCW 2006c)
- A review of existing conditions using GIS mapping to identify locations of sensitive receiving environments such as channels, watercourses, wetlands, national parks, conservation areas and nature reserves.
- A review of publicly available catchment-scale water quality conditions.
- A review of the existing and proposed rail corridor hydrological conditions to establish risks through the relationships between hydrology and water quality.
- The identification of water quality treatment measures that could be used to mitigate the impact of construction on water quality, following the principles of best practice.
- An assessment of the impact of the proposal during its operation.
- A review of quality treatment measures that could be used to mitigate the impact of operation on water quality based on guidelines issued by ARTC and the NSW Office of Environment and Heritage (OEH).

No baseline water quality sampling was undertaken for this assessment as the majority of watercourses are ephemeral and the majority of impacts to watercourses within the proposal area would be mitigated through the implementation of standard construction measures. For perennial watercourses in the study area publically available information was used to give an understanding of the likely water quality in the proposal site, which was considered sufficient for the purposes of this assessment. This available data would need to be supplemented by pre construction monitoring to create a reliable understanding of baseline water quality.

The potential impacts of the proposal are assessed qualitatively, with reference to standard water quality trigger values (ANZECC/ARMCANZ 2000) in lieu of site specific water quality data.

2.5.2 Outcomes sought in relation to water quality

Water quality outcomes sought, as summarised from the SEARs issued for the proposal, from the assessment and design are listed in Table 2.1 and identified against the agency requesting the documentation outcome.

Table 2.1 Required water quality outcomes

Agency	Desired performance outcome	Requirements	Where Addressed
DP&E	The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).	The Proponent must: • State the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values. • Identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment. • Identify the rainfall event that the water quality protection measures would be designed to cope with. • Assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes. • Demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: – Where the NSW WQOs for receiving waters are currently being met, they would continue to be protected. – Where the NSW WQOs are not currently being met, activities would work toward their achievement over time. • Justify, if required, why the WQOs cannot be maintained or achieved over time. • Demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented. • Identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments. • Identify proposed monitoring locations, monitoring frequency and indicators of surface water quality.	Section 3.1.1 Section 5.2 Section 6.2.1 Section 5 Section 5.2 Section 5.2 Sections 5 and 6 Sections 4.9 and 6 Section 7

Agency	Desired performance outcome	Requirements	Where Addressed
EPA	Soil and Water Management. The EPA recommends that the SEARs provide further details on the requirements for assessment and management of water quality impacts.	The Proponent must: • Identify the potential sources and volumes of discharges to waters (such as stormwater runoff and seepage). • Identify the need for off-site discharges during construction and any associated treatment requirements. • Describe receiving waters, including background water quality. • Assess potential impacts on receiving waters. • Identify measures and strategies to minimise/manage impacts on receiving waters. • The need for preparation of an erosion and sediment control plan, to be prepared in accordance with *Managing Urban Stormwater: Soils and Construction, Vol 1, 4th Ed* (Landcom 2004).	Section 4.10 and Section 5 Section 5.2 Section 4.7 and 4.8 Sections 5 and 6 Section 6 Section 6.2.5
OEH	Soils and water	The Proponent must: • Map the following features relevant to water and soils including: – Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment). – Groundwater. – groundwater dependent ecosystems. – proposed intake and discharge locations. • Describe background conditions for any water resource likely to be affected by the project, including: – Existing surface and groundwater. – Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations. – Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters. – Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government. • Assess the impacts of the project on water quality, including: – The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the project protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of	Sections 4.7, 4.9 and 4.10 Sections 3.1.1, 4.7, 4.8 and 4.11 Sections 5 and 6

Agency	Desired performance outcome	Requirements	Where Addressed
		the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction. – Identify proposed monitoring of water quality. • Assess the project impact on hydrology, including: – Water balance including quantity, quality and source. – Effects to downstream rivers, wetlands and floodplain areas. – Effects to downstream water dependent fauna and flora including groundwater dependent ecosystems. – Impacts to natural processes and functions within rivers, wetlands and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches). – Changes to environmental water availability, both regulated/licenced and unregulated/rules – based sources of such water. – Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options. – Proposed monitoring of hydrological attributes.	See separate Hydraulic and Flooding Assessment report (Technical Report 5)

3. Legislation, policy and guideline context

This section provides a review of the legislation and environmental planning instruments that are relevant to the water quality assessment of the proposal.

Water Management Act 2000

Two key pieces of legislation for management of water within NSW are the *Water Management Act 2000* and the *Water Act 1912*. These Acts control the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in NSW. The *Water Management Act 2000* recognises the need to allocate and provide water for the environmental health of NSW rivers and groundwater systems. The provisions of the *Water Management Act 2000* are being progressively implemented to effectively replace the requirements of *Water Act 1912*. Since 1 July 2004 the new licensing and approvals system has been in effect in those areas of NSW covered by commenced water sharing plans.

A controlled activity approval under the *Water Management Act 2000* is required for certain types of developments and activities that are carried out in or near waterfront land that have the potential to affect water quality. However, under section 115ZG of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the *Water Management Act 2000* is not required for State significant infrastructure. The design and construction of the proposal would take into account the NSW Office of Water's guidelines for controlled activities on waterfront land to enable the mitigation of potential impacts to water quality.

The assessment of land use changes on floodplains in NSW is managed under Part 8 of the *Water Act 1912.* Part 8 makes provisions for 'controlled works' – defined as works that affect, or are likely to affect, flooding and/or floodplain functions. Consideration of floodplain management aspects of the project will be addressed in the *ARTC Inland Rail – Narrabri to North Star Hydrology and Flooding Report* (GHD 2016).

Following the introduction of the *Water Management Act 2000* water sharing plans have been developed for the Gwydir Regulated River Water Sources, Gwydir Unregulated and Alluvial Water Sources, Lower Gwydir Groundwater Sources, Namoi Unregulated and Alluvial Water Sources, Upper and Lower Namoi Groundwater Sources, NSW Border Rivers Regulated River, NSW Murray-Darling Basins Porous Rock Groundwater, NSW Great Artesian Basin Groundwater Sources, NSW Great Artesian Basin Shallow Groundwater Sources. All of these cover part or all of the proposal site.

To preserve water resources in river and groundwater systems for the future, the competing needs of the environment and water users are to be balanced. Water sharing plans establish rules for sharing water between the environmental needs of the river or aquifer and water users (for town water supply, rural domestic water supply, stock watering, industry and irrigation).

Australian Rainfall and Runoff

Australian Rainfall and Runoff (Pilgrim et al 1987, Ball et al 2016) is a national guideline for the estimation of design flood characteristics in Australia. The approaches presented in Australian Rainfall and Runoff are essential for policy decisions and projects involving:

- Infrastructure such as roads, rail, bridges, dams and storm water systems
- Flood management plans for urban and rural communities

- Flood warnings and flood emergency management
- Estimation of extreme flood levels

Australian Rainfall and Runoff has been referenced in developing the assessment framework for the hydrology, flooding and water quality impacts associated with the proposal.

3.1.1 Water quality

Water quality guidelines

The National Water Quality Management Strategy (ANZECC/ARMCANZ 2000) has been developed by the Australian and New Zealand governments in cooperation with state and territory governments. Endorsed by the Australian and New Zealand Environment and Conservation Council (ANZECC) the strategy establishes objectives to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

The strategy contains healthy river guidelines for the protection of lowland river aquatic ecosystems (Australian and New Zealand guidelines for fresh and marine water quality, 2000 – also known as the ANZECC guidelines). These guidelines have been used to determine the existing condition of rivers and water quality objectives for the proposal.

Water quality objectives

Water quality objectives for the Gwydir, Namoi and Macintyre (Border) Rivers have been obtained from the NSW Environment Protection Authority (DECCW 2006a, 2006b & 2006c) and are provided in Table 3.1. The water quality objectives are consistent with the agreed national framework for assessing water quality set out in the ANZECC 2000 guidelines. The NSW Water Quality Objectives provide environmental values for NSW waters and the ANZECC 2000 guidelines provide the technical guidance to assess the water quality needed to protect those values. As all three catchments are part of the Murray-Darling Basin catchment and their water quality objectives are the same they have been combined into one column.

The drinking water objectives for the Gwydir, Namoi and Macintyre (Border Rivers) catchments were not considered due to the predominantly rural land use in the study area and the potential for water to be extracted for multiple uses. Drinking water objectives apply to all current and future licensed offtake points for town water supply and to specific sections of rivers that contribute to drinking water storages or immediately upstream of town water supply offtake points. The objectives also apply to sub-catchments or groundwater used for town water supplies. No drinking water supply points were identified within the proposal site.

Table 3.1 Water quality objectives for lowland rivers

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorous	50 µg/L		
	Total nitrogen	500 µg/L		
	Chlorophyll-a	5 µg/L		
	Turbidity	6–50 NTU		

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria
	Salinity (Electrical conductivity) (µS/cm)	125–2200 µS/cm		
	Dissolved oxygen	85–110%		
	pH	6.5–8.5		
Aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.		
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.		
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.		
Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms	Median bacterial content in fresh and marine waters of <1000 faecal coliforms per 100 mL, with 4 out of 5 samples <4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).		
	Enterococci	Enterococci Median bacterial content in fresh and marine waters of <230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL).		
	Algae & blue-green algae	<15 000 cells/mL.		
	Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.		
	Surface films	Use visual amenity guidelines.		
Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed	Turbidity	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (about 6 NTU).		
	Faecal coliforms	ANZECC 2000 Guidelines recommend: Median over bathing season of <150 faecal coliforms per 100 mL, with 4 out of 5 samples <600/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).		
	Enterococci	ANZECC 2000 Guidelines recommend: Median over bathing season of <35 enterococci per 100 mL (maximum number in any one sample: 60–100 organisms/100 mL).		
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note it is not necessary to analyse water for these pathogens unless temperature is greater than 24 degrees Celsius).		
	Algae & blue-green algae	<15,000 cells/mL		
	Nuisance organisms	Use visual amenity guidelines.		
	pH	5.0–9.0		
	Temperature	15°–35°C for prolonged exposure.		

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in tables 5.2.3 and 5.2.4 of the ANZECC 2000 Guidelines 2000.		
	Visual clarity and colour	Use visual amenity guidelines.		
Protecting water quality to maximise the production of healthy livestock	Algae & blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11,500 cells/mL and/or concentrations of microcystins exceed 2.3 µg/L expressed as microcystin-LR toxicity equivalents.		
	Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids in drinking water for livestock are given in table 4.3.1 (ANZECC 2000 Guidelines).		
	Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).		
	Chemical contaminants	Refer to Table 4.3.2 (ANZECC 2000 Guidelines) for heavy metals and metalloids in livestock drinking water. Refer to Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.		
Protecting the quality of waters applied to crops and pasture	Algae & blue-green algae	Should not be visible. No more than low algal levels are desired to protect irrigation equipment.		
	Salinity (electrical conductivity)	To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered including irrigation water quality, soil properties, plant salt tolerance, climate, landscape and water and soil management. For more information, refer to Chapter 4.2.4 of ANZECC 2000 Guidelines.		
	Thermotolerant coliforms (faecal coliforms)	Trigger values for thermotolerant coliforms in irrigation water used for food and non-food crops are provided in table 4.2.2 of the ANZECC Guidelines.		
	Heavy metals and metalloids	Long term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in table 4.2.10 of the ANZECC 2000 Guidelines.		
Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing	Blue-green algae	Recommend twice weekly inspections during danger period for storages with history of algal blooms. No guideline values are set for cyanobacteria in drinking water. In water storages, counts of <1000 algal cells/mL are of no concern. >500 algal cells/mL – increase monitoring. >2000 algal cells/mL – immediate action indicated; seek expert advice. >6500 algal cells/mL – seek advice from health authority.		
	Turbidity	5 NTU; <1 NTU desirable for effective disinfection; >1 NTU may shield some micro-organisms from disinfection. (see supporting information).		

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria
	Total dissolved solids	<500 mg/L is regarded as good quality drinking water based on taste. 500–1000 mg/L is acceptable based on taste. >1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste.		
	Faecal coliforms	0 faecal coliforms per 100 mL (0/100 mL). If micro-organisms are detected in water, advice should be sought from the relevant health authority. See also the Guidelines for Microbiological Quality.		
	pH	6.5–8.5		
	Chemical contaminants	See Guidelines for Inorganic Chemicals in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004).		

4. Existing environment

4.1 Local government areas

The proposal is located within the Narrabri Shire Council, Gwydir Shire Council and Moree Plains Shire Council local government areas.

4.2 Terrain and land use

The study area is characterised by relatively flat catchments (up to five per cent) with some portions of locally steeper catchments. Floodplain slopes are generally in the order of one-half to one per cent gradient. Along the longitudinal length of the rail corridor, terrain has a gradual regional fall from Narrabri to near Moree and then a rise to near chainage 725 and then a fall toward North Star. The terrain falls over the project length for approximately 330 meters AHD to near 24 metres AHD with local valleys located along the corridor (refer to Figure 4.1).

The majority of construction activities for the proposal would occur within the existing rail corridor of the Narrabri to North Star line.

Beyond the rail corridor, the study area and surrounding land is dominated by agricultural land use, with significant cotton, wheat, and livestock industries. This has resulted in a significant amount of cleared land compared to the remaining native bushland. This clearing has an impact on the resulting storm flows as it lowers the catchment roughness (a measure by which surface flow is impaired by the surface type), which quickens the catchment’s response time to rainfall and results in shorter and more intense catchment flow.

The relatively small pockets of uncleared native vegetation within the contributing catchments are mostly found in national parks and State forest.

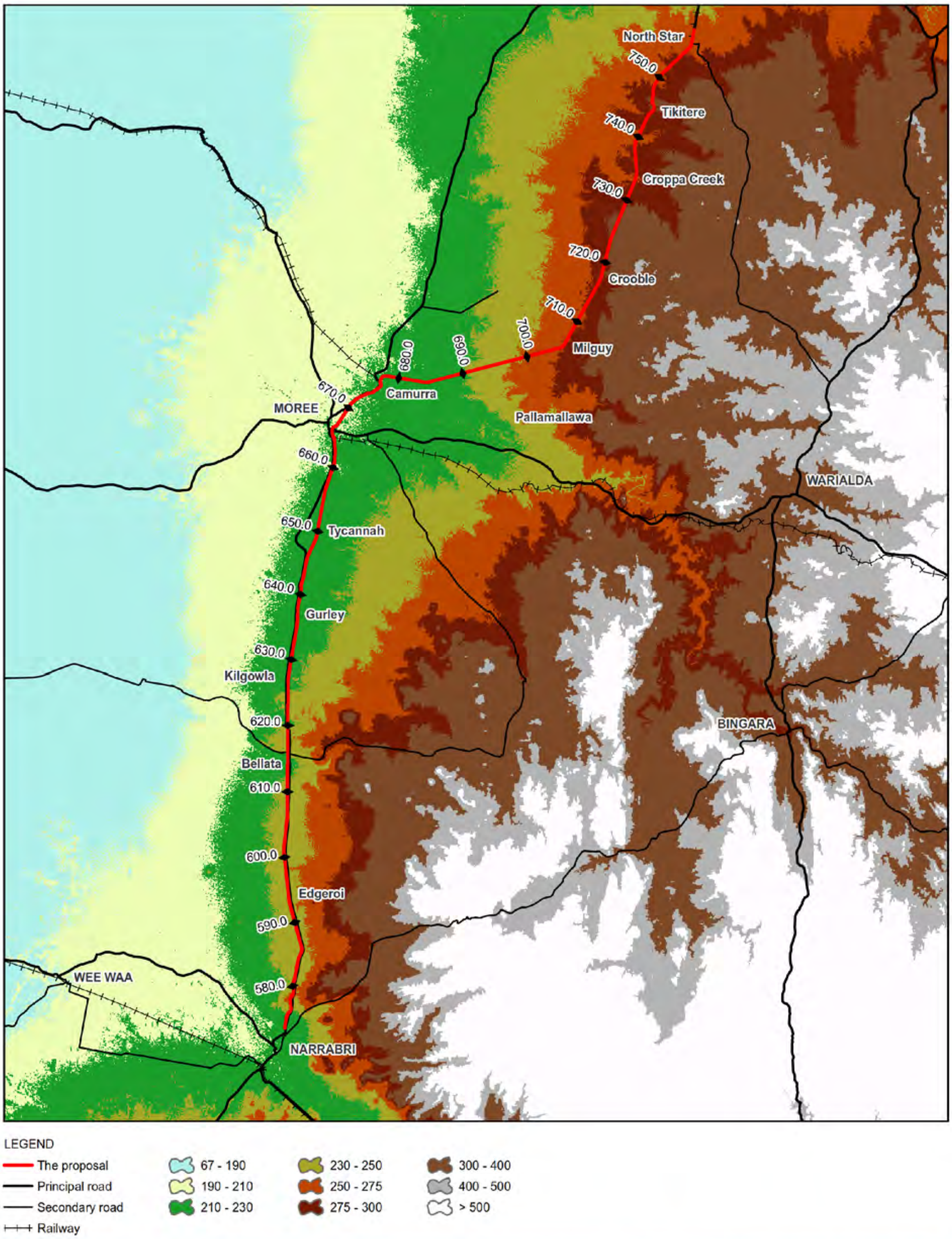
Relatively small and localised urban areas exist around the regional townships of Narrabri and Moree. There are also some mine and quarry sites within the contributing catchments. The urban, mining and quarrying land uses are well cleared. Figure 4.2 shows the land uses along the rail corridor along with forestry reserves, conservation reserves and national parks.

4.3 Climate

The Central West Region of NSW has a warm temperate climate, with large variations between summer and winter temperatures. Summers are hot and sunny with rainfall typically occurring as thunderstorms or short and intense storm events. Winters are cool and sunny with occasional cold fronts that bring periods of prolonged light rainfall.

A number of long-term Bureau of Meteorology (BoM) meteorological recording stations are located within or adjacent to study area, as listed in Table 4.1.

The mean annual rainfall recorded at these stations, as reported by the BOM, varies along the rail corridor with increasing toward the south, having an annual average rainfall about 620 millimetres, with the rainfall occurring relatively uniformly throughout the year.



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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Australian Rail Track Corporation
Inland Rail- Narrabri to North Star

Corridor and Catchment Topography

Job Number	22-17916
Revision	0
Date	02 Jun 2017

Figure 4-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

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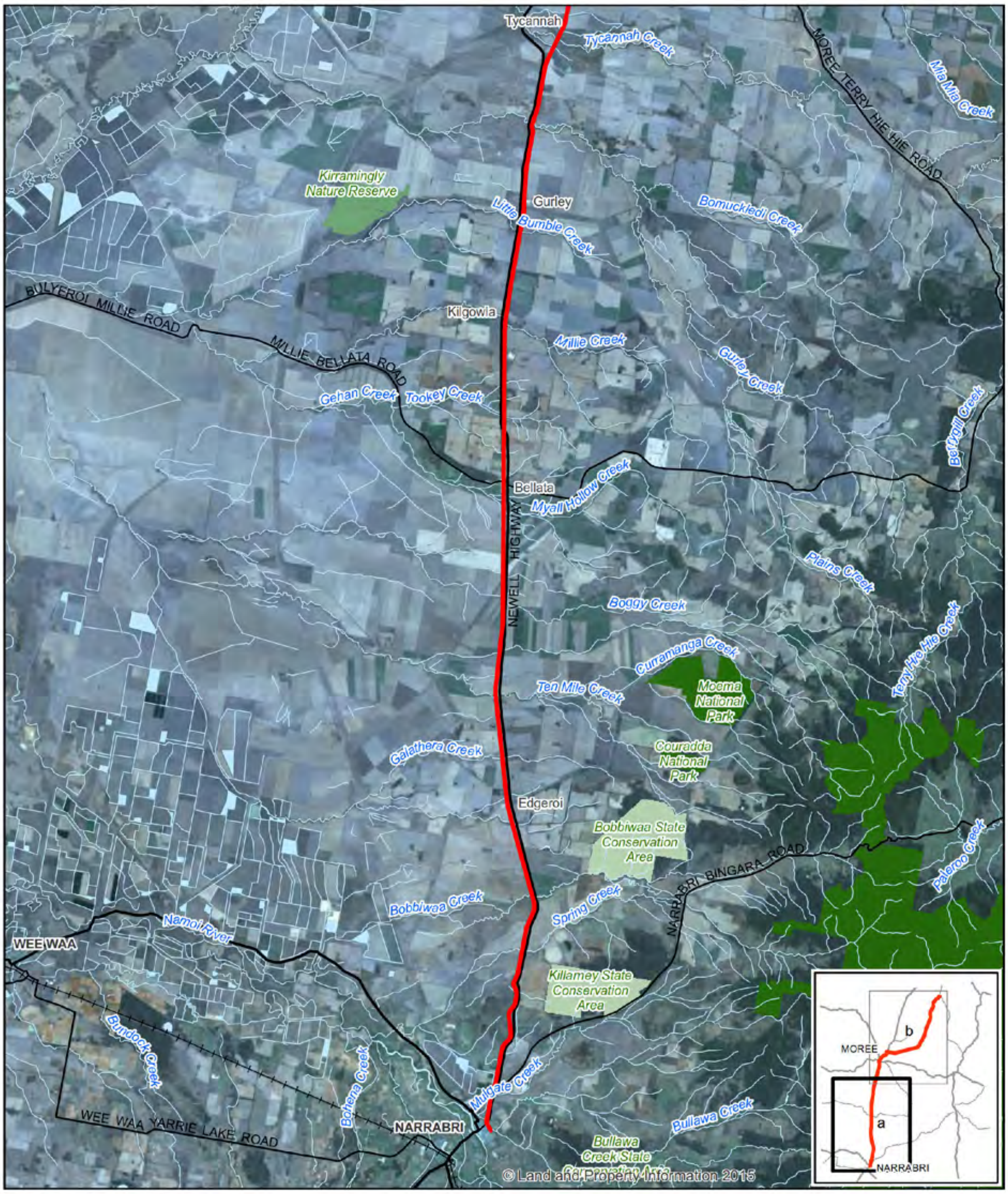
Data source: LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. Created by: gmcdiarmid, tmorton, kpsroba



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway
- Watercourse
- Waterbody
- National park
- Nature reserve
- State conservation area

Paper Size A4
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Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Inland Rail- Narrabri to North Star

Job Number | 22-17916
Revision | 0
Date | 02 Jun 2017

Land Use - Sheet 1

Figure 4-2a

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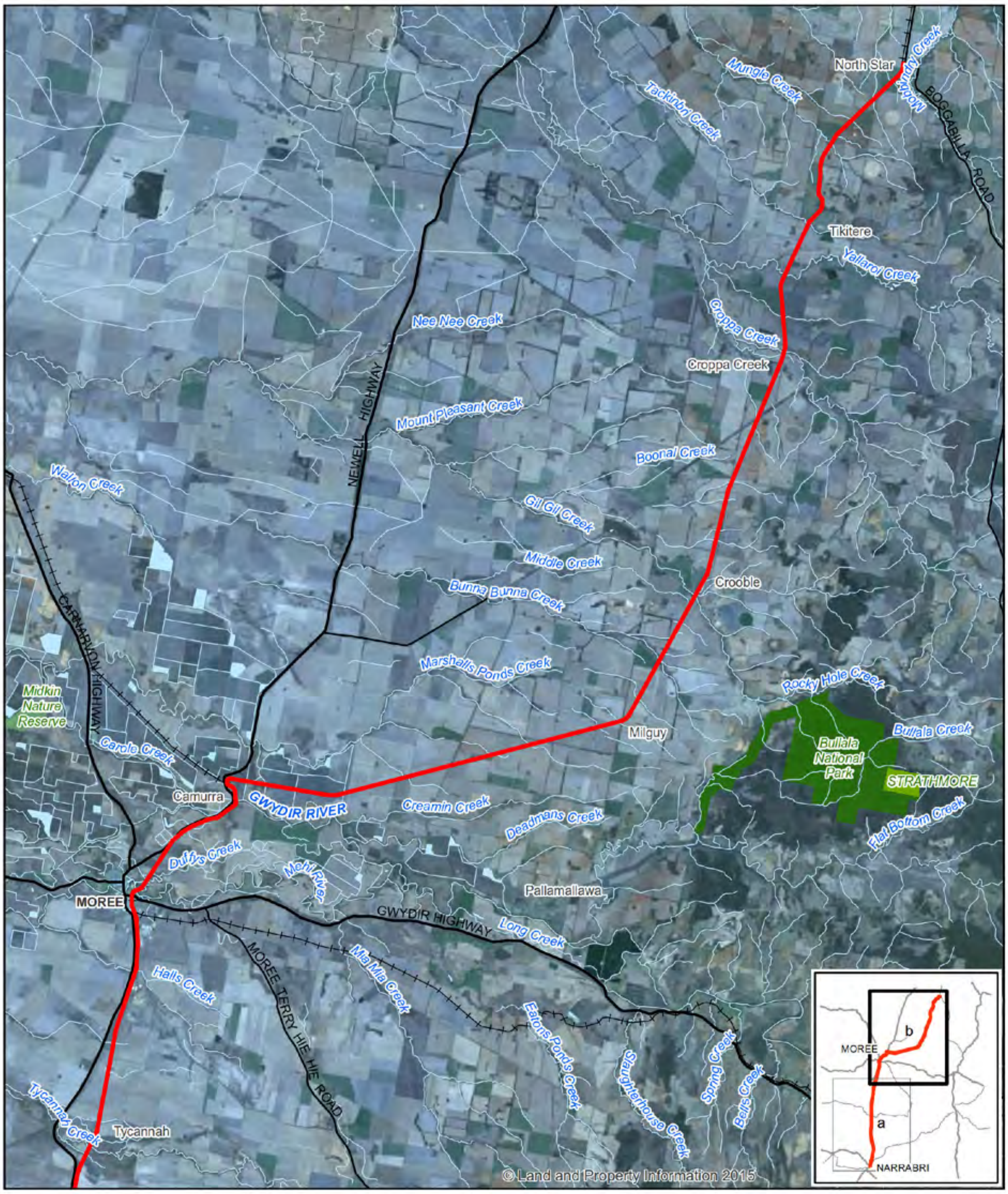
Data source: Geoscience Australia, 250K Topographic Data Series 3; LPI, Imagery, 2015. Created by: gmcdiarmid, kpsroba



LEGEND

The proposal
Principal road
Secondary road
Railway
Watercourse
National park
Nature reserve
State forest

Paper Size A4

0 1.5 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Inland Rail- Narrabri to North Star

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Date | 02 Jun 2017

Land Use - Sheet 2

Figure 4-2b

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Data source: Geoscience Australia, 250K Topographic Data Series 3; LPI, Imagery, 2015. Created by: gmcdiarmid, kpsroba

Table 4.1 Long term meteorological recording stations

Region	Name	Number	Latitude	Longitude	Starting year
Narrabri	Narrabri Bowling Club	054120	30.32	149.78	1870
Narrabri	Narrabri (Mollee)	063026	30.26	149.68	1926)
Moree	Moree (Mallowa (Narba))	053070	29.62	149.38	1967
Moree	Garah Post Office	053011	29.07	149.63	1906
North Star	North Star (Bonanza)	053076	28.95	150.26	1966
North Star	Tulloona (Coolanga)	053041	28.87	150.09	1882
North Star	Boggabilla Post Office	053004	28.60	150.36	1893

[A] 053070 Moree (Mallowa (Narba)) closed in 1950

4.3.1 Climate change impacts

The NSW and ACT Regional Climate Model (NARCLiM) provides projections for the potential climate change impacts for the New England North West region, which include the study area. Of particular importance is the predicted precipitation (rainfall) changes from 1990–2009 through to 2020–2039 and 2060–2079, summarised in Table 4.2.

Table 4.2 NARCLiM data summary

Parameter	Projected change (%) to 2020–2039	Projected change (%) to 2060– 2079
Annual mean rainfall change	-9 to 13	-8 to 24
Summer rainfall	-15 to 14	-10 to 42
Autumn rainfall	-9 to 47	-1 to 49
Winter rainfall	-26 to 15	-29 to 30
Spring rainfall	-11 to 19	--21 to -28

This estimate is consistent with advice from the Department of Environment and Climate Change (DECC 2007).

4.3.2 Historical climatic data

The historical rainfall and river flow data indicate the region has experienced a variety of significant climatic conditions, varying from severe droughts to large and significant floods.

An indication of the climatic variability is shown in Figure 4.3, which provides a diagrammatic representation of the years with complete rainfall records for Narrabri between 1870 and 2008. The minimum annual rainfall recorded in that period was 321 millimetres, for years on complete records, while the maximum was approximately 1,310 millimetres and the average was approximately 500 millimetres. As shown in Figure 4.3 there have been a number of periods with consecutive years of below average rainfall.

The Narrabri site has reported a relatively uniform monthly distribution of the mean rainfalls varying from a high of approximately 80 millimetres in January to a low of approximately 37 millimetres in August.

Because of the relatively low annual rainfall and a relatively high evaporation rate (about 1,600 to 1,900 millimetres per annum) most of the watercourses are ephemeral.

The climatic variability is reflected in the frequency, persistence and magnitude of stream flows.

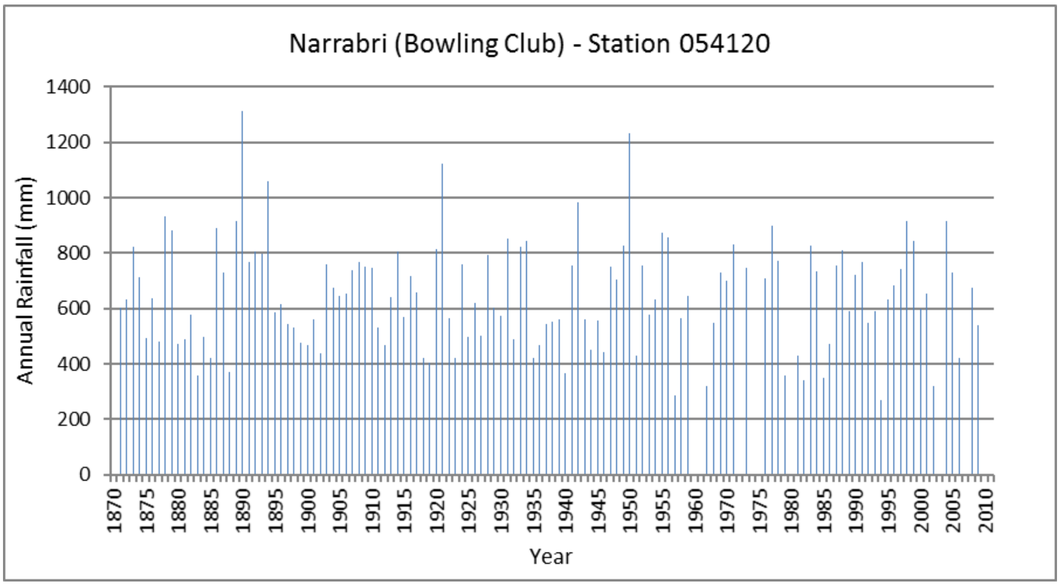


Figure 4.3 Narrabri rainfall – Station 054120

4.4 Licensed water extraction locations

A search of the NSW Water Register (DPI – Water 2016c) was undertaken to identify the number of Water Access Licences available for each surface water source. The information available on the NSW Water Register does not identify the location of the Water Access Licence and does not provide any information regarding licences issued under the *Water Act 1912.* The results of the search of the NSW Water Register are summarised in Appendix A.

The search of the NSW Water Register found that the surface water sources intersected by the proposal are potentially utilised for stock, domestic and town water supply. There are also a number of water access licences for extraction of water from unregulated rivers.

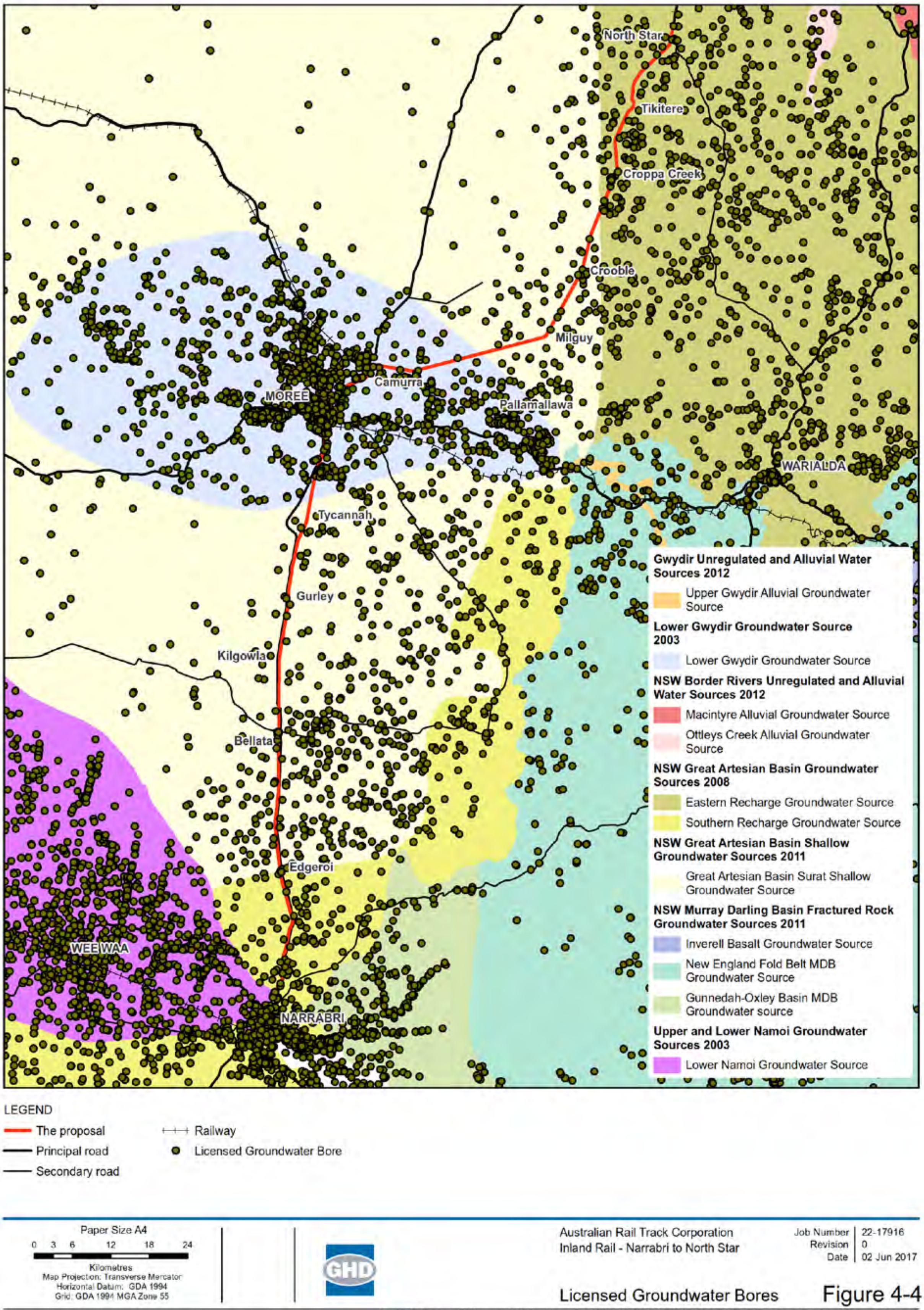
The licensed extraction locations (groundwater bores) within the proposal area are shown in Figure 4.4 and are detailed in Appendix B.

4.5 Groundwater sharing plan

The proposal lies within the Water Sharing Plans for the NSW Great Artesian Basin Groundwater Sources (NSW Government 2008), Lower Gwydir Groundwater Source, NSW Great Artesian Basin Shallow Groundwater Source (NSW Government 2011), Namoi Unregulated and Alluvial Water Sources (NSW Government 2012) and the Upper and Lower Namoi Groundwater Source (NSW Government 2003).

The Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources commenced in July 2008 and regulates the interception and extraction of water from the sandstone aquifers of the Great Artesian Basin within the boundaries of the water sharing plan.

The Water Sharing Plan for the NSW Great Artesian Shallow Groundwater Sources commenced in November 2011 and regulates interception and extraction of water from alluvium and all other geological formations to a maximum depth of 60 metres below ground surface within the boundaries of the water sharing plan. Groundwater sources that are included in other water sharing plans are excluded from the Water Sharing Plan for the NSW Great Artesian Shallow Groundwater Sources.



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Licensed Groundwater Bores **Figure 4-4**

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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Data source: OOW, Pineena, Groundwater, 2010; LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. Created by: gmcdiarmid, tmorton

The Water Sharing Plan for the Lower Gwydir Groundwater Source commenced in October 2006 and regulates the interception and extraction of water from the alluvial aquifer associated with the Gwydir River and its tributaries within the boundary of the water sharing plan. This water sharing plan is due for replacement in July 2019 and is currently undergoing a formal review (DPI Water 2016b).

4.6 Geology and soils

4.6.1 General

The study area is located generally within the Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary alluvium and colluvial deposits over Jurassic sedimentary rocks with Cainozoic mafic volcanic outcrops intermittently along the rail corridor.

Deep riverine deposits of black and red clayey silt, sand and gravels are predominantly associated with the near level terrain surrounding Moree, with alluvial deposits of gravel, sand, silts and clays with sandstone outcrops associated with the undulating terrain surrounding Narrabri.

4.6.2 Soil groups and characteristics

Soil characteristics along the length of the proposal were determined from the eSpade database. Appendix C provides a summary of the soil landscape groups along the proposal site. The dominant Great Soil Groups are shown in Figure 4.5.

Given soils in the study area are predominantly clays, which have limited water storage potential, the initial and continuing infiltration losses associated with the catchment are expected to be low. As a result, the catchments will show a rapid and continuous response to rainfall given the low rainfall losses, which will generate relatively high runoff rates.

4.6.3 Acid sulfate soils.

The proposal site is not located within the risk areas for acid sulfate soils, as mapped by OEH (1998).

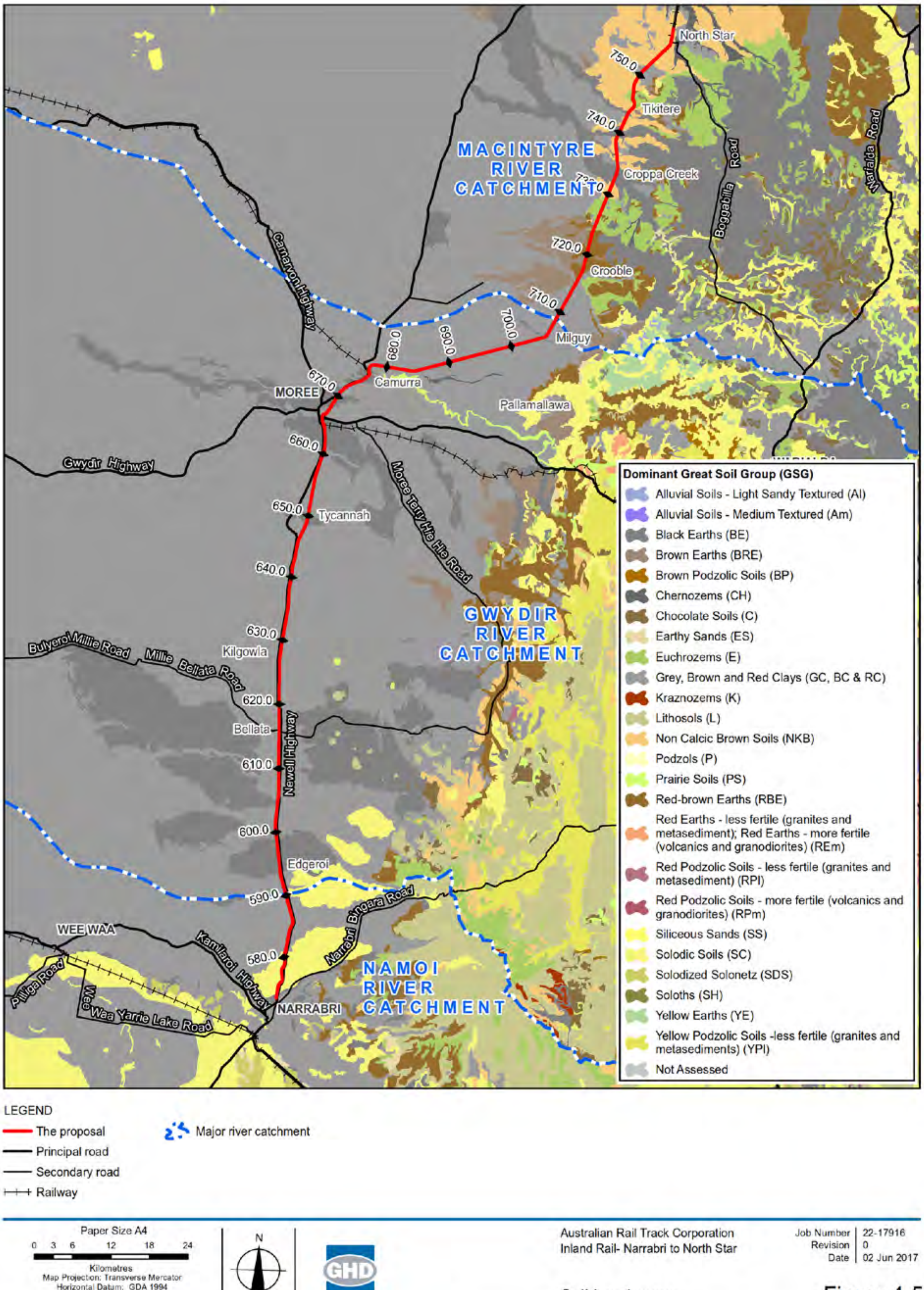
4.7 Watercourses

4.7.1 Major river and basin systems

The proposal is located within the major water catchments of the Namoi River Basin, Gwydir River Basin and the Macintyre River Basin.

The Namoi River starts in the western slopes of the Great Dividing Range flowing westwards through Lake Keepit towards Boggabri, Narrabri (and the proposed alignment) and Wee Waa, before meeting the Barwon River at Walgett. The Barwon River is a tributary of the Murray – Darling Basin (MDB), meeting the Darling River near Bourke. The Namoi River catchment covers an area of about 42,000 kilometres squared and is about 350 kilometres long. It is one of the Murray-Darling Basin’s major sub-catchments in NSW.

The Gwydir River starts west of Armidale, fed by the Rock River and Booroolong Creek. The Gwydir River flows north west to Lake Copeton, before turning west to Bingara and Moree, passing under the proposed alignment, before continuing westwards, meeting the Barwon River north of Collarenebri. The Gwydir River catchment covers an area of 26, 000 kilometres squared and is about 670 kilometres long. It is part of the Barwon catchment within the Murray-Darling basin.



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Soil Landscape

Figure 4-5

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\WaterQuality\2217916_WQ006_NNS_SoilLandscape_0.mxd

Data source: LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. OEH: Greater Soil Group, 2014. Created by: gmcdiarmid, tmorton, kpsroba

The Macintyre River starts west of Glencoe, flowing in a north west direction towards the NSW – Queensland border near Boggabilla. The Macintyre River catchment includes the Croppa Creek and Gil Gil Creek, both of which pass under the proposed alignment south of North Star. The Macintyre River catchment is one of the river systems that make up the Border Rivers catchment, which is part of the Murray-Darling Basin. Other river systems in the Borders River catchment in northern NSW include the Dumaresq and Severn River catchments. The Dumaresq and Macintyre rivers form the border between NSW and Queensland.

4.7.2 Watercourses crossed by the proposal

Surface water within the study area is predominately comprised of ephemeral watercourses (i.e. watercourses that only flow following periods of intense or prolonged rainfall), excluding the major perennial river systems identified in Section 4.7.1. This is because of the size of the contributing watercourse catchment area, the rainfall pattern in the region, and as there is no base flow resulting from groundwater expression. Further information regarding climatic conditions in the region is provided in Section 4.3.

Minor river catchments (those less than 1,000 square kilometres) along the existing rail corridor include:

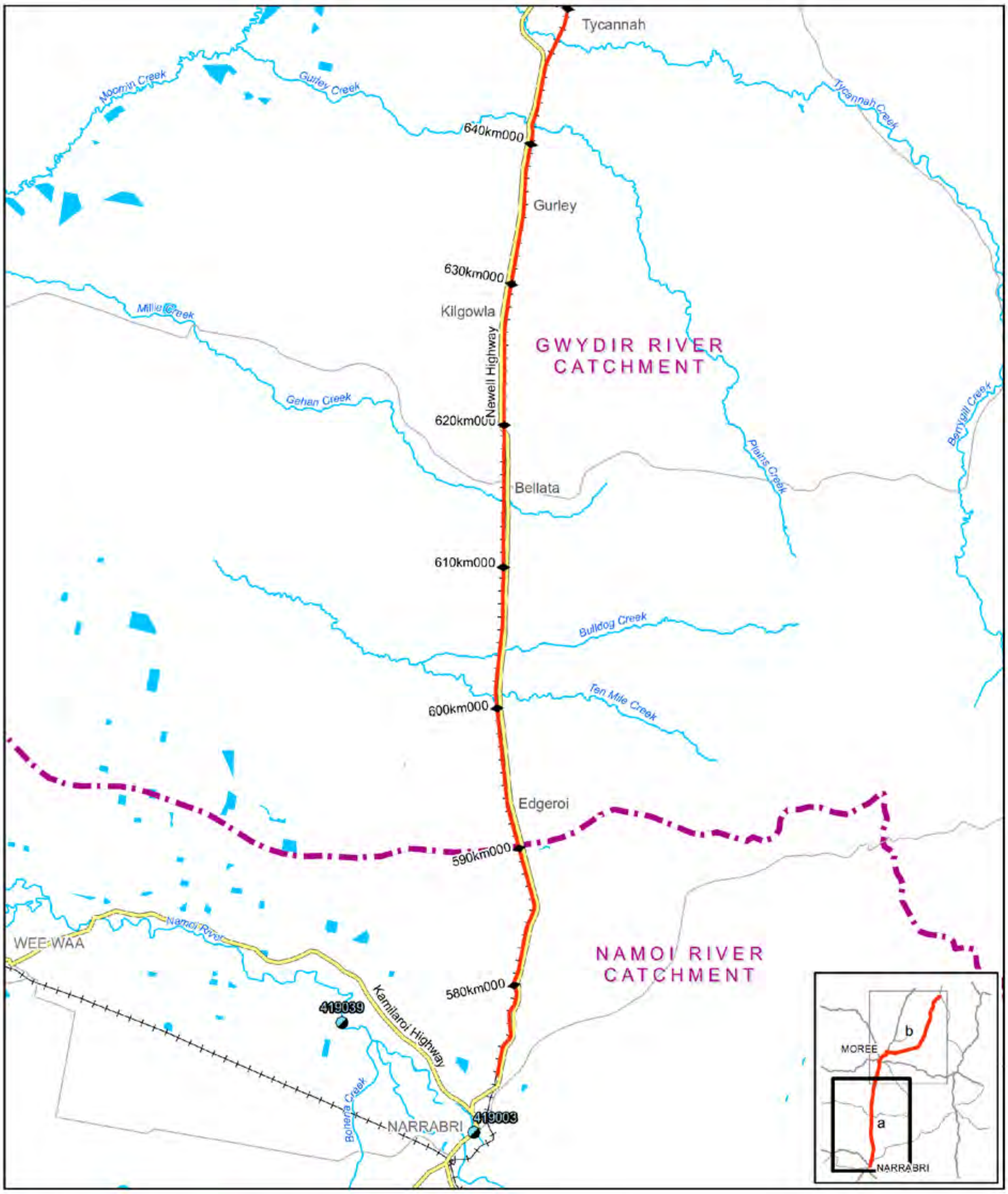
- Bobbiwa Creek
- Ten Mile Creek
- Boggy Creek
- Gehan Creek
- Waterloo Creek
- Little Bumble Creek
- Gurley Creek
- Halls Creek
- Mehi River
- Gil Gil Creek
- Croppa Creek
- Yallaroi Creek
- Mungle Creek

Figure 4.6 shows the locations of the named watercourses that are crossed by the proposal.

Table 4.3 provides details of all named watercourses and all un-named watercourses with stream order greater than third order crossed by the proposal including:.

- Stream order as derived from the topographic LPI Hydroline dataset
- The form and geomorphic condition of watercourses as assessed from aerial imagery and based on the River Styles framework (Brierley and Fryirs, 2005)

An inspection of these watercourses was undertaken and included the collection of photographs and a general condition assessment of the watercourses. The comments in Table 4.3 also include observations made during the general condition assessment.



LEGEND

- The proposal
- Monitoring location
- Major Road
- Secondary Road
- Railway
- Major river catchment
- Watercourse
- Waterbody

Paper Size A4

0 1.5 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Australian Rail Track Corporation
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Revision	1
Date	16 Aug 2017

Major Waterways - Sheet 1

Figure 4-6a

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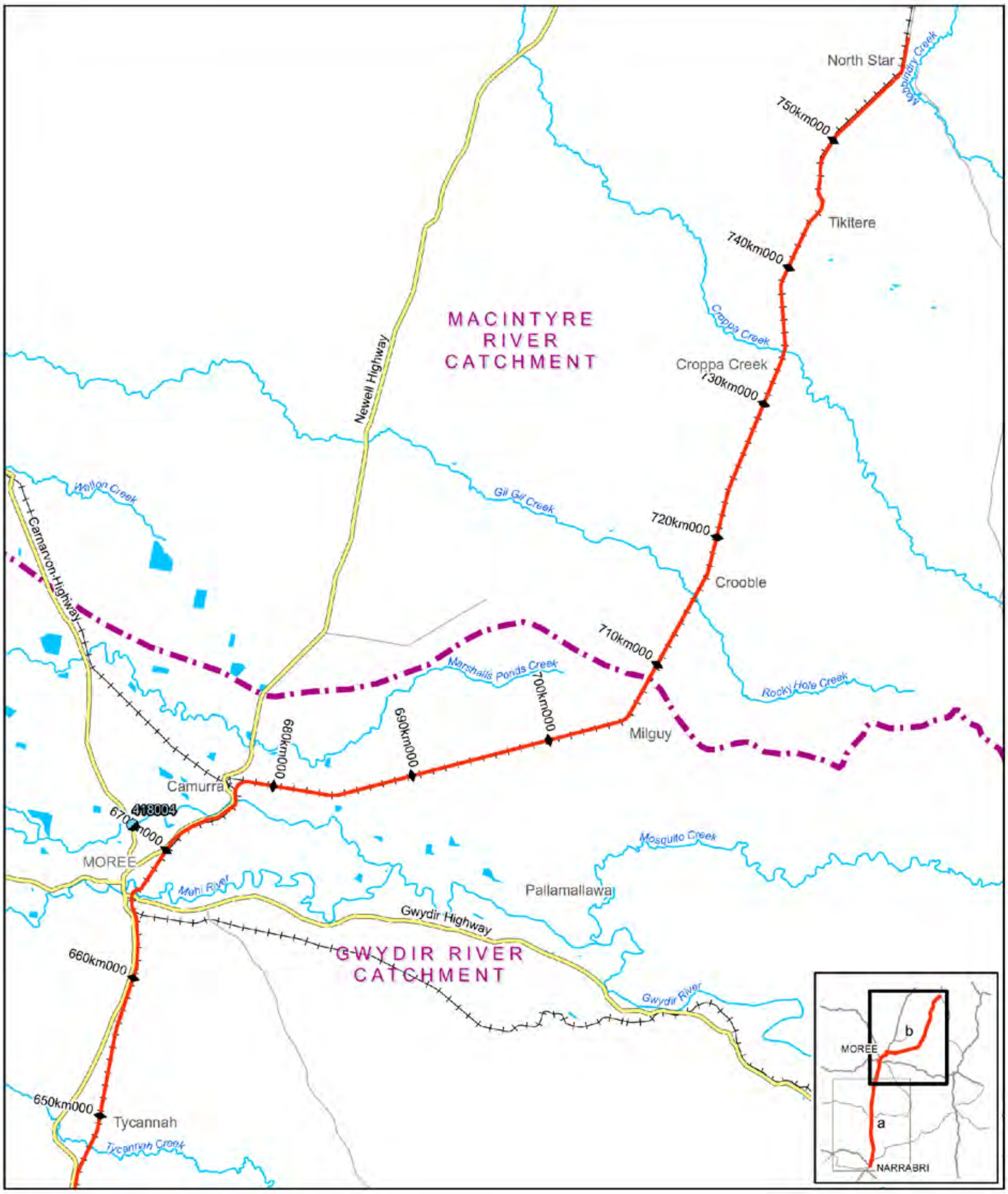
G:\22\17916\GIS\Maps\Deliverables\N2NS\WaterQuality\2217916_WQ008_NNS_MajorWaterways_DDP_1.mxd

Data source: DECCW: Catchment, 2012. Geoscience Australia, 250K Topographic Data Series 3; LPI,DTDB, 2015. Created by: gmcdiarmid, kpsroba



LEGEND

- The proposal
- Monitoring location
- Major Road
- Secondary Road
- Railway
- Major river catchment
- Watercourse
- Waterbody

Paper Size A4

0 1.5 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Australian Rail Track Corporation
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Major Waterways - Sheet 2

Figure 4-6b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\WaterQuality\2217916_WQ008_NNS_MajorWaterways_DDP_1.mxd

Data source: DECCW: Catchment, 2012. Geoscience Australia, 250K Topographic Data Series 3; LPI,DTDB, 2015. Created by: gmcdiarmid, kpsroba

Table 4.3 Details of third order and higher watercourses crossed by the proposal

River system	Chainage (km)	Watercourse	Flow regime	Stream order	River style	Condition	Comments
Namoi	574.75	Un-named	Ephemeral	3	Valley fill	Moderate	Stable, grassed valley with no defined channel.
	583.05	Spring Creek	Ephemeral	4	Low sinuosity fine grained	Poor	Unstable channel upstream with eroding banks. Eroded sediment being deposited on downstream side of existing railway. Downstream channel grassed and stable.
	586.55	Bobbiwa Creek	Ephemeral	4	Low sinuosity fine grained	Good	Stable, well vegetated channel.
Namoi (via Thalba Creek)	594.3	Tarlee Creek	Ephemeral	1	Valley fill	Moderate	Stable, undefined drainage line.
	596.85	Galathera Creek	Ephemeral	2	Valley fill	Moderate	Stable at crossing with channel incision and headcutting present about 100 metres downstream of existing railway.
	600.9	Ten Mile Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression. Occasional near perennial ponds present.
	602.85	Pan Creek	Ephemeral	2	Valley fill	Poor	Stable although constrained with floodway berms.
	604.3	Bulldog Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Generally stable with some bank erosion. Occasional small ponds.
	608.25	Boggy Creek	Ephemeral	3	Low sinuosity fine grained	Moderate	Stable, grassed channel.
	614.5	Gehan Creek	Ephemeral	4	Valley fill	Moderate	Stable, grassed valley with no defined channel.
	621.05	Tookey Creek	Ephemeral	3	Valley fill	Good	Stable, grassed valley with no defined channel.
	627.65	Waterloo Creek	Ephemeral	4	Low sinuosity fine grained	Good	Stable, grassed channel.
	634.2	Little Bumble Creek	Ephemeral	2	Valley fill	Good	Stable, grassed valley with no defined channel.
Mehi	642	Gurley Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression. Occasional near perennial ponds present.
	648.1	Tycannah Creek	Ephemeral	6	Low sinuosity fine grained	Good	Stable, well vegetated, low capacity channel. Anabranches.
	655.65	Clarks Creek	Ephemeral	1	Valley fill	Moderate	Stable, grassed valley with no defined channel.
	661	Halls Creek	Ephemeral	2	Valley fill	Moderate	Shallow, stable depression with occasional pools.

River system	Chainage (km)	Watercourse	Flow regime	Stream order	River style	Condition	Comments
	666.9	Mehi River	Perennial	5	Low sinuosity fine grained	Good	Stable channel with long perennial pools.
	667.7	Duffys Creek	Ephemeral	NA	Valley fill	Good	Shallow, stable depression. Ananbranch of Gwydir River.
Gwydir	668.45	Skinners Creek	Ephemeral	NA	Valley fill	Moderate	Shallow, stable depression. Ananbranch of Mehi River.
	676.75	Gwydir River	Perennial	8	Low sinuosity fine grained	Moderate	Channel subject to meander migration. Gentle bend at crossing. Long perennial pools.
Macintyre River (Gwydir River -via Gil Gil Creek)	699.05	Coolleearlee Watercourse	Ephemeral	2	Channelised fill	Moderate	Stable incised valley fill.
	704.05	The Ponds	Ephemeral	2	Valley fill	Moderate	Stable although constrained with floodway berms.
	705.55	Marshalls Ponds Creek	Ephemeral	2	Valley fill	Moderate	Stable although constrained with floodway berms.
	710.85	Bunna Bunna Creek	Ephemeral	3	Low sinuosity fine grained	Moderate	Stable, poorly defined channel set within broad depression.
	716.15	Gil Gil Creek	Ephemeral	5	Low sinuosity fine grained	Moderate	Stable, poorly defined channel set within broad depression.
Macintyre River (Gwydir River -via Whalan Creek)	734.4	Croppa Creek	Ephemeral	6	Low sinuosity fine grained	Good	Stable, well-vegetate channel.
	739.9	Yallaroi Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Generally stable with some evidence of past channel incision. Occasional small ponds.
	743.8	Tackinbri Creek	Ephemeral	2	Low sinuosity fine grained	Good	Shallow, stable depression, well vegetated.
	750.3	Mungle Creek	Ephemeral	3	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression.
	756.35	Dry Creek	Ephemeral	1	Valley fill	Poor	Undefined drainage in cropping paddocks.

The morphology of watercourses is characterised by three stream types:

- Low sinuosity fine grained systems exhibit relatively straight channels surrounded by continuous floodplains. The banks of this stream type are relatively stable due to the presence of cohesive fine grained materials. During periods of low rainfall, the stream type typically holds water in isolated pools.
- Channelised fill systems are generally lateral, stable channels of low sinuosity incised within flat and featureless floodplains. During periods of high flow, unprotected banks are prone to erosion.
- Valley fill systems are relatively flat, featureless valley floor surfaces, lacking a continuous, well defined channel. Typically, the substrate comprises fine alluvial silts and muds vertically deposited out of suspension.

Most watercourses are considered to be in moderate geomorphic condition because of historical disturbances associated with agricultural practices. These practices include vegetation clearing, stock-grazing impacts, construction of online farm dams and drainage improvements (such as channelising watercourses through excavation or bunding). Typically, poor condition reaches have been channelised to improve drainage and limit the extent of flooding. These reaches can also display evidence of ongoing channel erosion.

The existing rail corridor and associated infrastructure has had only minor localised impacts on watercourse form – primarily an increased propensity for scour and erosion immediately downstream of a few watercourse crossing structures.

4.8 Water quality

4.8.1 General

Water quality monitoring data for watercourses within the study area was reviewed. A National Water Quality Assessment (SKM 2011) has classified the water quality within river catchments and compared it to the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed aquatic ecosystems. No sampling was undertaken to allow a review of the parameters associated with water quality objectives other than aquatic ecosystems (i.e. visual amenity, primary recreation etc.). Table 4.4 indicates that in both the Namoi and Gwydir River catchments the water quality was relatively poor quality (refer to Table 4.4).

The Water Quality Assessment concluded that the main source of phosphorous in the Namoi catchment are natural sources including phosphorous rich soils, while soil erosion has introduced large volumes of suspended sediment to the Namoi River catchment.

A more recent State of the Environment report (Molino Stewart 2015) indicates that there has been a progressive reduction in recorded electrical conductivity values during the period 2011–12 to 2014–15 for the Central West region of NSW. The same report also indicates a reduction in recorded E. coli counts in watercourses over the period 2012–13 to 2014–15.

No water quality sampling data was collected as part of this assessment due to the ephemeral nature of many watercourses within the study area. Impacts to water quality due to the proposal would be largely associated with construction of the proposal. Therefore, as described in Section 7 baseline monitoring would be undertaken at perennial watercourses and potentially at ephemeral watercourses, prior to construction.

Table 4.4 Assessed water quality (SKM 2011)

Parameter	Namoi River catchment	Gwydir River lower catchment	Trigger value (refer to Table 3.1)
Turbidity	Fair 31% of samples exceeded guideline values	Fair Median values ranged from 4 to 190 NTU 52% of samples complied with ANZECC/ARMCANZ guideline value of 50 NTUs	6 - 50 NTU
Salinity	Fair 50% of samples exceeded guideline values	Poor 53% of samples exceeded the ANZECC/ARMCANZ guideline value Median values were generally higher in the tributaries and several were close to, or exceeded 1,000 µS/cm	125 - 2200 µS/cm
pH	Poor	Poor	6.5 – 8.5
Total Nitrogen	Very poor 91% of samples did not meet guideline values	Very poor 90% of samples exceeded guideline values	500 µg/L
Total Phosphorus	Poor 95% of samples did not meet guideline values	Very poor 95% of samples exceeded guideline values	50 µg/L

4.8.2 Perennial watercourse quality

While limited, electrical conductivity data was obtained for selected locations within the investigation area from the NSW Government Waterinfo website (accessed 6 March 2017 – refer to Table 4.5) for those monitoring locations closest to the proposal site (refer to Figure 4.6 for monitoring locations).

Table 4.5 Perennial watercourse qualities

Watercourse	Location	Number	Electrical Conductivity – Maximum (mS/cm)	Turbidity - Maximum (NTU)	Period
Narrabri Creek (419003)	Narrabri	419003	1037	‘NA	Feb 2002 - current
Namoi River (419039)	Mollee	419039	1031	2421	June 2012 July 2015
Gwydir River (418004)	Yarraman Bridge	418004	1893	NA	April 2002 - current

The data shows the maximum electrical conductivity significantly exceeded 1,000 micro-siemens per centimetre (μS/cm) corrected for 25° Celsius (ANZECC/ARMCANZ guideline value). The limited data did indicate that Gwydir water was more saline that that in the Namoi River catchment.

The Water Sharing Plan for the Upper and Lower Namoi Groundwater Source commenced in November 2006 and regulates the interception and extraction of water from the alluvial aquifers associated with the Namoi River and its tributaries within the boundaries of the water sharing plan.

The Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources commenced in October 2012 and regulates interception and extraction of water from surface water and alluvial aquifers within the boundaries of the water sharing plan. This water sharing plan does not cover alluvial groundwater associated with the Namoi River and its tributaries as this is covered by the Water Sharing Plan for the Upper and Lower Namoi Groundwater Source.

4.9 Sensitive receiving environments

A sensitive receiving environment is one that has a high conservation value, or supports human uses of water that are particularly sensitive to degraded water quality (DECC 2008). In the context of this proposal, sensitive receiving environments are considered to be:

- Wetlands
- Threatened ecological communities associated with aquatic ecosystems
- Key fish habitats as identified by the NSW Department of Primary Industry
- Recreational swimming areas
- Areas that contribute to drinking water catchments

Wetlands

The Gwydir Wetlands, were formed on the very flat floodplain of the Gwydir River. The wetlands consists of a complex network of flow paths and floodways. The Gwydir Wetlands are located approximately 60 kilometres west to northwest of Moree and the proposal. Segments of the wetland are listed under the Ramsar Convention, the Directory of Important Wetlands in Australia and the NSW reserve system.

Other wetlands in the study area include:’

- Morella Lagoon, Pungbopugal Lagoon and Boobera Lagoon, (Border Rivers catchment) which are part of a wetland complex that is listed as a site of national importance in the Directory of Important wetlands. This wetland complex is located a minimum of 30 kilometres north west of the proposal site.
- Downstream of Narrabri there are many wetlands, small lagoons and anabranches associated with the river (Namoi River catchment).
- Lake Goran (Namoi River catchment) which is listed as a wetland of national significance and is located about 110 kilometres south east of the proposal site.

Vegetation

An ecologic assessment of the proposal route is reported in the *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Biodiversity Assessment Report* (Umwelt 2017b). The following is extracted from this report.

The southern end of the proposal site is located immediately north of Narrabri on an embankment above the Namoi River. The proposal site traverses the Gwydir River floodplain. The northern end of the proposal site, at North Star, is located south of the Macintyre River within the Border Rivers basin.

The proposal site crosses a number of large watercourses, including rivers (Mehi River and Gwydir River), larger creeks (such as Mulgate Creek, Bobbiwa Creek, Gehan Creek, Tookey Creek and Gil Gil Creek) and other intermittent watercourses and canals constructed to convey irrigation waters.

Patches of native vegetation exist sporadically within and around the proposal site, and are typically associated with travelling stock reserves, road reserves or farm woodland remnants. These patches generally comprised a woodland community, with the dominant canopy species including bimble box (*Eucalyptus populnea*), belah (*Casuarina cristata*), silver-leaved ironbark (*Eucalyptus melanophloia*), and white cypress pine (*Callitris glaucophylla*). Extensive areas of natural grasslands also exist.

With regards to environmental values within the larger study area the Pilliga Scrub (Namoi River catchment) is the largest remaining dry sclerophyll forest west of the Great Dividing Range and is located in the Pilliga Nature Reserve and Pilliga State Conservation Area, about 25 kilometres south west of the proposal site.

Aquatic ecology

The *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Aquatic Ecology Assessment* (Umwelt 2017) details the threatened ecological communities and key fish habitats relevant to the proposal.

The Mehi and Gwydir rivers have both been identified as 'class 1 key fish habitat' in accordance with the *Policy and guidelines for fish habitat conservation and managemen*t (DPI, 2013). As a result, the design and construction of the project will have to consider the requirements of the NSW *Fisheries Management Act* (1994). A number of other watercourses are identified as having moderate fish community value.

Some of the watercourses intersected by the rail corridor comprise important aquatic ecosystems, in particular NSW DPI identified the Mehi River as good fish community value; while Gehan Creek, Waterloo Creek and Gil Gil Creek were identified as having moderate fish community value but with a high alien presence.

Native fish species reported as being likely to occur in the Mehi and Gwydir rivers include golden perch, spangled perch, Murray cod, freshwater catfish, purple spotted gudgeon, olive perchlet, Australian smelt, bony bream, carp gudgeon, unspecked hardyhead and Murray-Darling rainbow fish (DPI, 2015).

Groundwater dependent ecosystems

A review of the Australian Government's National Atlas of Groundwater Dependent Ecosystems identified the following groundwater dependent ecosystems in the study area:

- Watercourses and riparian vegetation either side of the proposal site along Gurly Creek, Gehan Creek, Mehi River, Gwydir River, and Croppa Creek.
- Riparian vegetation along Gil Gil Creek is identified as having a low potential for groundwater dependent ecosystems, while upstream of the proposal site there is a higher potential for groundwater dependent ecosystems.

- Floodplain waterbodies associated with Tycannah Creek upstream and downstream of the proposal site are mapped as groundwater dependent ecosystems.
- The Gwydir River wetlands.

4.10 Water demands

Estimated water demand for construction of the proposal maybe in the order of 150 megalitres, or about 75 megalitres per year, for earthworks and dust control. Likely water sources were identified, subject to the gaining of applicable approvals and access agreements and there being sufficient water at each site. These water sources are:

- Narrabri Shire Council (Wastewater) – five megalitres
- Multiple Private bores within five kilometres of the alignment – about five to ten megalitres per bore
- Several Private dams within ten kilometres of the alignment – about 20 megalitres each site
- Namoi River – ten to fifteen megalitres
- Gwydir River – ten to fifteen megalitres
- Mehi River – ten to fifteen megalitres
- Moree Shire Council (Wastewater) – about five megalitres

The actual water demand at the time of construction will be highly dependent upon matters including the final design, weather and the adopted construction methodology.

4.11 Hydrology

4.11.1 Surface water

The major rivers crossed by the proposal (Gwydir and Mehi rivers) are perennial watercourses. The remaining watercourses are ephemeral; therefore, the majority of watercourses traversed by the proposal have temporary or intermittent flow. The ephemeral watercourses flow during and after rainfall, and dry out in between rainfall events.

As surface water flow in the study area is primarily related to rainfall, the associated rainfall and runoff process of the catchment is the main contributor to watercourse flow experienced along the Narrabri to North Star rail corridor.

4.11.2 Groundwater

The results of the bore search and review of groundwater sharing plans (refer Section 4.5) identified that groundwater sources in the proposal corridor include alluvial sediments associated with the Gwydir River near Moree. Based on the results of the bore search, the alluvial sediments extend to over 40 metres below ground level. Alluvial groundwater associated with the Gwydir River would be recharged by rainfall infiltration and surface flows. Groundwater levels would be expected to rise following periods of above average rainfall and fall following periods of below average rainfall.

Near Narrabri, the proposal site may be underlined by alluvial sediments associated with the Namoi River. The results of the bore search identified two bores near Narrabri. One of these two bores extended to a depth of over 50 metres below ground level, and was identified to be extracting from alluvial sediments.

The alluvial aquifer is underlined by fractured rock. This fractured rock overlies the Great Artesian Basin aquifer. The fractured rock outcrops outside of the extent of the alluvial aquifer. There is potential for there to be perched groundwater in the fractured rock above the Great Artesian Basin. This perched groundwater system, if present, would expected to be low yielding. The bore search did not identify any registered bores that are likely to be extracting from this geological formation.

Outside the extent of the alluvial aquifers, the results of the bore search identified that the majority of registered bores extend to depths of greater than 100 meters below ground level. These bores are likely to be extracting from the Great Artesian Basin aquifer along creek lines intercepted by the proposal. These perched shallow groundwater sources would be recharged by rainfall infiltration with groundwater levels expected to rise following rainfall events.

Shallow alluvial sediments of depth of less than 10 to 20 metres below ground level may be intercepted along creek lines intercepted by the proposal. These perched shallow groundwater sources would be recharged by rainfall infiltration with groundwater levels expected to rise following rainfall events.

4.11.3 Groundwater hydrology

Within the alluvial sediments flow direction in the alluvial aquifer would correspond with the flow direction in the major rivers; that is, east to west near the proposal site. Within the shallow alluvial sediments along creek lines that may be intercepted by the proposal, groundwater flow would correspond to flow direction in these creek lines. These creeks generally flow east to west. Based on typical hydraulic conductivities for sand and sand and gravel mixes (as reported by Kruseman and de Ridder 1994), the hydraulic conductivity of the alluvial sediments may vary from one to 100 metres per day.

4.12 Flooding

4.12.1 Culvert locations and levels

Proposed culverts and underbridges would be located as close as practical to the existing locations of culverts and underbridges shown in Figure 2.1.

4.12.2 Flood level analysis

Flooding along the length of the proposal can be impacted by the rainfall and runoff from local catchments and the flooding regime in the regional river systems. Both sources of flooding have been considered in this assessment.

Local catchments

Existing condition flood levels, flood behaviour and impacts were assessed through combined hydrological and hydraulic flood modelling and interpretation of the data. Details of the predicted frequency and locations of overtopping of the existing track can be found in the *ARTC Inland Rail – Narrabri to North Star Hydrology and Flooding Report* (GHD 2017).

Regional catchments

A two dimensional hydraulic analysis was undertaken to assess the flow conditions in the Gwydir and Mehi Rivers and the associated floodplain. This assessment, provided in the Hydrology and Flooding report (GHD 2017), used earlier work undertaken for Moree Plains Shire Council (WRM 2017) to establish and calibrate the hydrologic and hydraulic models. Some modifications were made to the supplied model to include additional structures identified during fieldwork and to modify the terrain representation to reflect better the terrain form that would exist following proposed design forms.

A flood study has been completed, to draft form, for the Namoi River and associated floodplain near Narrabri (WRM 2016). Results from that analysis have been used for the examination of the flood regional flood levels near the southern end of the proposal. The study also considered local catchment flooding that has been compared to results from this study.

4.12.3 Adjacent land impacts

The predicted flood levels for the existing conditions, for the local catchment flooding were examined for a range of design events from the 50 per cent AEP through to an approximation of the Probable Maximum Flood (PMF) event. Within this range, the 0.5 per cent and 0.2 per cent were considered as representing a potential climate change impact.

Flood impacts from the regional flooding have been mapped but not specifically quantified in *ARTC Inland Rail – Narrabri to North Star Hydrology and Flooding Report* (GHD 2017).

Upstream flood effects – local catchment flooding

Flood levels

Flood levels for the existing conditions were assessed using the method summarised in Section 4.12.2.

The assessment indicated that the existing rail line overtops at several locations between Narrabri to North Star on a relatively regular basis, with overtopping being predicted for the 50 per cent AEP design local catchment flood event.

Observations from field interviews with stakeholders confirmed the identified areas of track overtopping and indicated the relative frequency on ballast washout. Available maintenance records from ARTC for historical flood events also confirmed the general areas of washout as being those identified as being at risk from damage.

Flooded areas

The upstream flooded areas have the potential to impact the surface water quality through the mobilisation of pollutants. Changes in the flood affectation area because of the proposal therefore have the potential to impact on regional surface water quality through an increase/decrease in the mobilisation of pollutants. The existing and predicted total areas of upstream flooding are summarised in Table 4.6 for local catchment flooding for flood events up to the adopted approximation for the Probable Maximum Flood (PMF). Table 4.6 shows that the area of inundation would decrease due to the proposal for the majority of flood events.

Table 4.6 Areas of upstream flooding

Design event (% AEP)	Area of inundation – existing conditions (ha)	Area of inundation – proposed conditions (ha)	Change
50	401.8	383.8	- 4.5 %
20	554.1	496.6	- 10.4 %
10	852.8	627.1	-26.5 %
5	1373.0	1009.1	- 26.5 %
2	2093.5	1777.3	- 15.1 %
1	2668.9	2515.3	- 5.8 %
0.5	3031.8	2893.7	- 4.6 %
0.2	3414.9	3465.5	+ 1.5%
PMF	9591.7	9159.6	- 4.5 %

Flood velocities

During events when the existing track does not overtop, the flow velocities on the floodplain would generally be low. Immediately upstream of a culvert on the floodplain there would be a localised increase in velocity to around 1.5 metres per second as the water approaches and enters the respective structure. The upstream velocity in defined watercourses would be larger than that on broad floodplain areas and is predicted to be generally less than two metres per second except in localised areas.

When the track overtops, a progressively larger proportion of the flow would pass over the rail embankment, which would be acting as a weir, than through the individual culverts.

Erosion and stability of watercourses

The predicted low velocities described above are not anticipated to result in watercourse instability.

Upstream flood effects – regional catchment flooding

Flood levels

Flood levels and velocities, hazards for the existing conditions near Moree were assessed in the study reported in the accompanying *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Hydrology and Flooding Assessment* (GHD, 2017).

The assessment indicated that the existing rail line overtops at several locations immediately north of Moree on a relatively regular basis with overtopping being predicted for the 10 per cent AEP design regional catchment flood event.

Observations from field interviews with stakeholders confirmed the identified areas of track overtopping and indicated the relative frequency on ballast washout on the floodplain.

Regional flooding around Narrabri was not predicted to affect the railway line along the length of the proposal (WRM 2016).

Flooded areas

The flooded area immediately adjacent to Moree for the regional flooding has not been specifically quantified.

Flood velocities

During events when the existing track does not overtop, the flow velocities on the floodplain would generally be low. The predicted flow velocities were typically in the range of 0.2 to 0.5 metres per second except in distinct waterways where the velocity rose to be in the range of 0.5 to 1.0 metres per second for the one per cent AEP event.

Erosion and stability of watercourses

The predicted low velocities described above are not anticipated to result in watercourse instability.

Downstream flood effects – local catchment flooding

Flood levels

Design flood levels downstream of the rail corridor have not been assessed. It is likely there will be localised changes in flood levels adjacent to the replacement culverts, due to altered culvert widths and changed flow velocities through the replacement culverts. These changes are expected to be generally confined to within the existing rail corridor due to the scour protection measures that will be installed during construction and that will assist in reducing discharge velocity and promote the spreading of discharges.

Flooded areas

The extent of flooded areas downstream of the rail corridor has not been quantified in this assessment because of the flood levels not being quantified.

Flood velocities

During events when the rail embankment is not being overtopped, the flow downstream of the culverts would generally be confined within or near to the individual watercourses.

At times when the embankment overtops (assuming the ballast does not erode) there would be a localised relatively high velocity of flow down the downstream face of the embankment. Since the embankment is generally not very high it is anticipated that the velocity on the face of the embankment is unlikely to exceed a value of about 2.5 metres per second. This could create an erosion of the downstream face of the embankment.

Historical records show the rail ballast would generally fail and wash out, at least for part of the overtopping length, prior to or about the same time as the overtopping of the rail. Under this circumstance there could be a flow on the downstream formation of the rail line of up to about two metres per second.

Periods of inundation

Watercourses downstream of culverts would be inundated for periods similar to the upstream areas, as no change in flows paths is proposed and additional culvert capacity is included to, as far as practical, offset the now removed track overtopping. Therefore, discharge rates and durations downstream of the culverts is expected to be generally comparable to the existing conditions.

Erosion and stability of watercourses

Watercourses located downstream of many existing culverts exhibit signs of erosion. This is inferred as being the result of progressive stream instability due to the increased watercourse flow velocity, the historical increased frequency of flow and the lengthening of the periods of saturation as compared to that prior to construction of the existing rail corridor.

At most locations, the length of the watercourse instability does not exceed about 50 metres. However, there are some localised areas where the effects extend further downstream of the individual structures. The increased instability at these locations is generally the result of head cut erosion, due to a number of factors, including (but not limited to):

- Concentrated, high velocity discharges from existing undersized culverts with inadequate energy dissipation and erosion and scour protection
- Dispersive soils with little or no vegetation coverage
- Straightening of watercourses to suit adjacent land uses, resulting in more concentrated flows

The proposed culvert upgrades will assist in reducing these factors, by increasing culvert size (i.e. spreading flows out over a wider flow path) and including suitable erosion and scour protection downstream (i.e. reduce flow velocities).

Downstream flood effects – regional catchment flooding

Flood levels

Design flood levels downstream of the rail corridor have not been explicitly assessed, however are not expected to be significantly impacted by the proposal, as outlined in *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Hydrology and Flooding Assessment* (GHD 2017).

A significant amount of flooding was shown for all regional events in excess of the 50 per cent AEP event, the smallest flood event considered. Modelling indicated that a significant area downstream of the rail line would be flooded for the one per cent AEP regional event. These areas are mapped in the hydrology and flooding assessment.

Regional flooding information available for the Narrabri area did not indicate an impact on the proposal area.

Flooded areas

The extent of flooded areas downstream of the rail corridor has not been quantified in this assessment as a result of the flood levels not being quantified.

Flood velocities

Predicted regional flood velocities for the 1 per cent AEP event were generally in the range of 0.2 to 0.5 metres per second on the downstream floodplain and increased to exceed 2 metres per second in small portions of the Gwydir and Mehi rivers.

Periods of inundation

Watercourses downstream of culverts would be inundated for periods similar to the upstream areas.

Erosion and stability of watercourses

The stability of watercourses influenced by regional flooding events is considered to be comparable to those associated with local flooding events.

5. Water quality impact assessment

5.1 Water quality risks

Table 5.1 identifies the main construction phase risks that are likely to impact the water quality adjacent to the proposal or in the receiving waters in an area likely to be directly impacted by the proposal. Table 5.2 provides the risks for the operational phase of the proposal.

Table 5.1 Water quality risks and potential mitigation measures during construction

Risk	Potential water quality impacts	Recommended measures to avoid, mitigate or minimise impacts
Litter dispersion	• Potential for litter to be blown off a construction area or transported off area by runoff and/or floods.	• Provide litter bins within construction compounds and regularly empty bins. • Implement appropriate practices through a CEMP. • Transport all general litter and waste off site to an appropriately licensed waste facility.
Sediment export	• Potential downstream transportation and deposition of eroded material. • Potential increased turbidity or sediment loads in watercourses due to runoff and/or discharge of sediment laden water.	• Develop and implement an appropriate erosion and sediment control plan for the CEMP using erosion and sediment measures described in *Managing Urban Stormwater – Soils and Construction* (Landcom 2008). • Regularly inspect and maintain erosion control measures until vegetation is established or permanent stabilisation measures are established. • Undertake discharge in accordance with the EPL, if required.
Nutrients exported off proposal area.	• Potential for export of nutrient into receiving environments during rainfall events.	• Promptly establish revegetation cover on disturbed areas using erosion and sediment measures described in *Managing Urban Stormwater – Soils and Construction.* • Minimise the application of fertiliser during vegetation reestablishment.
pH change in watercourses.	• Potential for pH to impact downstream waters as a result, primarily, of use of concrete.	• Design culverts to minimise onsite concrete work as much as practical. • Any wastewater and concrete slurry from mobile concrete plants to be captured and recycled or disposed of off-site.

Risk	Potential water quality impacts	Recommended measures to avoid, mitigate or minimise impacts
Oils and grease exported off proposal area.	• Potential transport of spilt oils and grease off site into receiving environments or the groundwater.	• Undertake plant maintenance and refuelling activities within appropriately bunded areas in construction compounds. • Undertake vehicle and equipment maintenance in accordance with manufacturer's specifications. • Use drip trays under machines to collect spills when refuelling in open areas. • No refuelling or equipment maintenances is to be undertaken within 25 m of watercourses. • Minimise onsite storage of oils and greases. • Implement good housekeeping through implementation of the CEMP. • Collect and discharge or dispose of water from vehicle washes in accordance with relevant regulatory requirements.

Table 5.2 Water quality risks and potential mitigation measures during operation

Risk	Potential water quality impacts	Recommended measures to avoid, mitigate or minimise impacts
Formation failing and causing downstream pollution.	• Potential for increased downstream sediment suspended load or bed load with potential localised deposition. • Potential for mobilisation of sediments or soil from upstream of the formation being mobilised and depositing downstream of the formation. • Potential for mobilisation of detained water from upstream and flushing watercourses leading to ecological or erosional impacts either upstream of downstream of the formation. • Potential for erosion downstream of watercourses downstream of new culverts as a result of longer flow durations and more water being directed through culverts.	• Selection of a formation level that is generally above the local catchment 1% AEP level to minimise the frequency of overtopping of the formation and potential wash out of ballast. • Installation of erosion protection measures at culverts to minimise erosion risk. • Minimise potential for creating ongoing moist areas of soil through selection of the proposal formation design. • Undertake regular inspections of formation and complete any required repairs promptly to maintain stability. • Undertake regular inspections of the downstream watercourses as part of the routine alignment inspections and implement remediation measures if required.

Risk	Potential water quality impacts	Recommended measures to avoid, mitigate or minimise impacts
Spills of oils and grease from rolling stock	• Potential for pollution of the soil or water by spilt oils and grease. • Potential spills of hazardous materials or contaminating material from the train.	• Clean up all localised significant spills as promptly as possible in accordance with ARTC operating procedures. • Undertake the transport of dangerous goods and hazardous materials in accordance with relevant legislation.
Dust off carriages	• Potential dust adjacent to the rail corridor and or progressive blockage of voids within ballast.	• Control operational speeds when transporting dusty products.
Maintenance activities	• Potential for mobilisation of sediments or soil from disturbed soil areas created by access and other machinery movements or creation of stockpiles. • Potential for litter to move off proposal corridor. • Potential for metals to be left on soil surface because of cutting or working on metal rails. • Potential for spills of chemicals and other material onto soil surface with possible transportation off the proposal corridor.	• Install temporary bunding around maintenance works area, where practicable. • Removal of all litter and debris from the corridor at the end of each day. • Manage spills of chemicals using standard ARTC operational protocols. • Undertake vehicle and equipment maintenance in accordance with manufacturers' specifications. • Undertake an inspection of the maintenance area on completion of work to ensure area is clean of all litter.

5.1.1 Potential unmitigated water quality impacts

Construction

The impact of unmitigated construction activities on receiving waters could include:

- Increased sediment loads from exposed soil during rainfall events, causing high sediment loads to be washed or deposited into receiving environments, with the potential to:
  - Smother aquatic life and inhibit photosynthesis conditions for aquatic and riparian flora
  - Impact breeding and spawning conditions of aquatic fauna
  - Change water temperature conditions due to reduced light penetration
  - Affect the ecosystems of downstream sensitive watercourses, wetlands and floodplains
  - Increase turbidity levels in receiving environments at locations where water is extracted for any potable purpose
- Increased sediment loads from discharge of sediment-laden water from dewatering of excavations
- Increased sediment loads from construction of the bridges and ancillary works over and adjacent to the major rivers

- Increased levels of nutrients, metals and other pollutants transported via sediment to receiving environments or via discharge of water to watercourses
- Chemicals, oils, grease and petroleum hydrocarbon spills from construction machinery directly polluting receiving environments
- Increased levels of litter from construction activities polluting receiving environments
- Contamination of watercourses because of disturbance of contaminated land
- Spillage of paints, epoxies and herbicides during construction

Given the limited degree to which the proposal would change the study area hydrology, not all impacts listed above are likely to remain an issue for consideration. The paragraphs below explore key water quality impacts in more detail following a review of the proposal and likely impacts.

Impacts of changes to surface water quantity on water quality

Changes to flow regimes, discussed in the *Australian Rail Track Corporation Inland Rail – Narrabri to North Star Hydrology and Flooding Assessment* (GHD 2017) can affect water quality in watercourses by changing the volumes and flow rates of water. A reduction in flow rate and volume of water could lead to stagnation of a watercourse. An increase in flow rate and volume of water could lead to increased erosion and turbidity of a watercourse. These changes may lead to long-term changes in levels of turbidity, nitrogen and phosphorus. These potential impacts relate to the protection of the receiving water quality and may affect the balance of aquatic ecosystems.

Impact on water quality due to construction in watercourses

The construction of in-stream structures in watercourses, such as culverts, may disturb the bed and banks of the watercourse and result in increased erosion, leading to increased volumes of sediment entering and polluting the watercourses.

The construction of bridges in watercourses may disturb the bed and banks of the watercourse and result in increased erosion, leading to increased volumes of sediment entering and polluting the watercourses.

Soil erodibility

Highly erodible soils are found throughout the study area (refer Section 4.6).

In areas where erodibility is moderate or high, if mitigation measures are not established prior to and during construction, sediment could be more easily eroded and transported into watercourses than in areas where soil is not as erodible. Inappropriate management may increase the turbidity of watercourses above the objectives levels (Table 3.1), with a resulting effect on receiving environments namely aquatic plants and fauna. This risk to water quality is to be managed in conjunction with those outlined for managing changes in water quantity and working within watercourses given the interrelationship between the issues.

Impact of earthworks and stockpiling

Construction of large excavations and embankments exceeding a single bench pose an elevated risk to water quality in receiving environments through the increased likelihood of movement of sediment off steep slopes. Mitigation to protect water quality during earthworks is required.

Earthworks materials, mulch and vegetation would be stored in stockpiles. Stockpiling is common practice given the volume of material likely to be moved and its timing cannot typically be done in a manner that facilities transport and final placement.

Stockpiling of earthworks poses a risk to downstream water quality during rainfall if the stockpiles are not managed appropriately. Sediments from the stockpiles could wash into watercourses, increasing levels of turbidity if no controls are in place.

Stockpiling of mulched vegetation from clearing of trees and shrubs poses a risk of tannins leaching into watercourses, and increased loads of organics in watercourses. The discharge of water that is high in tannins may increase the biological oxygen demand (BOD) of the receiving environment, which may in turn result in a decrease in available dissolved oxygen. Once discharged to the environment, tannins may also reduce visibility and light penetration, and change the pH of receiving waters. These impacts may affect aquatic ecosystems in receiving environments.

As discussed in Section 4.11.2 there is the potential to encounter perched groundwater during excavation, particularly near creek lines. The volume of water encountered is likely to be minimal and unlikely to exceed three megalitres per year. Dependant on the volume of water encountered dewatering of excavations may be required. Where discharge to surface water bodies is required, discharge water quality would be compliant with the EPL for the proposal. Potential discharge volumes will be confirmed during the detailed design.

The implementation of mitigation measures during earthworks and stockpiling of both soil and vegetation would be required to protect water quality, and identify and minimise the impacts on surface water and groundwater flow regimes and volumes.

Impact of construction spills on water quality

Chemicals, dangerous goods and hazardous materials that may be used during construction include – but would not be limited to – diesel fuels, oils, greases and lubricants, petrol, paints, epoxies, herbicides, gases (oxyacetylene), cements, and lime. Storage of these materials would be within the construction compounds, whose locations would be subject to the criteria described in Section 6.2.6.

Spills of these materials could occur during a storm event or by accident and the consequences could be detrimental to aquatic ecosystems if washed into a watercourse.

The quantities of chemicals, hazardous goods and dangerous materials required during construction are not expected to pose a significant risk, although mitigation would still be required.

The use of mobile concrete batching plants during construction could also result in the discharge of highly alkaline wastewater to surrounding watercourses if not controlled properly. The main sources of wastewater would be:

- Contaminated stormwater runoff
- Agitator washout
- Concrete batching area
- Slump stand
- Truck washing

The location of the plants would be wholly within the proposal site and would be subject to the same criteria as per that for the construction compounds.

Use of vehicle washdown areas could also result in the discharge of wastewater containing oil and petroleum hydrocarbons if not managed properly. All wastewater would need to be captured and recycled or disposed of off-site at an appropriately licensed facility.

Impacts of surface water on groundwater

In general, construction activities could result in changes to relative groundwater levels and potentially to groundwater quality. That impact is anticipated to be minimal for this proposal as excavation depths to install culverts will be very limited below the existing natural surface level. Potential risks to groundwater quality from surface water during construction include:

- Contamination by hydrocarbons from accidental fuel and chemical spills during construction activities, refuelling or through storage facilities.
- Contamination from contaminants in runoff.
- Intersection of the water table during excavation – this is considered unlikely given the depth to groundwater.
- Infiltration of surface water to groundwater sources. The infiltration process is generally effective in filtering polluting particles and sediment. As such, the risk of contamination of groundwater from any pollutants bound in particulate form in the surface water, such as heavy metals, is generally low.

Insoluble pollutants such as insoluble hydrocarbons (oils, tars, petroleum products) are unlikely to penetrate to the water table given the depth to groundwater. However, mitigation would still be required.

Soluble pollutants, such as pH altering solutes, salts and nitrates, as well as soluble hydrocarbons, may infiltrate through soils potentially into the groundwater system. Under certain pH conditions, metals (natural and anthropogenic) may also become soluble and could infiltrate groundwater. Mitigation measures are required in these circumstances.

Operation

Potential water quality impacts during operation could occur because of changes to hydrology or contamination of runoff.

During the operation of the proposal, the rail formation would have been capped with ballast, the embankments landscaped, the impacted watercourses would have been rehabilitated and the exposed soil would be revegetated thereby minimising the residual risk of soil erosion and transport of eroded sediments to watercourses.

Surface water

During the operational stage, there is a risk to surface water due to the release of pollutants from accidental spills of petroleum, chemicals or other hazardous materials as a result of leaks from vehicles, surface run-off from tracks and rail maintenance or rail accidents. Spills of this nature could pollute receiving environments if unmitigated. As the likelihood of spills is low, specific mitigation measures have not been prescribed. Any clean up of a spill or derailment would be completed in accordance with ARTC operational procedures.

During operation, surface water runoff would be managed through a drainage system that connects to cross drainage infrastructure at existing drainage lines and waterways. The drainage system would include measures such as scour protection at culvert outlets to minimise the potential for scouring and erosion. Where appropriate, culvert outlets would be lined to minimise scouring. This would minimise the potential for water quality impacts during operation.

Groundwater

No operational impacts are expected on the quality of groundwater during operation or maintenance of the proposal. Any material from wear or maintenance of the rail and rolling stock is expected to be retained on the soil surface or within the ballast and not be transported into the groundwater. Any chemical spill would be cleaned up as promptly as practical and would not be expected to migrate any significant depth into the soil.

5.2 Water quality objectives

As described above, if inadequately managed, the proposal has the potential to introduce the following pollutants to surrounding watercourses:

- Nitrogen and phosphorous – due to use of pesticides and herbicides for weed control during construction and operation (maintenance)
- Sediment laden run-off increasing turbidity– due to soil erosion and runoff during construction and operation
- Chemicals, oils, grease and petroleum hydrocarbons – due to use of a vehicle washdown area during construction and due to leaks and spills during construction and operation
- Concrete slurry and wastewater due to operation of mobile concrete batching plants

The key water quality objective is to protect downstream environments from the potential impacts of surface runoff and discharge during construction and operation. This is consistent with the ANZECC (2000) guidelines and objectives for water quality. The water quality objectives and their relevance to the proposal are defined in Table 3.1 and again in Table 5.3 for the Namoi, Gwydir and Macintyre (Border Rivers) river systems (they are the same for all three systems). Table 5.3 also includes an assessment of the proposal against water quality objectives for the Gwydir, Namoi and Border River catchments to determine how the proposal would be constructed and operated to either meet or improve the water quality objectives.

Table 5.3 Water quality objectives and relevance to proposal

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria	Relevance to the proposal
Aquatic ecosystems					
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorous	50 µg/L			Standard erosion and sedimentation control measures would be implemented during construction and works would comply with the construction EPL and ARTC's existing EPL and standard procedures for the operation of the proposal. This would result in the proposal having minimal impacts on surface water receivers. Vegetation removal within riparian zones would be undertaken in accordance with a biodiversity management plan, resulting in revegetation to an equivalent state.
	Total nitrogen	500 µg/L			
	Chlorophyll-a	5 µg/L			
	Turbidity	6–50 NTU			
	Salinity (Electrical conductivity) (µS/cm)	125–2200 µS/cm			
	Dissolved oxygen	85–110%			
	pH	6.5–8.5			
Visual amenity					
Aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.			Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Visual inspections of the aesthetic quality of waters would be undertaken during construction work within waterbodies.
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.			

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria	Relevance to the proposal
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.			Use of herbicides and pesticides during construction work would be undertaken in accordance with the CEMP and best guidance. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, which would improve water quality. Standard erosion and sedimentation control measures would be implemented during construction and works would comply with the construction EPL and ARTC's existing EPL and standard procedures for the operation of the proposal.
Secondary contact recreation					
Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms	Median bacterial content in fresh and marine waters of <1000 faecal coliforms per 100 mL, with 4 out of 5 samples <4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).			Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction and operation of the proposal would comply with the CEMP and construction EPL for the proposal and ARTC's existing EPL and standard operating procedures. This would result in the proposal having minimal impacts on surface water receivers. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, which would improve water quality. The immediate receiving watercourses are not currently used for secondary contact recreation, as the majority of watercourses within the proposal area are ephemeral. The discharge water quality would enable the potential for secondary contact recreation to be undertaken downstream of the proposal.
	Enterococci	Enterococci Median bacterial content in fresh and marine waters of <230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL).			
	Algae & blue-green algae	<15 000 cells/mL.			
	Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.			
	Surface films	Use visual amenity guidelines.			

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria	Relevance to the proposal
Primary contact recreation					
Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed	Turbidity	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (about 6 NTU).			Construction works would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction and operation of the proposal would comply with the CEMP and construction EPL for the proposal and ARTC's existing EPL and standard operating procedures This would result in the proposal having minimal impacts on surface water receivers. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, which would improve water quality. The immediate receiving watercourses are not currently used for primary contact recreation, as the majority of watercourses within the proposal area are ephemeral. The maintaining of current water quality within the proposal area would enable the potential for primary contact recreation to be undertaken downstream of the proposal.
	Faecal coliforms	ANZECC 2000 Guidelines recommend: Median over bathing season of <150 faecal coliforms per 100 mL, with 4 out of 5 samples <600/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).			
	Enterococci	ANZECC 2000 Guidelines recommend: Median over bathing season of <35 enterococci per 100 mL (maximum number in any one sample: 60–100 organisms/100 mL).			
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note it is not necessary to analyse water for these pathogens unless temperature is greater than 24 degrees Celsius).			
	Algae & blue-green algae	<15,000 cells/mL			
	Nuisance organisms	Use visual amenity guidelines.			
	pH	5.0–9.0			
	Temperature	15°–35°C for prolonged exposure.			
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in tables 5.2.3 and 5.2.4 of the ANZECC 2000 Guidelines 2000.			
	Visual clarity and colour	Use visual amenity guidelines.			

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria	Relevance to the proposal
Livestock water supply					
Protecting water quality to maximise the production of healthy livestock	Algae & blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11,500 cells/mL and/or concentrations of microcystins exceed 2.3 µg/L expressed as microcystin-LR toxicity equivalents.			Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction and operation of the proposal would comply with the CEMP and construction EPL for the proposal and ARTC's existing EPL and standard operating procedures This would result in the proposal having minimal impacts on surface water receivers. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, resulting in an improvement to water quality. The potential for waterbodies within the proposal area to be used for livestock water supply is considered low.
	Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids in drinking water for livestock are given in table 4.3.1 (ANZECC 2000 Guidelines).			
	Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).			
	Chemical contaminants	Refer to Table 4.3.2 (ANZECC 2000 Guidelines) for heavy metals and metalloids in livestock drinking water. Refer to Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.			
Irrigation water supply					
Protecting the quality of waters applied to crops and pasture	Algae & blue-green algae	Should not be visible. No more than low algal levels are desired to protect irrigation equipment.			Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction and operation of the proposal would comply with the construction EPL for the proposal and ARTC's existing environment protection licence and standard operating procedures. This would result in the proposal having minimal impacts on surface water receivers. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, which would improve water quality.
	Salinity (electrical conductivity)	To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered including irrigation water quality, soil properties, plant salt tolerance, climate, landscape and water and soil management. For more information, refer to Chapter 4.2.4 of ANZECC 2000 Guidelines.			
	Thermotolerant coliforms (faecal coliforms)	Trigger values for thermotolerant coliforms in irrigation water used for food and non-food crops are provided in table 4.2.2 of the ANZECC Guidelines.			
	Heavy metals and metalloids	Long term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in table 4.2.10 of the ANZECC 2000 Guidelines.			

Water quality objective	Indicator	Gwydir River Trigger value or criteria	Namoi River Trigger value or criteria	Border Rivers Trigger value or criteria	Relevance to the proposal
Homestead water supply					
Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing	Blue-green algae	Recommend twice weekly inspections during danger period for storages with history of algal blooms. No guideline values are set for cyanobacteria in drinking water. In water storages, counts of <1000 algal cells/mL are of no concern. >500 algal cells/mL – increase monitoring. >2000 algal cells/mL – immediate action indicated; seek expert advice. >6500 algal cells/mL – seek advice from health authority.			Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction and operation of the proposal would comply with the CEMP and construction EPL for the proposal and ARTC's existing EPL and standard operating procedures This would result in the proposal having minimal impacts on surface water receivers. There are drainage structures within the proposal area that are not operating effectively, causing increased sedimentation of adjacent watercourses. These structures would be replaced as part of the proposal, which would improve water quality. Based on the ephemeral nature of the majority of watercourses within the vicinity of the proposal it is considered unlikely that surface water would be extracted for domestic use in homesteads, however through undertaking works in accordance with standard construction practices the EPLs, and ARTC's existing standard operating procedures, the current water quality would be maintained if not improved.
	Turbidity	5 NTU; <1 NTU desirable for effective disinfection; >1 NTU may shield some micro-organisms from disinfection. (see supporting information).			
	Total dissolved solids	<500 mg/L is regarded as good quality drinking water based on taste. 500–1000 mg/L is acceptable based on taste. >1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste.			
	Faecal coliforms	0 faecal coliforms per 100 mL (0/100 mL). If micro-organisms are detected in water, advice should be sought from the relevant health authority. See also the Guidelines for Microbiological Quality.			
	pH	6.5–8.5			
	Chemical contaminants	See Guidelines for Inorganic Chemicals in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004).			

As described in Section 4.8 water quality information (SKM 2011) shows that the existing water quality is poor and generally does not meet the water quality objectives provided in Table 5.3. The poor quality is likely to reflect existing soil conditions and agricultural land use practices (described in Sections 4.2 and 0).

The proposal constitutes only a small component of the Gwydir, Namoi and Border River catchments, and progress towards meeting the NSW Water Quality Objectives depends on activities in the catchment as a whole. Water quality impacts would be generally limited to the construction phase and would be short-term only.

As described in Table 5.3 construction and operation would be undertaken in accordance with the management measures provided in Sections 6.2 and 6.3, which would minimise the potential for the proposal to reduce the quality of water in the surrounding watercourses. Discharge would be undertaken in accordance with the relevant EPLs meaning also that any discharge water would meet the water quality objectives provided in Table 5.3 and would be of better quality than that within the surrounding watercourses.

Additionally, the proposal (particularly the proposed replacement of culverts and raising of track formation to greater than the level of the one per cent AEP catchment flood event) would mean that flow in watercourses is generally maintained and, with suitable erosion and scour protection measures, erosion potential downstream from culverts is generally reduced. Implementing the proposed design control measures for the proposal would assist in maintaining existing water quality in downstream areas. They would also not prevent or hinder the development or implementation of any future strategies, in other parts of the catchments, that may assist in meeting overall water quality objectives for the catchments over the long term.

Further details of the beneficial impacts associated with the proposed design control measures is provided in Section 6.1.

6. Proposed mitigation measures and benefits

6.1 Design control measures

6.1.1 Selected formation level and formation profile

The proposed formation level has been selected to make the new rail level generally flood free one per cent AEP local catchment event, except at a limited number of level crossings.

The design of the proposed formation level has also considered the volume of materials along the track, the complexity of excavation along the track and the potential for reuse of excavated materials to minimise the need for material importation to create the new formation.

Benefits

This measure would:

- Minimise the volume of waste material created by the formation construction
- Minimise the need for importation of new fill material
- Decrease the area of flood inundation upstream for the majority of flood events, when compared to the existing conditions, hence decreasing the potential for mobilisation of pollutants (refer to Section 4.12.3)

6.1.2 Culvert locations

Culverts would be located at or adjacent to existing structures to avoid the creation of new flow paths across the rail line.

Benefits

This measure would:

- Prevent the formation of significant new flow paths and potential soil erosion areas downstream of the existing rail corridor, thereby reducing the potential for increased sedimentation of surrounding waterways.
- Minimise excavation for new structures thereby reducing the potential for increased sedimentation of surrounding waterways.
- Restrict the potential for new scour areas, and the potential for soil erosion, and significantly reduce the extent of existing erosion areas.
- Maintain the ecological and drainage functionality of existing watercourses downstream of the proposal.

Residual impacts of measure against water quality objectives

While this measure would have benefits, it would require the implementation of other design measures to restrict the potential for erosion at culvert locations.

6.1.3 Culvert form

The proposed culvert form has been selected to facilitate efficient construction and minimising impacts on watercourses. Culverts would be pre-cast off-site, and installed along the proposal site as the track upgrading works progress. The only onsite concrete usage and placement would be for the aprons and headwalls at each culvert structure.

Benefits

This measure would:

- Speed the culvert placement process as it would involve less site excavation and foundation preparation, which would minimise the potential for runoff and, erosion hazards at each culvert site.
- Speed the culvert placement process in watercourses, thereby reducing the disturbance time and associated potential for increased turbidity in watercourses.
- Minimise the amount of concrete to be placed on site, thereby minimising the potential impacts from changes in pH of water from the recently placed concrete.
- Reduce the amount of water required for concreting

Residual impacts of measure against water quality objectives

While this measure would have benefits, it would require the implementation of other design measures to further enhance the benefits from the measure. In addition, there would still be a short term minimal change in the pH of water passing through the culverts while the cast in-situ concrete treatments cure.

To minimise downstream erosion and sedimentation through reduced site disturbance periods there would be a need to implement this measure through the required CEMP.

6.1.4 Culvert levels and size

The culvert invert levels have been selected to match the existing invert levels to mitigate the creation of blockages to flow and fish passage (during times of stream flow) at the culverts. The culvert sizes have also been selected to minimise the increase in flow velocity through the culverts.

Benefits

This measure would:

- Facilitate fish passage through the structure during times of flow.
- Minimise the risk of downstream erosion by matching the level to the downstream soil level and avoiding a level drop and associated energy loss.
- Minimise the flow velocity through the structures as much as practical while having an appropriate number of culvert barrels.

Residual impacts of measure against water quality objectives

A minimal increase in flow velocity through some structures would occur with the predicted increase not exceeding 0.5 metres per second.

6.1.5 Culvert erosion control

A rock energy dissipation layer (a stabilisation blanket) would be provided across the full width of the culverts to reduce the flow velocity off the concrete apron and prior to flowing over the downstream soil. This would reduce the flow velocity of water exiting the culverts prior to discharging onto the ground surface, and thereby minimise potential downstream soil erosion.

Benefits

This measure would:

- Stabilise the soil and reduce the amount and extent of downstream soil erosion.
- Improve the transition from the flat concrete apron to the more irregular profile of the ground surface.
- Provide a rock blanket, which would provide a location for the trapping of some of the sediment load and would provide a relatively stable area for seed germination and vegetation establishment adjacent to the apron.

In addition, the area of placement of the rock would be disturbed during construction, and the rock placement would provide quick stabilisation of the immediate area against erosion.

Residual impacts of measure against water quality objectives

This control measure would reduce, but not eliminate, the potential for downstream erosion.

6.1.6 Watercourses downstream of culverts

The proposal would subject the reaches of watercourses downstream of some culverts to increased flow rates, flow volumes and flow velocities. This would occur when a replacement culvert, due to its more efficient conveyance of water, locally increases the velocity relative to that for the existing culvert or where the replacement culvert is wider than the existing culvert. Since the rail is not intended to overtop except at a minimal number of level crossing locations, there will for all runoff events be an increase in the flow volume, relative to that which would occur for the same rainfall event under existing conditions, passing through each culvert for flood events. These effects would occur as a result of:

- Minimisation of the amount of rail overtopping for the local catchment runoff events, except at a limited number of level crossings, for events smaller than the one per cent AEP local catchment event. This effect directs an increased total volume of water through the collective group of culverts.
- An increased flooding level at some upstream locations, with a corresponding increase in the duration of flow through the culverts. This effect would not be uniform with the magnitude of the flood events since, for small flood events, some culverts would drain more quickly than currently, but for the large events, the increased runoff volume passing through the culverts would result in a longer flow duration through the culverts.
- The provision of concrete culverts everywhere, to replace bridges with natural surface inverts or bridges with many piers, which would provide more efficient flow conveyance through the culverts and increase the flow velocity in the structures.

Erosion protection would be provided downstream of the culvert aprons, with culvert widths generally increased to allow discharges to occur over a wider area (compared to the existing culvert width). Local works to improve the connection between the upgraded culvert and the downstream watercourse may be required to improve local watercourse stability, with consideration of the transition from the small incised channels to the adjacent floodplain.

Benefits

The erosion protection measures would:

- Mitigate the potential erosive effect to some extent; to achieve an enhanced protection it would be necessary to extend the rock protection further toward the boundary of the existing rail corridor.
- Reduce the increase in flow velocity within the rail corridor to 0.5 metres per second, which would reduce the effect on adjacent private property.

During the construction phase, each individual structure would be examined to provide a site-specific extent of erosion protection to further mitigate this potential impact.

Residual impacts of measure

The assessment has indicated a residual erosion risk at about 15 culvert locations (of 228 culverts assessed) for a distance of about 100 metres from the extent of the rock protection and after that distance, the risk is predicted to become minimal. The predicted widening of the small incised watercourses has been assessed at a maximum of about 0.3 times the watercourse width when the watercourses are narrower than about 10 metres. The predicted potential widening then decreases inversely with the width of the watercourse, to be minimal when the watercourse width exceeds about 20 metres. As noted in Section 4.12.3, many of these watercourses have been previously impacted by erosion and scouring as a result of a number of factors. The proposed works would, in part, address some of these factors by improving scour protection measures downstream of the culverts.

The maximum widening is predicted to occur over a period of about two to 10 significant floods.

6.2 Construction phase control measures

6.2.1 Development and implementation of CEMP

A CEMP would be developed and implemented for the construction of the proposal. A component of the CEMP would be a Soil and Water Management Plan (SWMP; refer to Section 6.2.5).

As part of the CEMP, an Emergency Spill Plan or Emergency Response Plan would be developed. This would include measures to avoid spills of fuels, chemicals and fluids into any watercourses. The storage, handling and use of the materials would be undertaken in accordance with the *Occupational Health and Safety Act 2000* and WorkCover’s Storage and Handling of Dangerous Goods Code of Practice (WorkCover 2005).

The CEMP would include consideration of specific measures, such as:

- Selecting and implementing appropriate erosion and sediment control measures – the SWMP measures would be consistent with requirements of the *Managing Urban Stormwater: Soils and Construction Manual* (Landcom 2008). It is anticipated that construction would include installation and maintenance of silt fences together with other works described in the sections below. The design standard for erosion protection using silt fences would be the ten year AEP event while, should a sediment basin be applied, it would have a design criteria based upon the 5 day 80th percentile rainfall.
- Procedures and requirements for minimising the disturbance of watercourse beds during bridge construction and demolition of the existing bridges.
- Procedures for minimising waste and litter – the recycling of embankment materials would minimise the amount of excess spoil that needs stockpiling, storing or export off site, and minimise the amount of imported fill material required. Any litter would be exported off site and disposed of in an appropriate manner.
- Procedures for minimising the storage of liquids on site and uncontrolled onsite refuelling of machines (refer Section 6.2.2).

6.2.2 Spill containment

Storing and accidental spill of materials or liquids within construction compounds would be controlled by:

- Any stored liquids would be located within an appropriately sized container in a designated location within the construction compounds to trap any spill from the primary storage container.
- Machinery refuelling would occur away from water, within an area where spilt fuel can be contained and promptly cleaned up. Whenever possible the refuelling would be undertaken within a construction compound.
- Providing emergency spill containment packs on trucks traversing the proposal site.
- Providing staff training on spill management.

Benefits

These measures would:

- Avoid uncontrolled spills of stored chemicals onto and into the soil, surface water or groundwater.
- Minimise the potential for accidental spills of fuels and chemicals onto and into the soil, surface water or groundwater.
- Minimise the potential for adverse water quality impacts.

Residual impacts of measure against water quality objectives

While this potential impact on water quality cannot be eliminated, the proposed measures would minimise the potential for adverse water quality impacts as much as practical.

6.2.3 Culverts

All culverts will be constructed in a manner that minimises, as far as practical, the potential water quality impacts on the waterway. This would be achieved by:

- Restricting site disturbance for clearing and pier or abutment construction.
- Minimise the construction activities that may block the watercourse and prevent fish passage during times of flow or flood.
- Undertaking works within waterways in accordance with the NSW Office of Water's guidelines for controlled activities.

Benefits

These measures would:

- Restrict the amount of disturbed areas and the potential for soil erosion along with the transportation of material away from the proposal site as existing water pollution.
- Maintain the aquatic environment and fish habitat.

6.2.4 Soil and water management plan

The SWMP is recommended to include the following items relevant to water quality:

- Erosion and Sediment Control Plans for all stages of construction detailing the following:
  - Erosion and sediment control measures required before clearing and grubbing of the site.
  - Appropriate controls to be implemented prior to the removal of topsoil and start of earthworks for construction of the proposal within the catchment area of each structure.
  - Methods to manage upstream water so it does not lead to likely erosion of the construction areas.
  - Scour protection measures for haul roads and access tracks when these are an erosion hazard due to their steepness, soil erodibility or potential for concentrating runoff flow.
  - Methods to remove trees in intermittent watercourses, leaving grasses and small understory species undisturbed wherever possible.
  - Methods to stabilise temporary drains.
  - Methods to minimise erosion of all exposed areas, including (but not limited to) large batters and excavations.
- At-source erosion controls (such as check dams).
- Sedimentation basin construction and management.
- Protection of watercourses.
- Management of stockpiles.
- Water quality monitoring and checklists.
- Detailed consideration of measures to prevent, where possible, or minimise any water quality impacts.

Construction activities are required to incorporate management practices that minimise erosion potential and associated water quality risks. Recommended construction management requirements are:

- Minimising exposure of topsoil
- Minimising the extent of disturbed areas
- Minimising stockpiling
- Minimising the lengths of slopes using diversion drains to reduce water velocity over disturbed areas
- Installation of physical controls immediately prior to the commencement of other immediately adjacent works, including cross drainage to convey clean water around or through construction areas
- Revegetation or disturbed areas using methods such as spray mulching or the use of temporary cover crops as soon as works are completed

Specific measures and procedures for works within watercourses, such as the use of silt barriers and temporary creek diversions, would be implemented. Construction sequencing and temporary diversions of water during construction should be developed and designed to consider the impact of change on flow regimes and to minimise these changes throughout construction.

Physical controls that would be used to reduce the risk of water quality degradation due to erosion and sedimentation during construction could include:

- Sediment fences and filters to intercept and filter small volumes of non-concentrated construction runoff
- Rock check dams that are built across a swale or diversion channel to reduce the velocity of flow in the channel, thus reducing erosion of the channel bed and trapping sediment
- Level spreaders to convert erosive, concentrated flow into sheet flow
- Onsite diversion drains to collect runoff and direct it away from unstable and/or exposed soil to treatment facilities
- Offsite diversion drains to collect clean runoff from upstream of the proposal site and divert it around or through without it mixing with construction runoff
- Sedimentation basins to capture sediment and associated pollutants in construction runoff
- Specific measures and procedures for works within watercourses such as the use of silt barriers and temporary creek diversions
- Spill management procedures

The SWMP would include consideration of specific measures including:

- Selecting and implementing appropriate erosion and sediment control measures – the measures would be consistent with requirements of the *Managing Urban Stormwater: Soils and Construction Manual* (Landcom 2008). It is anticipated that the works would include installation and maintenance of silt fences together with other works described below.
- Protection of waterways from sediment plumes during bridge construction and bridge demolition.

- Restricting site access – access to the proposal site would be controlled to minimise the potential for soil disturbance and potential soil erosion.
- Placing any excess material stockpiles or temporary stockpiles in areas away from potential water flow – this would be done to avoid potential erosion of the stockpiles.
- Stabilising disturbed areas – disturbed soils would be revegetated and stabilised as soon as practical after completion of works in localised areas to minimise the length of the risk to surface erosion resulting from either wind or water.
- Stabilising access tracks with gravel, or equivalent – stabilisation of heavily trafficked access tracks would reduce the potential for the tracks to become dusty and subject to potential wind or water erosion.
- Dust control – areas that are becoming dusty would be watered, as required, to minimise dust generation and airborne pollution.

Benefits

These measures would:

- Minimise the potential for soil erosion from the proposal area and transportation of the sediment to downstream areas
- Minimise the creation of dust and airborne pollution
- Minimise the potential for litter and trash to be exported off site in an uncontrolled manner
- Minimise the potential for adverse effects of liquid spills

Residual impacts of measure against water quality objectives

Implementation of the CEMP is intended, in part, to minimise the areas of soil disturbance, the length of the disturbance and thus the potential for sediment export off a construction area. Even with the development, installation and maintenance it is possible for pollutant export during a significant rain or flood event.

The proposed measures are intended to mitigate, as much as practical, adverse impacts. Notwithstanding, there is the potential for some export of sediments and other pollutants off the proposal. The proposed measures are expected, except in a large flood event, to create a lesser sediment concentration in any construction area runoff that then off the adjacent rural land uses.

Implementation of the CEMP will assist in minimising adverse impacts on water quality in the watercourses.

6.2.5 Vehicle washdown and concrete batching plants

The location for any vehicle washdown facilities will be determined during the detailed design works for the proposal. All washdown facilities would be expected to be located within the construction compounds. The location of concrete batching plants and compounds would meet the criteria outlined in Section 6.2.6.

All wastewater from vehicle washdown areas and concrete batching plants would be captured and would either be disposed of to an appropriately licensed facility or treated prior to discharge to surface water bodies. All discharge water would comply with the water quality objectives provided in Table 5.3 and the relevant EPL requirements.

Benefits

Capturing all wastewater from these activities and discharging in accordance with relevant requirements would ensure the water quality objectives of surrounding watercourses are maintained or improved.

6.2.6 Construction compounds and mobile concrete batching plants

The location of compounds and mobile concrete batching plants would be wholly within the proposal site and would continue to be determined considering many criteria including the following:

- Being at least 50 metres from watercourses
- Where no or only minor clearing would be required, and not within areas identified as threatened communities or species habitat
- Having no significant impacts to utilities
- Being at least one kilometre from the nearest residence or other noise sensitive receiver where possible
- Not being on or near a site with known Aboriginal or non-Aboriginal heritage value
- Being relatively flat land

Benefits

Consideration of these criteria for the selection of compound sites and mobile concrete batching plants would minimise the probability of them being located in areas that could potentially flood and hence minimise the probability of the construction compounds and plants affecting the adjacent water quality for both surface water and groundwater.

6.2.7 Minimising construction footprint

The construction footprint for the proposal would be minimised through:

- Restricting vehicular access routes from public roads to the proposal area
- Planning works prior to construction, such that the length of time excavations remain open or material remains stockpiled is limited

Benefits

These measures would restrict the total area of soil disturbance as much as practical and minimise potential adverse water quality impacts as required by the water quality objectives. Minimisation of site disturbance is consistent with accepted construction practice.

Residual impacts of measure against water quality objectives

The above approach of minimising construction site areas restricts the potential for adverse water quality Impact. In the case of a large rainfall event, occurring during the construction period there may still be adverse impacts but these would be significantly reduced, relative to their possible extent without the minimisation of the construction area.

6.3 Operational phase control measures

6.3.1 Controlling train speed

Trains would be operated at or below the nominated design speed. Operation of trains at a speed greater than the design value could increase the potential for possible train derailments.

A derailment could lead to the spillage of material onto land adjacent to the rail corridor. While ARTC would undertake a site clean up to remove material spilt from the carriages, there would be the possibility of some residual small amounts of material escaping the clean up process and that material remaining on the land.

Benefits

Operating the trains so that they travel below the design speed would minimise the potential for accidental derailments and cargo spills.

The avoidance of derailments and thus spills would remove the potential for spilt material to be accidentally left on the land adjacent to the rail corridor following a clean up.

6.3.2 Track inspections after significant flood events

Track inspections would be in accordance with existing ARTC operating procedures. An inspection would be undertaken after each significant flood event, leading to a track shut down, and prior to the track reopening. These inspections would identify any areas of fault along the corridor.

Benefits of measure

This measure would reduce the potential for train damage and subsequent pollution and allow the controlled maintenance of the rail line.

7. Proposed monitoring program

Water quality monitoring is generally recommended to provide assurance of compliance with regulatory requirements and to immediately detect any environmental degradation during construction. The monitoring program would form part of the CEMP.

Because of the ephemeral nature of most watercourses it would not be practical to implement a routine monitoring program on all watercourses during construction. Instead, the sampling program will focus on the perennial watercourses crossed by the proposal site (Mehi and Gwydir rivers) and an opportunistic event-based sampling program is recommended for the ephemeral watercourses.

7.1.1 Objectives

The water quality objectives should be established prior to construction and following input from relevant agencies including, but not limited to, the NSW EPA and NSW DPI. The water quality criteria and trigger levels would be consistent with those listed in Table 5.3.

It is recommended that the objective for water quality is to cause no net change to receiving watercourses quality as a result of construction or operation of the proposal. Given this, monitoring should be undertaken pre, during and post construction and operation.

The objectives of pre-construction monitoring would be to:

- Identify parameters for monitoring during construction
- Determine the indicative existing water quality

The objectives of monitoring during construction would be to:

- Identify if any water quality problems are occurring as a result of construction activities
- Demonstrate compliance with legal and other monitoring requirements including the EPL

The objectives of operational phase monitoring would be to:

- Assess and manage impacts on the receiving waters as the proposal site stabilises
- Assist in determining when the proposal site has stabilising
- Identify water quality conditions following development

The surface monitoring framework would be developed in consultation with DPI (Water) and the EPA, however recommendations are provided below.

7.1.2 Sampling sites and regime

Sampling sites would be selected based on the agreed objectives. Potential locations include any perennial t watercourse that may potentially be impacted by the proposal, named watercourses (permanent and perennial), key fish habitats, and known and potential habitats of threatened ecological communities.

The construction phase has the highest potential to impact water quality, particularly as a result of rainfall events, where construction activities may result in the transport of sediment and particulates through runoff into receiving watercourses.

As part of the development of the CEMP there would be a risk assessment completed to identify the areas of greatest environmental risk when considering the location of construction compounds, specific activity risks and the forecast weather conditions. The risk assessment may focus water quality sampling on specific areas or identify more appropriate sampling frequencies than identified in the generic sampling program given below.

In advance of undertaking the risk assessment, it is intended that upstream and downstream water quality sampling should be undertaken in waterways during the construction phase at a particular culvert location within 24 hours of a rainfall event, when there is surface water flow, to support the effectiveness of implementation of the identified construction management practices. The surface water quality sampling frequency recommended for the proposal is summarised in Table 7.1. If the watercourse continually has water, sampling should be undertaken once each two weeks during the adjacent construction phase.

Table 7.1 Recommended water quality sampling frequency

Proposal phase	Sampling frequency per watercourse
Pre-construction	Minimum of three data sets (assuming rainfall generates runoff) for flowing watercourses within 500 m of rail corridor. Samples are to be taken within 24 hours of rainfall that induces a runoff event.
Construction	Minimum two samples per month for each sampling point when there is flow present. More frequent sampling (minimum daily) is recommended when works are be undertaken within the channel of a watercourse.

Parameters

It is recommended that the indicators provided in Table 7.2 be monitored.

As per AS/NZS 5667.1 1998 Water Quality Sampling Guidance, laboratory analysis is required to be undertaken by those registered with the National Association of Testing Authorities (NATA).

Table 7.2 Recommended water quality sampling parameters

Analyte	ANZECC/ARMCANZ (2000) triggers	Construction Phase
pH	6.5 – 8.5 [A]	Yes, when flow is occurring
Total Suspended Solids (TSS)		Yes, when flow is occurring
Oils and grease	No visible oils or sheen in discharge water	Yes, when flow is occurring
Electrical conductivity (EC)	125–2200 µS/cm [A]	Yes, when flow is occurring
Dissolved Oxygen (DO)	85–110% saturation [A]	Yes, when flow is occurring
Total Phosphorous (TP)	50 µg/L [A]	-
Total Nitrogen (TN)	500 µg/L [A]	-

[A] aquatic ecosystems (ANZECC /ARMCANZ 2000) in consultation with DPI (Water) and the EPA.

8. Conclusions

The proposal site is located within the Namoi, Gwydir and a small portion of the Macintyre river catchments and crosses several named watercourses. The majority of the watercourses are ephemeral, with the exception of the Namoi, Gwydir and Mehi Rivers and there is a minimal amount of water quality data to describe the existing conditions along the corridor. Publically available information indicated water quality within the Namoi River and Gwydir River catchments typically exceed guideline values for turbidity, salinity, pH, total nitrogen and phosphorus. The poor quality is likely to reflect existing soil conditions and agricultural land use practices within the study area.

Available data would need to be supplemented by pre construction monitoring of perennial watercourses (Namoi, Gwydir and Mehi Rivers) to create a reliable understanding of baseline water quality. A water quality monitoring program is recommended to effectively identify the existing water quality conditions.

Environmentally sensitive receiving environments are unlikely to be impacted by the proposal if appropriate water quality measures are implemented during the design and construction phases. Implementation of water quality measures would also minimise impacts to surface water quality within the study area.

A range of mitigation measures are proposed to protect the water quality of surface waters and groundwater. With the implementation of these measures, the water quality of surface waters and groundwater would be protected in accordance with the water quality objectives for the proposal. These impact mitigation measures are summarised below.

8.1 Design phase

The impact mitigation measures included in the design of the proposal include:

- Selecting the formation level and formation profile to achieve the targeted flood immunity while minimising adverse flooding impacts, maximising the reuse of excavated material and reducing adverse water quality impacts of the construction.
- Locating culverts under the rail line at locations generally consistent with the existing structure locations and consistent with the existing watercourse invert level to maximise the potential fish passage, minimise potential adverse water quality impacts and maintain existing ecological function.
- Selecting a culvert form to minimise onsite concrete work and the construction phase, which would minimise the potential water quality risks.
- Providing rock riprap immediately downstream of culverts to provide protection against erosion adjacent to the culvert aprons and in the watercourse through the downstream properties. While this measure has been considered in the design there is predicted to be a residual erosion risk downstream of culverts and this risk would need to be considered for each site to achieve appropriate site-specific designs.
- Using precast culvert segments, where practical, to minimise construction over watercourses that contain water at the time of construction.

8.2 Construction phase

The impact mitigation measures during the construction phase include:

- Preparing CEMPs to address site management measures so that adverse water quality impacts are managed. The CEMP would consider a broad range of issues that can help to meet the water quality objectives, including correct storage, handling and disposal of hazardous and dangerous good, management of potentially contaminated stockpiles etc.
- Preparing a Soil and Water Management Plan to detail the erosion control measures that would be implemented and maintained for the duration of the construction phase. This plan would be consistent with requirements in the *Managing Urban Stormwater: Soils and Construction Manual.* It would consider measures for erosion protection and control of run-off from the proposal site that may impact the protection of the downstream water quality.
- Preparing a spill management procedure, as part of the CEMP, for sedimentation events or contaminant spills.

8.3 Operational life of the proposal

The impact mitigation measures for the operational life of the proposal include:

- Controlling train speed to not exceed the design value
- Completing track inspections after significant flood events to identify any requirements for repairs on maintenance prior to recommencing services
- Application of appropriate environmental protection measures during maintenance works along the route of the proposal.

9. References

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Appendices

Appendix A – Surface water licences

Table A-1 NSW Water Register – Surface water licences (Department of Primary Industries, Water, 2016c) accessed 7 June 2016

Category	No. of WAL's	Total Share Component (ML or units)	Water made Available (ML)	Usage YTD (ML)
NSW Borders Rivers Regulated and Alluvial Water Sources 2012				
Croppa Creek and Whalan Creek Water Source				
Domestic and stock	9	65.5	65.5	0
Domestic and stock [domestic]	1	2	2	0
Domestic and stock [stock]	2	10	10	0
Unregulated river	20	9776	9776	0
Gwydir Unregulated and Alluvial Water Sources 2012				
Gil Gil Creek Water Source				
Domestic and stock	4	27.5	27.5	0
Domestic and stock [domestic]	1	1	1	0
Domestic and stock [stock]	2	10	10	0
Domestic and stock [town water supply]	1	43	43	0
Unregulated river	6	1421	1421	0
Moree Water Source				
Unregulated river	2	1700	1700	0
Tycannah Creek Water Source				
Domestic and stock	1	7	7	0
Domestic and stock [stock]	1	5	5	0
Unregulated river	6	2768	2768	0
Gurley Creek Water Source				
None				
Millie Creek Water Source				
Domestic and stock	4	29	29	0
Domestic and stock [stock]	1	5	5	0
Unregulated river	6	9967	9967	0
Namoi Unregulated and Alluvial Water Source 2012				
Spring and Bobbiwaa Creeks Water Source				
Domestic and stock [stock]	1	5	5	0
Unregulated river	3	976	976	0

Note:

WAL: Water Access Licence

YTD: Year to date

Appendix B – Groundwater bores

Table B-1 Registered groundwater bores

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW032260	90WA810411	Bore open thru rock	Private	131.3	(Unknown)	-	-	-	-29.1373	150.3022	Stock	Sandstone
GW038746	90BL101158	(Unknown)	(Unknown)	0	(Unknown)	-	-	-	-29.1287	150.3042	Stock	Sand, hard rock
GW000093	-	Bore	Private	62.4	Good	-	-	-	-30.2373	149.8106	Stock, Domestic	Unknown
GW000335	-	Bore open thru rock	Private	142.9	Fresh	-	-	-	-29.3415	150.2125	Public/Municipal	Shale, sand, Sandstone
GW034206	-	Bore open thru rock	Private	68.9	(Unknown)	0.83	16.6	35.1	-29.1287	150.3042	Recreation (Groundwater)	Sandy gravel, shale, sandstone
GW037919	-	Bore	Local Govt	76.2	-	-	-	-	-29.4957	149.8545	Town Water Supply	Shale, Sandstone
GW035337	90CA805032	Bore	Private	55.7	0-500 ppm	-	-	-	-29.4570	149.8592	Stock	Sandstone
GW007284	90WA810519	Bore	Other Govt	163.9	Fresh	-	-	-	-30.1176	149.7961	Stock	Shale, Sandstone
GW007525	90WA810825	Bore open thru rock	Private	114.3	Good	-	-	-	-30.1129	149.7997	Domestic	Shale, Sandstone
GW007830	90WA804905	Bore	Local Govt	51.2	Domestic	-	-	-	-29.4695	149.8511	Town Water Supply	Gravel, sand
GW014676	-	Bore	Local Govt	44.8	501-1000 ppm	-	-	-	-29.5190	149.8528	Stock, domestic	Sandstone
GW012570	90WA810898	Bore open thru rock	Private	149	Fresh	-	-	-	-29.3232	150.2233	Farming	Sandstone
GW010345	90WA810185	Bore open thru rock	Private	76.2	Good	-	-	-	-29.1287	150.3033	Stock	Sandstone
GW004629	90CA811407	Bore - GAB	Local Govt	605.9	501-1000 ppm	-	-	-	-29.9172	149.7890	Town Water Supply	Sand, gravel

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW005249	-	Bore open thru rock	Private	96.9	Good	-	-	-	-29.2123	150.2711	Public/Municipal	Sand, clayey gravel, clayey sand
GW021193	-	Bore	Local Govt	46.9	(Unknown)	-	-	-	-29.5179	149.8534	Unknown	Unknown
GW021200	-	Bore	Local Govt	44.9	0-500 ppm	-	-	-	-29.5190	149.8528	Domestic, industrial	Sand, gravel
GW028500	90WA810376	Bore open thru rock	Private	63	1001-3000 ppm	-	-	-	-29.1282	150.3036	Stock, domestic, irrigation	Sand
GW026723	90WA811323	Bore open thru rock	Private	110.3	0-500 ppm	-	-	-	-29.1234	150.3086	Stock	Coal, Sand
GW026889	-	Bore	Local Govt	53.3	Potable	-	-	-	-29.4680	149.8523	Stock	Silty clay, Sandstone
GW027080	90WA805443	Bore	Private	21.3	Potable	-	-	-	-29.4752	149.8464	Industrial	Gravel, Sand
GW025094	90WA805167	Bore	Local Govt	54.5	-	-	-	-	-29.5001	149.8553	Domestic	Gravel
GW026182	90CA805258	Bore	Private	36.9	-	50.52	9.9	-	-29.4495	149.8647	Industrial	Sand
GW018559	90CA805177	Bore	Private	46	(Unknown)	-	-	-	-29.4682	149.8483	Industrial	Clay, silt, sand
GW019465	90WA810982	Bore open thru rock	Private	67	Potable	-	-	-	-29.2554	150.2611	Industrial	Sand
GW019573		Bore	Other Govt	39.9	Potable	-	-	-	-29.4945	149.8531	Domestic, industrial	Sand gravel
GW019032	90WA810960	Bore	Private	130.1	7001-10000 ppm	-	-	-	-29.9290	149.7892	Irrigation	Gravel
GW061127	90BL132780	Bore	Private	103.9	(Unknown)	-	-	-	-30.1137	149.8006	Unknown	Unknown
GW067438	90BL137783	Bore	Private	23		-	-	-	-30.2834	149.7951	Town Water Supply	Gravel
GW070236	90BL151011	Bore open thru rock	Private	108.5	Fresh	-	-	-	-30.1422	149.8094	Public/Municipal	Gravel, Sand
GW070393	90CA805021	Bore	Private	55.4	Good	-	-	-	-29.4662	149.8578	Public/Municipal	Gravel, Sand

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW043778	90BL100738	Bore	Private	32.9	Good	-	-	-	-29.3848	150.0645	Domestic	Gravel
GW056943		Bore open thru rock	Private	150.3	(Unknown)	-	-	-	-29.1268	150.3042	Domestic	Shale, Shale sandstone
GW057765	90BL135008	Bore - GAB	Private	175.3	(Unknown)	1.26	-	-	-28.9498	150.3706	Domestic	Gravel
GW048891	90BL108175	Bore open thru rock	Private	163.1	Potable	-	-	-	-29.2634	150.2578	Commercial	Sandy clay, sandstone
GW053461	90CA806089	Bore	Private	54.9	(Unknown)	-	-	-	-30.2837	149.7953	Unknown	Unknown
GW901095	90CA811357	Bore	-	159	-	-	-	-	-30.2568	149.8070	Stock, domestic	Shale, Sandstone
GW901897	90CA805116	Bore	Private	53	Good	-	11	-	-29.4398	149.8764	Commercial	Shale, Sandstone
GW901898	90CA805116	Bore	Private	50	-	-	8	-	-29.4395	149.8728	Domestic	Shale, Sandstone
GW902115	90CA805213	Bore	-	34.3	-	-	-	-	-29.4036	149.9724	Domestic, irrigation	Gravel, Sandy gravel
GW966013	90BL251370	Bore	Private	15	-	-	11	-	-29.4764	149.8466	Unknown	Sandy clay
GW966014	90BL251360	Bore	Private	15	-	-	11	-	-29.4763	149.8463	Domestic	Unknown
GW966151	90BL251228	Bore	-	13	-	-	9	-	-29.4753	149.8475	Stock	Clay, sandy gravel
GW966152	90BL251229	Bore	-	13	-	-	9	-	-29.4753	149.8476	Domestic	Sandstone
GW966154	90BL251231	Bore	-	13	-	-	9	-	-29.4754	149.8475	Stock, domestic	Sandstone
GW966155	90BL251232	Bore	-	13	-	-	9	-	-29.4754	149.8476	Stock, domestic, irrigation	Sand, gravel
GW901977	90WA811415	Bore - GAB	-	868	-	-	-	-	-29.4744	149.8470	Domestic	Sandstone
GW966260	90BL251642	Bore	-	81	-	0.945	36	-	-29.1687	150.2906	Stock, irrigation, domestic	Sandstone

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW966066	90BL251363	Bore	Private	15	-	-	11	-	-29.4767	149.8461	Stock, domestic	Sandstone
GW966067	90BL251365	Bore	Private	15	-	-	11	-	-29.4766	149.8471	Stock, domestic	Sand Gravel
GW966071	90BL251367	Bore	Private	15	-	-	11	-	-29.4766	149.8466	Stock, domestic	Gravel
GW966072	90BL251368	Bore	Private	15	-	-	11	-	-29.4764	149.8469	Stock, domestic	Sandstone
GW966074	90BL251369	Bore	Private	15	-	-	11	-	-29.4763	149.8462	Stock, domestic	Sand, hard rock
GW965706	90BL247773	Bore	-	41	-	-	-	-	-29.4311	149.8801	Unknown	Unknown
GW030436	-	Bore - Nested (2)	NSW Office of Water	37.6	Good	-	-	-	-29.4040	150.0017	Recreation (Groundwater), domestic	Shale, sand, Sandstone
GW003995	90WA811087	Bore - GAB	Private	204.2	(Unknown)	-	-	-	-29.7540	149.7995	Irrigation	Sandy gravel, shale, sandstone
GW004082	90WA811099	Bore - GAB	Local Govt	540.5	(Unknown)	-	-	-	-29.9215	149.7892	Stock, domestic, irrigation	Shale, Sandstone
GW004361	-	Bore - GAB	Local Govt	851.2	501-1000 ppm	0	0	0	-29.4740	149.8469	Stock, domestic, irrigation	Sandstone
GW017750	-	(Unknown)	Private	41.4	(Unknown)	0	0	0	-29.4850	149.8495	Recreation (Groundwater)	Shale, Sandstone
GW018238	90WA805284	Bore	Private	19.8	Fresh	0	0	0	-29.4852	149.8499	Irrigation	Shale, Sandstone
GW026079	-	Bore	Private	19.8	Good	0	0	0	-29.4755	149.8469	Unknown	Gravel, sand
GW026883	90WA804905	Bore	Local Govt	46.3	Hard	0	0	0	-29.4668	149.8487	Town Water Supply	Sandstone
GW026886	90WA805751	Bore	Private	39.6	Potable	0	0	0	-29.4666	149.8523	Domestic	Sandstone
GW028999	90WA805485	Bore	Private	18.5	0-500 ppm	0	0	0	-29.4710	149.8492	Test bore /monitoring bore	Sandstone
GW029517	90WA811325	Bore open thru rock	Private	129.2	(Unknown)	0	0	0	-29.1306	150.3035	Test bore/ monitoring bore	Sand, gravel

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW061485	90WA805706	Bore	Private	42.7	Good	0	0	0	-29.4668	149.8559	Unknown	Sand, clayey gravel, clayey sand
GW063995	90WA805719	Bore	Private	36.6	Good	0	0	0	-29.4432	149.8700	Test bore/ monitoring bore	Unknown
GW011205	90WA810861	Bore	Private	173.7	Good	0	0	0	-29.9398	149.7884	Test bore/ monitoring bore	Sand, gravel
GW014371	90WA804905	Bore	Local Govt	57.9	(Unknown)	0	0	0	-29.4722	149.8503	Test bore/ monitoring bore	Sand
GW034587	90WA811043	Bore open thru rock	Private	178	(Unknown)	0	0	0	-29.2632	150.2545	Monitoring bore	Coal, Sand
GW965370	90CA811448	Bore	-	346	-	0	0	0	-28.9279	150.3939	Test bore/ monitoring bore	Silty clay, Sandstone
GW900084	90WA811429	Bore - GAB	Private	740.1	-	0	0	0	-29.4854	149.8492	Test bore/ monitoring bore	Gravel, Sand
GW966032	90BL251361	Bore	Private	15	-	0	11	0	-29.4763	149.8469	Test bore/ monitoring bore	Gravel
GW966065	90BL251362	Bore	Private	15	-	-	11	-	-29.4767	149.8464	Test bore/ monitoring bore	Sand
GW966068	-	Bore	Private	15	-	-	11	-	-29.4768	149.8467	Monitoring bore	Clay, silt, sand
GW966153	90BL251230	Bore		125	-	-	9	-	-29.4756	149.8477	Monitoring bore	Sand
GW902260	-	Bore	(Unknown)	-	-	-	-	-	-29.4963	149.8542	Monitoring bore	Sand gravel
GW045003	90BL103121	Bore	Private	60.4	(Unknown)	-	-	-	-29.1254	150.3053	Monitoring bore	Gravel
GW966069	90BL251366	Bore	Private	15	-	-	11	-	-29.4765	149.8471	Monitoring bore	Unknown
GW020096	90WA805385	Bore	Private	19	Potable	-	-	-	-29.4796	149.8517	Domestic, stock	Gravel
GW967507	90BL252888	Bore	-	60	-	-	-	-	-29.5567	149.8413	Monitoring bore	Gravel, Sand
GW967536	90BL151035	Bore	-	35	-	-	-	-	-29.4865	149.8499	Monitoring bore	Gravel, Sand
GW967707	90BL252822	Bore	-	130.5	-	-	15.9	-	-29.1274	150.3045	Monitoring bore	Gravel

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW967284	90BL252814	Bore	Private	15	-	-	13	-	-29.4763	149.8462	Domestic	Shale, Shale sandstone
GW967285	90BL252815	Bore	Private	15	-	-	13	-	-29.4768	149.8464	Domestic, stock	Gravel
GW968049	90BL254387	Bore	-	13.86	-	-	-	-	-29.4744	149.8488	Monitoring bore	Sandy clay, sandstone
GW968050	90BL254388	Bore	-	13.96	-	-	-	-	-29.4747	149.8487	Monitoring bore	Unknown
GW968051	90BL254388	Bore	-	10.8	-	-	-	-	-29.4749	149.8488	Monitoring bore	Shale, Sandstone
GW968052	90BL254388	Bore	-	13.36	-	-	-	-	-29.4753	149.8486	Monitoring bore	Shale, Sandstone
GW968053	90BL254388	Bore	-	13.6	-	-	-	-	-29.4753	149.8490	Monitoring bore	Shale, Sandstone
GW968644	-	Bore	Private	36.6	-	-	10.2	-	-29.4494	149.8644	Stock, irrigation	Gravel, Sandy gravel
GW969093	90BL254506	Bore - GAB	Private	144	-	1.8	38	-	-29.1582	150.2928	Domestic, stock	Sandy clay
GW970112	90WA812901	Bore - GAB	Private	60.96	-	0.44	-	-	-29.1284	150.30308	Unknown	Unknown
GW970670	90BL256114	Bore	Private	14.75	-	-	12.5	-	-29.4755	149.84778	Monitoring bore	Clay, sandy gravel
GW970671	90BL256115	Bore	Private	14	-	-	13	-	-29.47592	149.84719	Monitoring bore	Sandstone
GW970672	90BL256115	Bore	Private	14.95	-	-	13	-	-29.47569	149.84719	Monitoring bore	Sandstone
GW970673	90BL256115	Bore	Private	14.9	-	-	13	-	-29.47583	149.84736	Monitoring bore	Sand, gravel
GW970854	90WA829336	Bore	Private	15	-	-	11.2	-	-29.4775	149.84767	Groundwater remediation	Sandstone
GW970855	90WA829336	Bore	Private	15	-	-	11.2	-	-29.47747	149.84769	Groundwater remediation	Sandstone
GW970856	90WA829336	Bore	Private	15.3	-	-	11.5	-	-29.47742	149.84758	Groundwater remediation	Sandstone

ID	License No.	Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised Purpose	Strata
GW970526		Bore	Private	10	-	-	-	-	-29.91667	149.79111	Monitoring bore	Sand Gravel
GW970527		Bore	Private	5	-	-	-	-	-29.91781	149.79067	Monitoring bore	Gravel
GW970528		Bore	Private	5	-	-	-	-	-29.91767	149.79103	Monitoring bore	Unknown
GW069838	90WA813005	Bore - GAB	Private	119	-	3.8	27	-	-30.11453	149.80064	Stock, Domestic	Sandstone

Appendix C – Major soils groups

Table C-1 Major soil groups

Range Soil Type Occurs	Classification/ Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 573 - 575	337, 340, 342, 344, 7, 6, 336, 8, 6	Narrabri	Shallow (<15 cm) imperfectly drained Red-Brown earth occurs on hill crests, and imperfectly drained Prairie Soils occur in open depressions. Isolated areas of shallow (<3 cm) sandy loam also occur. Very deep (< 289 cm) poorly drained Grey Clay occurs in area.	• Cracks evident • Low to moderate soil erodibility	• Slight erosion hazard on plains • Moderate erosion hazard on slopes, with sheet erosion action occurring • No salting evident
CH 575 - 578	9, 1, 5	North of Narrabri	Deep (<100 cm) imperfectly drained Red-Brown Earth occurs on lower slopes and within drainage depressions. Deep (<100 cm) imperfectly drained Solodic Soils and moderately well drained Red-Brown Earth occurs on upper slopes.	• Cracks evident in clay layers • Low to moderate soil erodibility on upper slopes, and low soil erodibility on lower slopes • Moderate run-off from slopes	• Slight to moderate erosion hazard on upper slopes • Minor to moderate sheet erosion occurs on slopes • Minor wind erosion • No salting evident
CH 578 - 585	210, 2, 193, 175, 192	North of Narrabri	Moderately deep (<65 cm) loamy sandy top soil, with deep medium clay layers below extending to 273 cm. Deep (<273 cm) Solodic Soils and Brown Clays, deep (<341 cm) Grey Clay layers.	• Cracks evident in clay layers • Seasonal cracking when dry	• Erosion and salinity hazards not identified
CH 585 - 595	157, 158, 140, 293, 122	North of Narrabri to Edgeroi	Shallow (<10 cm) silty and sandy clay loam topsoil. Deep (<275 cm) imperfectly drained Brown Clay, Grey Clay and Alluvial Soils.	• Cracks evident in clay layers • Low run-off from plains	• Slight erosion hazard • No salting evident
CH 595 - 600	5, 87, 279, 69	North of Edgeroi	Deep (<120 cm) to very deep (<262 cm) imperfectly drained Grey Clay and very deep (<295 cm) Black Earth.	• Low run-off from plains	• Slight erosion hazard • No salting evident

Range Soil Type Occurs	Classification/ Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 600 - 615	278, 52, 34, 17, 90, 669, 470	Between Edgeroi and Bellata	Very deep (<271 cm) imperfectly to very poorly drained Brown Clay.	• Cracks evident in clay layers • Self-mulching when dry • High run-off from plains near Bellata	• Slight erosion hazard • No salting evident
CH 615 - 630	662, 49, 276, 50, 1, 4	North of Bellata	Moderately deep (<82 cm) poorly drained Black Earth occurs on plains. Deep (<120 cm) moderately well drained Grey Clay and deep (<150 cm) well drained Yellow Earth occurs on upper and flat plains.	• Cracks evident in clay layers • Black Earth is hardsetting when dry • Clays on flat plains are self-mulching when dry • Low to moderate runoff	• Slight erosion hazard • No salting evident
CH 630 - 645	416, 417, 657, 438, 16, 413, 412	North of Bellata to Gurley	Deep (<140 cm) very poorly drained Grey Clay and deep (<120 cm) imperfectly drained Brown Clay occur on flat plains. Deep (<132 cm) very poorly drained Grey Clay occurs in open drainage depressions.	• Seasonal cracking when dry, with some clays hardsetting when dry • High runoff in open drainage depressions • Low run-off occurs in plains	• Slight erosion hazards on plains • High erosion hazard in open drainage depressions, with moderate rill erosion and severe sheet erosion • No salting evident
CH 645 - 650	10, 411, 7, 9	Near Gurley creek	Deep (<117 cm) poorly drained Black Earth occurs on alluvium floodplains and drainage depressions.	• High run-off in drainage depressions • Gilgai-like drainage features that are very poorly drained • Clays in drainage depressions can be self-mulching when dry.	• Slight erosion hazard • No salting evident
CH 650 - 660	408, 407	Between Gurley Creek and Moree	Deep (<130 cm) very poorly drained Grey Clay occur on flat plains.	• Seasonal cracking when dry • Low run-off occurs in plains	• Slight erosion hazard • No salting evident
CH 660 - 680	655, 636, 634, 276, 1, 2, 277, 27	Moree to Gwydir River	Deep (<130 cm) very poorly drained Black Earth occurs on high banks of rivers. Very deep (<295 cm) clay occurs in open drainage depressions. Deep (<140 cm) poorly to very poorly drained Black Earth occurs on flat alluvium plains.	• Moderate to high run-off on river banks and drainage depressions • Low run-off occurs in plains • Some clays hardsetting, self-mulching or surface crusting when dry	• High erosion hazard on river banks • Slight erosion hazard on flat plains • No salting evident

Range Soil Type Occurs	Classification/ Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 680 - 690	72, 68, 411, 412	North east of Moree	Shallow (<8 cm) sandy clay loam topsoil for Red-brown Earth. Deep (<120 cm) moderately well drained Red-brown Earth and poorly to imperfectly drained Grey Clay occur on flat plains.	• Cracks evident in Grey Clay ranging from <5 to 20 mm • Self-mulching and seasonal cracking when dry	• Slight erosion hazard • No salting evident
CH 690 - 710	413, 70, 112, 418, 419	South west of Crooble	Shallow (<30 cm) sandy clay loam topsoils on mid-slopes. Deep (<140 cm) imperfectly drained Brown Clay and poorly drained Red-Brown Earth occur on mid-slopes. Shallow (<10 cm) sandy loam and sandy clay loam topsoil occurs on flat plains. Deep (<120 cm) imperfectly drained Brown Clay and Grey Clay occurs on flat plains.	• Low run-off • Self-mulching and seasonal cracking when dry	• Slight erosion hazard • No salting evident
CH 710 - 725	23, 24, 20	Crooble	Shallow (<8 – 41 cm) topsoils on flat plains of silty clay loam, clay loam and loamy sand. Deeper layers (<181 cm) of imperfectly drained medium silty clay, medium sandy clay and medium clay.	• Low run-off • Sands are loose when dry • Seasonal cracking occurs in clays when dry	• Slight erosion hazard • No salting evident
CH 725 - 735	2, 109, 25, 26	Croppa Creek	Deep (<150 cm) Grey Clay occurs on flat floodplains and upper slopes. Deep (<124 cm) layers of moderately well drained medium silty clay also occur on hillslopes. Moderate (<44 cm) layers of imperfectly drained silty loam occur on Coppa Creek bank slopes.	• Low runoff on hillslopes and creek banks • Cracking occurs on Grey Clay upper slopes • Loam has surface crusting and clays can be self-mulching when dry	• Slight erosion hazard on flat floodplains and hillslopes. Minor scald erosion on hillslopes (stable). • Extreme erosion hazard on upper slopes. Severe active sheet, rill and wind erosion. • Moderate erosion hazard on Coppa Creek bank slopes. Minor scalding (stable), moderate sheet erosion (partly stabilised) and minor rill erosion (partly stabilised). • No salting evident.

Range Soil Type Occurs	Classification/ Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 735 - 758	34, 108, 1a, 1b	Croppa Creek to North Star	Shallow (<10 cm) silty clay loam topsoil on mid-slopes. Deep (<135 cm) moderately well drained Brown Clay occurs on mid-slopes. Deep (<130) Black Earth occurs on flat plains and floodplains.	• Brown Clay is self-mulching when dry • Black Earth has seasonal cracking when dry • Low to moderate runoff on mid-slopes	• Slight erosion hazard • No salting evident

GHD

Level 3 GHD Tower 24 Honeysuckle Drive Newcastle NSW 2300
PO Box 5403 Hunter Region Mail Centre NSW 2310
T: (02) 4979 9999 F: (02) 4979 9988 E: ntlmail@ghd.com

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