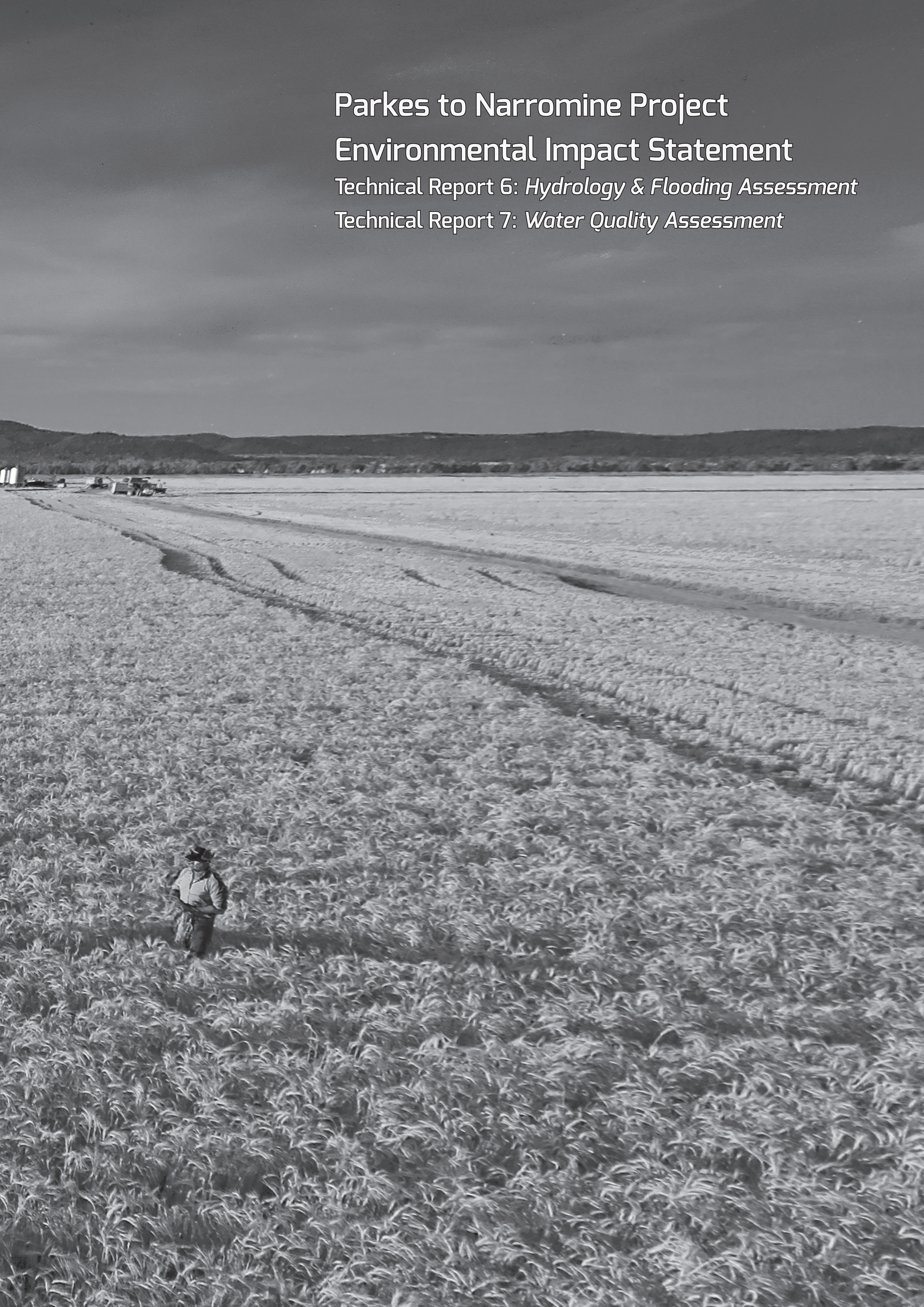
Parkes to Narromine Project
Environmental Impact Statement

Technical Report 6: *Hydrology & Flooding Assessment*
Technical Report 7: *Water Quality Assessment*



TECHNICAL REPORT 6:
Hydrology & Flooding Assessment

Australian Rail Track Corporation

Inland Rail - Parkes to Narromine

Hydrology and Flooding Assessment

June 2017

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Abbreviations

Abbreviation	Explanation
AEP	Annual exceedance probability
AHD	Australian Height Datum
ARI	Average recurrence interval
ARR	Australian Rainfall and Runoff
ARTC	Australian Rail Track Corporation
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DPI	NSW Department of Primary Industries
EIS	Environmental Impact Statement
EMA	Emergency Management Australia
EMP	Environment Management Plan
EPA	Environmental Protection Agency
GHD	GHD Pty Ltd
IFD	Intensity-Frequency-Duration
LiDAR	Light Detection and Ranging
AHD	Australian Height Datum
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
RCP	Reinforced concrete pipe
RORB	Runoff Routing model
RFFE	Regional Flood Frequency Estimation
SEARs	Secretary's Environmental Assessment Requirements
SRTM	Shuttle Radar Topography Mission

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 chance 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 years 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
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
Critical duration	The design rainfall duration that provided the greatest predicted flow rate in a catchment area
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
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
Existing rail corridor	The area of land that is identified for the continued operation of the rail line between Parkes and Narromine

Term	Explanation
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 water way 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
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
Minor structure	Has a design flow less than 50 m^3/s
Morphology	A particular form, shape or structure
Mulitcell	Multiple number of openings within a structure
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
Probability	A statistical measure of the likely frequency or occurrence of flooding
Proposal	The construction and operation of the Parkes to Narromine project
Proposal site	The proposal site comprises the total area of the existing rail corridor between the start and end chainages of the proposal, the new rail corridor for the new Parkes northwest connection, construction stage access tracks, construction compound areas and construction areas adjacent to culverts that are outside of the existing rail corridor
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

Term	Explanation
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
System of safe working	An integrated system of operating procedures and technologies used for safe operation of trains and the protection of people and property
Subsoil	The layer of soil below the topsoil
Topsoil	The upper or outermost soil layer. Typically 5 to 20 cm thick
Track	The combination of rails, rail connectors, sleepers, ballast, points, crossings and any substitute devices
Triangular hydrograph	A synthetic hydrograph, based on the estimated peak flood flow rate
Underbridge	A bridge supporting the track and passing over a watercourse, roadway, pathway, floodplain or some other similar feature
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 Parkes to Narromine section of Inland Rail ('the proposal').

The proposal would involve upgrading the existing rail line between Parkes and Narromine, including new crossing loops, some track realignment and replacement of culverts. The proposal also includes a new north to west connection between Inland Rail and the Broken Hill line (Parkes north west connection). Ancillary works will include upgrading, closing or consolidating level crossings, upgrading signalling and communications, establishing new fencing or upgrading existing fencing along the rail corridor, and relocating/protecting services and utilities.

This report

This report forms supporting documentation for the environmental impact statement (EIS) for the proposal and specifically addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs) regarding hydrology, hydraulics and flooding.

The proposal site

The proposal site is located within the Lachlan and Macquarie-Bogan river catchments. It crosses several named watercourses. The majority of the watercourses are ephemeral and there is a minimal amount of water quality data to describe the existing conditions. Soils within the proposal site are generally identified as being highly erodible.

Design methodology

The design development process included an integration of the track formation design, structure sizing, and an of the potential impacts of the proposal. Structures were sized using predicted flows that would arise from rainfall events over the local catchment areas. No detailed examination of the flooding impacts of the regional river (Macquarie River) on the reliability of the proposal was completed.

Structures under the formation were sized to provide a target performance requirement of conveying the one annual exceedance probability (AEP) flow while not having the upstream one per cent AEP ponding level above the top of formation.

Risk assessment

The hydrology and flooding risk assessments identified the following to be the main potential risks emanating from construction and operation of the proposal:

- Changes to flow paths across the rail corridor.
- Change to fish passage through culvert structures.
- Changes to flow rates and levels of surface waters and groundwater due to water extraction during construction.
- Changes to flood levels and flooding durations both upstream and downstream of the proposal with impacts upstream of the proposal being the more significant.
- Potential erosion effects in watercourses downstream of culverts.

The most noticeable change to flooding conditions would be a reduction in the frequency and extent of overtopping of the rail level as the proposal would result in a raising, in most areas, of the rail formation. In large floods this will force more water through culverts.

Mitigation measures

An extensive list of measures was incorporated into the design to mitigate adverse impacts, as much as practical, while achieving the design criteria of the proposal. Impact mitigation measures that either were implemented in the design, or are proposed, include:

- Maintaining culverts across the rail corridor at, or very close to existing locations to maintain the existing flow paths across the rail corridor.
- Maintaining culvert capacities as close as practical to the existing capacity to restrict the extent and amount of increased risk exacerbating downstream flooding conditions and erosion risks while not excessively exacerbating upstream flooding risks.
- Including a general raising of the rail level to remove the uncontrolled overtopping of the rail line for events of a magnitude up to the one per cent AEP magnitude except at a limited number of level crossings.
- Using pre-cast box culverts for the construction to minimise the amount of onsite concrete work and reduce the amount of water required on site during construction, and to speed the construction process.
- Sourcing the water required for construction from several locations to minimise the impact at the extraction locations.

Residual risks of proposal

Even with the implementation of these mitigation measures, some adverse effects of the proposal would remain, including:

- Changes to the upstream flooding regime. The magnitude of the effects are quantified in this document, and are expected to vary along the length of the proposal. The assessment indicated there would be some changes in flood levels and flood extents upstream of the proposal site. These changes would largely be a result of the lifting of the level of the rail formation; this would be partly counteracted by the provision of one per cent AEP culverts under the rail formation. There will also be an increase in the flooding duration upstream of the proposal because all floodwater has to drain through the provided culverts.
- The proposal would overtop at seven level crossings where the formation has only a minimal lift. These locations are identified in this report. Additional analysis may help to identify design improvements that could reduce the extent of modelled formation overtopping. The largest depth of overtopping is predicted as being 560 mm at Wyatts Lane level crossing with 400 mm depth of overtopping at both Brolgan Road and Bogan Road level crossings. The remaining overtoppings were no greater than 250 mm deep.
- An examination of potential public road closures was completed for the area within the available LiDAR survey. The road closure locations were similar in location to those for the existing conditions but the depths of water creating the closure did change. The analysis showed that some roads would close in design events at a distance from the proposal site due to the longitudinal grading of the road.

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. The Inland Rail programme (Inland Rail) involves the design and construction of a new inland rail connection, about 1,700 kilometres long, between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail would enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) has sought approval to construct and operate the proposal.

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) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

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 address the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs), issued on 8 November 2016 and the terms of the assessment bilateral agreement between the Commonwealth and the State of New South Wales under the EPBC Act.

1.2 The proposal

1.2.1 Location

The proposal is generally located in the existing rail corridor between the towns of Parkes and Narromine, via Peak Hill. In addition, a new connection to the Broken Hill rail line ('the Parkes north west connection') is proposed outside the existing rail corridor at the southern end of the proposal site near Parkes. The location of the proposal is shown in Figure 1-1.

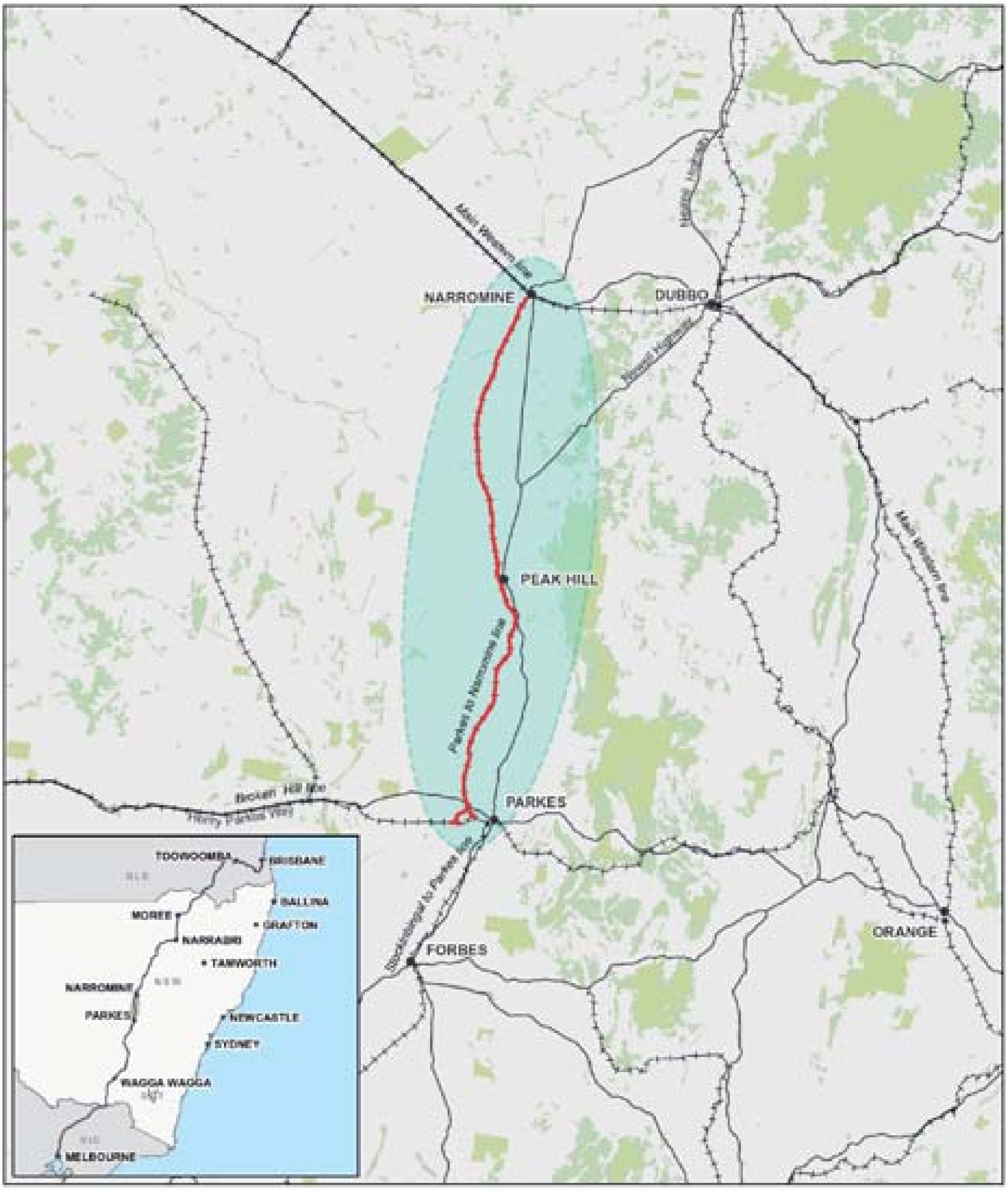
1.2.2 Key features

The key features of the proposal involve:

- Upgrading the track, track formation, and culverts within the existing rail corridor for a distance of 106 kilometres between Parkes and Narromine.
- Realigning the track where required within the existing rail corridor to minimise the radius of tight curves
- Providing three crossing loops within the existing rail corridor, at Goonumbla, Peak Hill, and Timjelly.
- Providing a 5.3 kilometre long rail connection to the Broken Hill Line to the west of Parkes ('the Parkes north west connection'), including a road bridge over the existing rail corridor at Brolgan Road ('the Brolgan Road 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.



LEGEND

- Proposal site
- Proposal location
- Rail lines
- Main roads

Paper Size A4

0 5 10 20 30

Kilometers

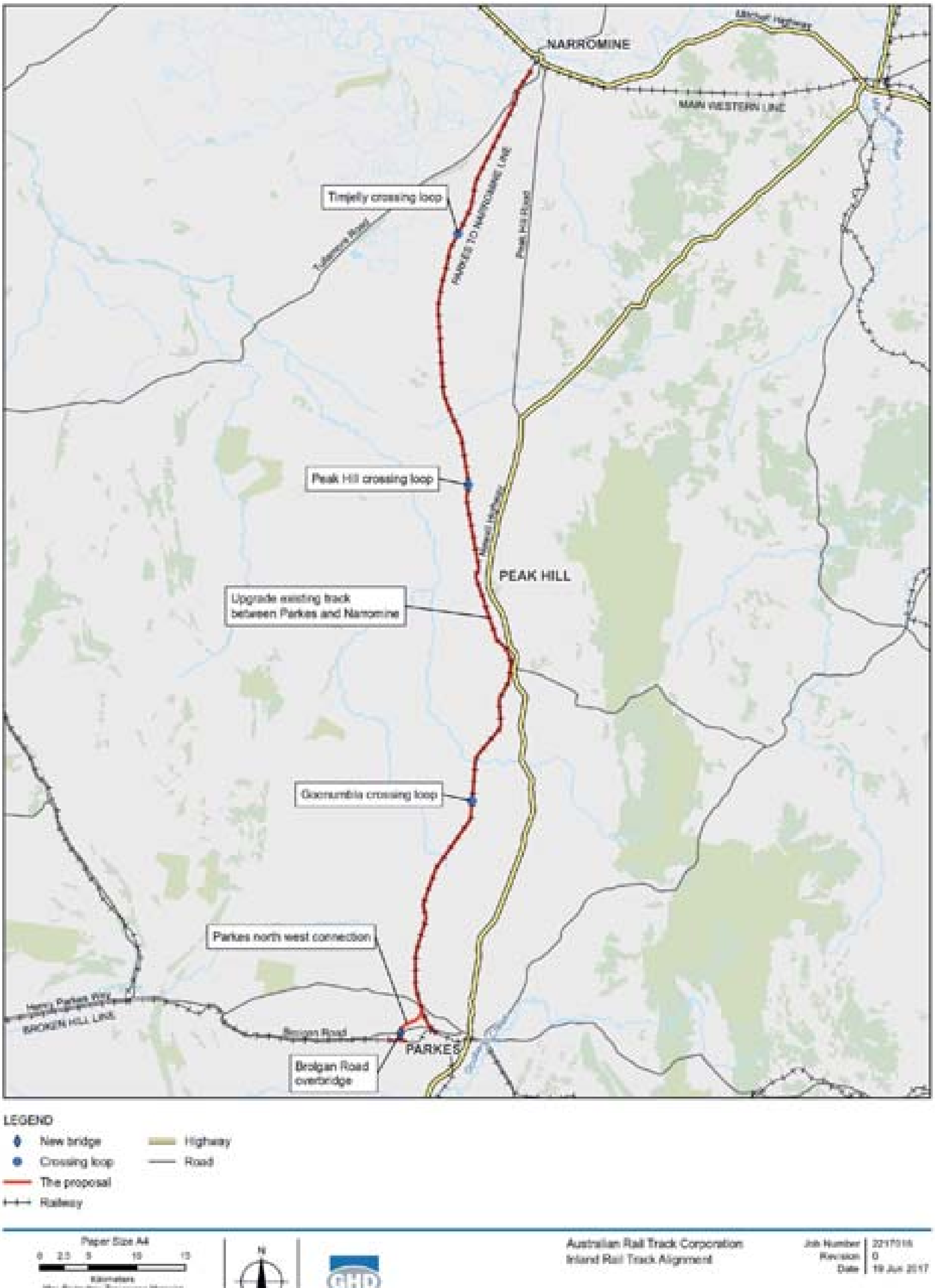
Australian Rail Track Corporation
Inland Rail Track Alignment

Job Number 2217
Revision 0
Date 30 Nov 2016

Location of the proposal

Figure 1-1

Data source: Commonwealth of Australia (Geoscience Australia), 2006 Topographic Data Series 3, 2006



Australian Rail Track Corporation
Inland Rail Track Alignment

Job Number 2217316
Revision 0
Date 19 Jun 2017

Key features of the proposal

Figure 1-2

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 18 months. Existing train operations along the Parkes to Narromine line would continue prior to, during, and following construction. Inland Rail as a whole would be operational once all 13 sections are complete, which is estimated to be 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 grain and ore 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 8.5 trains per day in 2025, increasing to 15 trains per day in 2040. The trains would be a mix of grain, intermodal (freight), and other general transport trains.

1.3 Purpose and scope of this report

This report provides the results of the hydrologic, hydraulic and flooding impact assessment of the proposal as required by the SEARS, Section 2.5.4 and 2.6.2. The report:

- Provides a brief overview of the proposal.
- Provides a brief overview of the available data.
- Describes the existing environmental conditions.
- Documents the hydrologic, hydraulic and flooding impacts of the proposal. Water quality issues and impacts are described in a separate report titled ARTC Inland Rail – Parkes to Narromine Water Quality Assessment (GHD 2017).
- Identifies proposed ongoing monitoring programs for the verification of predicted water extraction and flood impacts.

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	Outlines available data and provides a summary of the physical characteristics of the proposal site
4	Describes the existing hydrology and flooding of the proposal site
5	Contains an assessment of the hydrological and flooding risks associated with the proposal
6	Describes the proposed mitigation measures, and summarises the remaining hydrological and flooding impacts associated with the proposal
7	Describes hydrologic and hydraulic monitoring conditions
8	Provides a conclusion summarising key outcomes from the report

2. Assessment approach and methodology

2.1 Definitions

2.1.1 Study area

The study area for the hydrology and flooding investigation is considered the area that may be affected by the proposal directly (or indirectly). The analysis focussed on watercourses and associated floodplains that the proposal would cross.

Regional floods, typically due to flooding from major rivers and watercourses from rainfall, affect a significant portion of the two river basin catchments in the study area – the Lachlan River basin and the Macquarie-Bogan River basin, as detailed in Section 3.8.1.

2.1.2 Terminology

Hydrology

Hydrology refers to the estimation of runoff from a catchment. Runoff is generated when rainfall hits the ground. For any given catchment, the relationship between rainfall and runoff can be used to predict peak flow rates at a nominated discharge point by considering the catchment's characteristics including, but not limited to, its terrain, soil type, shape, land use, vegetation coverage, areas of inundation and water storage.

Surface water in the study area mainly comprises ephemeral watercourses and a small number of perennial major river systems that pass through the study area.

Flood event

A flood event can be either:

- An historical flood event that has occurred and 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.

Historical flood events may be compared with a design event of a similar size to indicate the likelihood of that specific event occurring. Design flood events are generally referenced to a probability using the term Annual Exceedance Probability (AEP).

The AEP relates to the chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, a five per cent AEP flood event has a five per cent (or one in 20) chance of occurring in any one year.

Structure

A structure in this report usually refers to a circular or rectangular culvert or underbridge that allows water to pass under an embankment (such as a rail embankment). Structures many either be single cell (one opening) or multi-cell (multiple openings).

2.2 Design objectives

In summary, the design objective for the proposal is to upgrade the rail line from near Parkes through to Narromine 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 an increase in the axle loading of carriages. This objective requires:

- Reconstructing embankments.
- Replacing structures.
- Easing rail curves.
- Building new sidings.

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 for hydraulic performance of the proposal are as follows:

- The flood immunity is defined as the one per cent AEP flood which is taken as being equivalent in magnitude to the 100 year ARI event.
- The flood immunity and serviceability limit state AEP is 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 areas or where it is not practical to design for a flood immunity greater than one per cent AEP.

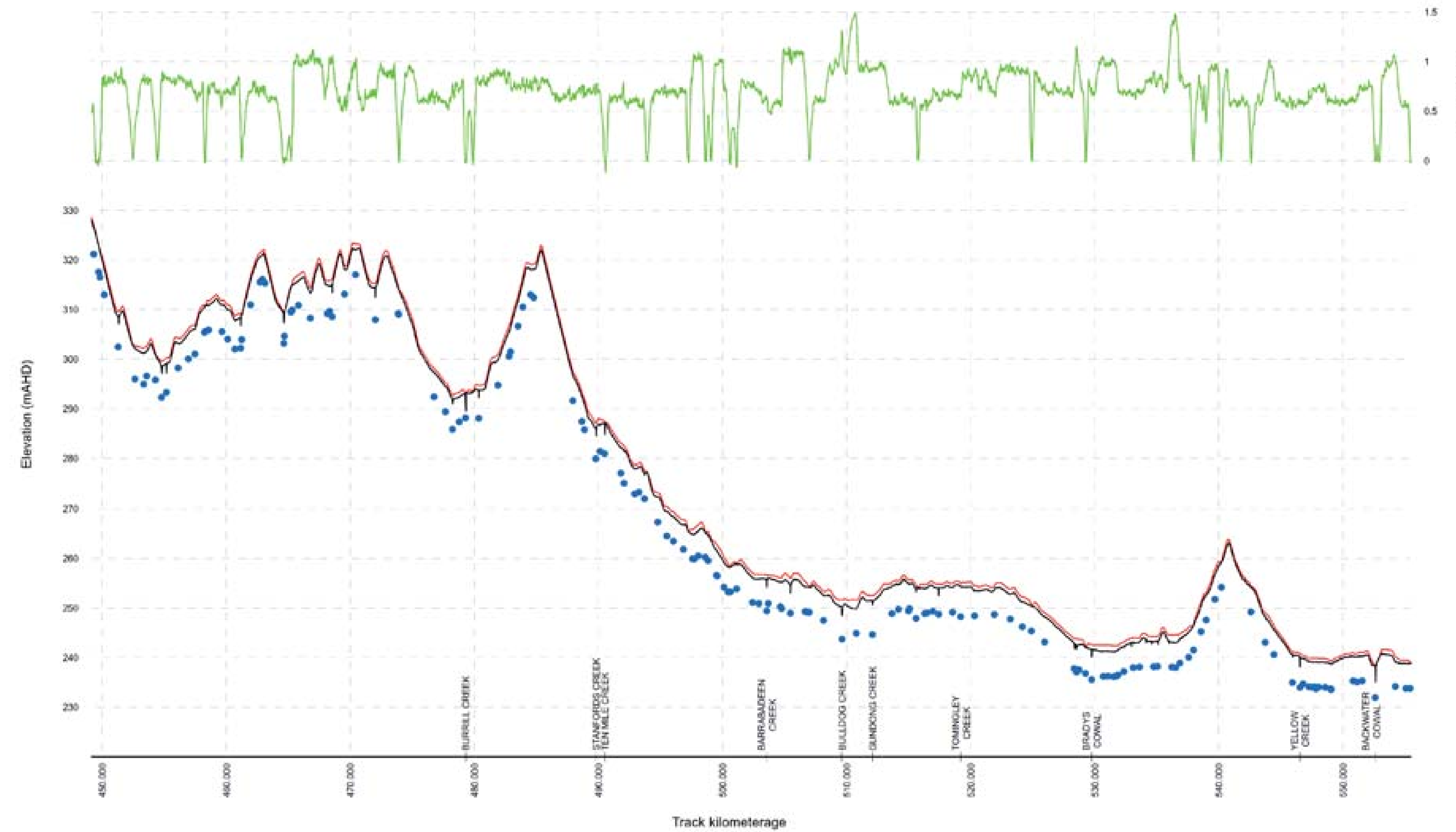
2.3 Design

2.3.1 Form

Engineering features of the proposal that would impact the hydrology and hydraulics would primarily be the raising of the existing rail embankment along the majority of the rail corridor across the floodplain. The embankment and upgraded structures would be required to permit an appropriate flow to minimise adverse flooding impacts.

The design process included initial flood modelling to identify the necessary locations for raising the track and upgrading structures to meet the adopted drainage performance requirements (refer to Section 2.2.1). The proposed design track level considers the required track level for flood immunity as well as other design requirements (such as maintaining the existing track elevation at level crossings).

Figure 2-1 provides the existing natural surface along the main corridor between Parkes and Narromine and the design track long section together with the location and quantities of lift between the existing track level and the design track level. No (or minimal) lift was applied at existing level crossings.



Paper Size A3

LEGEND
Design
Natural Surface
Track Lift
Culvert

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Design Track Alignment

Figure 2-1

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

The location of proposed structures along the same length of the proposal site are provided in Figure 2-2. The structures are offset eight metres below the track level for clarity. This figure also shows locations where the design includes no rail lift.

Figure 2-2 shows the locations of proposed culverts in plan view for the section of rail between Parkes and Narromine to assist with their location. The proposed structures are all located at, or very close to, the locations of the existing culverts.

The proposed Parkes north west connection would include three structures sized to match the corresponding main line culvert.

2.3.2 Proposal boundaries or assessment – Parkes to Narromine

The entire Inland Rail program extends from Melbourne and Brisbane. The proposal being considered within this report is the existing rail corridor between Parkes, at approximately chainage 449, and Narromine, at chainage 555.

An additional short section of new rain corridor known as the Parkes north west connection is also considered.

2.4 Relativity of conditions and impacts

2.4.1 Surface and below surface impacts

The proposal, as described in Section 2.3.1, primarily involves the construction of track and formation, culverts and other surface infrastructure, at or close to the ground surface. There would be a limited amount of below ground work which would be confined to structure foundations.

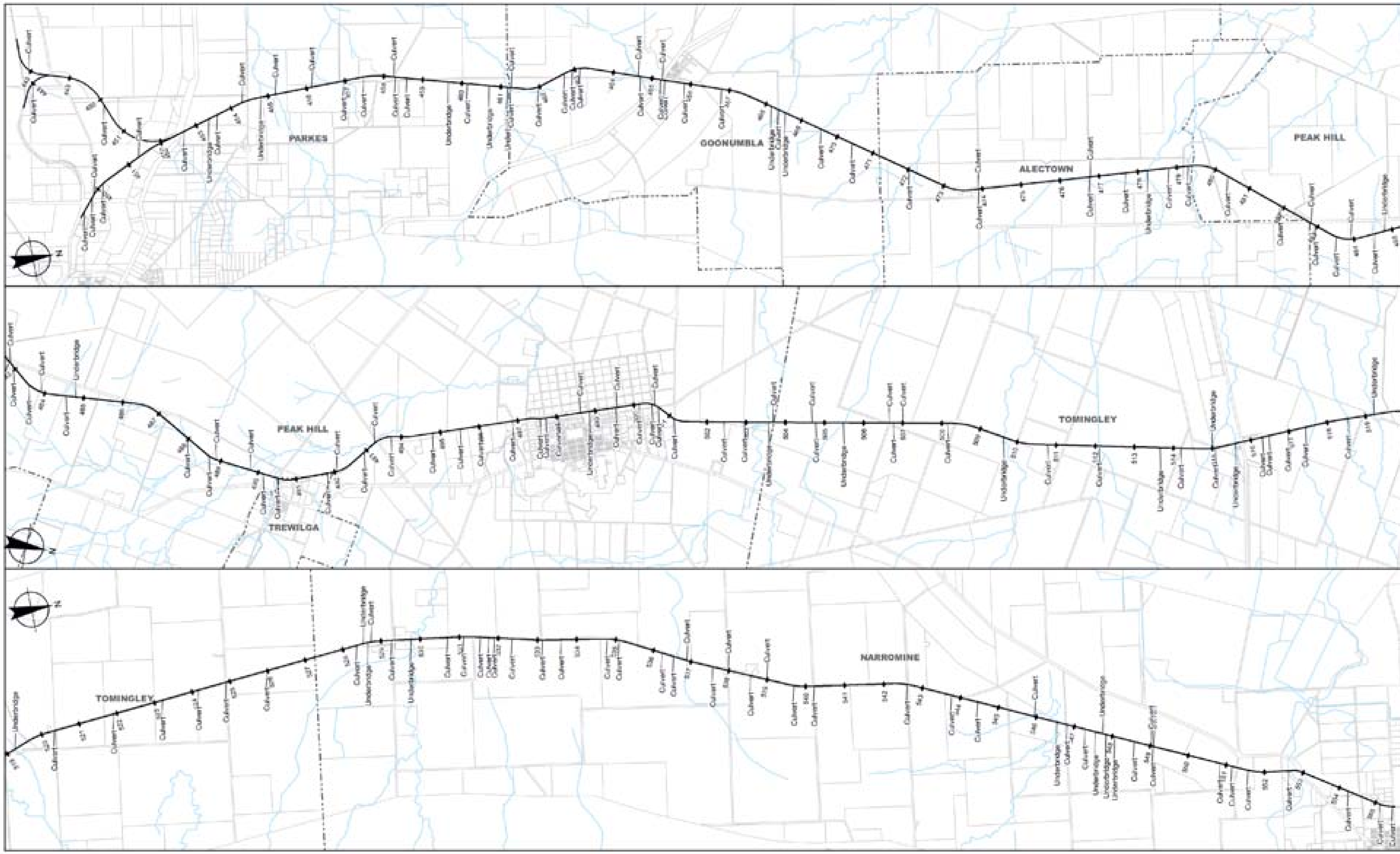
Because of this, this report focuses on the surface hydrology and flooding issues and impact assessment more than the below ground conditions and impacts.

2.4.2 Relativity of flow and flooding impacts

The proposal has the potential to impact surface flow and flooding conditions, impacting:

- Local catchment runoff and flooding conditions.
- Large river catchment flows and flooding conditions.

The proposal is designed to consider, and mitigate as far as practical, predicted impacts that would occur because of local catchment rainfall and runoff events. In this context, a local catchment is taken to represent one that is not a major river (Lachlan, Macquarie or Bogan Rivers). The three major river systems would potentially flood the proposal. It is considered impractical to use hydrologic and flooding in the regional rivers as necessarily controlling the size of all elements within the proposal.



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
- Lot boundary
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	29 Nov 2016

Proposed Culvert Locations

Figure 2-2

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

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

2.5 Hydrology

2.5.1 Methodology – surface water assessment

Estimated local catchment surface flow rates arriving at structures were developed based on the contributing catchment area and application of a design rainfall of varying duration to that catchment area.

For some localised areas, it was found that flows from adjacent local catchments would interact prior to flowing over the rail line. In these locations, the hydrologic and hydraulic assessment was required to consider the coincident flows from the adjacent local catchment areas.

Two flow configurations arose:

- Where the peak flow at a structure could pass through the structure without either the track overtopping or the catchment boundary being overtopped into the adjacent catchment (flow parallel to rail alignment), the flood level was determined based on the capacity of the structure in a particular catchment area.
- Where flow could not pass through the structure and the predicted water level resulted in overtopping of the rail level or overtopping of the adjacent catchment boundary – or both of the above conditions – the calculations were expanded to obtain a flood level that considered the hydraulic capacity of the structure. The resulting flow over the rail and/or the resulting flow into the adjacent catchment concurrently acknowledging all resulting outflow relationships to establish the resulting flood level of the initial structure and those subsequently affected. Flow over the top of the rail was assessed as a weir.

A detailed description of the hydrologic analysis assessment is provided in Appendix A. In summary, the process involved:

- Identification of the existing structures for the establishment of the base (existing) flooding conditions. For the design conditions, this involved identification of each watercourse and natural depression along the study area and assigning a structure to each location.
- Extraction of the existing structure geometry, level and form from existing ARTC data for the existing base case conditions.
- Determination of the local catchment area draining to each of the structure locations.
- Application of design rainfalls to each local catchment to determine the peak rate of runoff from the catchments for a broad range of design rainfall durations. The analysis of the peak flow rates, initially made using flows estimated from the Probabilistic Rational Method of calculations, were adjusted to better replicate comparative flows established using a RORB hydrologic model established for selected localised culverts.
- Establishment of a stage-storage volume relationship for the area immediately upstream of each rail crossing assuming a horizontal water surface extended from the rail line to the upslope intersection with the natural water surface.
- Formation of triangular hydrographs from the above peak flow rates; these were then routed through each stage-storage volume with the outlets from that catchment being through the structure (culvert or bridge), over the rail line if the flood level exceeded the minimum track level and potentially into the adjacent catchments.
- Repetition of the routing process for different rainfall durations to establish the one giving the highest flood level for each AEP when allowing, if required, flow interaction between catchments. This step directly linked to the hydraulic and flooding assessment.

- Progressively increasing the number of barrels forming a culvert for the design case, using the standard structure sizes, until desired design criteria were achieved.

The identification of the required combination of structure upgrade (i.e. inclusion of additional barrels) and local formation lift was undertaken using the process summarised in Figure 2-3. Initially, the feasibility of replacing the existing structures with similarly sized replacement culverts was assessed. If these like-for-like structures met the performance requirements (refer to Section 2.2.1), the structure was considered adequate. If the performance requirements were not met, additional barrels were added and the upgraded structure reassessed (Cycle A: refer to Figure 2-3) or the additional lifts added to the formation (Cycle B: refer to Figure 2-3). (This process is repeated until the performance requirements are met, or it is identified that the performance requirements cannot be reasonably met without excessive lifting of the formations (considered to be greater than one metre) or significant increase in the number of culvert barrels (considered to be 12 barrels).

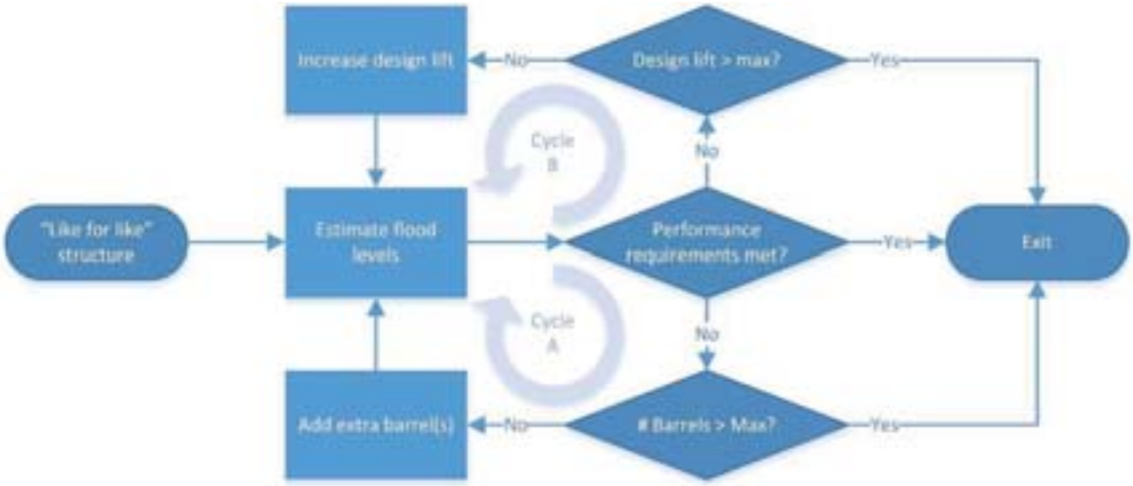


Figure 2-3 Formation and culvert size – selection process

2.5.2 Limitations of surface water analysis method

The adopted analysis contained a number of simplifications that were adopted to assist in the estimation of the potential impacts of the proposal in a timely manner and at a level of detail suitable for impact assessment. Details of the simplifications are provided in Appendix A.

These simplifications should be removed during future design stages through:

- Obtaining a broader and more reliable terrain representation upstream of the existing rail corridor to permit a more reliable definition of flow paths, catchment boundaries, connections (overflows) between adjacent catchments and other hydraulic features. This would also allow for a more accurate representation of storage effects upslope of the culverts.
- Adoption of more comprehensive and rigorous hydrologic and hydraulic analysis techniques to represent better the catchment response to rainfall and the catchment flow paths, directions and velocities for overland flows and watercourses. A more comprehensive hydraulic analysis technique would also permit a more rigorous assessment of the extent of upstream flood extents and impacts as the current analysis adopted a horizontal flood surface upstream of the existing rail corridor and upstream of the proposal. It would also allow the design of the proposed culverts to be refined to either reduce the estimated impacts or improve the reliability of the proposal.

- Use of landowner feedback information to validate the more comprehensive hydrologic and hydraulic analysis.
- Consideration of flows through, and possibly under, the ballast and formation. The current analysis assumes that the ballast and formation are impervious. In areas of deep ballast, flood levels may be affected by flows through the ballast.
- Consideration of local flow velocities and scour, including around bridge piles. Detailed modelling of watercourse flows, including flow velocities, shear stress and duration may be required to identify suitable erosion and scour protection measures. This is particularly true around bridge piles, which may be subject to turbulent flows resulting in deep scour holes around the piles.
- Consideration of effects of downstream flood levels on the culvert flows. In this current assessment, the downstream effects have not been considered due to the interaction between downstream catchments, extent and quality of terrain definition and potential for local farm works that could affect flow conditions. This would allow culverts to be modelled under tailwater control conditions.
- Consideration of the potential flow interaction of regional flood events with the local catchments. The current analysis has only considered flood events resulting from rainfalls on individual and small groups of catchments immediately upstream of the existing rail corridor. Floodwaters from the Macquarie River spilling into Backwater Cowal or from the Macquarie River floodplain flowing onto into the Bogan River floodplain (Bradys Cowal) have not been assessed but could affect the flooding conditions along the rail corridor. The breakout of the Macquarie River during large flood events is considered the only regional flooding issue that may influence the proposal.
- Undertake watercourse specific inspections and tailored modelling and analysis to understand better the flow interactions between catchments, tailwater influences and flooding duration. In particular, the interactions between Macquarie River, Backwater Cowal and the Bogan River.

2.5.3 Methodology – groundwater assessment

The methodology applied to the groundwater assessment included identification of the geological formations, the main groundwater sources, the characteristics of the sources and licensed extraction points from the groundwater. The potential impacts on groundwater were qualitatively assessed.

2.5.4 Outcomes sought in relation to hydrology

Hydrologic outcomes identified by government agencies as being required in the assessment are detailed in Table 2-1.

2.6 Flooding

2.6.1 Methodology

The proposal includes the raising or reconstruction of significant lengths of rail across large, relatively flat areas, including floodplains. During small floods, flows are conveyed through the defined incised channels, where they exist, while for larger flow rates the water flow would occur within the incised channels and over the floodplain areas. As a minimum, a structure was retained at or near the location as in the existing case to minimise potential hydrologic and hydraulic impacts of any redirections of flow or creation of new flood ponding areas that could not drain. At a few locations, the culvert position was repositioned by a few metres to better position the culvert at the low point along the rail corridor. The flood management objectives of conveying flow across the rail corridor and the culvert size were considered in conjunction with the selection of the rail formation level along the length of the proposal.

The flood impacts attributable to the proposal were identified by quantifying the flooding behaviour of the base case and comparing that with the flooding behaviour for the case with the proposal constructed.

Flood behaviour of the proposal was established using the assessment methodology as described in Appendix A.

The flooding assessment considered flood flows generated within the local catchment areas upslope of the proposal, with no consideration of the influence of downstream flooding on tailwater conditions. Tailwater effects on the flooding upstream of the existing rail corridor would only occur when the tailwater level was sufficiently high that it would impact the adopted culvert inlet control conditions and cause higher upstream flood levels to occur. At times when tailwater conditions do influence the culvert flow there is a need for correct quantification of the tailwater level, as this level will directly influence the flood level upstream of the culvert.

Changes to flooding behaviour derived from the assessment were used to define the proposal impacts. These areas were then overlaid on aerial photography and available information to identify the impacts on public and private property including built-up areas, farm infrastructure, cropping areas, grazing and forested areas, likely evacuation routes and flood refuges.

This process allowed identification of the magnitude of the predicted impacts for a range of flooding parameters and flood magnitudes. Based on these identified impacts, the proposal was assessed against the flood management objectives.

Stakeholder engagement meetings were undertaken following the initial flooding assessment to obtain feedback on the assessment of the predicted existing condition flood levels and extents. Landowner feedback is provided in diagrammatic form in Chapter 4.

Table 2-1 Required hydrologic outcomes

Agency	Desired performance outcome	Requirement	Where Addressed
DP&E	Long-term impacts on surface water and groundwater hydrology are minimised. Environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	• Describe the existing hydrologic regime for surface and groundwater resources likely to be impacted by the proposal, including stream orders. • Assess (and model if appropriate) the impact of the proposal (including ancillary facilities) during construction and operation on surface and groundwater hydrology, including: – Natural processes within rivers, wetlands, and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health, aquatic connectivity and access to habitat for spawning and refuge. – Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses. – The effects of proposed water management during construction and operation on natural hydrologic attributes and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems. – Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Section 3.8.2, Table 3-4 and Figure 3-5 Section 2.5 / Appendix A Table 3-3, Section 6.2 and Section 6.3 Table 5-1 and Section 6.3 Section 3.4 and Section 3.6
DPI	DPI Fisheries needs to be consulted concerning the crossing methodology and site-specific mitigation measures for replacement of culverts and bridges in watercourses that are considered Key Fish Habitat.	• Design and construct bridges, culverts and temporary access tracks across all watercourses in accordance with appropriate guidelines. • Replace watercourse crossings with minimal impact on the aquatic environment. • Provide details on methods duration and timing of dredging, and the proposed mitigation measures to protect riparian and aquatic habitat. • Minimise temporary watercourse crossings for heavy machinery. Consult with DPI Fisheries concerning any temporary measures that would result in blocking fish passage.	Sections 6.2.1, 6.2.2, 6.2.4 Sections 6.3.3 and 6.3.4 Sections 6.2.1, 6.2.2, 6.2.4 Sections 6.2.1, 6.2.2, 6.2.4 Noted

The Parkes north west connection was analysed using the same method as for the main rail line between Parkes and Narromine. No historical data was found for this section of the proposal.

2.6.2 Outcomes sought in relation to flooding

Flooding outcomes from the assessment are detailed in Table 2-2 against the agency requesting the outcome.

2.7 Legislation, policy and guideline context

A range of legislation, policy and guidelines directs the way water resources are managed in NSW. Key documents relevant to the proposal are outlined below.

2.7.1 General

Water Management Act

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 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. 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. However, the design and construction of the proposal would take into account the NSW Office of Water's guidelines for controlled activities on waterfront land. Development on floodplains 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. Part 8 was amended in 1999 to allow for more strategic control of such works through the preparation of suitably developed floodplain management plans. This allows for a broader consideration of issues in the approval of existing and proposed controlled works. Eventually, the *Water Management Act 2000* will contain all of the floodplain management provisions in Part 8; however, until Part 8 is repealed, both pieces of legislation are referenced.

Following introduction of the *Water Management Act 2000*, water sharing plans were developed that cover part or all of the proposal:

- Lower Macquarie Groundwater Sources
- Lachlan Regulated River
- Lachlan Unregulated and Alluvial Water Sources
- Macquarie Bogan Unregulated and Alluvial Water Sources
- Macquarie and Cudgegong Regulated Rivers.

A water sharing plan is generally in place for 10 years, but may be suspended from time to time under Section 49(a) of the Act due to severe water shortages.

To preserve water resources in river and groundwater systems for the future, the competing needs of the environment and water users are required 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).

Table 2-2 Required flooding outcomes

Agency	Desired performance outcome	Requirement	Where Addressed
DP&E	The proposal minimises adverse impacts on existing flooding characteristics. Construction and operation of the proposal avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, and dam failure.	• Assess and model impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (including potential climate change impacts) and quantify: • Detrimental increases in the potential flood affectation of other properties, assets and infrastructure. – Consistency (or inconsistency) with applicable council floodplain risk management plans. – Compatibility with the flood hazard of the land. – Compatibility with the hydraulic conveyance in floodways and storage areas of the land. – Downstream velocity and scour potential. – Impacts of the proposal on existing emergency management arrangements for flooding, and consultation with State Emergency Services and council. – Any impacts the proposal may have on social and economic costs to the community as consequence of flooding.	Section 6 Sections 6.3.1, 6.3.4, 6.3.5, 6.3.6 and 6.3.7 Section 6.3.5 Sections 6.3.5 Sections 6.3.7 Sections 4.3.4 and 6.3.4 Sections 4.3.6 and 6.3.6 Section 6.3.6
OEH	Flooding impacts are minimised.	• Define and map features as described in the Floodplain Development Manual (DIPNR 2005) including: – Flood-prone land – Flood planning area – Hydraulic categorisation. • Describe the flood assessment undertaken to assess the design flood levels for events, including a minimum of the 1 in 10 year and 1 in 100 year flood levels, and the probable maximum flood, or an equivalent extreme event. • Assess the effect of the proposal (including fill) on the flood behaviour under the following scenarios:	Sections 4 and 6 Sections 6, Appendices A, B and G Sections 6, Appendices A, B and G

Agency	Desired performance outcome	Requirement	Where Addressed
		– Current flood behaviour for a range of design events as identified earlier. This includes the 1 in 200 and 1 in 500 year flood events as proxies for climate change effects – Design forms.	
		• Consider and document: – Impacts of the full range of flood events including up to the probable maximum flood. – Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affectation of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. – Relevant provisions of the NSW Floodplain Development Manual (DIPNR 2005). • Assess the impacts on the proposal on flood behaviour, including: – Any detrimental increases in the potential flood affectation of other properties, assets and infrastructure. – Consistency with council floodplain risk management plans. – Compatibility with the flood hazard of the land. – Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. – Potential for adverse effect to beneficial inundation of the floodplain environment. – Any direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. – Any impacts upon existing community emergency management arrangements for flooding. – Any specific measures to manage risk to life from flood.	Section 6 Sections 4 and 6 Section 6 Section 2.7.3 Sections 6.3.1, 6.3.4, 6.3.5 6.3.6 and 6.3.7 Section 2.7.3 Sections 4.3.6 and 6.3.6 Sections 4.3.4 and 6.3.4 Sections 4.3.4 and 6.3.4 Sections 4.3.4 and 6.3.4 Sections 4.3.6 and 6.3.6

Agency	Desired performance outcome	Requirement	Where Addressed
		– Emergency management, evacuation and access, and contingency measures considering the full range or flood risk. • Social and economic costs resulting from flooding.	Sections 4.3.6 and 6.3.6 Section 6.3.6

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 stormwater systems.
- Flood management plans for urban and rural communities.
- Flood warnings and flood emergency management.
- Estimation of extreme flood levels.
- Reference was made to Australian Rainfall and Runoff in developing the methodological framework for assessing impacts on hydrology, flooding and water quality.

2.7.2 Floodplain development

Primary requirements for floodplain development are detailed in the Floodplain Development Manual (DIPNR 2005). Key policy and guidelines documents focusing on specific needs of the community and stakeholder in relation to floodplain development are summarised below.

Floodplain development manual

The Floodplain Development Manual (DIPNR 2005) was gazetted as the manual pertaining to the development of flood-liable land. The manual highlights the requirements consistent with the *Water Act 1912* to manage the risks resulting from natural hazards in order to reduce the impact of flooding on individual owners and occupiers of flood-prone property and to reduce private and public losses resulting from floods.

The Floodplain Development Manual encourages the completion of floodplain works to be completed so that:

- The passage of floodwaters is unobstructed.
- Temporary pondage of floodwaters is maintained.

Local government requirements

Local government requirements are consistent with the principles established in the Floodplain Development Manual in respect to the location and permissible impacts of development projects. However, for some developments, local government authorities have minimum development requirements.

A floodplain risk management study and plan (FRMS&P) was adopted by Narromine Shire Council in 2009 and is available on the counil's website (http://www.narromine.nsw.gov.au/development/flooding). The Narromine FRMS&P covers the floodprone areas of Narromine township only and does not cover the proposal site. The FRMS&P,classifies the land areas to the north of the proposal site as being *intermediate floodplain* and *high hazard ponding area*. The subsequent *Flood policy for development in urban floodplains* (Lyall & Assocaites 2011) indicates that residences within these hazard categories should include floor levels above the one per cent AEP flood level (plus 0.5 metres), and reliable pedestrian and vehicle access is required during the one per cent AEP flood for the *high hazard ponding areas*.

A floodplain risk management plan for Parkes Shire Council is not currently publically available.

Hazard

Flood preparedness, flood hazard and emergency management guidelines have been developed and are available from the State Emergency Services (SES 2014a, 2014b). Emergency Management Australia (EMA 1999, 2009a, 2009b, 2009c) and Australian Rainfall and Runoff (Engineers Australia 2015) also provide guidelines in respect to hazard categorisation and management.

These guidelines would be considered in the assessment of changes to potential road closures and road safety.

ARTC guidelines

The ARTC Track Drainage Design and Construction Practices Manual details minimum design criteria and construction practices expected by ARTC throughout the planning, design, construction and operation of the rail line.

3. Available data

This chapter presents a discussion on the physical characteristics of the study area. It is based on information in available reports and studies along with information supplied by ARTC and NSW and Australian government departments in support of the proposal.

3.1 Local government areas

The proposal is located in the Parkes Shire Council and Narromine Shire Council local government areas.

3.2 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 the study area, as listed in Table 3-1.

Table 3-1 Meteorological recording stations

Region	Name	Number	Latitude	Longitude	Starting year
Parkes	Goonumbla (Coradgery)	050016	32.97	148.06	1882
Parkes	Parkes Airport AWS	065068	33.13	148.24	1941
Parkes	Alectown (Cawdor)	065100	32.99	148.23	1992
Narromine	Bowling Club	054120	30.32	149.78	1870
Narromine	Alagalah Street	051037	32.24	148.24	1886
Narromine	Mumble Peg	051005	32.06	148.24	1881

The mean annual rainfall recorded at these stations varies along the alignment. The average annual rainfall is about 540 millimetres. Rainfall occurs relatively uniformly throughout the year.

3.2.1 Design rainfalls

Design rainfall data was obtained from the BoM Intensity Frequency Duration (IFD) generation process based on Australian Rainfall and Runoff (Pilgrim *et al.*, 1987 and Ball *et al.*, 2016). The rainfall IFD patterns for Parkes and Narromine are effectively the same for both ends of the proposal. Therefore, the section of proposed track between Parkes and Narromine could be adequately represented by a single rainfall IFD pattern. A comparison of the 1987 and 2013 IFD data showed only minor differences.

3.2.2 Climate change impacts

The NARCLiM climate change models provide recent projections for the potential climate change impacts for the greater Central West and Orara regions, which include the study area. Of particular importance is the predicted precipitation (rainfall) changes from 1990–2009 through to 2020–2039 and 2060–2079. The data is summarised in Table 3-2.

Table 3-2 NARCLiM data summary

Parameter	Projected change (%) to 2020–2039	Projected change (%) to 2060–2079
Annual mean rainfall change	-5 to 0	5 to 10
Summer rainfall	5 to 10 through -5 to 0	10 to 20
Autumn rainfall	5 to 10	10 to 20
Winter rainfall	-5 to 0 through -10 to -5	5 to 10
Spring rainfall	-20 to -10 through -10 to -5	-10 to -5

From the available NARCLiM modelling, climate change was assessed by adopting an increase in adopted rainfall IFD intensity varying from 10 to 30 per cent to account for estimated rainfall changes. This estimate is consistent with advice from Department of Environment and Climate Change (DECC 2007).

As indicated in the SEARs, consideration of the 0.5 per cent and 0.2 per cent ARI events was used as a surrogate for the specific evaluation of climate change impacts.

3.3 Terrain

Three sets of topographical data covering the study area were obtained:

- Survey model obtained through LiDAR survey and aerial imaging.
- Digital Elevation Model (DEM) obtained through Shuttle Radar Topography Mission (SRTM).
- Localised site survey at early work locations supplied to selected culvert locations.

The adopted terrain model is presented in Figure 3-1; it shows the general landform adjacent to the study area. This was formed from LiDAR (where available) and SRTM outside the LiDAR corridor. The higher portion of the rail corridor is toward the southern end.

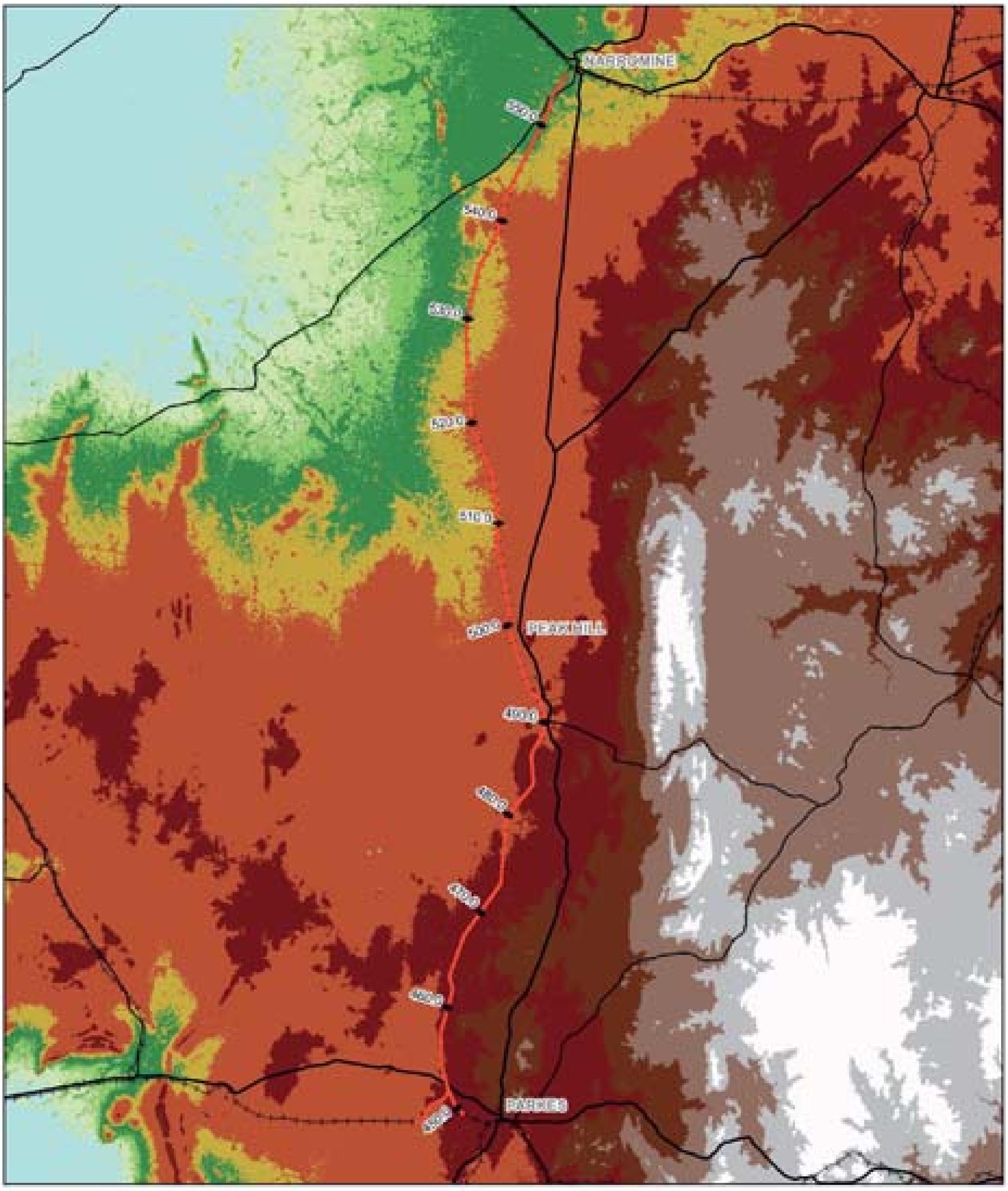
3.3.1 LiDAR

A topographic survey model (0.5 points per square metre) was obtained through LiDAR imaging and provided by ARTC. Data validation showed the largest array of data set points had a mean difference of 0.348 metres and a standard deviation of 0.056 metres.

Catchment boundaries and rail track level were defined using the developed terrain model. Flood extents were mapped by extending the predicted flood levels upstream of the rail corridor until the terrain surface is reached. Flood extents were restricted to the LiDAR survey model extent, as extrapolation into the SRTM area was unreliable for mapping flood extents.

3.3.2 Shuttle radar

Topographic data generated by the SRTM program was used for terrain outside the LiDAR corridor where necessary to define catchment boundaries that extend beyond the supplied information. The resolution of the Digital Elevation Model is 30 metres. The reported vertical accuracy of the data is plus or minus 10 metres; however, the accuracy is expected to exceed this figure given the generally flat landscape. The SRTM data was used to form the terrain model outside the LiDAR corridor.



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway

< 220
220 - 225
225 - 230
230 - 240
240 - 250
250 - 300
300 - 350
350 - 400
400 - 500
500 - 600
> 600

Paper Size A4
0 2 4 8 12 16
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17316
Revision	0
Date	23 Nov 2016

Corridor and Catchment Topography

Figure 3-1

3.3.3 Site survey

ARTC provided a limited amount of field survey data adjacent to a very limited number of culvert locations. The provided survey data comprised of a few spot levels at each culvert location.

3.3.4 Adopted levels

The different data sets gave differing levels for the existing top of the ballast and track. Since this assessment began when only the LiDAR survey was available, it was adopted as the standard with all other survey levels adjusted to match these levels as closely as possible.

Figure 2-1 provides a long section that was derived from the adopted terrain model along the rail corridor. This long section was extracted from the developed terrain model. The long section also shows, offset vertically by eight metres, the proposed structure locations.

3.4 Water demands

Estimated water demand for construction of the proposal is 75 to 100 megalitres for earthworks and dust control (about 50 to 70 megalitres per annum). 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:

- Parkes Shire Council – five megalitres.
- Private bores near chainages 708, 716, 724, 738, 748 and 778 – three megalitres per bore. Each bore is within five kilometres of the proposal site.
- Parkes North and Peak Hill mines – 10 to 15 megalitres for each mine.
- Private dams near chainages 730, 782 and 798 – 10 megalitres at each site.
- Macquarie River – 10 megalitres.
- Narromine Shire Council – 5 megalitres.

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

3.5 Geology and soils

3.5.1 General

The study area is located generally within the Central Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary aged red silty alluvium over folded and faulted Silurian and Ordovician aged sedimentary and minor metamorphic sequences, which outcrop intermittently along the rail corridor.

Thick reactive brown and grey clay soils are predominantly associated with the near level terrain north of Peak Hill, while moderately thick red and brown sandy and silty clay soils are typically associated with the undulating terrain south of Peak Hill.

3.5.2 Soil groups and characteristics

Soil characteristics along the length of the proposal were determined from the eSpade database. Table 3-3 provides a summary of the soil landscape groups along the proposal site while Table 3-4 provides information on dominant soil groups. The dominant Great Soil Groups are shown in Figure 3-2.

3.5.3 Acid sulfate soils

No acid sulfate soils are expected to be encountered in the study area.

Table 3-3 Soil landscape groups

Range soil type occurs	Classification / profile no.	Location	Soil types	Soil landscape	Erosion / salinity
CH 450–455	Parkes	Parkes and Forbes	Shallow to moderately deep (<60 cm), moderately well drained Red Earths, and Red Podzolic Soils occur on side slopes. Lower slopes have moderately deep (>80 cm) imperfectly drained Red Brown Earths. Narrow drainage lines have deep (>150 cm) poorly drained Brown Solodic Soils.	• Stoniness • Sodicity / dispersibility • Hardsetting surfaces (localised) • Low permeability	• High water erosion hazard • Salinity (localised) • Moderate to high erodibility
CH 450–460	Brolgan Plain	Plains west of Parkes, including Brolgan Plain	Deep (>100 cm) imperfectly drained Red Brown Earths and Non-calcic Brown Soils occur on the plains. Deep (>100 cm) moderately well drained Red Podzolic Soils and Red Earths also occur on some plains.	• Sodicity / dispersibility • Hardsetting surface (localised) • Flood hazard • Foundation hazard • Seasonal waterlogging (localised).	• Low to moderate erosion hazard • Topsoils have high erodibility • Clay-rich subsoils have moderate erodibility
CH 450–465	Goonumbla	Vicinity of Goonumbla and Cooks Myalls	Shallow (<10 cm) well drained Lithosols and shallow (<50 cm) moderately well drained Red Podozlic Soils occur on crests. Shallow (<50 cm) moderately well drained Red Earths / Euchronsems and Red Podzolic Soils occur on upper and mid-slopes. Moderately deep (>80cm) moderately well drained Non-Calcic Brown Soils occur on lower slopes.	• Stoniness • Hardsetting surfaces (localised). • Rock outcrop	• Moderate to high water erosion hazard • Moderate topsoil erodibility • Very low subsoil erodibility
CH 460–480	Cooks Myalls	Between Parkes and Bogan Gate	Moderately deep (>50 cm), moderately well drained Red Podzolic Soils, and deep (>100 cm) poorly drained Red Solodic Soils occur along drainage lines and lower slopes. Shallow to moderately deep (<80 cm) well-drained Terra Rossa Soils, Red Podzolic Soils and Red Earths / calcareous Red Earth intergrades occur on limestone and sandstone/chert/siltstone bedrock.	• Alkalinity (localised) • Sodicity / dispersibility (localised) • Hardsetting surfaces (localised) • Seasonal waterlogging (localised)	• High water erosion hazard • Salinity (localised) • High erodibility (localised) •

Range soil type occurs	Classification / profile no.	Location	Soil types	Soil landscape	Erosion / salinity
			Moderately deep (>60 cm), moderately well drained Non-calcic Brown Soils occur on some slopes. There are small areas of gilgai soils.		

Table 3-4 Major soil groups

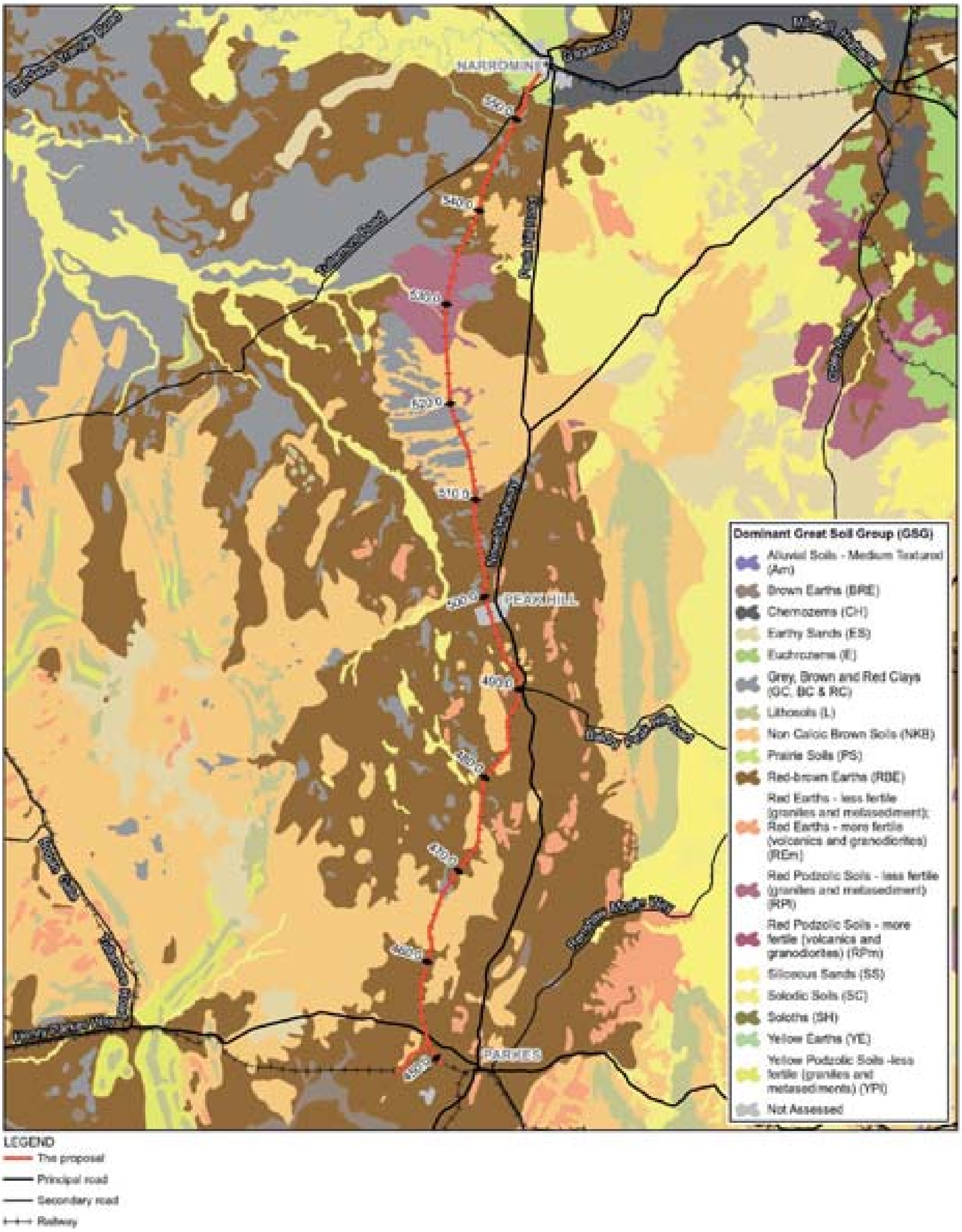
Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
CH 465–470	North of Goonumbla	Shallow (<40 cm) imperfectly drained Red Clays occur on flat alluvial plains.	• Low permeability • Seasonal cracking when dry • Low runoff	• High erosion hazard • No salting evident • Moderate soil erodibility
CH 470–480	North of Goonumbla	Shallow (<40 cm) moderately well drained Red Podzolic Soils occur on lower and upper hillslopes.	• Slowly permeable • Hardsetting when dry • Moderate runoff	• Moderate erosion hazard • Moderate soil erodibility • No salting evident
CH 475–485	Between Trewilga and Parkes	Moderately deep (<105 cm) reddish brown sand acts as topsoil on flat topography. Very deep (>170 cm) moderately well drained Red Clay and Red Podzolic Soils occur on flats and hillslope depressions.	• Moderate to high soil erodibility • Permeability varies • Moderate to high runoff	• Very high to high erosion hazard • Minor (<150 cm) active gully erosion • No salting evident
CH 480–490		Shallow (<5 cm) sandy loam topsoils, and shallow (<40 cm) imperfectly drained Red Podzolic Soils occur on upper and lower hillslopes.	• Moderate soil erodibility • Hardsetting when dry • Moderate to high runoff	• High erosion hazard • No salting evident
CH 485–490		Shallow (<20 cm) sandy loam topsoil occur on upper slopes, and silty loam and sandy clay loams occur on lower slopes. Shallow to moderately deep (<60 cm) poorly drained Non-calcic Brown Soils and moderately drained Red Podzolic Soils occur on lower slopes, and moderately well drained Grey-brown Podzolic Soils occur on upper slopes.	• Moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• Slight–moderate erosion hazard • No salting evident
CH 490–500	Between Trewilga and Peak Hill	Moderately shallow (<35 cm) moderately well drained brown clay loam topsoils occur on batters and within gullies.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Very high to high erosion hazard on batters and within gullys • Moderate erosion hazard on lower slopes

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
		Moderately deep (<80 cm) brown medium to heavy clay Red Podzolic Soils occur on batters and within gullies. Moderately deep (<50 cm) and moderately well drained Non-Calcic Brown Soils and moderately deep (<95 cm) Yellow Podzolic Soils occur on lower slopes.		• Moderate (<1.5 m) active gully erosion • No salting evident
CH 500–510	North of Peak Hill	Shallow (<20 cm) topsoil layers of silty clay loam and sandy clay loam occur. Moderately deep (<90 cm) moderately well drained Non-calcic Brown Soils, and moderately deep (<40 cm) moderately well drained Red and Brown Podzolic Soils occur on hillslopes and flat plains.	• Moderate soil erodibility • Hardsetting when dry • High to moderate runoff on hillslopes • Low runoff on flat plains	• High erosion hazard near Peak Hill (CH 500), moving to moderate erosion hazard • No salting evident
CH 510–520	South west of Tomingley	Shallow (<15 cm) layers of fine sandy loam topsoil. Moderate (<50 cm) layers of moderately well drained Non-Calcic Brown Soils and Red Brown Earth.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Slight erosion hazard • No salting evident
CH 510–520	South west of Tomingley	Moderately deep (<70 cm) very poorly drained Grey Clay occurs within depressions (gilgai) on flat plains.	• Moderate soil erodibility • Seasonal cracking • No runoff	• Moderate erosion hazard • No salting evident
CH 520–525	West of Tomingley	Moderately shallow (<40 cm) moderately well drained loamy sand top soils. Moderately deep (<95 cm) moderately well drained Earthy Sands and Red Podzolic Soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate to low runoff	• Earthy sands have high erosion hazard • Moderate erosion hazard for Red Podzolic Soils • No salting evident
CH 525–535	North west of Tomingley	Shallow (<25 cm) poorly drained sandy clay and silty clay loam topsoil occur on flat plains. Moderately deep (<90 cm) imperfectly drained Yellow Podzolic Soils occur in depressions. Poorly drained deep (<150 cm) brown chromosol and moderately deep (<90 cm) solodic soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • High to moderate runoff	• Solodic soils on flat plains have high erosion hazard • Moderate erosion hazard for Brown Chromosol and Yellow Podzolic Soils • No salting evident
CH 535–545	South of Narromine	Shallow (<30 cm) silty loam topsoil occurs on lower slopes and shallow (<10cm) clay loam topsoil on flat plains.	• High to moderate soil erodibility • Hardsetting when dry	• High erosion hazard • No salting evident

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
		Moderately deep (<110 cm) moderately well drained Red Brown Earth occur on lower slopes and flat plains.	• Low to moderate runoff	
CH 540–550	South of Narromine	Shallow (<10 cm) topsoil layer of poorly drained Red Brown Earth occurs on plains. Deep (<120 cm) layers of moderately well drained Brown Clay and imperfectly drained Grey Clay occur on flat plains and floodplains. Moderately deep (<95 cm) poorly drained Grey Clay occurs in depressions (such as Backwater Cowal).	• High to moderate soil erodibility on flat plains and floodplains • Low soil erodibility in depressions • Hardsetting when dry • Low to moderate runoff	• Slight erosion hazard • No salting evident
CH 550–555	Narromine	Shallow (<28 cm) topsoil layer of silty clay loam occurs on flat plains. Moderately deep (<65 cm) imperfectly drained Red Brown Earth and deep (<100 cm) layers of Non-calcic Brown Soils. Drainage of Non-Calcic Soils varies from poorly drained to moderately well drained.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident
CH 465–470	North of Goonumbla	Shallow (<40 cm) imperfectly drained Red Clays occur on flat alluvial plains.	• Low permeability • Seasonal cracking when dry • Low runoff	• High erosion hazard • No salting evident • Moderate soil erodibility
CH 470–480	North of Goonumbla	Shallow (<40 cm) moderately well drained Red Podzolic Soils occur on lower and upper hillslopes.	• Slowly permeable • Hardsetting when dry • Moderate runoff	• Moderate erosion hazard • Moderate soil erodibility • No salting evident
CH 475–485	Between Trewilga and Parkes	Moderately deep (<105 cm) reddish brown sand acts as topsoil on flat topography. Very deep (>170 cm) moderately well drained Red Clay and Red Podzolic Soils occur on flats and hillslope depressions.	• Moderate to high soil erodibility • Permeability varies • Moderate to high runoff	• Very high to high erosion hazard • Minor (<150cm) active gully erosion • No salting evident
CH 480–490		Shallow (<5 cm) sandy loam topsoils, and shallow (<40 cm) imperfectly drained Red Podzolic Soils occur on upper and lower hillslopes.	• Moderate soil erodibility • Hardsetting when dry • Moderate to high runoff	• High erosion hazard • No salting evident
CH 485–490		Shallow (<20 cm) sandy loam topsoil occurs on upper slopes, and silty loam and sandy clay loams occur on lower slopes.	• Moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• Slight to moderate erosion hazard • No salting evident

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
		Shallow to moderately deep (<60 cm) poorly drained Non-calcic Brown Soils and moderately drained Red Podzolic Soils occur on lower slopes, and moderately well drained Grey-brown Podzolic Soils occur on upper slopes.		
CH 490–500	Between Trewilga and Peak Hill	Moderately shallow (<35 cm) moderately well drained brown clay loam topsoils occur on batters and within gullies. Moderately deep (<80 cm) brown medium to heavy clay Red Podzolic Soils occur on batters and within gullies. Moderately deep (<50 cm) moderately well drained Non-Calcic Brown Soils and moderately deep (<95 cm) Yellow Podzolic Soils occur on lower slopes.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Very high to high erosion hazard on batters and within gullys • Moderate erosion hazard on lower slopes • Moderate (<1.5m) active gully erosion • No salting evident
CH 500–510	North of Peak Hill	Shallow (<20 cm) topsoil layers of silty clay loam and sandy clay loam. Moderately deep (<90 cm) moderately well drained Non-calcic Brown Soils, and moderately deep (<40cm) moderately well drained Red and Brown Podzolic Soils occur on hillslopes and flat plains.	• Moderate soil erodibility • Hardsetting when dry • High to moderate runoff on hillslopes • Low runoff on flat plains	• High erosion hazard near Peak Hill (CH 500), moving to moderate erosion hazard • No salting evident
CH 510–520	South west of Tomingley	Shallow (<15 cm) layers of fine sandy loam topsoil. Moderately deep (<50 cm) layers of moderately well drained Non-Calcic Brown Soils and Red Brown Earth.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Slight erosion hazard • No salting evident
CH 510–520	South west of Tomingley	Moderately deep (<70 cm) very poorly drained Grey Clay occurs within depressions (gilgai) on flat plains.	• Moderate soil erodibility • Seasonal cracking • No runoff	• Moderate erosion hazard • No salting evident
CH 520–525	West of Tomingley	Moderately shallow (<40 cm) moderately well drained loamy sand top soils. Moderately deep (<95 cm) moderately well drained Earthy Sands and Red Podzolic Soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate to low runoff	• Earthy sands have high erosion hazard • Moderate erosion hazard for Red Podzolic Soils • No salting evident

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
CH 525–535	North west of Tomingley	Shallow (<25 cm) poorly drained sandy clay and silty clay loam topsoil occurs on flat plains. Moderately deep (<90 cm) imperfectly drained Yellow Podzolic Soils occur in depressions. Poorly drained deep (<150 cm) brown chromosol and moderately deep (<90 cm) solodic soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • High to moderate runoff	• Solodic soils on flat plains have high erosion hazard • Moderate erosion hazard for Brown Chromosol and Yellow Podzolic Soils • No salting evident
CH 535–545	South of Narromine	Shallow (<30 cm) silty loam topsoil occurs on lower slopes and shallow (<10 cm) clay loam topsoil occurs on flat plains. Moderately deep (<110 cm) moderately well drained Red Brown Earth occurs on lower slopes and flat plains.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident
CH 540–550	South of Narromine	Shallow (<10 cm) topsoil layer of poorly drained Red Brown Earth occurs on plains. Deep (<120 cm) layers of moderately well drained Brown Clay and imperfectly drained Grey Clay occur on flat plains and floodplains. Moderately deep (<95 cm) poorly drained Grey Clay occurs in depressions (such as Backwater Cowal).	• High to moderate soil erodibility on flat plains and floodplains • Low soil erodibility in depressions • Hardsetting when dry • Low to moderate runoff	• Slight erosion hazard • No salting evident
CH 550–555	Narromine	Shallow (<28 cm) topsoil layer of silty clay loam occurs on flat plains. Moderately deep (<65 cm) imperfectly drained Red Brown Earth and deep (<100 cm) layers of Non-calcic Brown Soils. Drainage of Non-Calcic Soils varies from poorly drained to moderately well drained.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident



Paper Size A4

0 2 4 8 12 16

Kilometres

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

N

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

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Great Soil Groups

Figure 3-2

3.5.4 Bore data

Searches of the NSW Groundwater Bore Database (DPI – Water 2016a) (undertaken on 1 June 2016) and of the DPI – Water Pinneena Database were undertaken to identify registered bores within 250 metres of the proposal.

The search identified 19 registered bores. Bore locations are shown in Figure 3-3 and details are provided in Appendix C.

A number of the identified bores had cancelled licences. Fourteen bores were registered for a combination of stock, domestic or irrigation use. Two bores were registered as town water supply, there was one test bore, and two bores were unknown.

The majority of the bores were near Narromine. The majority of these bores intercept alluvial sediments associated with Macquarie River. Yields were not reported for the majority of registered bores, but a yield of over 50 litres per second was reported at one registered bore that intercepted deep alluvial sediments.

Outside the vicinity of Narromine, the majority of identified bores are more than 70 metres deep and are assumed to be intercepting groundwater from the fractured rock groundwater source.

3.5.5 Groundwater sharing plans

The proposal lies within the water sharing plans for the:

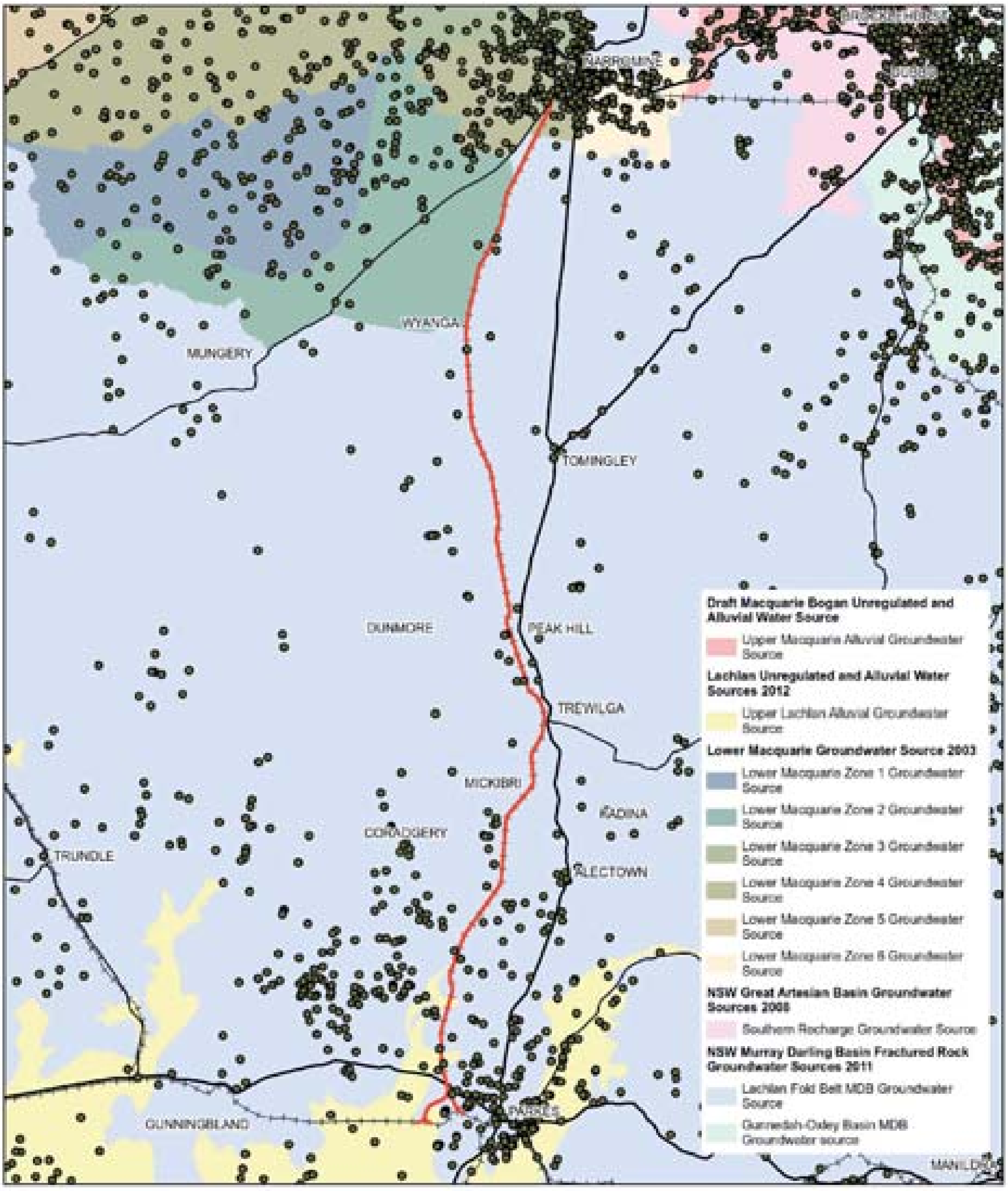
- Lachlan Unregulated and Alluvial Water Sources (NSW Government 2012a)
- NSW Murray Darling Basin Fractured Rock Groundwater Sources (NSW Government 2011)
- Lower Macquarie Groundwater Source (NSW Government 2003)
- Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Government 2012b).

The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources commenced in September 2012 and regulates the interception and extraction of water from unregulated rivers and alluvium within the defined water sharing plan area. The proposal lies within the Upper Lachlan Alluvial Groundwater Source of this water sharing plan as shown in Figure 3-3.

The Water Sharing Plan for the NSW Macquarie-Darling Basin Groundwater Source commenced in January 2012. It regulates the interception and extraction of water from fractured rock groundwater sources and from unmapped alluvial sediments that overlay outcropping fractured rock within the defined water sharing plan area. The proposal lies within the Lachlan Fold Belt Macquarie-Darling Basin Groundwater Source of this water sharing plan as shown in Figure 3-3.

The Water Sharing Plan for the Lower Macquarie Groundwater Source commenced in October 2006. This water sharing plan is due for extension/replacement in July 2017 and is currently undergoing a formal review (DPI – Water 2016b). It regulates the interception and extraction of water from the alluvium and Great Artesian Basin within the defined water sharing plan area. The proposal lies within the Lower Macquarie Zone four groundwater source and lies on the boundary of the Lower Macquarie Zone 2 groundwater source of this water sharing plan as shown in Figure 3-3.

The Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources commenced in October 2012. It regulates the interception and extraction of water from unregulated rivers and alluvium within the defined water sharing plan area.



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway
- Licensed Groundwater Bore

Paper Size A4

0 2 4 8 12 16

Kilometres

Map Projection: Transverse Mercator

Horizontal Datum: GDA 1994

Grid: GDA 1994 MGA Zone 55

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Licensed Groundwater Bores

Figure 3-3

3.6 Water sources

3.6.1 Licensed extraction points

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 D.

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

3.7 Land uses

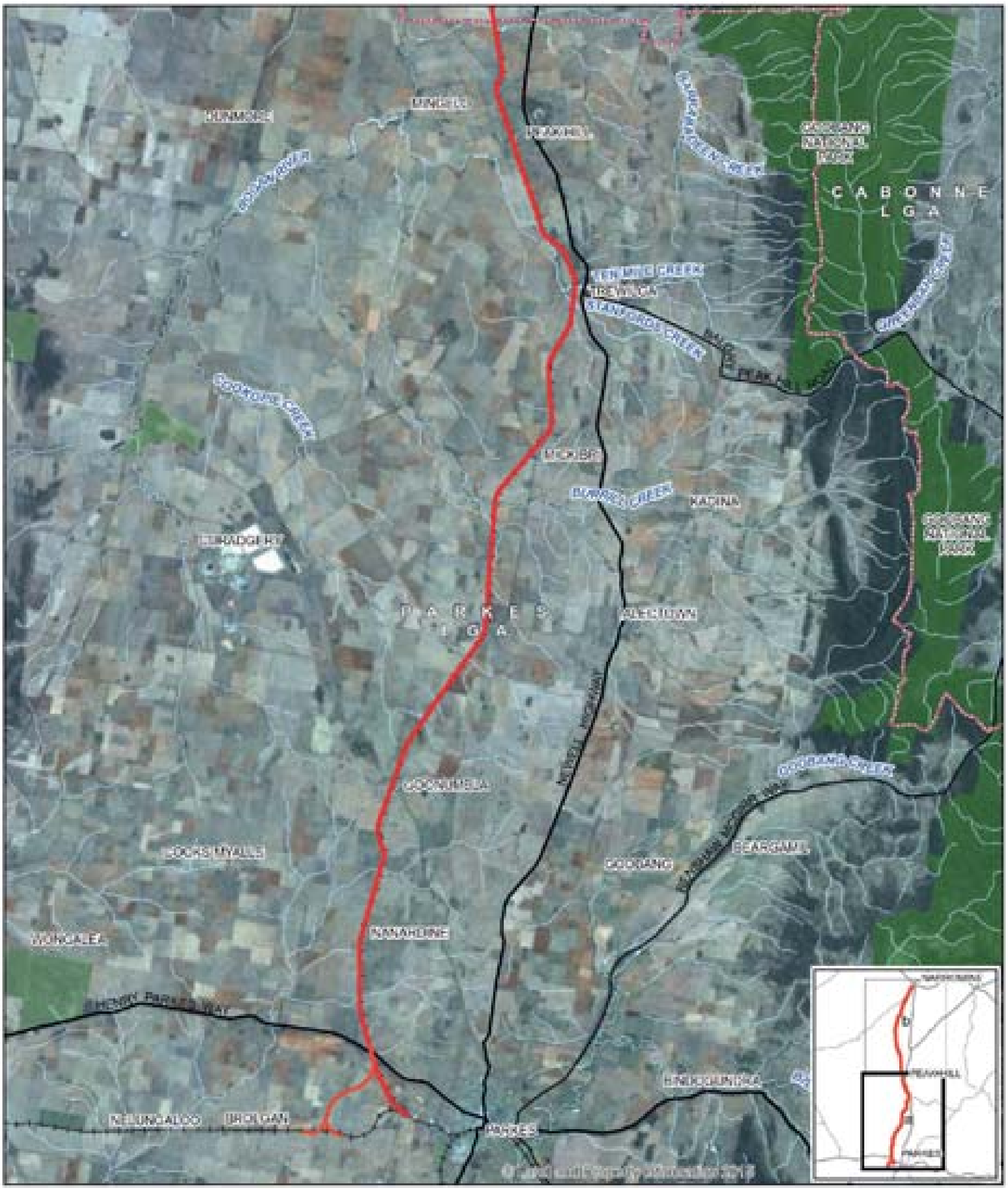
Most of the proposal would be built within the rail corridor for the Parkes to Narromine line.

Beyond the rail corridor the study area and surrounding land is dominated by agricultural uses, particularly cotton, wheat, and livestock. These industries, have resulted in significant clearing when compared to native bushland. This clearing has an impact on the resulting storm flows by lowering the catchment roughness (a measure by which surface flow in impaired by the surface type), which quickens the catchment's response time to rainfall and results in shorter, more intense catchment flows.

In addition to the agricultural land uses, scattered areas of retained bushland in the form of national park or State forest result in relativity small pockets of uncleared native vegetation within the contributing catchments.

Relatively small and localised pockets of urban areas are centred around the regional townships of Parkes, Peak Hill and Narromine with the occasional mine and quarry within the contributing catchments. The urban, mining and quarrying land uses are well cleared.

Figure 3-4 shows the land uses along the rail corridor along with forestry reserves, conservation reserves and national parks. As shown, the flatter portions of the catchments are generally used for agricultural uses.



LEGEND

- The proposal
- Local Government Area
- Principal road
- Secondary road
- Railway
- Watercourse
- Forestry reserve
- Conservation reserve

Paper Size A4

0 1 2 4 6 8

Australian Rail Track Corporation
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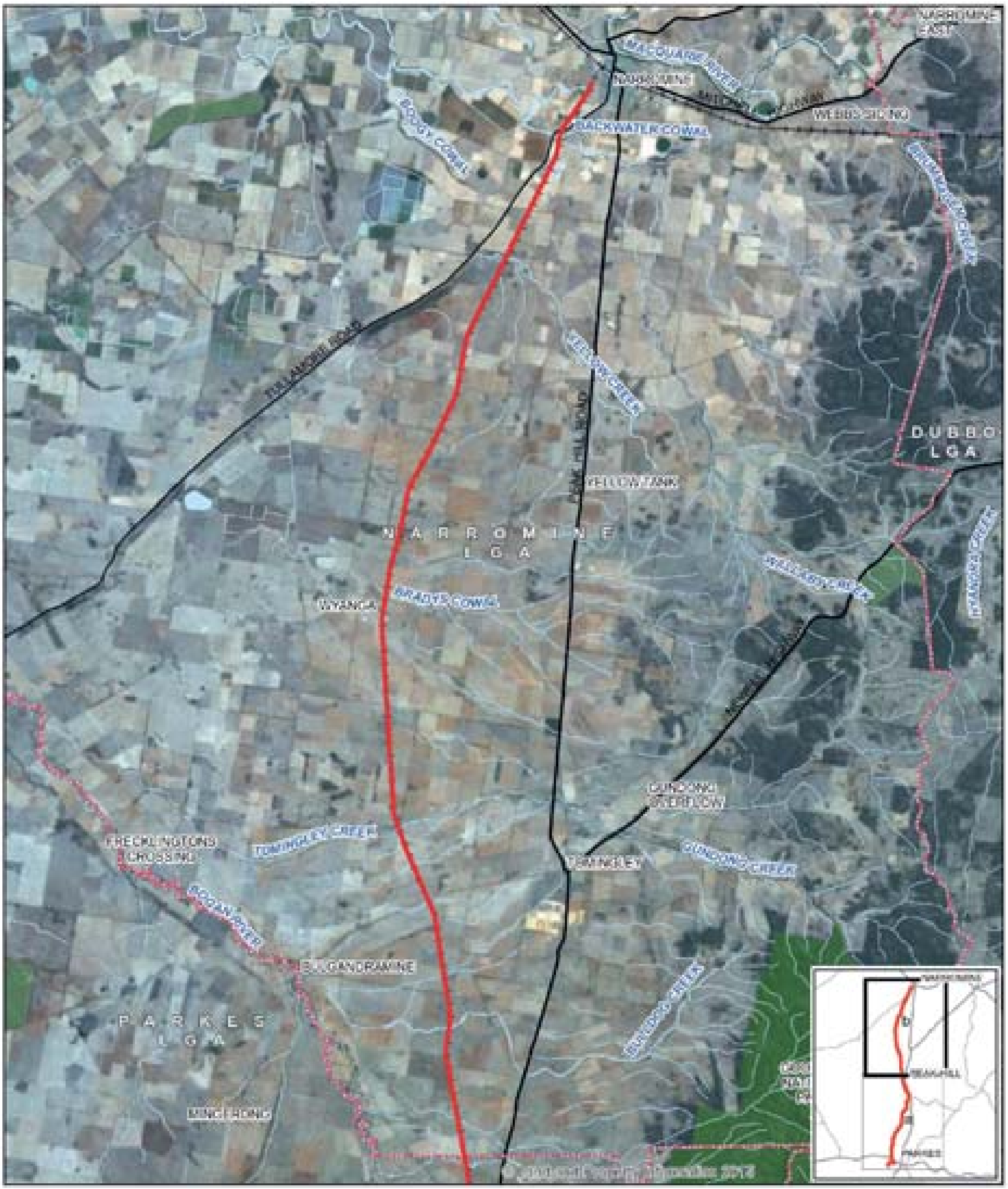
Land Use - Sheet 1

Figure 3-4a



LEGEND

- The proposal
- Local Government Area
- Principal road
- Secondary road
- Railway
- Watercourse
- Forestry reserve
- Conservation reserve

Paper Size A4

0 1 2 4 6 8

Kilometres

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

Australian Rail Track Corporation
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Job Number 22-17916
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Date 23 Nov 2016

Land Use - Sheet 2

Figure 3-4b

3.8 Watercourses

3.8.1 Major river and basin systems

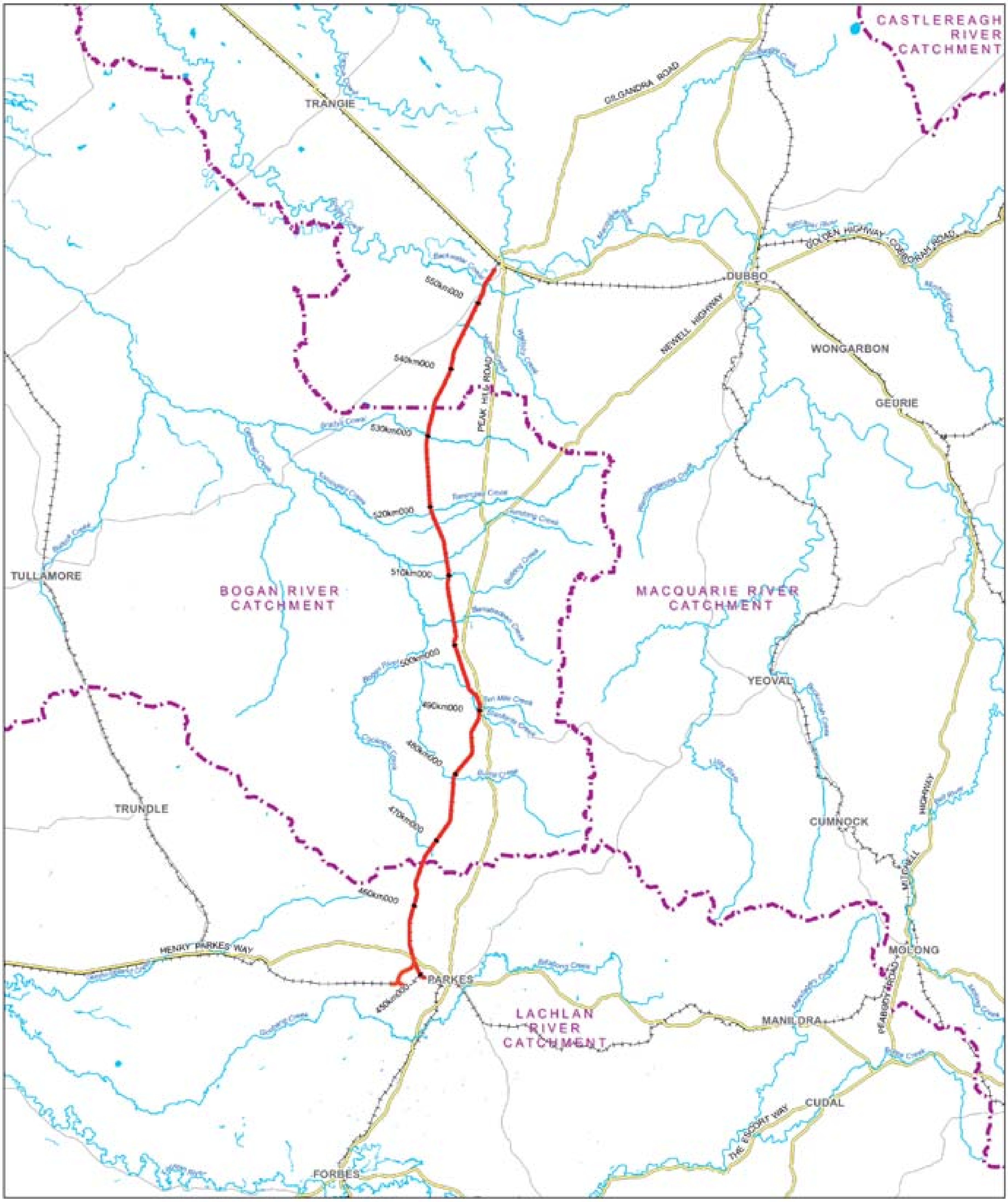
The proposal is located within the major water catchments of the Lachlan River Basin and the Macquarie-Bogan River Basin as shown in Figure 3-5.

The Lachlan River starts in the east as a chain of lakes formed by the confluence of Hannans Creek and Mutmutbilly Creek catchments. Travelling west the river system passes south of Parkes and the rail corridor. Ridgey Creek, one kilometre east of the proposal, is the closest of the significant Lachlan River tributaries. The proposal origin at Parkes to chainage 465.500 lies within the Lachlan River Basin. The Lachlan River, while a tributary of the Murrumbidgee River and a contributor to the Murray-Darling Basin, effectively terminates in the west as a large, expansive system of wetlands known as the Great Cumbung Swamp. The Lachlan River basin therefore connects only to the Murray-Darling Basin during periods of major flood (NSW Fisheries Scientific Committee 2005).

The Macquarie River starts in the east at the confluence of the Campbells River and Davies Creek, within Bathurst, and travels north west past the towns of Wellington, Dubbo and Narromine to the Macquarie Marshes. The Macquarie Marshes drain via the lower Barwon River into the Darling River and the broader Murray-Darling Basin. The waters of the Macquarie River and its tributaries are impounded for flood control and irrigation by Burrendong Dam, a large reservoir with capacity of 1,188 gigalitres located near Wellington and the Cudgegong Dam.

The Bogan River lies within the Macquarie-Bogan River Basin and is located west of the proposal, making it a receiving environment rather than a potential contributor to flooding. The Bogan River drains via the Lower Barwon River into the Darling River and the broader Murray-Darling Basin.

Combined, the Macquarie and the Bogan Rivers form the Macquarie-Bogan River Basin.



LEGEND

- Parkes to Narromine Rail Line
- Major Road
- Secondary Road
- Railway
- Watercourse
- Waterbody
- Major river catchment

Paper Size A3

0 2,500 5,000 10,000 15,000 20,000

Metres

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

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Major Watercourses

Figure 3-5

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

3.8.2 Watercourses

Surface water within the study area is predominately comprised of ephemeral watercourses, excluding the major perennial river systems identified in Section 3.8.1. This classification is a result of the size of the contributing watercourse catchment area, the rainfall pattern experienced in the region, and no base flow resulting from groundwater expression. Minor rivers (those less than 1,000 square kilometres) include:

- Burrill Creek
- Stanfords Creek
- Ten Mile Creek
- Barrabadeen Creek
- Bulldog Creek
- Gundong Creek
- Tomingley Creek
- Bradys Cowal
- Yellow Creek.

Table 3-5 provides details on the main watercourses 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).
- The watercourses assessed including all named watercourses and all un-named watercourses with stream order greater than third order.

The morphology of watercourses is characterised by three stream types, as follows:

- 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, this stream type typically holds water in isolated pools.
- Channelised fill systems are generally laterally, 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. This includes clearing of vegetation, stock grazing impacts, construction of online farm dams and drainage improvements (e.g. channelising watercourses through excavation or bunding). Typically, poor condition reaches have been channelised to improve drainage and limit flood extents. These reaches can also display evidence of ongoing channel erosion.

The 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. It is considered that at some locations the channelized form downstream is the combined result of erosion and scouring induced by the culverts, and channelization of the watercourse to allow the surrounding area to be used for agricultural purposes (ie crops).

Figure 3-5 shows the larger creeks along the proposal site along with the broad regional context of the larger watercourses.

The Macquarie River and Backwater Cowal are in close proximity adjacent to Narromine. Large regional floods in the Macquarie River may still break out causing flow in the Backwater Cowal. Records from the historical flooding in 1955 indicate a break out did occur upstream of Narromine near Webbs Siding into Backwater Canal but works have been completed on the east west railway since that flood. Any breakout, not considered in this assessment, from the Macquarie River into Backwater Canal could significantly increase design flow rates to be greater than those from the relatively large local catchment area.

Table 3-5 Watercourses crossed by the proposal site

Catchment	Chainage (km)	Watercourse	Flow regime	Stream Order	River Style	Condition	Comments
Lachlan	455.2	Un-named	Ephemeral	3	Valley fill	Poor	Stable although modified to flow within floodway.
Lachlan	461.15	Un-named	Ephemeral	3	Channelised fill	Moderate	Stable, grass-lined trapezoidal channel.
Bogan	472.05	Un-named	Ephemeral	3	Channelised fill	Moderate	Stable, grass-lined trapezoidal channel.
Bogan	478.25	Un-named	Ephemeral	3	Valley fill	Moderate	Some channelisation downstream.
Bogan	479.3	Burrill Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable channel with near permanent ponds.
Bogan	489.8	Stanfords Creek	Ephemeral	4	Channelised fill	Poor	Incised channel with minor levels of bank erosion downstream.
Bogan	490.55	Ten Mile Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Stable, grass-lined trapezoidal channel.
Bogan	503.6	Barrabadeen Creek	Ephemeral	5	Low sinuosity fine grained	Poor	Incised system with unvegetated upper banks, although relatively stable. Near permanent pools.
Bogan	509.65	Bulldog Creek	Ephemeral	4	Valley fill	Moderate	Large pool immediately downstream of rail corridor. Mound to the south indicates pool was likely excavated.
Bogan	512.1	Gundong Creek	Ephemeral	4	Channelised fill	Poor	Excavated straight channel downstream with moderate levels of bank erosion. Upstream valley fill in moderate condition.
Bogan	517.43	Unnamed	Ephemeral	4	Valley fill	Poor	Relatively stable, minimal vegetation and watercourse shape converts to floodplain downstream of culvert
Bogan	519.2	Tomingley Creek	Ephemeral	4	Valley fill	Good	Stable, well-vegetated creek in narrow valley set within a Gilgai landscape.
Bogan	529.8	Brady's Cowal	Ephemeral	4	Low sinuosity fine grained	Moderate	Stable, grassed channel. Large excavated pond on downstream side of rail corridor.
Macquarie	546.55	Yellow Creek	Ephemeral	3	Valley fill	Moderate	Stable, well-vegetated system. Online dams.

Catchment	Chainage (km)	Watercourse	Flow regime	Stream Order	River Style	Condition	Comments
Macquarie	552.65	Backwater Cowal	Ephemeral	5	Valley fill	Moderate	Stable, broad depression – infilled paleo-channel – well-vegetated with ground cover species. Receives flow from Wallaby Creek catchment and flood flows from the Macquarie River.

3.9 Flow rates

Historical flood level and flow data was extracted from publicly available data bases (http://waterinfo.nsw.gov.au/ and Pineena). The extracted data was then subject to a flood frequency analysis to determine the magnitude of design floods based on the historical data.

3.9.1 Gauging data

The gauging stations considered in the analysis are listed in Table 3-6.

Table 3-6 Flow gauging station considered in assessment

Station no	Station name	Latitude	Longitude	Start date	End date	Catchment area (km^2)
Macquarie River Basin						
421006	Macquarie River at Narromine	32.22	148.24	2/01/1913	1/08/1980 (flow) 31/07/1978 (depth)	25,950
421048	Little River at Obley No. 2	32.71	148.55	24/06/1986	28/07/2015 A	612
421076	Bogan River at Peak Hill No. 2	32.72	148.13	11/11/1980	19/02/2002 (flow) 31/10/2013 (depth)	1,036
421084	Burrill Creek at Mickibri	32.90	148.22	19/09/1973	2/03/1999	163
Lachlan River Basin						
412004	Lachlan River at Forbes, Cottons Weir	33.41	147.99	29/07/1970	29/07/2015 A	19,000
412086	Goobang Creek at Parkes	33.18	148.18	16/06/1968	14/03/1989	670
A Date of analysis.						

Log Pearson flood frequency analyses were undertaken on observed historic records to determine the likelihood of the specified flow rate being exceeded in a given year.

As the local catchment areas considered in the local catchment flood modelling (refer to Sections 4.3 and 6.2.5) are generally significantly smaller than those of the gauging stations, it is not feasible to directly compare the modelled local catchment flows to the observed flow data from the gauging stations. In addition, the smaller gauged catchments include limited available relatively short period data and therefore are unlikely to capture the full range of floods in the area.

3.10 Flooding conditions

3.10.1 Flooding causes

Flooding for the study area may be influenced by floods from two sources (or a combination of these sources):

- Flooding may be caused by high flows in the major rivers (Macquarie or Lachlan); these are termed regional floods in this report, and are the result of rainfall over a significant portion of the respective river basin catchment.
- Flooding may be caused by rainfall over the local catchment draining to an individual underbridge or group of culverts in isolation of the regional flooding behaviour.

Due to the topography, it is unlikely that the Lachlan River could affect flooding conditions at the Parkes end of the proposal.

The flooding causes and their consideration within this assessment are summarised in Table 3-7.

Table 3-7 Flooding causes

Flooding source	Details	Note
Flooding from major river systems.	Major regional river flood extents Macquarie River catchment	Not considered in the flooding assessment of the proposal, as it is impractical to make the rail flood-free against this source of regional flooding.
Flooding from local catchments.	Local rainfall and runoff events of catchments upstream of the proposal	Considered in the flooding and water quality assessment.

At several locations along the proposal site, flow can discharge from one local catchment into the next prior to overtopping the rail level. This effect has been considered through a flow redistribution approach.

Backwater effects for water ponding on the downslope side of the track were not considered due to the significant increase in variables introduced into the analysis through their inclusion. (Refer to Section 2 for further details on why backwater effects were not assessed).

During the detailed design stage of this proposal, there should be as described in Section 3.5.2 an analysis and refinement of design details adjacent to each culvert and this should specifically consider downstream backwater effects on all culverts within the proposal.

3.10.2 Historical flooding

At the commencement of this investigation publicly available historical flood information was sourced. Available information was limited to the major rivers within the study area. During this investigation, there has been consultation with Councils, agencies and landowners to obtain further information on both historical flooding, design flood predictions and current studies. As part of the detailed design, consultation is to be undertaken with Councils, landowners, and government agencies to continue to obtain detailed, localised flood knowledge that would inform the detailed design of each section of the proposal. Information sourced through the landowner consultation is discussed in Section 4.3.7.

Below is a summary of the publicly available historical flood data available at the start of the investigation for the major river systems.

Macquarie River – Narromine area

The Macquarie River rises in the Great Dividing Range near Oberon, Lithgow and the Mid-Western Regional local government areas. Boggy Cowal, also known as Backwater Cowal, and Brady's Cowal, located south of Narrabri, rise in the Sappa Bulga Range. Backwater Cowal is reported as an old abandoned channel of the Macquarie River.

The most severe flooding near Narromine has been generated by rainfalls over the headwaters of the Macquarie River. The worst floods experienced in the township of Narromine are reported as those of 1867, 1892, 1926, 1950, 1955 and 1956 (SES 2014a). The 1955 flood was reported as being the worst with floodwaters breaking the banks of the Macquarie River upstream of Narromine and flowing south to Backwater Cowal and the Bogan River. The more recent floods were reportedly less severe.

The largest recorded flood at the Narromine gauge (which was operational from 1913 to 1978) was about 251.5 metres AHD in 1955 (SES 2014a). The 1955 event has been ascribed about a 0.9 per cent AEP magnitude.

The Macquarie River (Narromine to Oxley Station) Flood Management Plan (DWE 2008) indicates that the 1955 flood overflowed the rail line at Webbs Siding immediately east of, and upstream of, Narromine to flow overland across the southern floodplain of the Macquarie River.

That report indicates a repeat of this would be unlikely for a similar size flood because of subsequent rail repairs and track raising at the overtopping location. In addition, the hydrology within the Macquarie River catchment at Narromine has been impacted by the construction of significant water storages since the floods of the 1950s. The storages include Burrendong Dam and Cudgegong Dam (http://waterinfo.nsw.gov.au/).

At Baroona, about 12 kilometres upstream of Narromine, the Macquarie River was recorded as reaching 244.69 metres AHD in 2010 along with a similar level in 1990.

Floodwaters are generally reported as being relatively shallow (less than one metre deep) and relatively slow moving in the area near Narromine.

Flooding occurs in the Macquarie River in all seasons (SES 2014a). Typical flood-producing conditions are as follows:

- In summer, heavy rainfalls can occur because of cyclonic low-pressure systems from northern Australia creating relatively short intense rainfalls.
- In winter, flooding frequently results from troughs associated with southern depressions from the western areas of Australia and these can produce significant rainfalls over extended periods of days.
- From November to March, convective thunderstorms can produce intense short duration rainfalls that may be very localised and create flash flooding in local watercourses.

Upstream of Narromine the Macquarie River flooding is generally confined to the relatively narrow and well-confined floodplain. Webbs Siding, near Narromine, has been a location of significant flood breakouts.

Narromine has a levee that provides protection against the more frequent and smaller floods but is expected to overtop during flood events larger than the one per cent AEP event.

The SES Flood Plan (SES 2014a) indicates that an event larger than the 1955 flood would likely break out of the Macquarie River upstream of Narromine and flow across country and may potentially find its way south to the Bogan River and Backwater Cowal. These breakouts should be considered in more detailed during subsequent design stages. The SES Flood Plan (SES 2014a) also indicates that road closures typically occur at:

- Tomingley Road (four locations north of Tomingley: Newell Highway intersection)
- Tomingley West Road (two locations between Newell Highway and Peak Hill Railway Road)
- McNivens Road (south of Tomingley)
- Two crossings of Wallaby Creek (east of Tomingley Road) about five kilometres upstream of the rail line
- Tullamore – Narromine Road at Backwater Cowal.

Goobang Creek – Parkes area

The Parkes local government area covers parts of the headwaters of the Bogan River, a tributary of the Macquarie River, and Goobang Creek, a tributary of the Lachlan River.

Flooding is reported as occurring in any season (SES 2014b). In summers, troughs moving south westerly can cause short intense periods of rain while in winter the floods tend to be caused by troughs moving from the south west and can produce rainfalls over extended periods. During the late spring, summer and early autumn period thunderstorms can create flash flooding.

Goobang Creek has a tributary, Billabong Creek, located upstream of Parkes. The headwaters of Goobang Creek are north east of Parkes.

Floods are reported as generally rising rapidly, are contained generally within the creek lines and adjacent flat areas and fall quickly (SES 2014b). Goobang Creek, downstream of Parkes and downstream of Tichborne, does widen onto a broader floodplain area where longer duration flooding can occur. Flooding within Parkes is reported to be restricted to local urban drainage overflows or surcharges.

The SES Local Flood Plan for Parkes (SES 2014b) indicates that main flood-induced road closures around Parkes, in the area of interest include:

- Parkes to Wellington road, east of the proposal, which closes at Goobang Creek for periods of up to three hours.
- Parkes to Eugowra Road, south east of the proposal, which is regularly cut at the low level crossing of Goobang Creek and can be closed for periods of up to two days.
- the Newell Highway, which can be cut for up to a day at Tichborne, south of Parkes.

No road closures near the proposal were identified as being relatively regular.

Parkes north west connection

No flooding information was identified for this location due to the lack of existing rail infrastructure.

3.11 Sensitive ecological areas

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:

- Nationally important wetlands.
- national parks, nature reserves and State conservations areas, such as the Macquarie Marshes Nature Reserve downstream of Warren, which is also listed as a Ramsar Wetlands site.
- 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.

The Macquarie Marshes is considered one of the most sensitive inland watercourse areas in NSW. Located between Warren and Carinda, with the upstream end located about 100 kilometres downstream of Narromine, the Macquarie Marshes have been subjected to extensive hydrologic and ecological studies over the last few decades. Some of the more recent studies have included MDBA (2012) and Hogendyk (2007).

A result of the studies of the Macquarie Marshes and the national importance of the wetlands has led to the development of an adaptive management plan for the area (DECCW 2010) which provides a synthesis of information from prior projects and action plans.

Specific impacts of the proposal are unlikely to be observed at the Macquarie Marshes due to the distance of that area from the site of the proposal.

4. Existing environment

4.1 Regional context

4.1.1 Catchments

The study area includes numerous watercourses within portions of the Lachlan River and Macquarie-Bogan River basins. Both river basins eventually drain to the Murray River.

Watercourse catchments crossed by the proposal range in size from small unnamed tributaries of less than a square kilometre to large rivers. The regional catchments (large river catchments) extend in some instances to the Great Dividing Range and encompass large areas. Catchments for the major river systems (Lachlan River and Macquarie River) extend east to the Great Dividing Range. Most of the small catchments draining to the majority of structures under the rail line are located nearer to the rail corridor and have a modest topographic relief.

As discussed in Chapter 3, land use in the catchment areas has undergone significant change with the progressive move to more intensive cropping practices, general development and construction of major water storage dams.

4.1.2 Climate

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 demonstrated in Figure 4-1 which provides a diagrammatic representation of the years with complete rainfall records for Narromine between 1886 and 2013. The minimum annual rainfall recorded in that period was 217 millimetres while the maximum was about 1,386 millimetres and the average was about 527 millimetres. As indicated in Figure 4-1 there have been a number of periods with consecutive years of below average rainfall.

The Narromine site has also reported a relatively uniform monthly distribution of the mean rainfalls, from a high of 56.7 millimetres in January to a low of 36.3 millimetres in September.

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

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

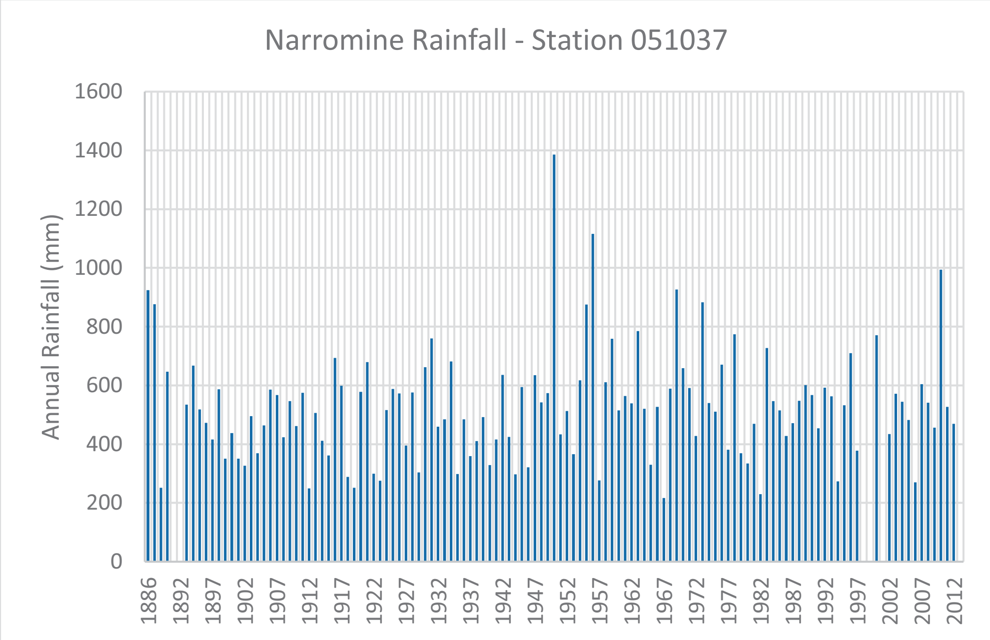


Figure 4-1 Narromine rainfall

4.1.3 Terrain and land use

The study area is characterised by relatively flat catchments (gradients of up to five per cent) with some locally steeper portions. Floodplain slopes are generally about one-half to one per cent gradient. Along the length of the rail alignment, terrain has a gradual fall from Parkes to Narromine from about 330 metres AHD to about 240 metres AHD with regional valleys located along the alignment. The steepest portion of the rail corridor occurs just after Mickibiri Bridge with a one per cent longitudinal grade indicating the generally flat nature of the locale.

Most catchments include cleared areas used for agriculture, grazing and rural residential land. Small urbanised areas are focussed around Parkes, Peak Hill and Narromine.

4.2 Hydrology

4.2.1 Surface water

Most watercourses in the study area are ephemeral, with temporary or intermittent flow. Flow occurs during and after rainfall, with the watercourses drying out in between rainfall. However, the major river systems, the Lachlan River and Macquarie River, are perennial systems.

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 along the Parkes to Narromine rail corridor. Adopting the delineated catchment areas for the nominated watercourses, catchment flow rates were established using the scaled Probabilistic Rational Method (PRM) (refer to Appendix A). Watercourses are labelled in accordance with the identified structures under the existing Parkes to Narromine rail corridor.

The scaled PRM method provided a means of assessing the likely flood affectation areas for the length of the proposal, identifying areas for upgrades (i.e. additional culverts and raising of the formation) to reduce the risk of the track level being overtopped during flood events. It is expected that more localised, detailed modelling will be undertaken during the detailed design stage to ensure the proposed structures and rail levels meet the design objectives.

Appendix B the existing structure type and configuration along with the predicted design flood levels. Flood levels are provided to the nearest 0.01 metre AHD for comparison purposes, with results for the design condition, and they should not be interpreted as having that level of accuracy.

The developed flow rates were compared to the available gauging flow data reported in Section 3.9.1.

Comparative design flow estimates

Comparative design flow estimates arriving at selected culvert locations were compared to those predicted using the Regional Flood Frequency Estimation (RFFE) method (Ball *et al*., 2016). To simplify the analysis, culverts with catchments that were unlikely to interact with the adjacent catchments were preferred. These were selected by analysing the culvert invert levels and inter-catchment spill levels for all catchment along the rail corridor. Of these, five catchments were selected where the potential for transfers between adjacent catchments was considered minimal for design storm events (up to the one per cent AEP flood event), and represented a range of catchment areas and culvert types.

The flow rates summarised in Table 4-1 show significant variability. However, the RORB model results were considered most likely to represent the local flood response, as it is based on dynamic modelling of the design storm event and includes estimates of the initial and continuing infiltration losses. The PRM estimates were therefore adjusted (using a multiplier) to better match the RORB results (refer to Table 4-2).

It is expected that as part of the detailed design process, design flows reporting to each culvert will be verified and hydraulic modelling updated to refine the culvert design to minimise flooding impacts.

Table 4-1 Comparative flow estimates

Culvert chainage	Event (% AEP)	Original PRM flow (m^3/s)	RORB flow (m^3/s)	RFFE (m^3/s)	RORB / PRM
451.332	50	1.5	1.8	-	1.2
	20	2.9	4.1	-	1.4
	10	4.2	6.3	12.8	1.5
	2	10.2	19.7	-	1.9
	1	14.5	27.5	39.1	1.9
464.694	50	2.1	3.0	-	1.4
	20	4.0	6.4	-	1.6
	10	5.9	9.7	25.6	1.6
	2	14.3	31.6	-	2.2
	1	20.3	43.8	77.6	2.2
466.824	50	0.5	0.8	-	1.5
	20	1.0	1.6	-	1.5
	10	1.5	2.5	10.5	1.6
	2	3.7	8.8	-	2.4
	1	5.3	12.3	31.7	2.3
469.524	50	0.6	1.0	-	1.6
	20	1.2	1.9	-	1.6
	10	1.7	2.9	10.7	1.7
	2	4.2	10.0	-	2.4
	1	6.0	14.0	32.5	2.3
484.581	50	0.3	0.4	-	1.4

Culvert chainage	Event (% AEP)	Original PRM flow (m^3/s)	RORB flow (m^3/s)	RFFE (m^3/s)	RORB / PRM
	20	0.5	0.6	-	1.1
	10	0.8	1.0	4.4	1.3
	2	1.9	3.4	-	1.8
	1	2.8	4.7	13.1	1.7

Table 4-2 PRM multipliers

Event (% AEP)	PRM multiplier
50	1.4
20	1.5
10	1.5
5	1.7
2 (and greater)	2.0

4.2.2 Groundwater

The results of the bore search and review of groundwater sharing plans (refer to Section 3.9) identified that groundwater sources in the rail corridor include alluvial sediments near Narromine, associated with the Macquarie River. Based on the results of the bore search, the alluvial sediments extend to up to 80 metres below ground level. Alluvial groundwater associated with the Macquarie 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.

To the south of Narromine, the proposed corridor is underlain by fractured rock associated with the Lachlan Fold Belt. Based on the results of the bore search, groundwater bores intercepting the fractured siltstone and sandstone rock aquifer are deeper than 70 metres below ground level. Groundwater in the fractured rock aquifer is not expected to be present near the ground surface.

Shallow alluvial sediments 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.

The alluvial sediments near Narromine, associated with the Macquarie River, flow direction in the alluvial aquifer would correspond with the flow direction in the Macquarie River – that is, east to west near the proposal. 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 (Kruseman and de Ridder, 1994), the hydraulic conductivity of the alluvial sediments may vary from one to 100 metres per day.

Within the fractured sandstone and siltstone aquifer of the Lachlan Fold Belt, groundwater flow directions are expected to correspond with the dip of the strata and surface elevation from east to west and south to north. Based on typical hydraulic conductivities for sandstone and fractured or weathered rock (Kruseman and de Ridder, 1994), the hydraulic conductivity of the sandstone and siltstone of the Lachlan Fold Belt may vary from 0.001 to 1 metres per day.

4.3 Flooding

Existing condition flood levels, flood behaviour and impacts were assessed for local catchment rainfall and runoff events through combined hydrologic and hydraulic flood modelling and interpretation of the data. The hydrologic and hydraulic modelling methodology used for this assessment is detailed in Appendix A.

As indicated in Section 2.5, this assessment does not consider the flooding from the major river systems. The 1 per cent AEP flood level in the Narromine area is estimated at about 239 to 240 metres AHD for flooding from the Macquarie River.

4.3.1 Existing culvert locations and levels

The location and level of structures were extracted from existing information. Figure 2-1 and Figure 2-2 show the locations of the existing culverts between Parkes and Narromine.

4.3.2 Flood level analysis

The flood levels were predicted using the methodology detailed in Appendix A. Appendix B provides a tabulation of the existing structure form for each structure, as well as the modelled flood levels for the 50, 20. 10, 5, 2, 1, 0.5 and 0.2 per cent AEP flood events as well as the probable maximum flood for each culvert.

A second table in Appendix B provides the design flow rates.

Results of the analysis indicated that the existing track would regularly overtop during local catchment flood events. As discussed in Section 4.3.4 and 4.3.7 this finding was confirmed during stakeholder consultation meetings. In some locations, the overtopping was predicted to extend for several consecutive kilometres of track. The extent of the overtopping and impacts of the overtopping are discussed in Section 4.3.3.

4.3.3 Formation overtopping

Locations and extents of rail overtopping

The flood modelling gave predictions that the rail line would overtop at specific locations for a range of design flood events. The overtopping locations for the one per cent AEP local catchment event are shown by the red indicators in Figure 4-2. As can be observed from Figure 4-2 an extensive length of the track is predicted to overtop in the local catchment one per cent AEP event. Appendix E provides details of the catchments for one per cent AEP rail overtopping and the catchment having rail overtopping for lesser events.

The extent and maximum depth of rail line overtopping is summarised in Table 4-3. This table indicates predicted depths of rail overtopping of 400 mm being reached in the five per cent AEP event with there being significant lengths of track overtopped for all considered events of twenty per cent AEP magnitude.

Table 4-3 Rail overtopping

Design event (% AEP)	Overtopping length (m)	Maximum overtopping depth (m)
50	69	0.22
20	1,036	0.29
10	2,177	0.33
5	3,039	0.40
2	4,758	0.49
1	7,175	0.54

Compliance to indicative ETD-10-02 requirements

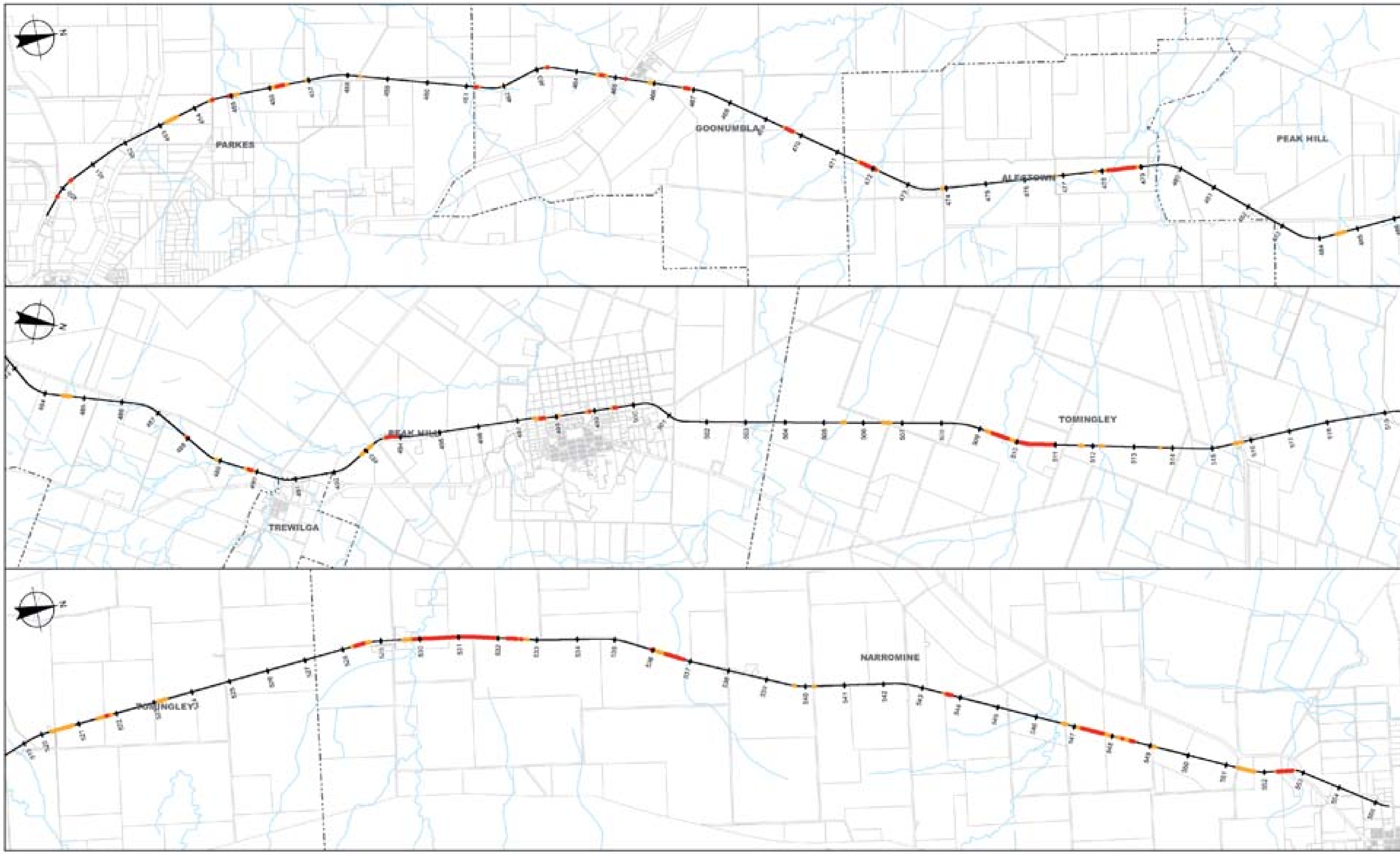
Technical Note ETD-10-02 is not strictly applicable to the existing formation condition as the combined ballast depth, sleeper depth and rail size is less than that for the design condition. An evaluation of the compliance for three assumed depths has been determined to provide a basis for comparison to the design condition.

Table 4-4 provides a summary of the extent of compliance to the nominated Technical Note requirements for the upstream flood waters to be below the top of shoulder of the formation for four assumed depths of ballast, sleeper and rail. The analysis has been completed this way since the actual depth to the top of formation has not been specifically quantified, however field estimates of existing ballast depths ranged from less than 300 millimetres up to about 800 millimetres. A typical existing ballast depth was therefore considered to be within this range, however 582 millimetres has been nominated by ARTC as the reference ballast depth.

Figure 4-3 provides a summary of the magnitude of the ballast, and Appendix F provides greater details on the predicted results. As would be expected, smaller more frequent flood events are expected to result in less overtopping of the track, at fewer locations.

Table 4-4 Formation non-compliance under existing conditions

Design event (% AEP)	Extent of rail overtopping (km)			
	Assumed 720 mm depth to top formation	Assumed 600 mm depth to top formation	Assumed 582 mm depth to top formation	Assumed 400 mm depth to top of formation
50	17.71	13.58	12.91	7.79
20	21.01	16.68	16.08	9.89
10	22.98	18.37	17.82	11.74
5	25.32	21.04	20.44	13.92
2	31.67	25.90	25.32	18.64
1	35.13	28.37	27.64	20.62



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

- Watercourse
- Lot boundary
- Suburb boundary
- Overtopped - rail
- Flood level above formation

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
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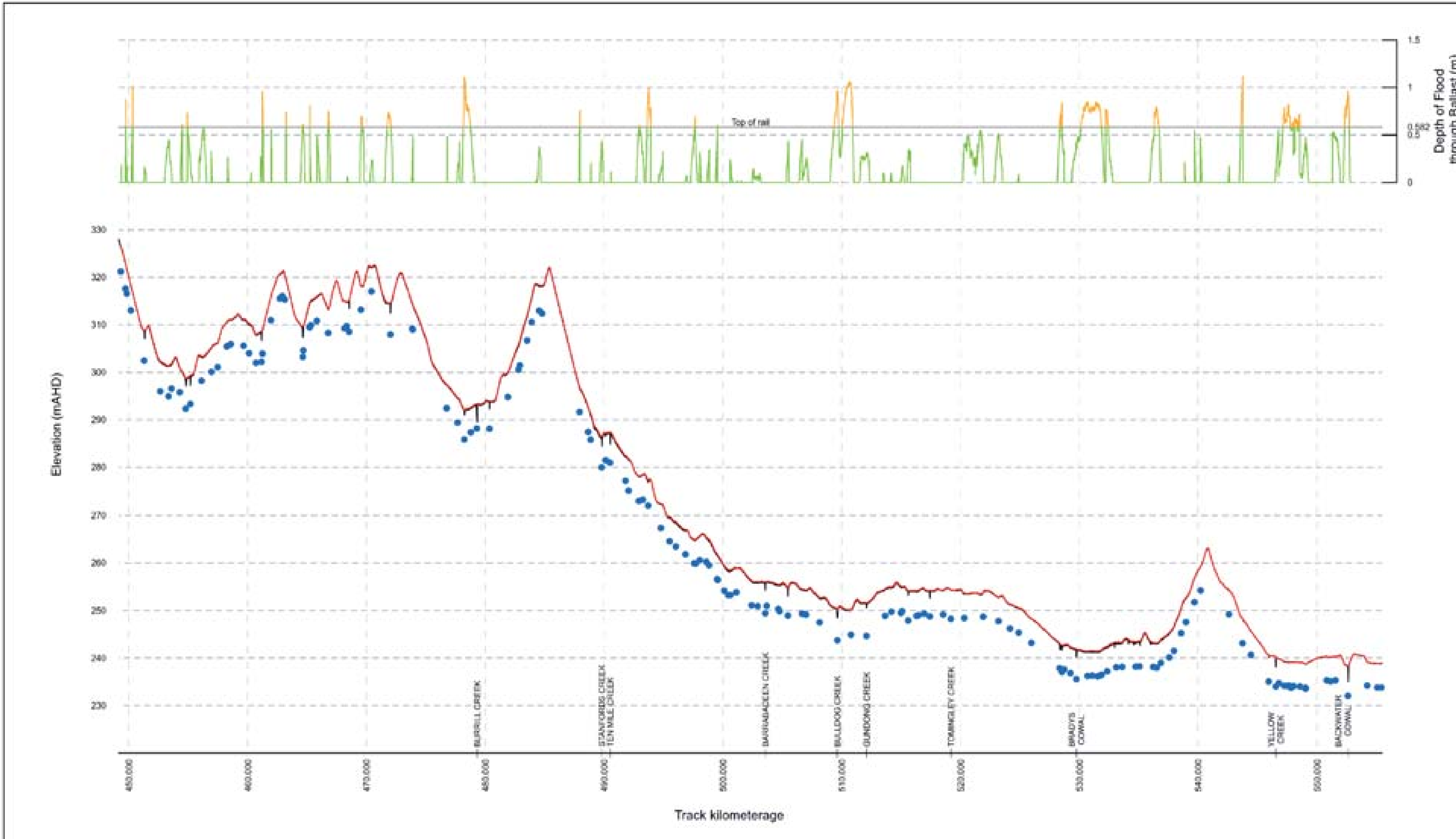
Existing Track Overtopping

Figure 4-2

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

Data source: ARTC imagery, 2014.



Paper Size A3

LEGEND
- Existing
- Natural Surface
- Culvert
- Flood through ballast
- Flood through ballast - overtopping rail

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	1
Date	28 Apr 2017

Existing Track Alignment and Flooding of Ballast

Figure 4-3

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

Level crossings

The predicted flood levels indicate that several sections of the rail corridor within the vicinity of public road crossings would be overtopped for the various design events. Table 4-5 indicates the level crossings that are predicted to be within the vicinity of rail overtopping in the various local catchment design conditions.

Table 4-5 Rail overtopping near level crossings under existing conditions

Chainage	Public level crossing	Level crossing overtopping depth (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
449.771	Brolgan Road	0.01	0.04	0.04	0.13	0.24	0.29
454.498	Back Tradle Road	-	-	-	-	-	-0.03
461.246	Wyatts Lane	-	-	-	-	0.29	0.38
465.251	Bogan Road	0.04	0.19	0.20	0.21	0.22	0.23
497.704	Atwells Lane	-	-	-	0.04	0.08	0.11
499.562	Tullamore Road	-	-	-	0.02	0.02	0.02

4.3.4 Adjacent land impacts

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

Upstream flood impact – existing conditions

Figure 4-5 shows the predicted upstream flood extents in a diagrammatic form for events that have been evaluated while Table 4-6 lists the areas of local catchment inundation for flood events up to the PMF. The predicted upstream flood extents included in Figure 4-5 have been estimated by mapping those areas upslope of the rail corridor that have a lower ground elevation than the maximum modelled flood level at the adjacent rail corridor. Therefore, the areas mapped as 50% AEP (ie light green) represent those areas that lie below the 50% AEP local catchment flood level modelled at the adjacent rail corridor. Each successive colour represents the additional area that lies below the modelled flood level at the adjacent rail corridor for each local design flood event. The mapped areas are therefore considered to represent those areas where the local flood levels are affected by rail corridor. Flooding outside of these areas is expected however not likely to be appreciably affected by the rail corridor.

Figure 4-5 should not be read to imply that flooding does not occur downstream of the rail corridor – rather, this downstream area has not been mapped as the flood extent would not be expected to change appreciably as a result of the proposal.

As previously indicated, this assessment has not considered a potential break out from the Macquarie River into Backwater Canal. The occurrence of such a break out would increase the extent of flood inundation upstream of the existing rail corridor south of Narromine and may also lead to overtopping of the rail in the same location.

Table 4-6 Areas of upstream flooding – existing conditions

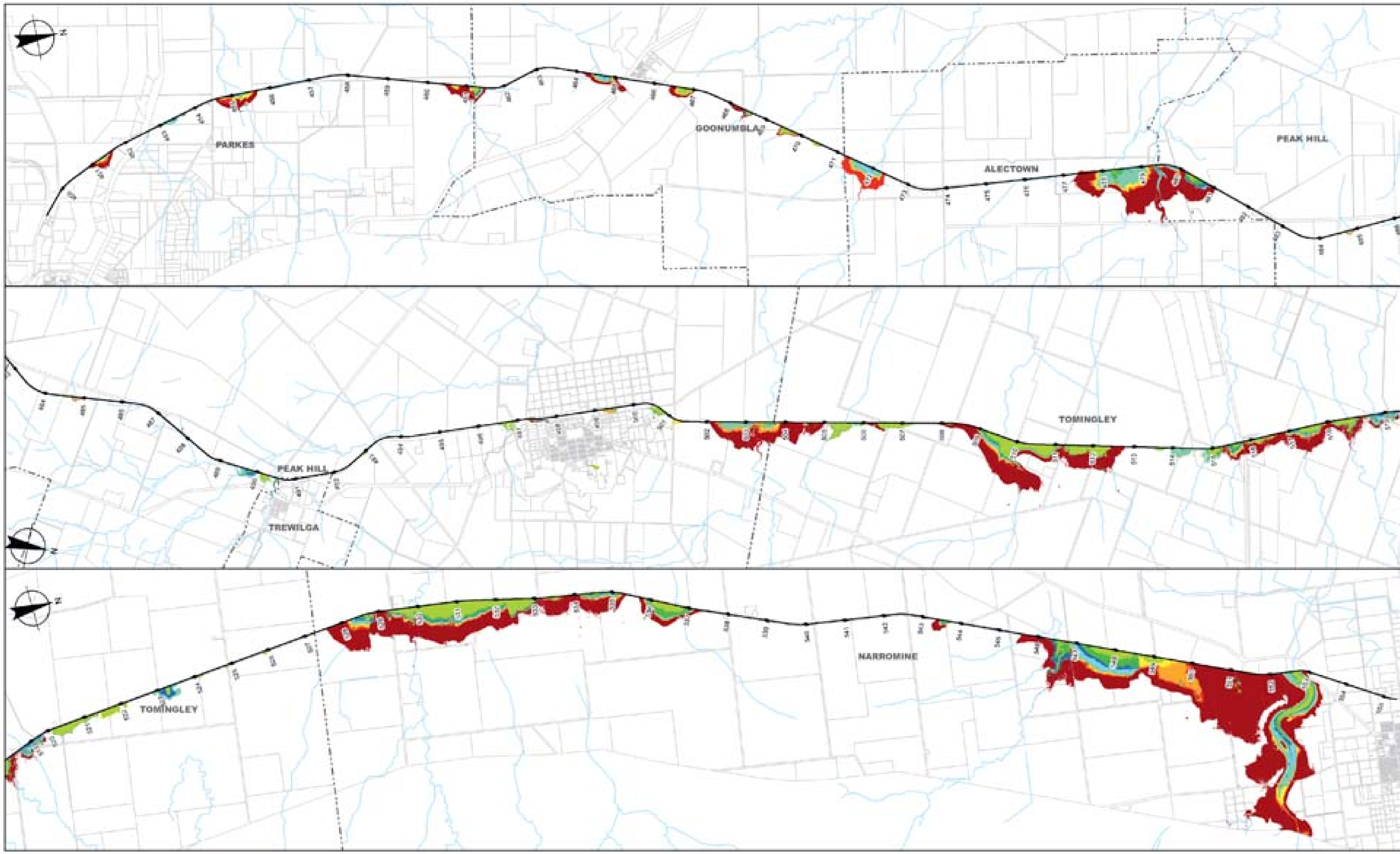
Design event (% AEP)	Area of inundation (ha)
50	355.9
20	480.1
10	553.3
5	648.2
2	840.0
1	938.0
0.5	1,044.8
0.2	1,146.5
PMF	2,720.8

Upstream flood velocities

When the existing track is not overtopped, the flow velocities on the floodplain would generally be low. Immediately upstream of a culvert there would be localised increases in velocity as the water approaches and enters the respective structure. The approach velocities on the floodplain are not expected to exceed a value of about 1.5 metres per second.

The upstream velocity in defined watercourses would be larger than that on broad floodplain areas. For these locations, the velocity is predicted to be less than two metres per second except in localised areas where the watercourse is constricted.

When the track overtops, some floodwater passes over the rail embankment instead of through the culverts, with the embankment acting as a levee. This would result in an increased flow velocity over the floodplain areas downstream of the rail embankment.



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

- Inland Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- 5% AEP
- 1% AEP
- 0.5% AEP
- 0.2% AEP
- PMF

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Inland Rail - Parkes to Narromine

Existing Flood Impact Areas

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Figure 4-4

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Upstream period of flooding

Periods of flooding for local catchment flood events vary with the size of the local catchment, but are predicted to be generally less than about nine hours for the smaller catchments and extending to about 36 hours for some of the larger catchments during most design storm events. The estimate of flood duration considers local catchment areas only, with flood duration defined as the time taken for flood depths to fall to less than 0.1 metre. The existing data suggests that some areas of flooding in the most low-lying areas, for regional flood events, could extend over several days or in some cases weeks.

Upstream watercourses

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

Downstream flood effects

Downstream of the rail corridor, there is expected to be a general reduction in design flood levels, for events up to the one per cent AEP event, in most areas. There may be localised changes in levels immediately downstream of replacement structures but these are expected to be confined to the rail corridor due to the design measures that are proposed.

Downstream flood velocities

When the track level is not being overtopped, the flow downstream of the culverts would generally be confined within the individual watercourses.

At times when flooding overtops the rail level (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.

Downstream periods of Inundation

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

Downstream 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.

4.3.5 Road flooding

An analysis was undertaken to assess the locations and potential depths of road overtopping that would occur under existing conditions. The locations where the predicted levels overtop the roads within the LiDAR corridor are listed in Table 4-7. This analysis considered the roads identified in the functional hierarchy as being higher than local roads.

The maximum flood level in each catchment was assessed and then the lengths of roads impacted were determined by applying a horizontal design water surface and comparing the road levels to the design flood levels. Application of this method indicates the potential for some roads to have a higher maximum inundation depth than that at the location where the same road crosses the rail line.

Table 4-7 Public road overtopping under existing conditions

Road	Maximum depth overtopping (m)						Maximum length overtopping (m)
	50 % AEP	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP	
Alectown West Road	0.00	0.01	0.02	0.03	0.04	0.05	7
Bogan Road	0.00	0.10	0.11	0.12	0.13	0.14	2
Bulgandramine Road	0.02	0.07	0.08	0.09	0.10	0.11	61
Peak Hill Railway Road	0.00	0.00	0.00	0.00	0.09	0.09	40
Tomingley Road	0.00	0.00	0.00	0.00	0.47	0.78	80
Tomingley West Road	0.00	0.00	0.00	0.00	0.18	0.33	110
Wyanga Road	0.00	0.00	0.00	0.00	0.08	0.14	55

These predicted closure locations are in close agreement with information from the SES (SES 2014a).

The maximum depth of water predicted for the road closures did not necessarily occur where the public road crossed the rail line at the level crossing location, as the maximum depth was dependent upon the road profile within the flooded area.

The public roads overtopped under existing and design conditions are shown in Section 6.3.5.

4.3.6 Building impacts

An inspection of the imagery indicated that no buildings were likely to be inundated for the predicted one per cent AEP local catchment flood events. The detailed maps of impacted areas provided in Appendix J also show the locations of buildings adjacent to the proposal. It should be noted that the flood affectation areas included in Appendix J are not flood extents, but extent to which the modelling indicates that the rail corridor, either existing or developed, influences flood levels.

The landowner consultation did reveal that in one of the areas where flood levels were underestimated floodwater has previously reached the rear of one of the dwellings.

4.3.7 Landowner feedback on predicted flood conditions for the existing rail corridor

Groups of landowners were consulted during the study process to obtain specific information on historical flood levels and historical flood extents. At the time of consultation, there were flood extent figures available and these were shown to residents as a means of conveyance of information. The landowner feedback is summarised on Figure 4-5.

Feedback from the landowners indicated:

- There has been significant flooding along the existing rail corridor in 1990, 2010, 2012 and 2016.
- Damage to both ballast, formation and culverts was reported by landowners for these same historical events.
- Historical breakouts of flow between adjacent catchments has occurred several kilometres upstream of the existing rail corridor. Some of these breakouts, such as from Tomingly Creek and Fiddlers Creek, was indicated as occurring outside the extent of the supplied LiDAR survey data.
- In some areas, shown on Figure 4-5, flows occurred as overland flows outside of defined watercourses. The adopted analysis method gave reasonable representation of the flooding behaviour but there were areas identified where the identified historical flooding extent exceeded the predicted extents. Further analysis would be required to confirm the cause for this but partial culvert blockage, unknown flow diversions and the analysis method itself could have been contributing factors to the differences. There were no areas where the flooding extent was reported to be less than the predicted extent.

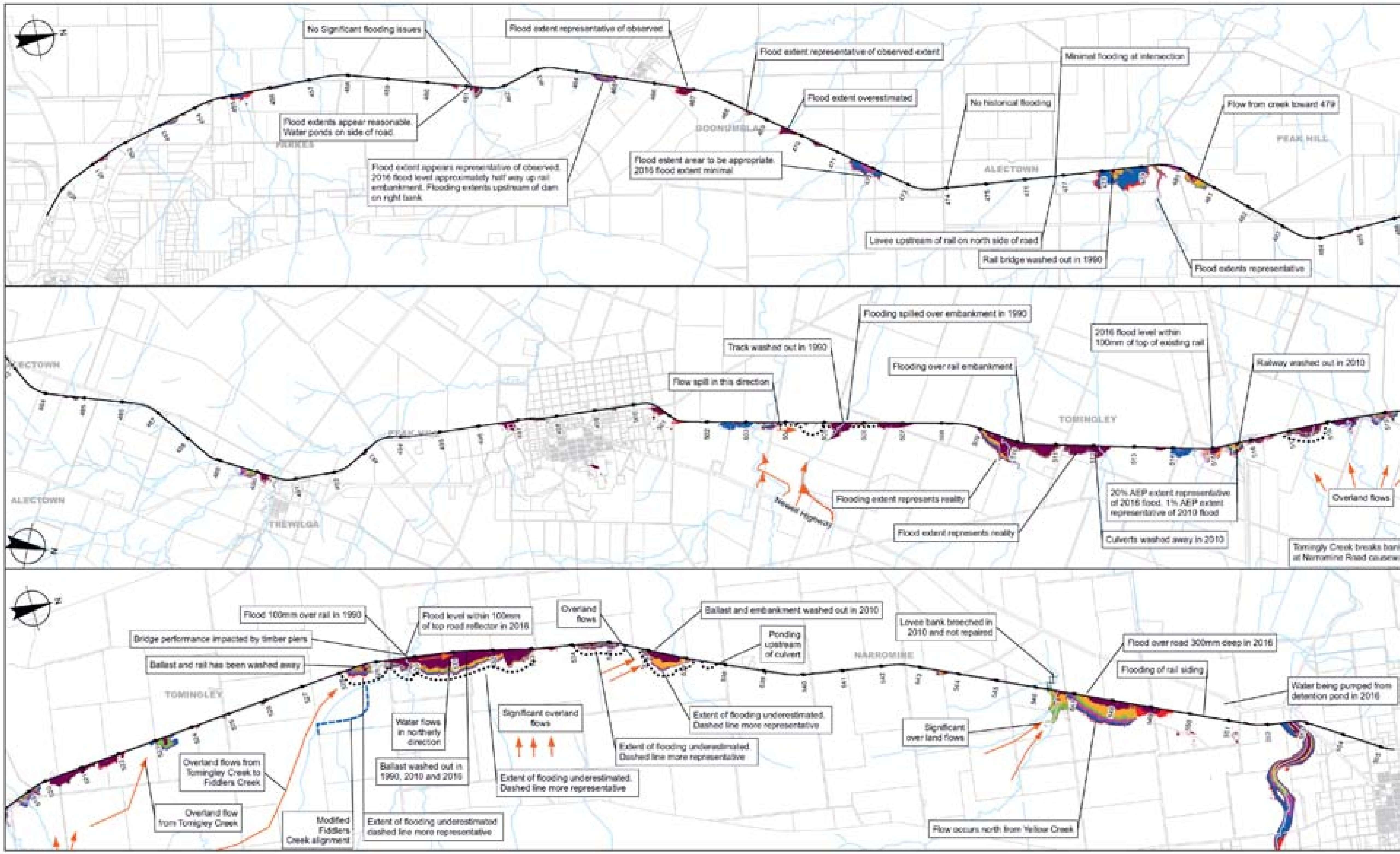
No feedback was provided by landowners on the potential breakout from the Macquarie River to the Backwater Cowal near Moree.

The above feedback does not distinguish between large scale flooding and local catchment flooding. As a result, it is not possible to compare directly the above feedback to the local catchment flood analysis undertaken for the purposes of model verification. Therefore, the above feedback should be considered in future hydrologic and hydraulic assessments for the proposal.

An examination of the magnitude of large floods at Macquarie River (Station 421031 – Gin Gin), located downstream of Narromine, shows the floods of 1990, 1998, 2000, 2010 and 2016 had peak levels of between 11.3 and 12 metre gauge height with the event of September 2016 being smallest.

At Bogan River (Station 421076 – Peak Hill No 2) the April 1990 flood was the largest historical event, the 2016 event was next largest and the 2010 event was about 200 millimetres lower than the 2016 event.

A maximum benefit of the community feedback would be achieved through a comprehensive data gathering exercise (collecting rainfalls, more accurate definition of flood levels, greater terrain detail) and incorporating that information into future design advancement hydrologic and hydraulic analysis for the detailed design phase for the proposal.



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

- Inland Rail
- Watercourse
- Lot boundary
- XXXX Levee Bank
- Modified Creek
- Overland flow path
- Community estimated flood extent
- 50% AEP
- 20% AEP
- 10% AEP
- 2% AEP
- 5% AEP
- 1% AEP

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Existing Flood Impact Areas
Community Feedback

Job Number	22-17916
Revision	0
Date	28 Apr 2017

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

5. Risk assessment

5.1 Background

The hydrologic and hydraulic/flooding risk assessments considered potential impacts during both construction and operation. The assessments analysed changes to the surface flow paths and rates, and groundwater flow paths and rates that could result from the proposal.

5.2 Risk assessment – hydrology

An assessment of the potential hydrologic risks, and measures to avoid, mitigate or minimise them, is provided in Table 5-1. The risks and impacts listed in Table 5-1 are discussed in the following sections.

Table 5-1 Hydrologic risks, potential impacts and mitigation measures

Risk	Potential hydrologic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact on surface water flow in watercourses	• Modified surface flow volume or rate downstream of the rail corridor	• Maximise the manufacture of concrete structures off site at locations where water is readily available • Select concrete mixes that minimise water requirements • Minimise the volume of surface water extracted for construction • Minimise the installation of culverts that create localised surface water ponding
	• Changed surface flow paths across the rail corridor	• Install a culvert structure at each low point along the rail corridor when low point cannot be removed through grading within corridor • Minimise regrading of terrain along the rail corridor • Install appropriately sized culvert and bridge structures along the corridor
Construction period Impact on surface water flow in irrigation channels or constructed drains	• Restricted water passage along irrigation drains or constructed channels	• Maximise the manufacture of as many concrete structures off site at locations where water is readily available • Select concrete mixtures that minimise water requirements • Minimise the volume of groundwater extracted for construction. • Install appropriately sized structures where each irrigation channel or constructed drain is crossed • Minimise new crossings of irrigation channels or constructed drains

Risk	Potential hydrologic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact on groundwater flow	• Modified groundwater flow volume or rate downstream of the rail corridor	• Maximise the manufacture of concrete structures off site at locations where water is readily available • Minimise the installation of culverts that permanently or intermittently intercept groundwater • Minimise the volume of water extracted from groundwater for construction • Minimise groundwater extraction at individual sites
Operational period Impact on natural surface flow in watercourse	• Modified surface flow volume or rate downstream of the rail corridor	• Avoid installation of culverts that create localised surface water ponding • Select structure sizes to match the existing flow regime • Avoid any track crossings of watercourses that can create ponding
	• Changed surface flow paths across rail corridor	• Install a culvert structure at each low point along the rail corridor where the low point cannot be removed through grading within the rail corridor • Minimise regrading of terrain along the rail corridor • Install appropriately sized culvert along the rail corridor
Operational period Impact on surface water flow in irrigation and other channels/drains	• Restricted water passage along irrigation drains or constructed channels	• Install appropriately sized structures where each irrigation channel or constructed drain is crossed • Minimise new crossings of irrigation channels or constructed drains
Operational period Impact on groundwater	• Modified groundwater flow volume or rate downstream of the rail corridor	• Avoid installation of culverts that permanently or intermittently intercept groundwater • Avoid installation of culverts that create localised surface water ponding where surface water infiltrates into the groundwater • Avoid any track crossings of watercourses that can create ponding

5.2.1 Potential unmitigated hydrologic impacts – construction

Impact of modified surface flow volume or rate downstream of the rail corridor

Construction of the proposal could modify flow volumes and rates downstream of the rail corridor through the extraction of surface water, which could reduce the availability of water to landowners (the extraction of water from storages would be subject to approvals and agreements). In addition, changing the flow rate and/or duration of flow through culverts that are constructed could create additional erosion either upstream or downstream of the respective culverts where flow conditions are modified significantly.

No bridges are proposed. In the unlikely event that design advancement indicates that bridges are feasible to replace structures, then then the design would be targeted at minimising, as much as practical, any ongoing groundwater impacts. There would be a residual redirection of alluvial flows around the piers but this impact would not extend more than five metres radially from each pier.

Impact of surface flow paths across the rail corridor

The proposal has been designed, and drainage elements sized, to minimise the number of locations and extents of track where the rail formation would overtop. The design has been developed to prevent formation overflow, except at a limited number of level crossings, for events up to the one per cent AEP event for local catchment runoff. This would reduce the extent of formation overtopping during flood events and restrict the flow crossing points to the proposed culvert locations.

Repositioning culverts – hence changing the locations where floodwater crosses the rail corridor – would have the following potential impacts:

- Creation of new erosion areas downstream of the rail corridor at each new culvert location.
- Loss of cropping areas downstream of the rail corridor (unless flow diversions are provided).
- Redirection of frequent flows away from existing water storage dams downstream of the rail corridor and loss of a water supply to the farms.
- Low areas immediately upstream of the rail corridor would not completely drain, leading to new areas of ponding immediately after each runoff event. To maintain existing flow paths it may be necessary to redirect flows upstream of the corridor in some very isolated areas.

Impact of restricted water passage along irrigation drains or channels

During construction, there is the potential for temporary partial blockage of irrigation drains because of material slumping, temporary cofferdams or other works within the irrigation drains. Such blockages could reduce the amount of water available for irrigation while flow is constricted. Construction methods, including placement of material stockpiles, should be designed to minimise the potential for blockages to occur.

Impact of modified groundwater flow volume or rate downstream of the rail corridor

Construction of the proposal could modify groundwater flow volumes and rates downstream of the rail corridor through:

- Extraction of groundwater, which could reduce the availability of water to landowners (the extraction of water from bores would be subject to appropriate approvals and agreements).
- Changes to the volume of available groundwater for irrigation extraction purposes.

5.2.2 Potential unmitigated hydrologic impacts – operation

Impact of modified surface flow volume or rate downstream of the rail corridor

During operation, ongoing modification to flow volumes and rates downstream of the rail corridor could occur because of changes to the flow rate and/or duration of flow through culverts that are constructed for the proposal. This could create additional erosion either upstream or downstream of the culverts where flow conditions are modified significantly.

Impact of modified surface flow paths across the rail corridor

Repositioning culverts – hence changing the locations where floodwater crosses the rail corridor – would have the following potential impacts:

- Creation of new erosion areas downstream of the rail corridor at each new culvert location.
- Loss of cropping areas downstream of the rail corridor (unless flow diversion is provided).
- Redirection of frequent flows away from existing water storage dams downstream of the rail corridor and loss of a water supply to the farms.
- Low areas immediately upstream of the rail corridor would not completely drain, leading to new areas of ponding immediately after each runoff event. To maintain existing flow paths it may be necessary to redirect flows upstream of the corridor.

These ongoing impacts during operation would be generally more significant than those during the relatively short construction period.

Impact of restricted water passage along irrigation drains or channels

Irrigation drains and channels may be partially blocked by debris falling from the formation, such as ballast material or litter from passing trains. The potential impacts of partial blockage of irrigation drains during the life of the proposal could reduce the amount of water available for irrigation. The proposal design avoids this potential impact by nominating that any irrigation drain would have a replacement culvert constructed with a capacity matching the existing capacity.

Impact of modified groundwater flow volume or rate

Groundwater flow volumes and rates downstream of the corridor could be modified because of ongoing extraction of water for the operation of the rail corridor. However, ongoing water extraction is not planned during operation of the proposal.

5.3 Risk assessment – hydraulics and flooding

An assessment of the potential flooding risks, and measures to avoid, mitigate or minimise them, is provided in Table 5-2. The risks and impacts listed in Table 5-2 are discussed in the following sections.

Table 5-2 Flooding risks, potential impacts and mitigation measures

Risk	Potential hydraulic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact of raising the rail formation	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures) • Additional impacts downstream of structures	• Install each structure prior to or concurrent with rail formation construction to minimise potential adverse impacts
Construction period Impact of reducing watercourse capacity	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures)	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure • Do not reduce watercourse flow areas • Locate spoil mounds where they do not affect flow paths and patterns
Operational period Impact of raising the rail formation height on increased flooding	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures) • Additional impacts downstream of structures	• Retain structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure while balancing with the raised formation level
Operational period Impact of reducing watercourse capacity	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures)	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure • Do not reduce watercourse flow areas • Locate spoil mounds where they do not affect flow paths and patterns
Operational period Impact of increased watercourse	• Reduced upstream flooding depths and extents • Increased downstream flood depths • Increased downstream building impacts • Increased impacts on adjacent downstream infrastructure (e.g. road closures) • Increased downstream watercourse scour	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure • Minimise any increase in watercourse flow areas

5.3.1 Potential unmitigated impact of changed hydraulics and flooding conditions – construction

Impact of raising the rail formation

The proposal generally includes raising the formation level between 0.3 metres and 1.0 metres, with a number of locations being raised up to about 1.5 metres. Raising the rail formation level could create several potential impacts:

- It could increase the upstream flood level and flood extent because of the increased head required to pass the flow through replacement structures. Increasing the size of the replacement culverts, or providing a greater number of culverts, could reduce this impact but it would increase the potential impacts downstream of the rail corridor.
- It could prevent the flows up to at least the one per cent AEP event from overtopping the rail corridor. Under existing conditions, many areas of the rail corridor overtop in relatively small design rainfall events. Raising the formation level would reduce the extent and frequency of any overtopping. Reducing the extent of areas where flood water crosses the line could:
  - Reduce upstream flow velocities should the upstream flood levels be increased
  - Reduce the uncontrolled flow of water over the rail formation
  - Increase the risk of erosion downstream of the culverts
  - Redirect flood flow paths immediately downstream of culverts
  - Increase the duration of flooding upstream of the culverts.

Impact of reduced watercourse area at culverts

Many of the impacts of reducing the watercourse area and flow capacity at culverts (by reducing the size of the culverts) would be essentially the same as those identified for raising of the formation height. Reducing culvert sizes could increase upstream flood levels and flood extents because of the increased head required to pass the flow through replacement structures; to achieve the same performance criteria would create the need for higher formation levels.

Reducing culvert sizes could also create an increased flow velocity through the culverts and increase the risk of additional downstream scour. Forcing this water to cross the line at a restricted number of locations could:

- Reduce upstream flow velocities should the upstream flood levels be increased
- Increase the risk of erosion downstream of the culverts
- Redirect flood flow paths immediately downstream of culverts
- Increase the duration of flooding upstream of the culverts

During construction, should a flood event occur, there would be periods when there may be redirections of floods around the end of sections of raised embankment. It is not possible to predict whether this would happen.

5.3.2 Potential unmitigated impact of changed hydraulics and flooding conditions – operation

Impact of raising the rail formation

Raising the rail formation level would have similar impacts on flooding as those identified during construction (refer to Section 5.3.1).

Impact of reduced watercourse area at culverts

Reducing the watercourse area and flow capacity at culverts (by reducing the size of the culverts) would have similar impacts on flooding as those identified during construction (refer to Section 5.3.1).

Impact of increased watercourse area at culverts

Increasing the watercourse area at culverts could:

- Reduce upstream flood levels and flood extents because of the reduced head required to pass the flow through replacement structures, which would permit floodwater to pass downstream more quickly than currently.
- Create a potentially increased flow velocity through the culverts, which would increase the risk of additional downstream scour.
- Increase upstream flow velocities towards the culvert and increase the upstream scour risk.

6. Proposed mitigation measures and benefits

6.1 Background

The proposal design includes design measures to minimise the residual impacts. This chapter assesses the effectiveness and benefits of these measures, and the predicted residual impacts.

6.2 Design control measures

6.2.1 Formation level and profile

The proposed formation level would generally be above the predicted one per cent AEP local catchment flood level and would therefore comply with internal ARTC requirements and control the frequency of uncontrolled track overflows.

The design of the 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 to import material to create the new formation.

Benefits

These measures would have the following benefits:

- Reduce the extent and frequency of the track overtopping. the overtopping would be restricted to areas at level crossings for the one per cent aep event. no other rail overtopping is predicted to occur for events up to the magnitude of the one per cent aep event. this approach would still create residual effects, as described below.
- Minimise the volume of waste material created by the formation construction.
- Minimise the need for importation of fill material.
- Reduce the potential adverse water quality and pollution impacts of construction activities.

Residual impacts of measure

The selected formation level would:

- Remove the uncontrolled overtopping of the rail line for design events with the discharge across the rail corridor only occurring at culverts.
- Increase upstream flood levels and flooding durations.
- Increase the risk of further erosion downstream of existing structures.

Each of these potential impacts is examined below in the following sections.

6.2.2 Culvert form

The proposed culvert form has been selected to facilitate quick construction and minimise construction period impacts. The selected culvert form is a complete pre-cast four-sided box culvert that would be transported to site and placed in position. The only onsite concrete usage and placement would be for the aprons and headwalls at each culvert structure. Erosion protection has been provided downstream of each culvert apron to minimise the flow velocity as it exits off the culvert apron.

Benefits

This measure would have the following benefits in terms of the hydrology, hydraulics and flooding objectives:

- It would require less site excavation and foundation preparation and, therefore, speed up culvert placement and minimise the potential for extended construction periods. The shorter construction periods would also enhance opportunities to undertake construction between runoff events in the ephemeral watercourses.
- It would reduce the amount of water required along the route of the proposal for concrete placement. An estimated 75 to 100 megalitres of water would be needed for construction, as described in Section 3.4, which would be used primarily for dust suppression. This is discussed in detail in Section 3.4.
- Erosion protection would mitigate the potential effect to some extent. To enhance protection against this effect it would be necessary to extend the rock protection further toward the rail corridor boundary. The proposed rock erosion protection would reduce the increase in flow velocity within the rail corridor to 0.5 metres per second and reduce the effect on adjacent private property.

Residual impacts of measure

The assessment has indicated a potential residual erosion risk at about 12 culvert locations (of 145 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 30 per cent of the existing 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.

The maximum widening is expected to occur over a period of about five to 10 significant floods.

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. When this happens, there could be a flow on the downstream formation of the rail line of up to about two metres per second.

6.2.3 Culvert locations

New or replacement culverts across the rail corridor would be located at the terrain low points along the proposal. This will place them at, or adjacent to, existing structures to avoid the creation of new flow paths across the rail line.

In the Parkes north west connection section of the proposal new culverts will be located in identified existing flow paths.

Benefits

This approach would:

- Prevent the formation of significant new flow paths and potential soil erosion areas downstream of the rail corridor.
- Minimise excavation for new structures.
- Restrict the potential for new scour areas and significantly reduce the extent of existing erosion areas.

- Maintain flow paths and watercourses to maintain their existing ecological and drainage functionality.

6.2.4 Culvert levels and size

The proposed culvert invert levels would match the existing invert levels to mitigate the creation of blockages to flow and fish passage (during times of stream flow) at culverts. The structures would be sized to minimise the increase in flow velocity through the culverts, as described in Appendix A.

Benefits

Selecting invert levels to match the existing levels would:

- Facilitate fish passage through the structure during times of water 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.

Residual impacts of measure

There would be a minimal increase in the flow velocity through some structures during relatively low flow conditions, relative to the current conditions. This would result from the culverts providing a hydraulically more efficient flow cross-section than the existing structures.

The increased upstream flood levels at culverts will also increase the flow velocity through the culverts for the larger flows when, for the existing rail formation, the track would overtop. The maximum increase in velocity is expected to range between 0.5 metres per second and 1 metres per second, based on the estimated changes to flood levels, flow rates and culvert dimensions (refer to Appendix G). This is discussed in detail in Section 6.3.3.

Maintaining the culvert inverts to match the existing invert levels would minimise the potential for creation of a scour hole at the downstream end of the culverts.

6.2.5 Construction staging

Construction of the proposal would commence once all necessary approvals are obtained, and the detailed design is complete. It is anticipated that construction would take about 18 months, commencing in mid-2018, and concluding in the fourth quarter of 2019. Construction along the existing rail corridor would progress from south to north is planned to involve three stages:

- Stage 1 – Parkes to Goonumbla
- Stage 2 – Goonumbla to Narwonah
- Stage 3 – Narwonah to Narromine.

The Parkes north west connection, is planned to be completed in the same period.

Where possible, particular construction activities would be planned considering the weather forecast to minimise the risks of potential heavy rainfall and surface runoff events.

Benefits

Although these measures would not prevent construction during periods of rainfall, the risk of having disturbed construction areas during rainfall would be minimised.

6.2.6 Construction access and tracks

Construction access to the rail corridor would be carefully controlled and co-ordinated to minimise site disturbance and inconvenience to landholders. Access to the proposal area is planned to be from public roads and existing tracks.

An access track exists along the majority of the proposal within the current rail corridor. Where necessary, this would be upgraded at watercourses. Any new access along the corridor would be formed and stabilised with a gravel blanket to minimise the risk of the watercourse being substantively damaged by vehicles. The design form would conform to guidelines for the maintenance of fish passage. The gravel layer would be as thin as practical for stability.

Should it be necessary at any location to permit a continuous water flow across the access track, then a pipe would be placed in the water and gravel placed around the pipe to keep vehicle tyres out of the water. The pipe and gravel would be removed at the end of the construction period to accord with requirements to minimise impacts on watercourses and fish access.

Benefits

These measures would minimise the potential disturbance of watercourses where they are crossed by construction traffic.

6.2.7 Construction compounds

Two types of construction compounds are proposed – minor storages that will be used for temporary storage of items such as concrete box culverts and turnouts and larger compounds. The larger compounds would comprise amenities, parking, refuelling areas, stockpiles and hazardous material storage areas.

The minor storages will be located within the rail corridor. The larger compounds will be located at least 50 m from watercourses and outside the 5 per cent AEP flood extent to minimise the potential for flood impacts on surrounding lands.

The final construction compound locations will be selected by the contractor and will be in the Construction Environmental Management Plan.

Benefits

Restricting the number and size of the compounds would minimise the construction disturbance area. Positioning them at distance from watercourses would minimise the potential for flooding.

6.2.8 Stockpiles

Stockpiles of excess material (spoil mounds) would be located as close as practical to the source of the material. The final location and sizing of the spoil mounds would be undertaken as part of detailed design, however it is likely that there would be spoil mounds along the majority of the length of the proposal. Spoil mounds have the potential to remove local flood storage and divert surface water flows from existing flow paths, which could affect local flooding. The mounds would be positioned so that they had gaps between adjacent mounds to permit drainage away from the track and they would be located where there would be no induced flooding impact.

Spoil mound locations would be developed as the design is advanced and documented in the Construction Environmental Management Plan.

Benefits

Implementation of this strategy would minimise the potential for changes to flooding conditions along the corridor. No adverse flooding impact is expected from the placement of spoil mounds.

6.2.9 Construction water use

As described in Section 3.4 water would be required for dust control, soil compaction and vegetation establishment. The required volume of water for these uses would be dependent upon the climatic conditions at, and following, construction.

Likely sources of water would be external to the rail corridor (identified in Section 3.4) and include the potential extraction of surface water and groundwater from pre-approved locations. The potential impacts from the extraction of surface and/or groundwater are discussed in Section 5.2.1. Water would also be trucked to the proposal site as required.

Benefits

Water used during construction would be sourced from various sources to minimise hydrologic impacts at a single location.

Residual impacts of measure

Extraction of water would reduce the volume of stored water until volumes are replenished again by rainfall/recharge. This would have a minor short-term impact on the available surface water volumes.

6.2.10 Potable water use

Potable water for human consumption would be supplied via bottled water or potable water tanks. Non-potable wash water would be supplied by the use of trailer-mounted storage tanks.

6.3 Summary of impacts and benefits

6.3.1 Upstream flood levels

Predicted design flood levels for each local catchment are provided in Appendix G. Figure 6-1 provides a plot of the design flood levels along the existing corridor for the one per cent AEP event. Appendix G also contains a tabulation of the design flow rates (which are unchanged from those included for the existing conditions in Appendix B), design flood levels for all design AEP events and the changes in design flood levels from those for the existing conditions.

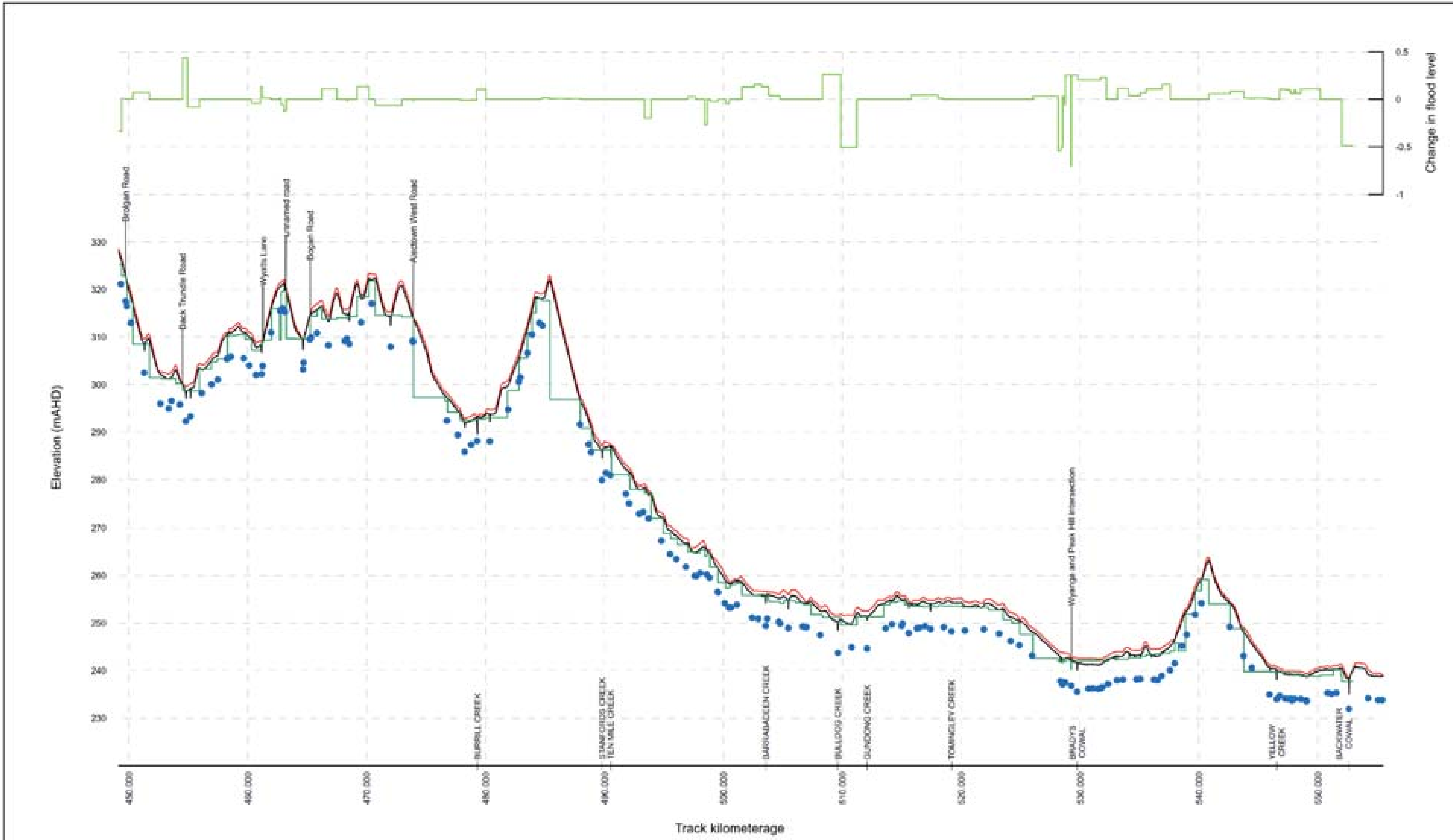
Because of the analysis method the design long section plot shows as a series of horizontal water surfaces with changes in level being caused where flow passes from one catchment to the adjacent catchment.

The top half of Figure 6-1 shows the change in design flood level from that for the base or existing case. Along much of the alignment it is seen that there is a minimal change in the flood levels. However, there are locations where the change in design flood level approaches half a meter.

The predicted levels show variances to those for the existing (base case) situation (Appendix B) because of:

- the increased culvert sizes being required to keep, where possible, the design upstream level below the top of the formation level to maximise compliance with ETD-10-02 (ARTC 2016)
- the raised formation height, which, to achieve operational reliability, creates a barrier to overland flows for events up to the one per cent AEP magnitude
- the raised formation height, which increases flood levels for events greater than those for the existing conditions for events larger than the structure design capacity.

The impacts of the raised flood levels are discussed in the following sections.



Paper Size A3

LEGEND
Design
Natural Surface
Culvert
Design flood level
Change in flood level (existing to design)

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	25 Nov 2016

Design Track Alignment with Change in 1% Flood Levels **Figure 6-1**

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

6.3.2 Formation and rail overtopping

Locations and extents of rail overtopping

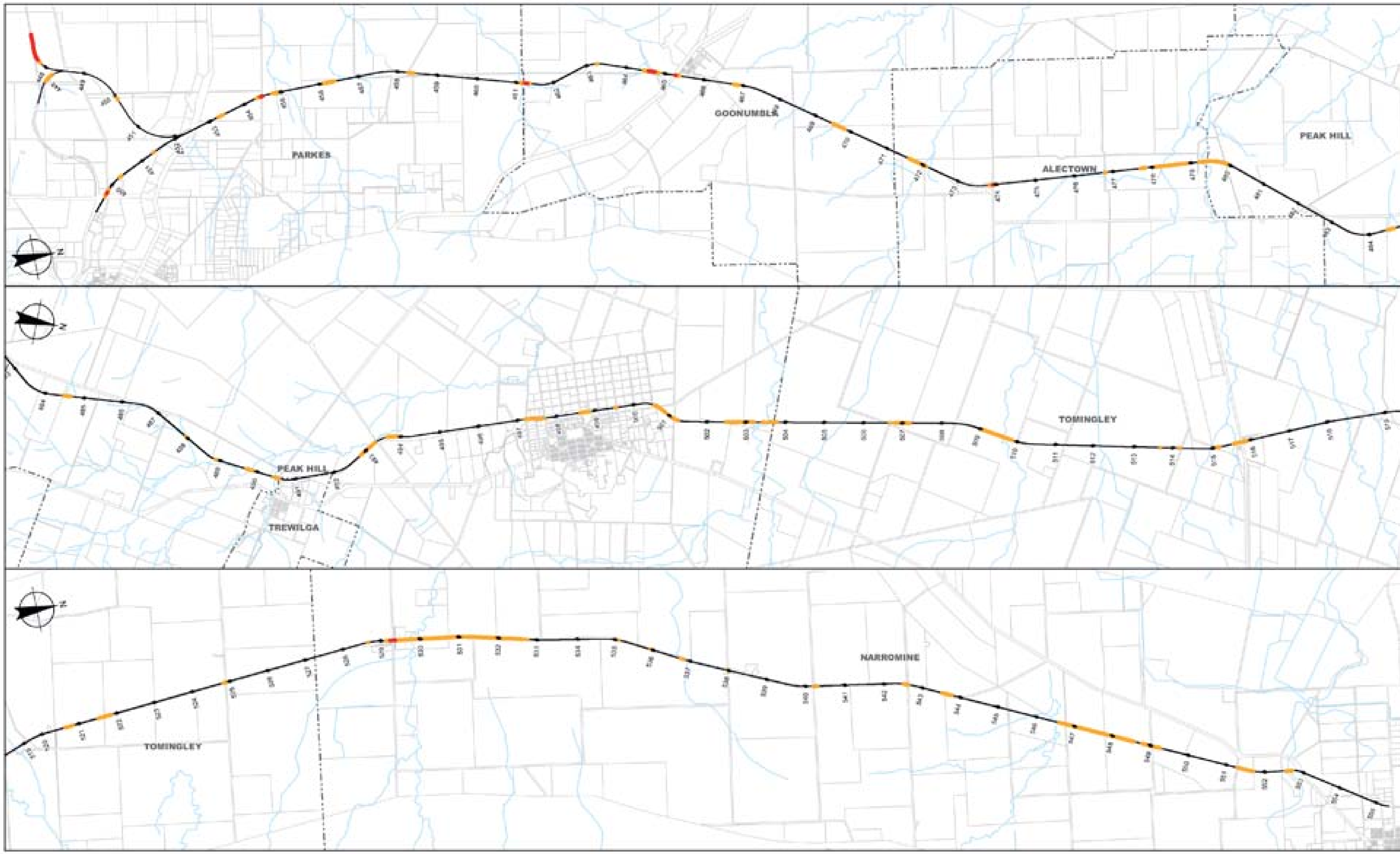
The flood modelling gave predictions that the rail line would overtop at specific locations for a range of design flood events. The overtopping locations for the one per cent AEP event are shown by the red indicators in Figure 6-2.

The predicted overtopping only occurs within the vicinity of road level crossings while the remainder of the formation would be elevated above the one per cent AEP level. During the concept design it was decided that public road level crossings would not be raised and this lead to the rail overtopping in areas where there was a significant depth of existing and future flooding.

It is predicted that a total of 405 metres of rail line would overtop for the one per cent AEP event, as shown in Table 6-1, compared to about 7.2 km of rail line that would over top for the one per cent AEP event (refer to Table 4-3).

Table 6-1 Summary of Rail Overtopping at Level Crossings – 1% AEP event

Feature	Track chainage	Overtopping length (m)	Applied design lift (m)	Maximum overtopping depth (m)
Brolgan Road level crossing	449.734 to 449.771	37	0.05	0.40
Back Tradle Road level crossing	454.457 to 454.508	53	0.04	0.25
Wyatts Lane level crossing	461.246 to 461.313	62	0.09	0.56
Level crossing – unnamed road	464.580 to 464.743	158	0.04	0.21
Bogan Road level crossing	465.251 to 465.268	19	0.00	0.40
Alectown West level crossing	473.918 to 473.920	3	0.03	0.01
Wyanga and Peak Hill Roads intersection/level crossing	529.250 to 529.368 (approx.)	74	0.13	0.13



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
- Overtopped - rail
- Flood level above formation
- Watercourse
- Lot boundary
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Rail Overtopping
1% AEP Conditions

Figure 6-2

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

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

As shown in Figure 6-2, a lesser length of the track rail is predicted to overtop in the local catchment one per cent AEP event, compared to the existing condition (Figure 4-2). Appendix H provides details of the catchments of one per cent AEP rail overtopping and the catchment having rail overtopping for lesser events.

Figure 6-3 shows the design long section together with the depth of water through or over the ballast (as a line) on the top half of Figure 6-3. When the line at the top of Figure 6-3 is green it means the water is ponding above the base of the ballast and when the line is shown as orange the rail is predicted to be overtopping. At approximately half of the locations where water is within the ballast the depth of water exceeds half the ballast depth.

Compliance with indicative ETD-10-02 requirements

Table 6-2 shows the extent of noncompliance with the nominated Technical Note (ETD-10-02: ARTC 2016) requirements for the upstream flood waters to be below the top of shoulder of the formation assuming a total depth of ballast, sleeper and rail of 800 millimetres.

Table 6-2 Formation non-compliant (ETD-10-02) – design conditions

Design event (% AEP)	Extent of noncompliance to ETD-10-023 (km) Assumed 800 mm depth to top formation
50	2.951
20	3.727
10	5.883
5	8.161
2	12.241
1	17.097

The smaller flood events would overtop less of the track at a reduced number of locations.

Comparing the predicted results for the existing rail formation and the design formation shows there is a reduction in both the extent of rail overtopping and the non-compliance with the requirements of ETD-10-02 (ARTC 2016). A more comprehensive listing of the non-compliances is provided in Appendix I.

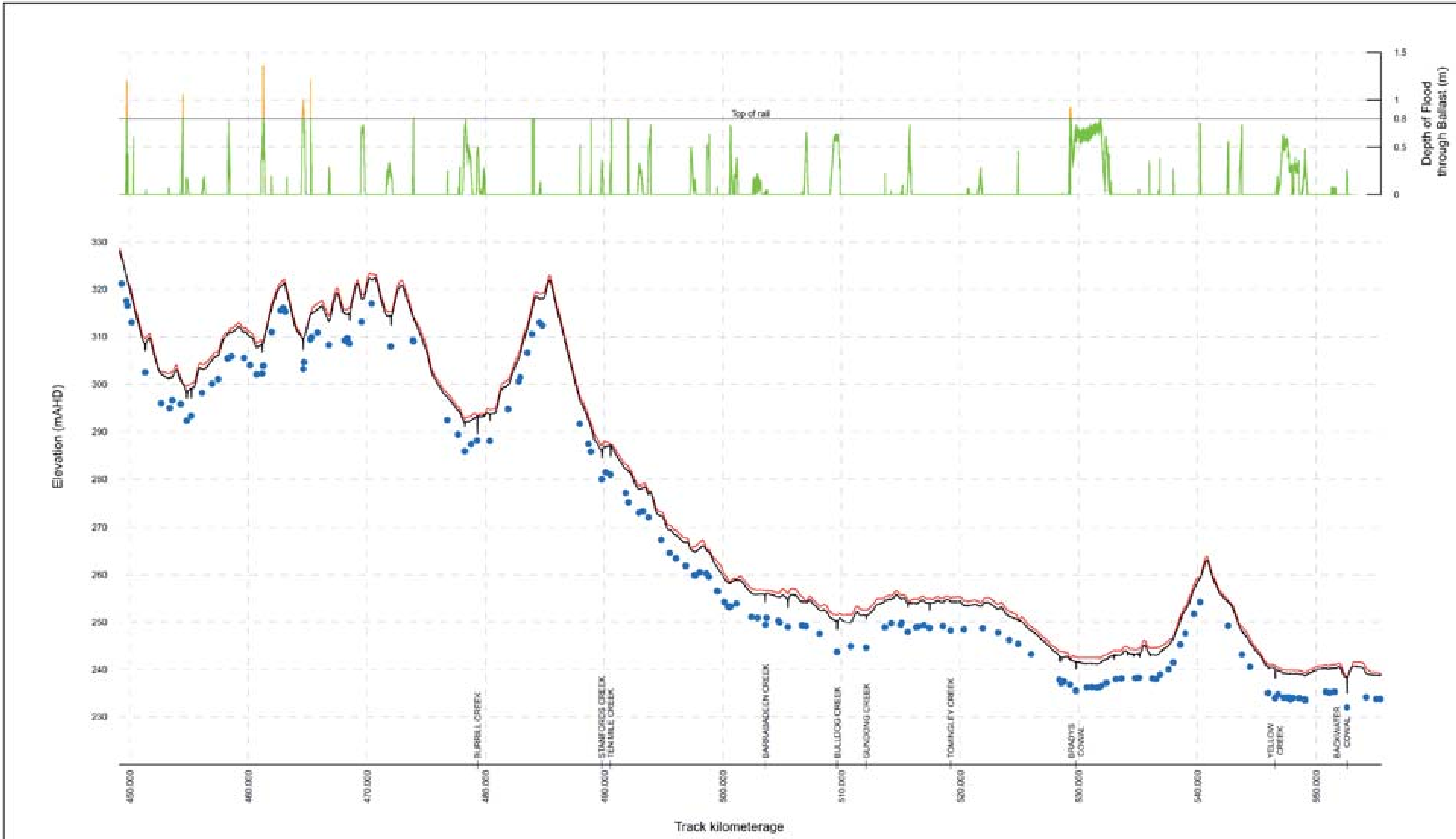
Further assessment would be undertaken during detailed design to identify opportunities to improve flood immunity. This assessment would include consideration of culverts adjacent to flood overtopping areas, as well as additional track raising, which may improve the flood immunity of the overtopping areas.

6.3.3 Surface water flows

The majority of surface water impact would result from any new ponding areas formed adjacent to proposed structures. This impact is likely to be minimal, and generally associated with existing ponding areas. Local drainage works may be included in the final design to minimise the impacts associated with these potential ponding areas. The proposed structures under the rail formation have been selected and sized to convey flows at rates similar to existing structures, which would minimise surface water redirections or restrictions.

Cumulative impacts on the existing surface water regime would be localised to areas along the rail corridor.

Construction of the proposal would not impact the low discharge flow paths across the rail line. Consequently, the existing surface water flows would continue as they currently occur. The proposed culvert inverts and sizes have been selected to maintain any existing fish passage across the rail corridor.



Paper Size A3

LEGEND
Design
Natural Surface
Culvert
Flood through ballast
Flood through ballast - overtopping rail

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	25 Nov 2016

Design Track Alignment and Flooding of Ballast

Figure 6-3

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

6.3.4 Adjacent land

The predicted flood levels for the existing conditions were examined for a range of design events from the 50 per cent AEP through to the PMF event. Within this range, the 0.5 per cent and 0.2 per cent were considered as representing a potential climate change impact assessment.

Upstream flood impact – design conditions

Figure 6-4 shows the predicted upstream flood extents in a diagrammatic form for events that have been evaluated while Table 6-3 provides numeric values for the flood affected areas for various design events. Table 6-3 also provides the change in the flood affected area relative to that predicted for the existing track level. From Table 6-3 it can be seen that the proposal is expected to result in reduced areas of flooding for flood events up to the two per cent AEP event, with an increase in the area of flood affectation for larger events. Flood affected areas are reduced for the smaller flood events as a result of the proposed structures being sized to convey the one per cent AEP event, as a result the proposed structures are generally more efficient than the existing structures result in reduced flood affected areas for small flood events. Conversely, the proposed raising of the track level reduces (or removes) the track overtopping during larger flood events, resulting in increased flood affected areas for events above the two per cent AEP event (refer to Table 6-3).

Figure 6-5 shows the change in existing and design flood extents for the one per cent AEP event, with detailed views of the modelled flood impacts on properties near the proposal provided in Appendix J. Based on the results of the modelling flooding depths would increase by an average of about 200 millimetres during the one per cent AEP, when compared to the existing conditions.

Table 6-3 Areas of upstream flooding – design conditions

Design event (% AEP)	Area of inundation (ha)		
	Existing	Design	Change (design – existing)
50	355.9	242.0	-113.9 (-32%)
20	480.1	363.9	-116.1 (-24%)
10	553.3	454.8	-98.5 (-18%)
5	648.2	579.9	-68.3 (-11%)
2	840.0	821.9	-18.1 (-2%)
1	938.0	1,036.5	+98.5 (+11%)
0.5	1,044.8	1,146.2	+101.3 (+10%)
0.2	1,146.5	1,283.3	+136.8 (+12%)
PMF	2,720.8	3,162.1	+441.3 (+16%)

Upstream flood velocities

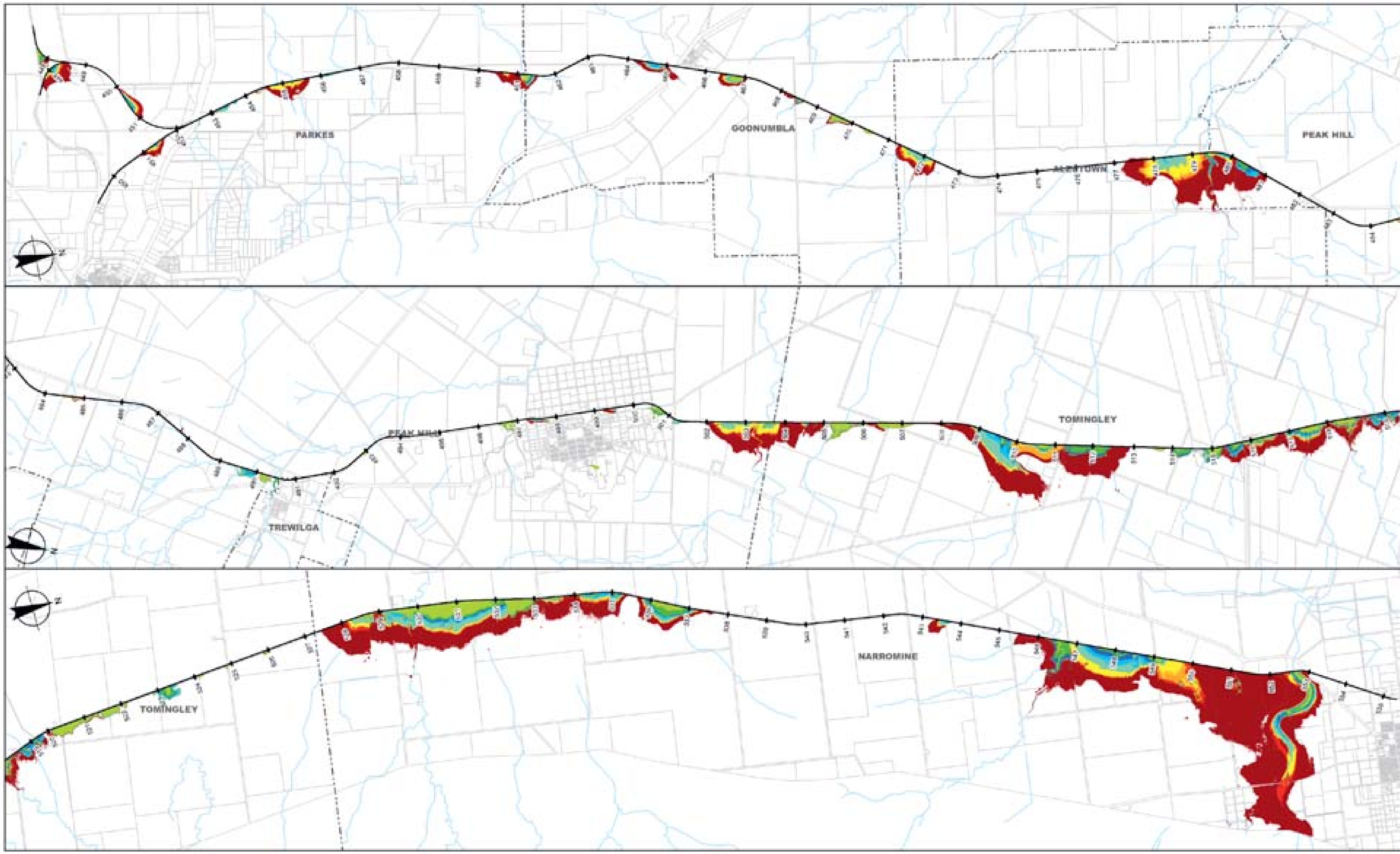
When the proposed rail level is not overtopped, the flow velocities on the floodplain would generally be low. Immediately upstream of a culvert, there would be a localised increase in velocity as the water approaches and enters the respective structure. The approach velocities on the floodplain are not expected to exceed a value of about 1.5 metres per second, which is comparable to the existing conditions.

The upstream velocity in defined watercourses would be larger than that on broad floodplain areas. For these locations, the velocity is predicted to be less than two metres per second except in localised areas.

When the rail line overtops in an extreme event or at level crossings, there would be flow over the rail, which would be acting as a weir. This would mean there would not be a localised increase in the flow velocity over the floodplain areas in the larger events, as compared to those for the smaller events when downstream floodplains are effectively flooded by almost still water.

Even in the extreme events when formation overtopping occurs, flow velocity would be generally less than the existing situation.

Further analysis, to be undertaken as part of detailed design, would help to refine the impacts of the proposal on flow velocities, and identify the requirement for any supplementary erosion and scour protection works required to mitigate further impacts.



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

- Inland Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- 0.2% AEP
- PMF

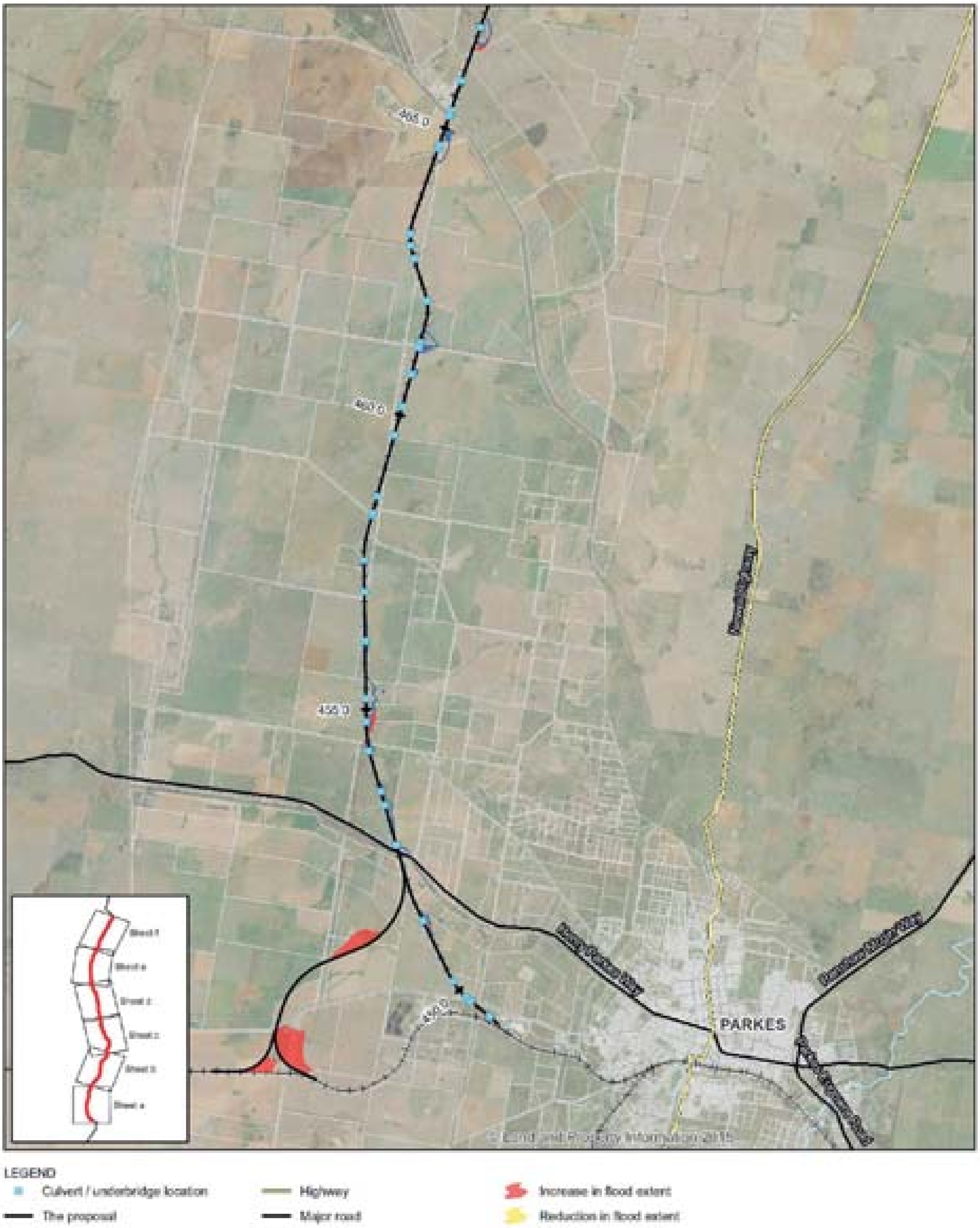
Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Design Flood Impact Areas

Figure 6-4

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



LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Highway
- Major road
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

0 500 1,000 2,000 3,000

Metres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17916
Revision 0
Date 21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5a

LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Highway
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

0 500 1,000 2,000 3,000

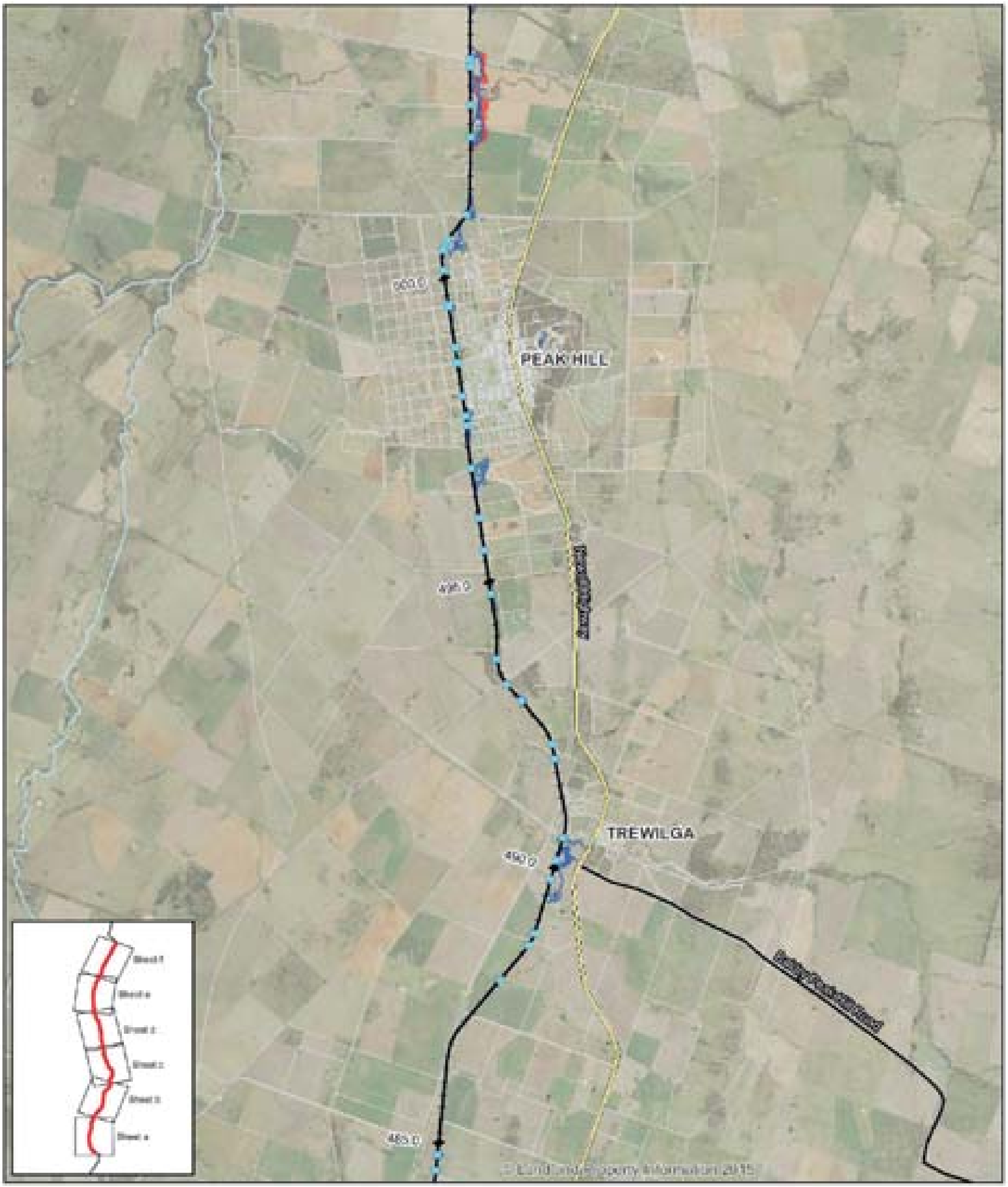
Metres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17916
Revision 0
Date 21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5b



LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Highway
- Major road
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

0 500 1,000 2,000 3,000

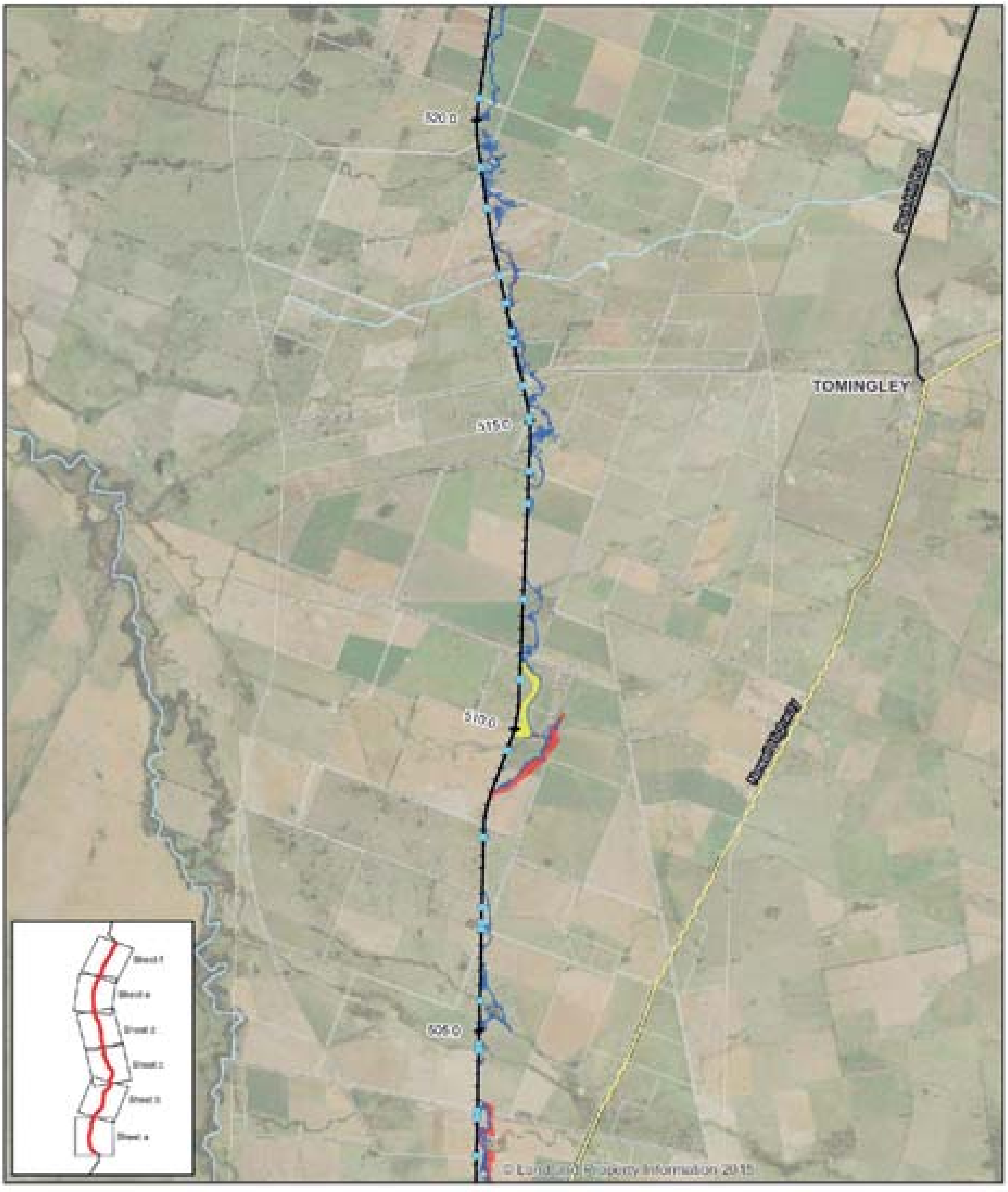
Metres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5c



LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Highway
- Major road
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

0 500 1,000 2,000 3,000

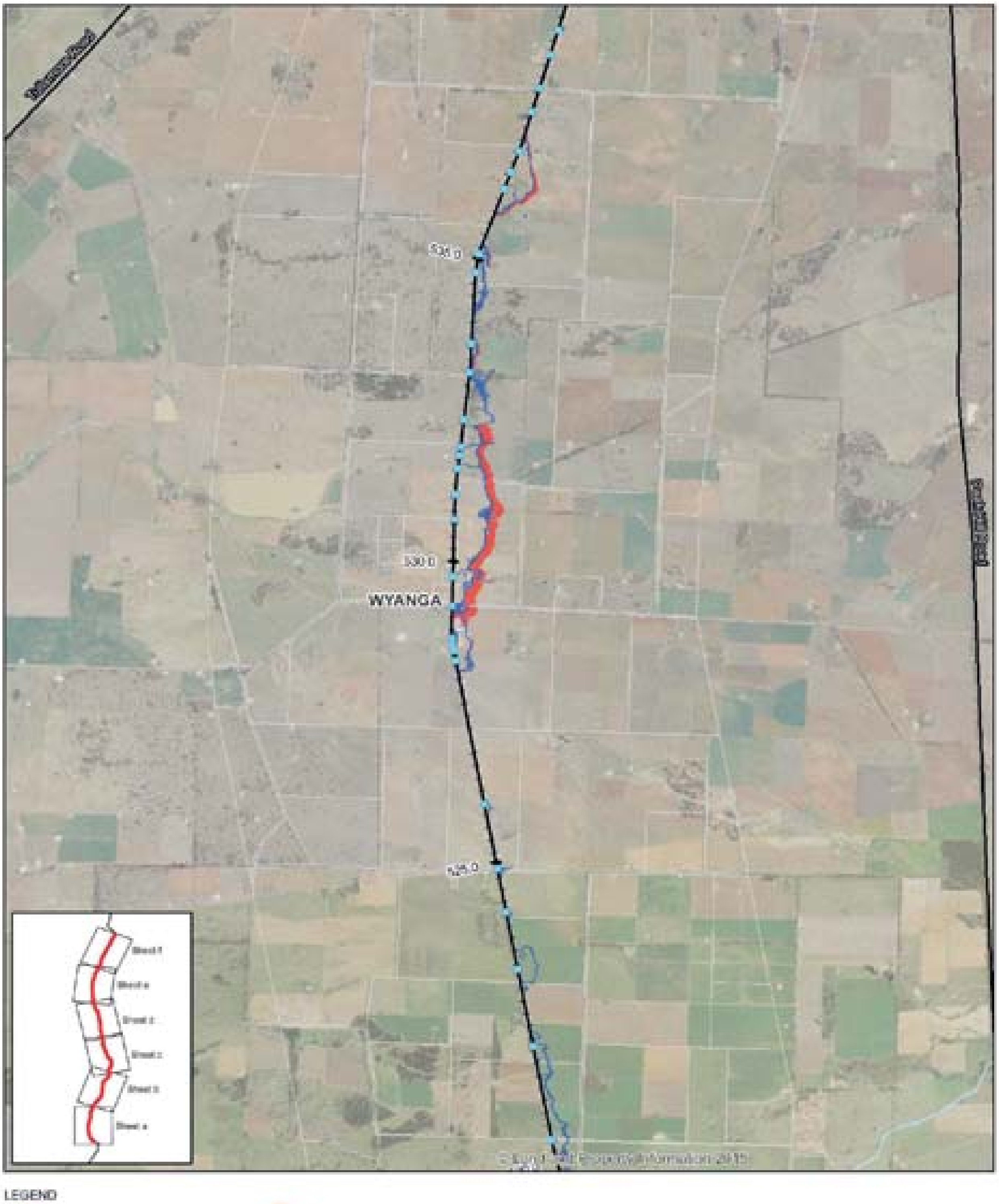
Metres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17916
Revision 0
Date 21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5d



LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Major road
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

Metres

Map Projection: Transverse Mercator

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
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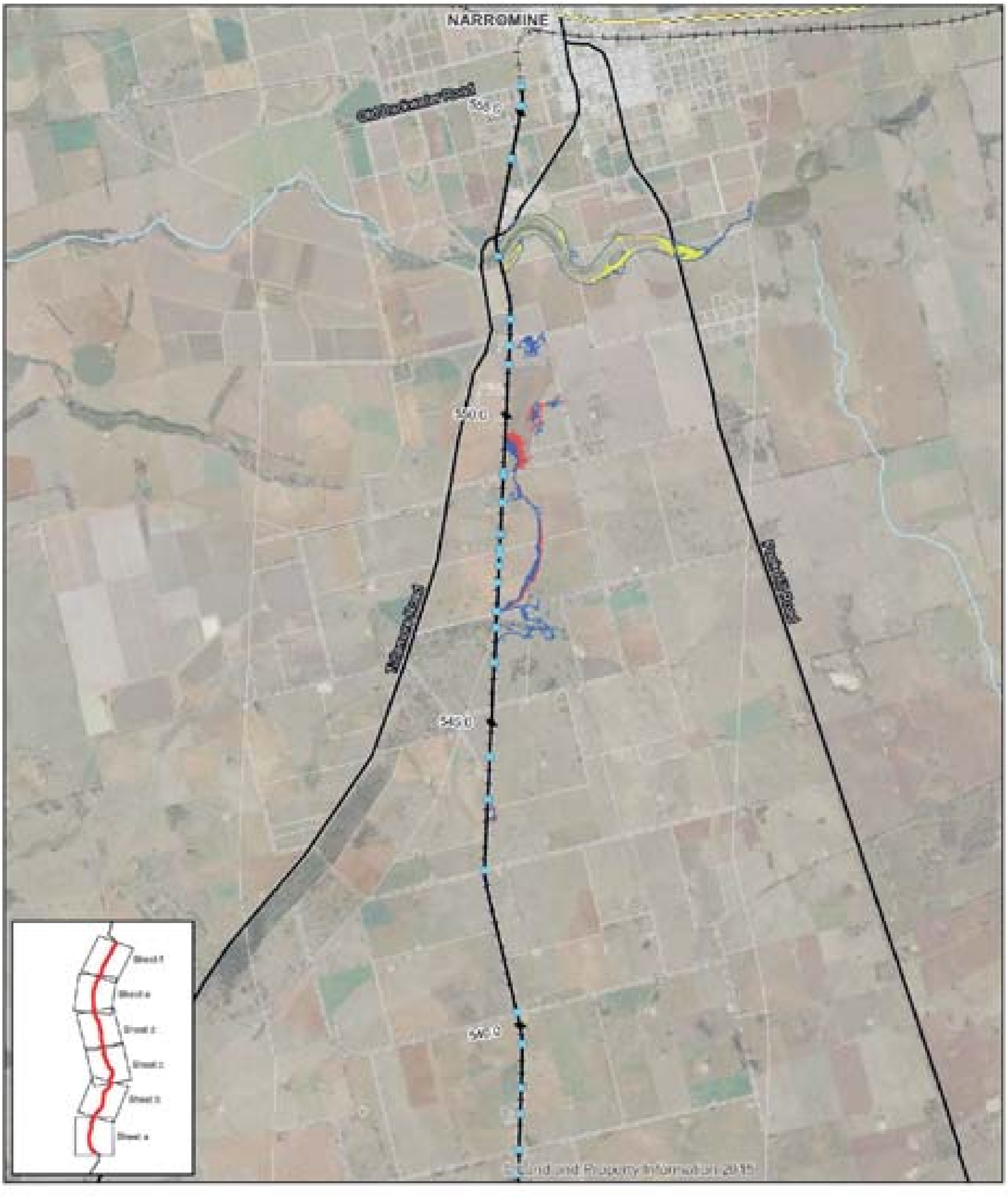
Date	21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5e



LEGEND

- Culvert / underbridge location
- The proposal
- Cadastre
- Highway
- Major road
- Railway_LPI_DTDB_2012
- Watercourse
- Increase in flood extent
- Reduction in flood extent
- Existing 100 year flood extent

Paper Size A4

0 500 1,000 2,000 3,000

Metres

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

GHD

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	21 Jun 2017

Detailed Changes to 1% AEP Flood Level Impact Extents

Figure 6-5f

Upstream period of flooding

Local catchment flood events are predicted to have a critical duration (ie the rainfall duration that will provide the greatest local catchment runoff rate) of generally from less than one hour to around 36 hours, comparable to the existing conditions (refer to Section 4.3.4). Critical duration is generally related to catchment area, with larger catchments having a longer critical duration design storm event. Local catchment runoff hydrographs for these rainfalls would expect to last for around 10 to 100 hours when not considering the effect of local ponding within the individual catchments.

For comparison purposes for this study, flooding has been taken as having ceased when the predicted flow through a structure has reduced to less than 0.1 metres deep at the respective culvert.

The change in inundation period from the existing duration of flooding will vary depending on the magnitude of the flood event. The flooding period for more frequent flood events (ie less than about the 50 per cent AEP flood event) is generally expected to be comparable to the existing conditions as a result of the increased culvert capacities allowing flood waters to drain away sooner with reduced flood levels upstream. For larger flood events, the raised rail level results in increased upslope flood levels, with more floodwater discharging through the culverts. As a result, the period of flooding is expected to increase for larger flood events, however the increase is generally expected to be less than ten hours.

The actual duration of flooding is dependent upon the temporal rainfall pattern and in conditions when there are days of rainfall the durations could extend longer than for the critical duration design storms.

During extended periods of rainfall, the duration of flooding may exceed this estimate. Similarly, a more rigorous analysis undertaken as part of design advancement for the project could provide longer inundation periods because of a better definition of localised depressions in the terrain or a greater flow interaction between adjacent catchments.

The existing data suggests that some catchments, for regional flood events, flooding of land could extend over several weeks.

Upstream watercourses

The predicted low velocities described above are not anticipated to create watercourse instability. The changes in the average velocity of flows approaching the new structures was assessed as generally being less than 0.1 metres per second.

Downstream flood level effects

Downstream of the rail line there is expected to be a general reduction in design flood levels for events up to the one per cent AEP event, in most areas. There may be localised changes in levels immediately downstream of replacement structures but these are expected to be confined closely to the rail corridor due to the proposed design measures.

Downstream flood velocities and erosion potential

A number of watercourses downstream of the rail corridor currently show signs of erosion and scouring because of the existing culverts associated with the rail line. Flow velocities within the watercourses downstream of each culvert is a function of the flood depth and flow capacity of the culvert. Where the culvert sizes are to be increased, or where local rail lifting will result in increased upstream flood levels, flow velocities within the downstream watercourses will increase (compared to the existing conditions).

Initial modelling indicates that for the one per cent AEP event about 50 per cent of the culverts within the proposal are expected to have flow velocities (within the culvert structure) less than approximately 2.5 m/s, and 75 per cent less than 3.5 m/s. A small number of culverts are estimated to have maximum flow velocities (within the culvert structure) greater than 5 m/s. Scour protection in the form of large rocks would be provided adjacent to the downstream end of each culvert.. In addition, a rock energy dissipation layer (a rock blanket) is proposed across the full width of the culverts to reduce the flow velocity of water exiting the culverts prior to discharging onto the ground. The flow velocity is anticipated to be reduced when it crosses the downstream boundary of the rail alignment, so that it does not exceed the existing flow velocity for the same event at that location by more than 1 m/s for the larger design events.

The presence of the rock blanket would stabilise the soil and reduce the amount and extent of potential downstream soil erosion and, thereby this control measure would:

- Provide an improved transition from the flat concrete apron to the more irregular profile of the ground surface.
- Provide a location for trapping some of the sediment load and provide a relatively stable area for seed germination and vegetation establishment adjacent to the apron.
- Quickly stabilise the immediate area against erosion during the period of disturbance while the blanket is being placed.

The provided rocks will act as energy dissipaters to reduce the flow velocities after they exist from the downstream end of the culverts. It is anticipated that the flow velocity at the downstream edge of the corridor will be reduced to a value within approximately 1 m/s of to the existing velocity for the culverts having the highest flow velocities.

However, there remains a risk of further erosion of the watercourses downstream of each new culvert because of increased flow rates, volumes and velocities during flood events.

Additional modelling is recommended to be undertaken during detailed design to improve the estimation of flow velocities that will assist in the identification of necessary energy dissipaters and other scour protection measures.

Downstream periods of inundation

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

6.3.5 Public road flooding

The analysis of public road overtopping was undertaken using the same methodology as for the existing track profile. Design flood levels along the corridor were determined and intercepted, assuming horizontal water surfaces, with the adjacent landform.

The locations where the predicted levels overtop the roads within the LiDAR corridor are listed in Table 6-4. Figure 6-6 shows the locations of the overtopping. In this analysis, we have considered the roads identified in the functional hierarchy as being higher than local roads.

The maximum flood level in each catchment was assessed and then the lengths of roads impacted were determined by applying a horizontal design water surface and comparing the road levels to the design flood levels. This method indicated the potential for some roads to have a higher maximum inundation depth than at the location where the same road crosses the rail line.

Table 6-4 Public road overtopping – design conditions

Road	Maximum depth overtopping (m)						Maximum length overtopping (m)
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	
Alectown West Road	0	0.01	0.02	0.03	0.04	0.05	7
Bogan Road	0	0.05	0.11	0.12	0.13	0.14	2
Bulgandramine Road	0	0.03	0.08	0.09	0.10	0.11	61
Peak Hill Railway Road	0	0	0	0	0.11	0.20	70
Tomingley Road	0	0	0	0	0	0	0
Tomingley West Road	0	0	0.11	0.31	0.32	0.33	110
Wyanga Road	0	0	0	0.13	0.57	0.65	181

The assessment found that the maximum depth of water predicted for the closures did not necessarily occur, where the public road crossed the rail line, at the level crossing location, as the maximum depth was dependent upon the road profile within the flooded area.

When comparing the results in Table 6-4 with those for the existing conditions in Table 4-7, it is seen that the impacts on the closure depths and locations would be minimal, with one per cent AEP flood depths over the roads exceeding 0.3 metres (the flood depth above which vehicles become unstable: NSW Government, 2005) at two locations: Tomingley West Road and Wyanga Road.

Figure 6-6 shows the locations and extent of the predicted local road closures for both the existing conditions and the design form.

Tomingley Road is not expected to overtop for the one per cent AEP design condition. The overtopping for Alectown West Road, Bogan Road, Bulgandramine Road and Tomingley Road West are expected to maintain hazards that are comparable to the existing case (DIPNR 2005). Some road upgrade works may be required to maintain (or improve) road accessibility during flooding.

The predicted depths of road overtopping for the one per cent AEP event do change from the existing case to the design case with increases in depths of water over the roads at Peak Hill Railway Road, and Wyanga Road. The increase in overtopping depth at Peak Hill Railway Road is predicted as 0.11 metres while that for Wyanga Road is more significant with an increase of 0.51 metres estimated. There is a corresponding increase in the length of overtopping for Peak Hill Railway Road and Wyanga Road.

It is considered that the overall impact of the proposal on road closures due to flood hazards would not significantly impact the operation of the SES, emergency planning or significantly increase the associated community disruption. Additionally, the flood risk management plan measures currently being implemented by Narromine (e.g. reliable access for pedestrian or vehicles) would generally not be hindered by the proposal. The modelling indicates that flood depths at some local sections of public roads increase, whilst others decrease. However, the modelling generally indicates that the potential for public roads to be close due to flood hazards remains relatively unchanged (or slightly reduced).

Given that the increase in flood levels is only expected to within areas already subject to flooding, the proposal would not require changes to existing community emergency management arrangements for flooding and there would not be increased social and/or economic costs to the community as consequence of flooding.

Ongoing liaison with local councils, Roads and Maritime Services, emergency services and the community would be undertaken as part of the detailed design phase to identify potential opportunities to improve the impacts of the proposal on road flooding.

6.3.6 Building impacts

An inspection of the imagery indicated that no buildings are likely to be located within the region that is predicted to be influence by the design rail corridor during the one per cent AEP flood. Appendix J contains figures that provide detailed views of the modelled flood impacts on properties within the vicinity of the proposal. It should be noted that the extents included in Appendix J are not modelled flood extents, but areas where the modelling indicates that the local flood levels will be influenced by the rail corridor.

Further modelling would be undertaken during detailed design to determine how the proposal can be modified so that the existing flooding characteristics with regards to property inundation are not worsened. Design modifications would likely consist of culvert resizing and potentially changes to the proposed formation height in the vicinity of the properties identified above.

6.3.7 Surface water sources

The proposal is expected to have some local impacts during construction as a result of surface water extractions to supply construction water. During operations, no appreciable ongoing impact on surface water resources is expected as a result of the proposal.

The proposal would generally maintain the location of bridges and culverts, with the capacity of new structures generally exceeding that of the existing structures. Therefore, it is considered that the currently flow conveyance within floodways would be preserved or improved.

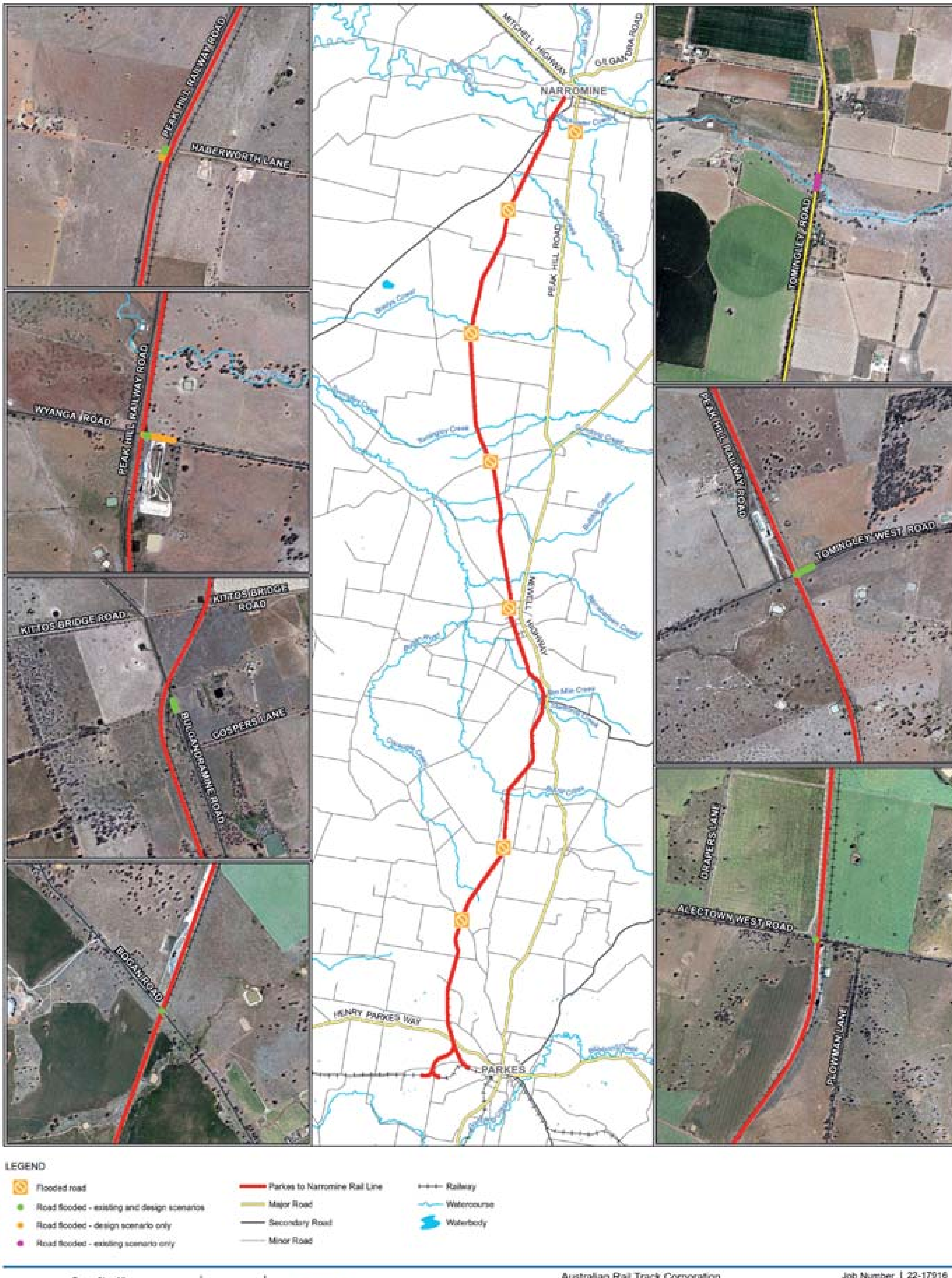
Similarly, as the proposed culvert locations are the same as the existing culvert locations, it is considered that the local flood storage areas would also remain relatively unchanged.

6.3.8 Groundwater sources

The majority of groundwater impact along the rail corridor would occur during the construction period when water is being sourced for dust suppression and general construction work. A number of extraction locations have been identified to minimise localised effects and a monitoring program has been developed to mitigate the extent of any impact. Groundwater will generally be extracted under existing groundwater access licences by arrangement with the licence holder.

It is possible the proposal may have a short term impact on flows within the alluvial layer as a result of water used during the construction period. The lateral extent of the projected impacts would be localised around any individual extraction location and is unlikely to extend more than about 50 metres from the extraction point.

Ongoing operation of the proposal would not require the sourcing of groundwater so the long term groundwater impact would be negligible.



Paper Size A3
0 1,750 3,500 7,000 10,500 14,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number | 22-17916
Revision | 0
Date | 23 Nov 2016

Major Roads Impacted by Floodwaters
1% AEP Flood Event

Figure 6-6

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: DCDB, LGA, 2012, roads, 2006; ARTC, railway, 2013. Created by: tmorton, sporola, gmotbarnid

7. Monitoring program

7.1 Flood event monitoring

It would be impractical to monitor the flood impacts during the any individual flood event. Therefore, a more feasible monitoring program is proposed in this section.

7.1.1 Flooding during the construction

Should a flood event occur during the construction phase then the following would be undertaken to verify the design performance and impact predictions, or to refine the design should there be a significant difference between the actual and predicted flood impacts and behaviour. The following steps would be implemented:

- The construction area would be inspected for damage and any required maintenance completed.
- The presence of any culvert blockages in the construction area, if present, would be recorded and cleaning undertakes as required.
- Where there is a significant variance between the predicted flood levels and the observed levels on the recently constructed stage of the works, landowners would be consulted to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values for the recently constructed stage of the works.
- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.
- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures would be recorded.

7.1.2 Flooding following commencement of operation

As soon as practical, if the rail corridor is closed, after the track is considered safe:

- The track would be inspected and the flood levels along the length of the rail corridor would be recorded for verification against the predicted flood levels.
- The presence of any culvert blockages would be recorded.
- Where there is a significant variance between the predicted flood levels and the observed levels, landowners would be consulted to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values.
- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.
- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures shall be recorded.

7.2 Surface water extraction monitoring

Monitoring of surface water extraction would be undertaken at each extraction location during the period to determine and confirm the total volume of extracted water. The monitoring would also confirm the volumetric extraction impact on each extraction location. Planned extraction locations are identified in Section 3.4.

The monitoring process and program would include recording record of the extraction volume for each load of water to confirm the volume extracted from each location.

Where an extraction is undertaken from a farm dam, the maximum extractable volume would be confirmed as part of the initial landowner consultation and extraction would terminate should the volume of the recorded extraction reach the agreed volume.

7.3 Groundwater extraction monitoring

Groundwater monitoring would be undertaken at each extraction location during the period of the extraction and at a less frequent period following the cessation of extraction at each location to identify the groundwater recovery process.

Potential water sources are identified in Section 3.4. The extraction of water from these sources would be subject to necessary licensing that would be obtained by the contractor prior to construction.

The monitoring process and program would include:

- Installation, if not already present, of a water level monitor at each agreed and approved extraction location prior to any extraction being undertaken.
- Prior to each load of extracted water, the groundwater level would be measured and recorded, along with the time and date of the start of the extraction.
- For each load of extracted water, the extracted volume of water and the groundwater level would be recorded at the completion of the extraction.
- The above data would indicate if there is a significant drawdown in the groundwater level or rebound in groundwater level between extractions.
- In the event of a groundwater drawdown without rebound between consecutive extraction days exceeding a value of 0.3 metres then further extractions from that location would be suspended until the rebound has shown a recovery of the groundwater level of not more than 0.1 metres. In the event that the appropriate recovery is not achieved then no further extractions would be made from that site.

8. Conclusion

This report presents an assessment of the existing hydrologic and hydraulic conditions along the length of the proposal and identifies the existing flooding regime and the extents of impacts of existing flooding.

8.1 The design development process

The design development process included an integration of the track formation design and structure sizing, and an assessment of the potential impacts of the proposal. Structures were sized based on the predicted flows that would arise from rainfall events over the local catchment areas. No detailed examination of the flooding impacts of the regional river (Macquarie River) on the reliability of the proposed has been completed.

Structures under the formation were then sized to provide a target performance requirement of conveying the one per cent AEP flow while not having the upstream one per cent AEP ponding level above the top of the rail formation. That target performance was not achieved at all locations and exceptions to the requirement are identified in this report.

The structure sizing was based on the evaluation of the required number of pre-cast box culvert units, of selected standard sizes, to achieve the required hydraulic performance. The discharge capacity of the structures was assessed based on the assumption that the discharge rate was directly related to the flood level immediately upstream of the culverts and ignored the downstream effects. This approach was necessary to establish a potential design solution as consideration of downstream backwater effects would have made the analysis impractical. The analysis, while considering flow through structures, also considered, where appropriate, the flow over the rail line and the interaction of flows between adjacent local catchments upstream of the rail corridor.

The assessment method provides a reasonable means of estimating the potential flood impacts associated with the proposal however additional analysis is recommended within sensitive areas during detailed design to ensure the proposal results in minimal impacts on surrounding land users.

8.1.1 Future works

A number of additional works have been identified during the assessment that are to be completed as part of the detailed design process, including:

- Detailed flood modelling of major structures (or adjacent structures) to:
  - Minimise the regional flooding impacts
  - Better represent the catchment response to rainfall and the catchment flow paths, directions and velocities for overland flows and watercourses
  - Provide improved estimated of the extent of upstream flood extents and impacts, including flow velocities, shear stress and duration may be required to identify suitable erosion and scour protection measures
  - Estimate the potential for erosion and scour around bridge piles, and scour protection measures that may be required
  - Assist in identifying refinements to the design (both rail lift and culvert configurations) to either reduce the estimated impacts or improve the reliability of the proposal
  - Potentially include consideration of flows through, and possibly under, the ballast and formation

  - Consider of effects of downstream flood levels (ie tailwater control conditions) on flows through the culverts.
- Investigate potential upgrades to the road level crossings and other roads that may be affected by flooding because of the project. this is intended to reduce the impacts of flooding on track reliability as well as improve emergency access and egress on public roads during flood events.
- Investigate the potential to include additional rail lifts to make the ballast flood free for the full length of the rail corridor (ie meet the requirements of ETD-10-02: ARTC (2016)).
- Obtaining a broader and more reliable terrain representation upstream of the existing rail corridor to permit a more reliable definition of flow paths, catchment boundaries, connections (overflows) between adjacent catchments and other hydraulic features, in particular the breakout of floodwaters from the Macquarie River into Backwater Cowal or the Bogan River floodplain (Bradys Cowal). This would also allow for a more accurate representation of storage effects upslope of the culverts.
- Undertake watercourse specific inspections and tailored modelling and analysis to understand better the flow interactions between catchments, tailwater influences and flooding duration. In particular, the interactions between Macquarie River, Backwater Cowal and the Bogan River.

8.2 Impact assessment

The proposal was assessed to identify specific impacts, including changes to flooding levels and extents, impacts on adjoining road and land (such as public road closures, extents of flooding and level crossing closures of the rail line).

The assessment found that:

- There are a number of locations where the proposal does not meet the flood immunity requirement (ETD-10-02). If necessary, additional analysis may be undertaken to identify design improvements to remove some or all locations where the flood immunity requirement is not met. Such design improvements may include additional structures, local drainage works, or further raising the rail formation. Potential modifications to the proposal will be considered further during the detailed design process.
- There would be some changes in flood levels upstream of the proposal. These changes would largely be a result of the lifting of the level of the rail formation, with this being counteracted in part by the provision of one per cent AEP culverts under the rail formation. The impacts associated with changes to flood levels, including increased flood levels within private properties at a number of locations, would depend on land use and private infrastructure within the affected area. Additional discussions with the owners of the affected properties would be undertaken to determine the consequences of the expected impacts and, where necessary, identify mitigation measures to reduce the impacts.
- The proposal would overtop at a limited number of level crossings where the rail formation would only be raised minimally.
- Some of the predicted public road closures would be observed at locations that are not immediately adjacent to the proposal.

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Appendices

Appendix A – Hydrologic and hydraulic analysis methodology

A1. Analysis evolution

Initial assessments were undertaken to assist in the provision of technical information to define the reliability for the track and reconcile early p requirements. A series of assessments were undertaken during the initial stages to evaluate various upgrade works (culverts to various AEP capacities and various track lifts) to assist that process.

Results of those initial assessments have been superseded by the issue of Technical Note ED-10-02 which has defined the definition of flood immunity. Section A6.5 provides a detailed discussion of the implications of the Technical Note.

Results provided within this report have been completed and evaluated against the Technical Note requirements.

A2. Standard culvert sizes

Culvert sizes were selected from the developed standard geometries which are shown, for a single leg length for each culvert style, in Figure A-1.

Within the geometries shown in Figure A-1 there were a variety of clear vertical opening heights (leg lengths) developed as being available. The leg lengths were:

- Culvert Type A – 300 mm; 400 mm; and 500 mm.
- Culvert Type B – 500 mm; 700 mm; 900 mm; 1100 mm; 1300 mm; and 1500 mm.
- Culvert Type C – 1200 mm; 1500 mm; 1800 mm; 2100 mm; 2400 mm; and 3,000 mm.

A3. Selection of structure upgrade

Culverts

To select the new culvert size for the culvert upgrades the steps followed were adopted:

- The level difference between the existing culvert invert level and the proposed track level was determined.
- That gave the maximum culvert leg length (of those listed above) after allowing for ballast and rails over the culverts. The maximum culvert leg length was adopted for the culvert.
- The number of barrels forming a culvert was progressively increased until either (a) the required flood level was achieved for the one per cent AEP event, or (b) the number of culvert barrels became unrealistically large.

When considering the selection of upgraded culvert sizes, flow interaction was permitted between adjacent upstream catchments.

At some locations it was not possible to obtain a potentially realistic number of culvert cells that would achieve the desired flood immunity. This was primarily a result of the rail level between adjacent culverts being sufficiently low that the rail would overtop while further increasing the number of culvert cells did not achieve the desired flood immunity.

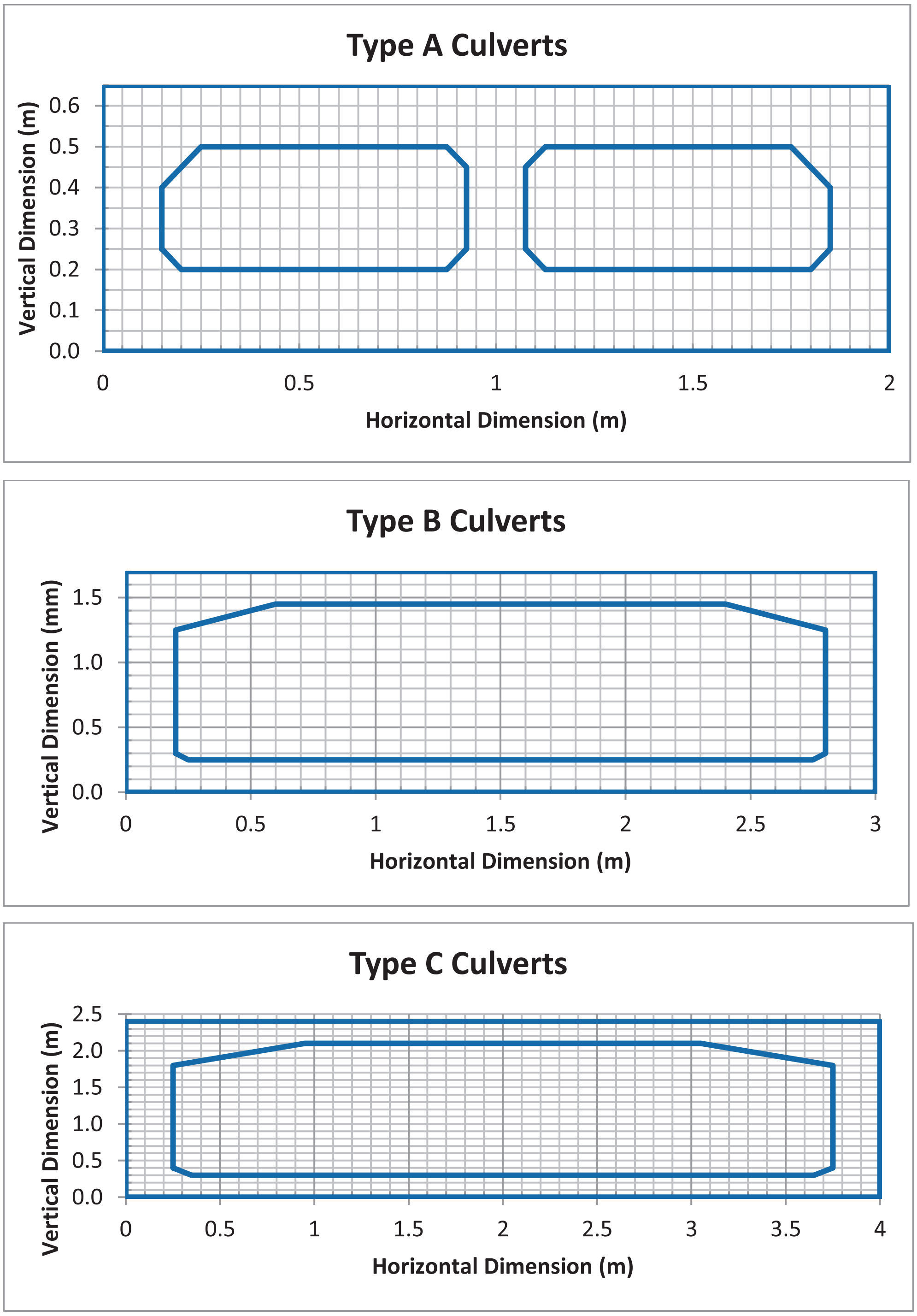


Figure A-1 Typical structure sizes

Bridges

Bridge lengths for structures over the minor watercourses were selected to suit standard bridge planks while achieving, as a minimum, a watercourse consistent with the calculated culverts required at the location.

A4. Interaction of track lifts and culvert sizes

The geography of the proposal area, in particular the dynamics of flood flows within the floodplains being analysed, means that no culvert may be considered in isolation.

Changes to a culvert (such as increasing or decreasing the capacity or locally raising the rail level) have the potential to alter flood flows across a wide floodplain area, altering patterns of rail overtopping and flood extents.

In addition, the maximum design height of a culvert can be affected by the local rail level. Where the rail levels are lifted, there is the potential to increase the design height of a culvert, which in turn may allow for the reduction in the number of culvert barrels while maintaining a comparable hydraulic capacity. As such, there is potentially an infinite number of rail lift and culvert combinations that may adequately meet the design objectives.

The upgrade options included in this report aim to balance the specified design objectives with physical limitations and impacts on the surrounding land users. It is expected that the selected culverts and track lifts will be further refined during the detailed design process.

A5. Hydrologic analysis

A5.1 Overview

Estimated local catchment surface flow rates arriving at structures were developed based on the contributing catchment area and application of a design rainfall of varying duration to that catchment area.

For several catchment areas it was found that flows from adjacent local catchments would interact prior to flowing over the rail line. In these locations the hydrologic and hydraulic assessment was required to consider the coincident flows from the adjacent local catchment areas.

Two flow configurations arose:

- In circumstances where the peak flow at a structure could pass through the structure without either the (a) track overtopping or (b) the catchment boundary being overtopped into the adjacent catchment (flow parallel to rail alignment), the flood level was determined based on the capacity of the structure in a particular catchment area.
- In circumstances where flow could not pass through the structure and the predicted water level resulted in (a) overtopping of the rail level or (b) overtopping of the adjacent catchment boundary or (c) both of the above conditions, the calculations were expanded to obtain a flood level that considered the hydraulic capacity of the structure, the resulting flow over the rail and/or the resulting flow into the adjacent catchment concurrently acknowledging all resulting outflow relationships to establish the resulting flood level of the initial structure and those subsequently affected. Flow over the top of the rail was assessed as a weir.

A5.2 Analysis Process

The hydrologic elements of the analysis were identical for the structure sizing tor replacement culverts for the one per cent AEP event and the evaluation of the performance for structures.

The process involved:

- Identification of the existing structures for the establishment of the base flooding conditions. These structure locations were for the most part retained for the design condition to minimise potential hydrologic and hydraulic impacts downstream of the structures.
- The structure size was identified from either existing geometry information or from the culverts selected during this design process.
- Determination of the local catchment area draining to each of the structure locations from the combined LiDAR / SRTM DEM.
- Application of design rainfalls to each local catchment to determine the peak rate of runoff from the catchments for a broad range of design rainfall durations. The analysis of the peak flow rates was completed using the Probabilistic Rational Method of calculations. These flows were then adjusted to better replicate comparative flows established using a RORB hydrologic model that had been used to evaluate design flows for ten of the local catchment areas.
- A stage -storage volume relationship was established for the area located immediately upstream of each structure for the length of the rail corridor. The storage volumes were calculated by assuming a horizontal upstream water level extending from the rail corridor to the natural ground level (as defined by the LiDAR terrain model).
- Triangular hydrographs formed from the above peak flow rates and assuming a hydrograph duration of twice the design rainfall duration were then routed through each storage volume with the outlets from that catchment being through the structure (culvert or bridge), over the rail line if the flood level exceeded the minimum track level and potentially into the adjacent catchments.
- The routing process was repeated for different rainfall durations to establish the one giving the highest flood level for each AEP when allowing, if required, flow interaction between catchments.
- For the design case the number of barrels forming a culvert was progressively increased, using the standard structure sizes, to meet the nominated design criteria.

A5.3 Catchment delineation

Catchment areas and catchment boundaries were identified from the client supplied LiDAR together with patched in SRTM data in areas where the catchment extended outside the supplied LiDAR corridor data.

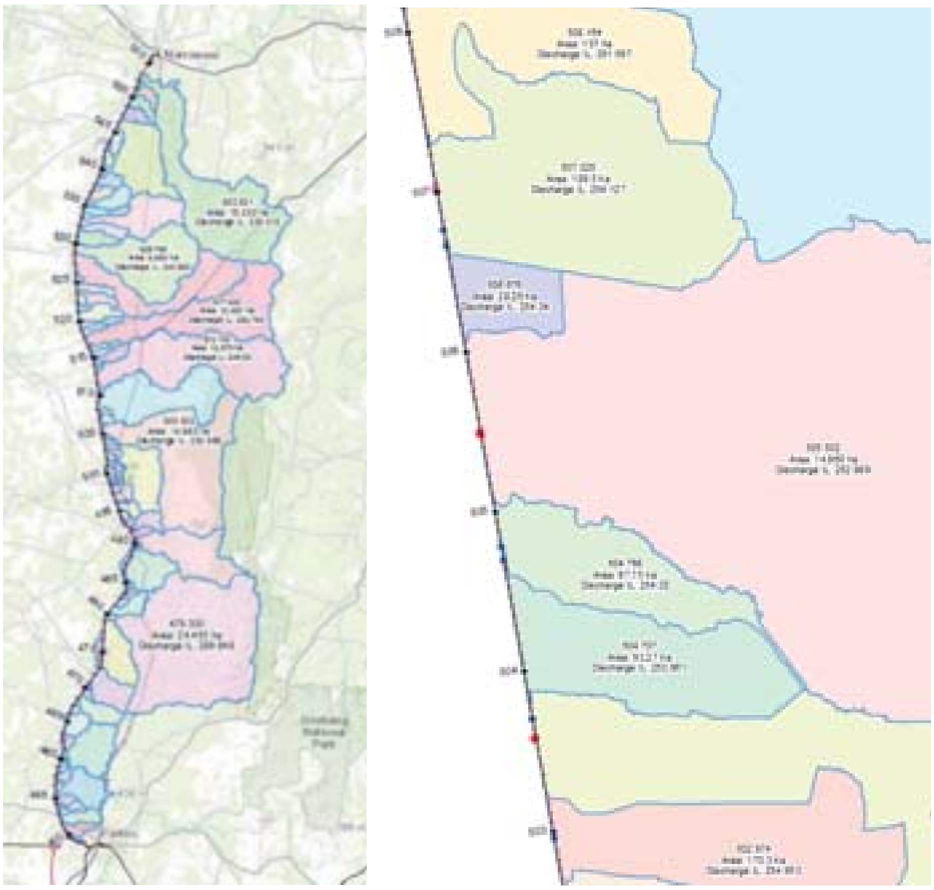
The process used to delineate the catchment areas included:

- Identification of all culvert locations – initial locations for structures were identified from earlier proposal documentation. The chainages provided within that report were mapped onto the proposal aerial image.
- Minor adjustments were made to the plotted culvert locations to ensure that the identified low point along the track formation centreline was identified as the culvert location.

- The area draining to each culvert location was then determined from the terrain model formed from the LiDAR and SRTM data. An example of the catchment delineation is shown in Figure A-2. Figure A-2 shows, on the left, the overall catchment delineation for the length of the proposal while the right hand image shows an enlarged view of a localised portion of the project.

On that figure the culverts and underbridges are represented by red dots, the large culverts by pink dots and the small culverts by blue dots. The catchment for each culvert is delineated by a light blue line with catchment areas shown by different colourings to clearly identify individual catchments.

- For each catchment area the following were determined:
  - Catchment area.
  - Lowest track level along the section of track crossing the catchment.
  - Catchment boundary levels between adjacent catchment areas were extracted from the supplied LiDAR survey.



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– (a) Overall study area (b) Localised catchments

Figure A-2 Catchment delineation

A5.4 Catchment storage volumes

Storage volumes located upstream of each culvert were determined by applying a series of horizontal slices, a slice per assumed flood level, that were intersected with the catchment terrain model to determine a flood stage and storage volume relationship.

A6. Hydraulic analysis

A6.1 Overview

The hydraulic analysis for the culverts was integrated with the hydrologic analysis. The difference being restricted to the hydraulic analysis converting the flow rates into flow depths using specified rules.

A6.2 Assumed flow conditions

The hydraulic elements of the culvert sizing and assessment were based on the culverts acting under inlet control ie, the flow depth upstream of the culvert was assumed to be directly related the culvert geometry (size and number of barrels and the flow rate) and independent of the downstream flood level.

Since the analysis was restricted to local catchment rainfall and runoff events this gave realistic predicted flow conditions. During the rising limb of a flood hydrograph the culverts will initially act under inlet control. Should rainfall occur over two catchment areas across a culvert then the water level would raise at both ends of the relevant culvert and in this circumstance the maximum flow rate through the culvert would be reduced by backwater effects. This would also provide a situation of not being able to size the culverts without some assumption as to the downstream flood level.

A6.4 Analysis Mode

The hydraulic elements of the analysis of the system performance was slightly different to that when determining the size of a required structure.

For culvert analysis the hydraulic elements included:

- Assuming a flood level upstream of a culvert
  - Determination of the capacity of the culvert when acting under inlet control for the assumed upstream flood level.
  - Determining whether the assumed flood level would overtop the rail and there was not flow into/out of an adjoining catchment – when the assumed flood level would overtop the rail, the flow over the rail was determined using a weir flow formulation that reflected the actual track profile.
  - Determining whether the assumed flood level would overtop the rail and there was flow into/out of an adjoining catchment – when the assumed flood level would overtop the rail, the flow over the rail was determined using a weir flow formulation that reflected the actual track profile over the entire potential overflow length across the adjacent catchments.
  - Determining whether the assumed flood level would overtop the ridge between adjacent catchments giving flow transfer between adjoining catchments – when the assumed flood level would overtop the ridge, the two local catchments were treated as a single, larger catchment with the associated culverts considered in concert.
- Applying storage routing to consider the conveyance of flow into the derived storage volume, the potential outflow and transfer rates and change in volume of the entire storage areas.

A6.5 Design mode

Analysis for the design mode included all the steps described above. An additional overarching iteration was required to progressively upgrade the number of barrels in a culvert until either and acceptable geometry was determined to achieve the required maximum upstream flood level for the one per cent AEP event, or, an unrealistic number of barrels was required to achieve compliance to Technical Note ETD-10-02.

Rail overtopping locations

The extent of rail overtopping has been determined by evaluating the rail level, at about two metre increments, throughout each catchment and comparing the rail level to the flood level for that catchment.

In some locations the track maps as overtopping when it is not overtopping at the adjacent culverts. This occurs as a result of the track formation being lower between culverts than at the culverts.

The predicted depth of track overtopping is determined as being the difference between the predicted flood level and the local track level.

Appendix B – Existing structure details

This appendix provides a summary of the existing structures between Parkes and Narromine considered within the assessment, the modelled local upstream catchment critical duration flow rates and flood levels for a range of design flood events.

Details of the existing structures were collected during a field inspection by GHD and ARTC staff in September 2014.

Track Lift:	Existing
Structures:	Existing

Kilometerage	Existing Structure	Structure Invert (as modelled) (mAHD)	Existing Rail Low Point (as modelled) (mAHD)
449.350	Concrete Box, 4 x 1.2	325.27	326.61
449.765	Steel Pipe, 9 x 0.6	322.59	322.94
449.852	Steel Pipe, 4 x 0.6	321.57	322.03
450.204	Steel Pipe, 2 x 0.45	316.84	317.37
451.332	Concrete Box, 16 x 1.8 x 0.9	307.14	308.91
452.721	Concrete Box, 4 x 1.5 x 1.5	299.76	302.48
453.403	Timber Girder, 4 x 1.83	299.67	301.53
453.642	Steel Pipe, 4 x 0.6	300.52	301.72
454.353	Steel Pipe, 7 x 0.9	299.66	300.38
454.844	Timber Girder, 17 x 3.05	297.09	298.86
455.228	Steel Pipe, 13 x 1.2	297.22	298.89
456.184	Steel Pipe, 5 x 1.05	302.45	303.44
456.992	Steel Pipe, 4 x 0.6	304.40	305.29
457.486	Steel Pipe, 5 x 0.6	304.89	306.37
458.285	Steel Pipe, 1 x 0.9	310.45	310.78
458.323	Concrete Box, 1 x 0.9 x 0.6	309.60	310.96
458.648	Steel Pipe, 3 x 0.6	310.26	311.21
459.676	Steel Rail, 1 x 1.9	310.18	311.27
460.127	Concrete Box, 3 x 0.9 x 0.6	309.05	310.18
460.698	Timber Girder, 4 x 1.83	306.00	308.11
461.157	Timber Girder, 7 x 3.66	306.72	308.71
461.252	Steel Pipe, 10 x 0.6	308.14	309.23
461.980	Steel Pipe, 2 x 0.6	315.09	316.36
462.814	Concrete Box, 2 x 0.9 x 0.6	319.12	320.86
463.019	Steel Pipe, 2 x 0.6	319.86	321.35
463.224	Steel Pipe, 2 x 0.6	319.52	320.14
464.694	Concrete Box, 4 x 3.0 x 1.4	307.38	309.84
464.746	Steel Pipe, 1 x 1.2	309.66	314.86
465.265	Steel Pipe, 2 x 0.6	314.48	314.92
465.310	Steel Pipe, 2 x 0.45	314.65	315.00
465.366	Steel Pipe, 1 x 0.6	314.95	315.27
465.859	Steel Pipe, 1 x 0.6	315.87	316.18
466.824	Steel Pipe, 5 x 1.2	313.27	313.59
468.176	Steel Rail, 2 x 1.6	313.86	314.99
468.366	Steel Pipe, 3 x 0.6	313.69	315.03
468.565	Timber Girder, 5 x 4.27	313.37	315.08
469.524	Steel Pipe, 4 x 1.05	318.02	318.33
470.467	Steel Pipe, 2 x 0.75	322.03	322.34
472.030	Concrete Box, 6 x 2.4 x 1.5	311.80	314.73
473.905	Steel Pipe, 1 x 0.6	313.49	314.60
473.938	Steel Pipe, 1 x 0.6	313.33	314.30
476.771	Steel Pipe, 1 x 0.6	296.52	297.75
476.796	Steel Pipe, 1 x 0.6	296.85	298.19
477.703	Steel Pipe, 6 x 0.9	293.41	294.54
478.262	Timber Girder, 8 x 1.83	290.32	292.17
478.796	Steel Pipe, 6 x 0.6	291.37	292.70
479.300	Concrete Box, 6 x 3.6 x 3.0, 5 x 3.6 x 1.5	289.55	293.33
480.350	Steel Pipe, 14 x 1.05	292.09	294.07
481.921	Steel Pipe, 8 x 0.6	298.48	299.98
482.824	Steel Pipe, 4 x 0.75	305.55	305.95
482.947	Steel Pipe, 5 x 0.9	305.29	306.93

Track Lift:	Existing
Structures:	Existing

Kilometerage	Existing Structure	Structure Invert (as modelled) (mAHD)	Existing Rail Low Point (as modelled) (mAHD)
483.549	Steel Pipe, 3 x 0.6	311.16	312.11
483.940	Steel Pipe, 8 x 0.75	315.39	315.87
484.581	Steel Pipe, 8 x 0.6	318.03	318.36
484.829	Timber Girder, 3 x 1.83	316.52	318.40
487.960	Steel Pipe, 2 x 0.9	296.41	296.85
488.908	Steel Pipe, 7 x 0.6	290.83	291.22
489.844	Steel Pipe, 20 x 1.2	284.47	286.26
490.189	Steel Pipe, 4 x 0.9	286.26	287.18
490.553	Concrete Box, 8 x 3.4 x 1.4	284.79	287.34
491.834	Steel Pipe, 5 x 1.65	281.79	282.19
492.079	Steel Pipe, 7 x 1.2	279.98	281.92
492.947	Steel Pipe, 10 x 0.6	278.03	278.35
493.293	Steel Pipe, 1 x 0.9	278.31	278.62
493.749	Steel Pipe, 5 x 0.6	276.77	277.40
494.815	Steel Pipe, 7 x 0.6	272.11	272.52
495.535	Steel Pipe, 5 x 0.6	269.43	269.78
496.067	Steel Pipe, 4 x 0.6	268.24	268.64
496.885	Steel Pipe, 7 x 0.6	266.75	267.04
497.613	Steel Pipe, 7 x 0.6	263.99	265.02
497.760	Concrete Pipe, 2 x 0.45	264.15	265.03
498.061	Steel Pipe, 1 x 0.6	265.10	265.87
498.625	Steel Pipe, 4 x 0.6	263.81	265.54
498.870	Timber Girder, 4 x 0.41	264.07	264.76
499.545	Steel Pipe, 3 x 0.45	260.83	261.88
499.577	Steel Pipe, 4 x 0.45	260.76	261.88
500.138	Steel Pipe, 4 x 0.45	258.33	259.39
500.482	Steel Pipe, 4 x 0.6	257.31	258.50
500.558	Steel Pipe, 2 x 0.6	257.54	258.51
500.663	Concrete Pipe, 2 x 0.6	257.43	258.59
501.167	Steel Pipe, 4 x 0.75	257.72	259.06
502.456	Steel Pipe, 12 x 0.6	255.12	256.22
502.974	Steel Pipe, 6 x 0.6	254.95	256.12
503.599	Timber Girder, 10 x 1.22	253.57	256.14
503.720	Steel Pipe, 4 x 0.6	254.90	256.29
504.707	Steel Pipe, 7 x 1.05	253.96	255.57
504.798	Steel Pipe, 9 x 0.9	254.02	255.56
505.502	Timber Girder, 15 x 1.22	252.99	255.00
506.676	Steel Pipe, 12 x 0.6	254.30	254.64
507.025	Concrete Box, 1 x 2.44 x 0.4	254.13	254.48
508.164	Steel Pipe, 5 x 0.6	251.60	252.74
509.640	Timber Girder, 5 x 1.83	248.52	250.46
510.815	Steel Pipe, 1 x 0.6	249.19	250.23
512.108	Steel Pipe, 5 x 1.2	249.53	251.77
513.671	Timber Girder, 2 x 1.22	253.69	254.46
514.218	Steel Pipe, 4 x 0.45	253.93	254.99
515.011	Timber Girder, 10 x 1.22	253.76	255.17
515.084	Steel Pipe, 6 x 0.6	253.92	255.31
515.601	Timber Girder, 5 x 1.22	252.78	254.30
516.313	Steel Pipe, 6 x 0.6	252.90	254.21
516.484	Steel Pipe, 4 x 0.6	253.52	254.25
516.980	Steel Pipe, 4 x 0.75	253.61	254.56

Track Lift:	Existing
Structures:	Existing

Kilometerage	Existing Structure	Structure Invert (as modelled) (mAHD)	Existing Rail Low Point (as modelled) (mAHD)
517.428	Concrete Box, 9 x 1.2 x 0.6	252.59	254.36
518.556	Steel Pipe, 5 x 0.75	253.46	254.50
519.224	Timber Girder, 3 x 4.27	252.67	254.51
520.339	Steel Pipe, 3 x 0.6	253.40	253.72
521.918	Steel Pipe, 4 x 0.6	253.24	253.56
523.223	Steel Pipe, 5 x 0.6	251.80	253.08
524.180	Steel Pipe, 4 x 0.6	250.41	251.52
524.906	Steel Pipe, 3 x 0.6	249.87	250.70
525.984	Steel Pipe, 4 x 0.75	247.17	248.47
528.371	Concrete Box, 12 x 1.2 x 0.4	241.77	243.09
528.540	Timber Girder, 1 x 1.8	241.70	242.82
528.668	Steel Rail, 4 x 0.91	241.70	243.76
528.741	Steel Pipe, 5 x 0.45	241.72	242.87
529.274	Concrete Box, 1 x 3.0 x 0.4	240.18	242.34
529.768	Timber Girder, 15 x 1.22	240.65	241.93
530.705	Steel Pipe, 3 x 0.6	241.23	241.94
531.132	Steel Pipe, 5 x 0.75	241.19	241.51
531.543	Steel Pipe, 4 x 0.6	241.17	241.48
531.757	Steel Pipe, 2 x 0.6	241.30	241.65
531.906	Steel Pipe, 4 x 0.6	241.54	242.44
532.351	Steel Pipe, 4 x 0.9	242.07	242.42
533.149	Steel Pipe, 6 x 0.75	242.96	243.29
533.611	Steel Pipe, 9 x 0.6	242.88	243.22
534.776	Steel Pipe, 5 x 0.75	242.76	243.41
535.106	Steel Pipe, 2 x 0.9	242.64	243.50
536.243	Steel Pipe, 11 x 0.6	242.85	243.35
536.539	Steel Pipe, 7 x 0.6	242.98	243.31
536.891	Concrete Box, 3 x 0.9 x 0.4	243.86	244.25
537.571	Steel Pipe, 7 x 0.6	245.06	245.44
537.993	Steel Pipe, 2 x 0.6	246.44	246.79
538.563	Steel Pipe, 2 x 0.6	250.28	252.47
539.013	Steel Pipe, 11 x 0.9	252.15	252.56
539.707	Steel Pipe, 3 x 0.6	256.79	257.18
540.226	Steel Pipe, 2 x 0.6	259.11	259.54
542.605	Steel Pipe, 4 x 0.6	253.56	254.55
543.766	Steel Pipe, 4 x 0.6	247.61	248.48
544.452	Steel Pipe, 4 x 0.6	244.87	248.40
545.968	Steel Pipe, 13 x 0.9	239.59	240.88
546.542	Timber Girder, 12 x 1.83	238.11	240.10
546.812	Steel Pipe, 4 x 0.6	239.26	240.07
547.282	Steel Pipe, 2 x 0.6	238.51	239.43
547.559	Steel Rail, 9 x 0.45	238.58	239.36
547.739	Steel Rail, 7 x 0.45	238.45	239.41
547.841	Steel Rail, 7 x 0.45	238.12	239.31
548.064	Steel Rail, 2 x 1.22	238.58	239.37
548.581	Steel Pipe, 2 x 0.6	238.55	239.40
549.027	Steel Pipe, 2 x 0.75	238.15	238.99
549.072	Steel Pipe, 4 x 0.75	237.67	238.96
549.090	Steel Pipe, 1 x 0.75	237.76	240.41
550.835	Steel Pipe, 4 x 0.6	240.02	240.32
551.146	Steel Pipe, 4 x 0.6	240.12	240.43

Track Lift:	Existing
Structures:	Existing

Kilometerage	**Existing Structure**	**Structure Invert (as modelled) (mAHD)**	**Existing Rail Low Point (as modelled) (mAHD)**
551.571	Steel Pipe, 4 x 0.6	240.18	240.54
552.631	Concrete Box, 8 x 4.2 x 2.4	235.01	237.99
554.243	Steel Pipe, 3 x 0.6	239.21	239.21

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	Local Catchment Area (ha)	Local Catchment Probablistic Ration Method Peak Flow Rate (m^3/s)								
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
449.350	54.2	0.394	0.808	1.2	2.01	3.88	5.53	6.64	8.86	74.3
449.765	4	0.0482	0.0989	0.147	0.247	0.478	0.68	0.964	1.29	9.96
449.852	16.2	0.151	0.31	0.459	0.774	1.5	2.13	2.71	3.62	29.3
450.204	11.3	0.113	0.233	0.345	0.58	1.12	1.6	2.08	2.78	22.2
451.332	492	2.1	4.29	6.32	10.6	20.4	29	34	45.3	407
452.721	792	3	6.08	8.95	15.1	28.9	41.1	48.4	64.4	587
453.403	333	1.58	3.21	4.74	7.98	15.4	21.8	25.5	34	301
453.642	40.5	0.313	0.643	0.952	1.6	3.09	4.4	5.35	7.14	59.3
454.353	40.5	0.313	0.642	0.952	1.6	3.09	4.4	5.35	7.13	59.3
454.844	270	1.34	2.74	4.06	6.81	13.1	18.7	21.8	29	256
455.228	2010	5.9	11.9	17.6	29.4	56.2	79.9	96.1	128	1200
456.184	91.9	0.593	1.21	1.8	3.02	5.83	8.3	9.81	13.1	112
456.992	22.3	0.195	0.401	0.593	1	1.93	2.75	3.44	4.59	37.4
457.486	238	1.22	2.5	3.7	6.22	12	17.1	19.9	26.5	233
458.285	0.0264	0.000727	0.0015	0.00219	0.00371	0.00698	0.00999	0.0234	0.0313	0.208
458.323	16.1	0.151	0.309	0.458	0.772	1.49	2.12	2.71	3.61	29.2
458.648	87	0.569	1.16	1.72	2.9	5.59	7.96	9.43	12.6	107
459.676	70.2	0.482	0.986	1.46	2.46	4.74	6.76	8.03	10.7	90.6
460.127	67.5	0.467	0.957	1.42	2.38	4.6	6.55	7.81	10.4	87.9
460.698	58.7	0.419	0.859	1.27	2.14	4.13	5.88	7.04	9.39	78.9
461.157	3030	7.96	16.1	23.6	39.3	75.5	107	130	174	1650
461.252	212	1.12	2.29	3.39	5.7	11	15.6	18.2	24.3	213
461.980	19.5	0.175	0.36	0.532	0.897	1.73	2.47	3.11	4.15	33.7
462.814	2.65	0.0341	0.0701	0.104	0.175	0.339	0.482	0.709	0.947	7.24
463.019	1.22	0.0177	0.0365	0.0541	0.0912	0.176	0.251	0.399	0.533	3.98
463.224	1.17	0.0171	0.0352	0.0523	0.088	0.17	0.243	0.387	0.517	3.85
464.694	2450	6.8	13.8	20.2	33.8	65	92.1	111	149	1400
464.746	0.00792	0.000291	0.000598	0.000842	0.00144	0.00258	0.0037	0.00959	0.0128	0.082
465.265	19.4	0.175	0.359	0.532	0.896	1.73	2.47	3.11	4.15	33.7
465.310	0.496	0.0083	0.0171	0.0253	0.0427	0.0826	0.118	0.205	0.274	1.99
465.366	23.4	0.203	0.416	0.616	1.04	2	2.85	3.56	4.75	38.8
465.859	0.429	0.00733	0.0151	0.0224	0.0377	0.073	0.104	0.184	0.246	1.78
466.824	127	0.761	1.55	2.3	3.87	7.47	10.6	12.5	16.6	143
468.176	56.8	0.408	0.837	1.24	2.09	4.02	5.73	6.87	9.17	77
468.366	0.0626	0.00146	0.003	0.00443	0.0075	0.0144	0.0205	0.0444	0.0593	0.404
468.565	1210	4.08	8.29	12.2	20.5	39.4	55.8	66.3	88.4	816
469.524	150	0.865	1.76	2.61	4.39	8.47	12.1	14.1	18.8	163
470.467	31.5	0.257	0.527	0.781	1.31	2.54	3.61	4.44	5.92	48.8
472.030	1880	5.6	11.4	16.7	27.9	53.7	76.1	91.4	122	1140
473.905	45.8	0.346	0.708	1.05	1.77	3.41	4.85	5.86	7.82	65.2
473.938	0.073	0.00165	0.00341	0.00504	0.00852	0.0163	0.0233	0.0497	0.0665	0.455
476.771	0.348	0.00615	0.0126	0.0188	0.0316	0.0612	0.0873	0.158	0.211	1.52
476.796	189	1.03	2.1	3.1	5.22	10.1	14.3	16.7	22.3	194
477.703	503	2.13	4.35	6.43	10.8	20.8	29.5	34.5	46	413
478.262	2850	7.62	15.3	22.6	37.7	72.4	103	125	166	1580
478.796	0.75	0.0118	0.0242	0.036	0.0605	0.117	0.167	0.279	0.373	2.74
479.300	24400	35.5	71.6	104	173	330	465	614	815	8250
480.350	859	3.18	6.45	9.49	16	30.6	43.5	51.3	68.4	625
481.921	135	0.797	1.63	2.42	4.07	7.83	11.2	13.1	17.4	150
482.824	137	0.807	1.65	2.44	4.1	7.91	11.3	13.2	17.6	152
482.947	20.3	0.181	0.372	0.551	0.927	1.79	2.55	3.21	4.28	34.8
483.549	5.6	0.0636	0.131	0.193	0.326	0.63	0.898	1.24	1.65	12.9
483.940	32.3	0.262	0.538	0.796	1.34	2.59	3.69	4.53	6.04	49.8
484.581	54.1	0.393	0.805	1.19	2.01	3.88	5.52	6.62	8.83	74.1
484.829	42.4	0.325	0.666	0.987	1.66	3.21	4.57	5.53	7.39	61.5
487.960	26.9	0.227	0.466	0.689	1.16	2.24	3.19	3.95	5.27	43.3
488.908	164	0.923	1.89	2.79	4.69	9.05	12.9	15.1	20.1	174
489.844	2600	7.1	14.4	21.1	35.3	67.7	95.8	116	155	1470
490.189	63	0.444	0.908	1.34	2.26	4.36	6.22	7.42	9.9	83.4
490.553	5300	11.9	24	35.1	58.7	112	159	198	263	2540
491.834	264	1.32	2.7	3.99	6.71	12.9	18.4	21.5	28.6	252

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	**Local Catchment Area (ha)**	**Local Catchment Probablistic Ration Method Peak Flow Rate (m^3/s)**								
		50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
492.079	734	2.82	5.76	8.48	14.2	27.4	38.9	45.8	60.9	554
492.947	135	0.797	1.63	2.41	4.05	7.82	11.1	13	17.4	150
493.293	3.1	0.0389	0.0799	0.119	0.2	0.386	0.55	0.797	1.06	8.17
493.749	17.7	0.162	0.333	0.493	0.831	1.6	2.28	2.9	3.87	31.3
494.815	110	0.683	1.4	2.07	3.48	6.71	9.56	11.2	15	129
495.535	401	1.8	3.68	5.44	9.15	17.6	25	29.2	38.9	347
496.067	52.3	0.383	0.784	1.16	1.95	3.77	5.37	6.46	8.62	72.2
496.885	411	1.84	3.75	5.54	9.31	17.9	25.5	29.8	39.7	354
497.613	129	0.77	1.57	2.33	3.92	7.56	10.7	12.6	16.8	145
497.760	4.66	0.0547	0.112	0.166	0.28	0.542	0.772	1.08	1.44	11.2
498.061	16.8	0.156	0.32	0.474	0.798	1.54	2.19	2.79	3.72	30.1
498.625	9.34	0.0968	0.199	0.295	0.496	0.959	1.37	1.81	2.41	19.1
498.870	2.64	0.034	0.0698	0.104	0.174	0.337	0.481	0.708	0.945	7.22
499.545	64.5	0.452	0.923	1.37	2.3	4.44	6.33	7.55	10.1	84.9
499.577	0.00244	0.00013	0.000266	0.00035	0.000601	0.000989	0.00141	0.00401	0.00537	0.0331
500.138	1.55	0.0218	0.0448	0.0665	0.112	0.216	0.309	0.478	0.638	4.8
500.482	0.538	0.0089	0.0183	0.0271	0.0458	0.0886	0.126	0.218	0.292	2.12
500.558	10.7	0.108	0.221	0.328	0.552	1.07	1.52	1.99	2.66	21.2
500.663	148	0.853	1.74	2.58	4.33	8.37	11.9	13.9	18.6	161
501.167	328	1.56	3.17	4.69	7.87	15.2	21.6	25.2	33.6	297
502.456	115	0.704	1.44	2.13	3.58	6.9	9.83	11.6	15.4	132
502.974	170	0.948	1.94	2.87	4.83	9.31	13.3	15.5	20.7	179
503.599	3510	8.86	17.8	26.2	43.7	83.8	119	145	194	1850
503.720	0.00179	0.000108	0.00022	0.00028	0.000483	0.000769	0.0011	0.00319	0.00427	0.0261
504.707	93.3	0.6	1.23	1.82	3.05	5.9	8.4	9.91	13.2	113
504.798	67.8	0.468	0.959	1.42	2.39	4.61	6.57	7.83	10.4	88.2
505.502	15000	25.2	50.1	73.6	122	233	329	426	566	5650
506.676	28.3	0.236	0.483	0.716	1.21	2.33	3.32	4.1	5.47	44.9
507.025	189	1.03	2.1	3.11	5.24	10.1	14.4	16.8	22.4	195
508.164	137	0.806	1.64	2.43	4.1	7.91	11.2	13.2	17.6	152
509.640	7300	14.9	30.2	44.1	73.5	141	199	251	334	3250
510.815	72.4	0.493	1.01	1.49	2.52	4.86	6.92	8.23	11	92.8
512.108	13000	22.6	45.1	66.5	110	211	298	384	509	5060
513.671	50	0.37	0.758	1.12	1.89	3.65	5.19	6.25	8.34	69.7
514.218	73.2	0.497	1.02	1.51	2.54	4.9	6.98	8.29	11.1	93.6
515.011	560	2.32	4.72	6.96	11.7	22.5	31.9	37.4	49.9	449
515.084	0.0105	0.000357	0.000736	0.00105	0.00179	0.00326	0.00466	0.0118	0.0158	0.102
515.601	188	1.02	2.09	3.1	5.2	10	14.3	16.7	22.2	194
516.313	236	1.22	2.48	3.67	6.18	11.9	16.9	19.7	26.3	231
516.484	22.9	0.2	0.41	0.606	1.02	1.97	2.81	3.51	4.68	38.2
516.980	0.353	0.00622	0.0128	0.019	0.032	0.062	0.0884	0.16	0.214	1.53
517.428	10500	19.4	38.9	56.8	94.9	181	257	327	435	4300
518.556	250	1.27	2.59	3.83	6.43	12.4	17.6	20.6	27.4	241
519.224	417	1.86	3.79	5.6	9.41	18.1	25.8	30.1	40.1	358
520.339	854	3.16	6.42	9.47	15.9	30.5	43.4	51.1	68.2	622
521.918	128	0.765	1.57	2.31	3.89	7.51	10.7	12.5	16.7	144
523.223	159	0.903	1.84	2.73	4.59	8.86	12.6	14.7	19.7	170
524.180	585	2.39	4.87	7.18	12.1	23.2	33	38.6	51.5	465
524.906	429	1.9	3.87	5.73	9.61	18.5	26.3	30.7	41	366
525.984	110	0.683	1.4	2.07	3.48	6.71	9.56	11.2	15	129
528.371	0.377	0.00657	0.0135	0.0201	0.0338	0.0654	0.0933	0.168	0.224	1.61
528.540	0.685	0.0109	0.0224	0.0333	0.0561	0.109	0.155	0.261	0.348	2.55
528.668	7050	14.5	29.4	42.9	71.8	137	194	244	325	3170
528.741	1.24	0.018	0.037	0.055	0.0926	0.179	0.256	0.405	0.541	4.04
529.274	0.176	0.00344	0.00708	0.0105	0.0177	0.0343	0.0489	0.0952	0.127	0.894
529.768	8590	16.8	33.8	49.4	82.3	158	223	282	376	3690
530.705	0.00222	0.000123	0.000251	0.000327	0.000563	0.000918	0.00131	0.00375	0.00502	0.0308
531.132	857	3.17	6.44	9.51	15.9	30.6	43.4	51.3	68.3	624
531.543	27.6	0.231	0.474	0.702	1.18	2.28	3.25	4.02	5.37	44.1
531.757	685	2.69	5.46	8.05	13.5	26	37	43.4	57.9	525
531.906	0.0117	0.000387	0.000797	0.00114	0.00194	0.00355	0.00508	0.0128	0.0171	0.111
532.351	3690	9.16	18.5	27.1	45.3	86.7	123	151	202	1920

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	**Local Catchment Area (ha)**	**Local Catchment Probablistic Ration Method Peak Flow Rate (m^3/s)**								
		50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
533.149	2.33	0.0306	0.0629	0.0933	0.157	0.304	0.433	0.645	0.861	6.56
533.611	99.8	0.631	1.29	1.91	3.22	6.21	8.85	10.4	13.9	119
534.776	531	2.22	4.53	6.69	11.2	21.6	30.7	36	48	431
535.106	60.6	0.429	0.881	1.3	2.19	4.23	6.03	7.2	9.61	80.9
536.243	913	3.32	6.74	9.93	16.6	32	45.5	53.7	71.6	655
536.539	395	1.78	3.65	5.38	9.02	17.4	24.7	28.9	38.5	343
536.891	69.8	0.48	0.983	1.45	2.45	4.72	6.72	8	10.7	90.2
537.571	458	1.99	4.07	6	10.1	19.4	27.6	32.2	43	385
537.993	0.525	0.00871	0.0179	0.0266	0.0448	0.0867	0.124	0.214	0.286	2.08
538.563	0.00205	0.000117	0.000239	0.000309	0.000531	0.000859	0.00123	0.00353	0.00472	0.0289
539.013	293	1.43	2.92	4.31	7.24	14	19.8	23.2	30.9	273
539.707	1.09	0.0162	0.0332	0.0493	0.0831	0.161	0.229	0.368	0.492	3.66
540.226	2.16	0.0288	0.0591	0.0878	0.148	0.286	0.407	0.61	0.816	6.19
542.605	6.52	0.0721	0.148	0.22	0.369	0.715	1.02	1.38	1.85	14.5
543.766	256	1.29	2.64	3.9	6.56	12.6	18	21	28	246
544.452	0.00332	0.000159	0.000326	0.000437	0.000751	0.00127	0.00182	0.00504	0.00674	0.042
545.968	433	1.91	3.9	5.75	9.66	18.6	26.5	30.9	41.2	368
546.542	5090	11.6	23.2	34.2	57	109	154	191	256	2460
546.812	0.284	0.00518	0.0106	0.0158	0.0267	0.0515	0.0735	0.136	0.182	1.3
547.282	2.23	0.0296	0.0607	0.0901	0.152	0.294	0.418	0.625	0.835	6.35
547.559	0.526	0.00872	0.0179	0.0266	0.0448	0.0868	0.124	0.214	0.287	2.08
547.739	0.191	0.0037	0.00761	0.0113	0.019	0.0368	0.0525	0.101	0.135	0.955
547.841	525	2.21	4.49	6.64	11.1	21.4	30.5	35.7	47.5	428
548.064	0.279	0.00509	0.0105	0.0156	0.0262	0.0507	0.0724	0.134	0.179	1.28
548.581	0.0184	0.000547	0.00113	0.00163	0.00278	0.00517	0.0074	0.0179	0.024	0.157
549.027	25.9	0.22	0.452	0.669	1.13	2.18	3.1	3.84	5.13	42
549.072	568	2.34	4.77	7.03	11.8	22.7	32.2	37.8	50.4	454
549.090	0.00393	0.000178	0.000365	0.000496	0.00085	0.00146	0.00209	0.00571	0.00765	0.0478
550.835	444	1.95	3.97	5.87	9.84	19	27	31.5	42	376
551.146	77.8	0.522	1.07	1.58	2.66	5.13	7.31	8.67	11.6	98.1
551.571	1.23	0.0179	0.0368	0.0546	0.092	0.178	0.254	0.402	0.538	4.01
552.631	15000	25.3	50.4	74	123	234	331	426	569	5670
554.243	0.000722	6.54E-05	0.000131	0.000151	0.000261	0.000365	0.000517	0.00163	0.00218	0.013

NW Link 1 (approx. 450)	157	0.894	1.83	2.7	4.54	8.76	12.5	14.6	19.5	169
NW Link 2 (approx. 448)	1340	4.4	8.91	13.2	22	42.3	59.9	71.5	95.3	882
NW Link 3 (approx. 448)	10	0.102	0.21	0.311	0.524	1.01	1.44	1.9	2.54	20.2

Note: The above table includes the local catchment areas only and does not include the interaction of some adjacent catchments.

Track Lift:	Existing
Structures:	Existing

Kilometerage	Modelled Flood Level (mAHD)								
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
554.243	239.21	239.22	239.23	239.24	239.25	239.26	239.26	239.26	240.58
552.631	235.91	236.39	236.74	237.39	238.39	238.70	238.87	239.05	241.39
551.571	240.18	240.19	240.20	240.21	240.22	240.23	240.23	240.23	240.58
551.146	239.01	239.02	239.03	239.04	239.05	239.06	239.06	239.06	240.58
550.835	239.01	239.02	239.03	239.04	239.05	239.06	239.06	239.06	240.58
549.090	237.66	237.67	237.68	237.69	237.70	238.56	238.77	238.93	240.38
549.072	237.97	237.97	237.97	237.97	237.97	238.56	238.94	239.05	240.15
549.027	238.29	238.29	238.29	238.29	238.29	238.56	238.94	239.05	240.11
548.581	238.33	238.33	238.34	238.35	238.36	238.56	239.01	239.15	240.11
548.064	238.35	238.41	238.46	238.58	238.64	238.84	239.09	239.18	240.11
547.841	238.38	238.65	238.78	238.97	239.11	239.18	239.23	239.29	240.11
547.739	238.48	238.67	238.84	239.01	239.17	239.27	239.35	239.40	240.11
547.559	238.57	238.68	238.86	239.10	239.19	239.36	239.42	239.47	240.23
547.282	238.58	238.69	238.87	239.15	239.20	239.41	239.48	239.52	240.34
546.812	239.26	239.27	239.28	239.29	239.30	239.41	239.48	239.53	240.36
546.542	239.04	239.47	239.74	239.75	239.76	239.77	239.77	239.77	240.65
545.968	239.72	239.73	239.74	239.75	239.76	239.77	239.77	239.81	240.93
544.452	244.87	244.88	244.89	244.90	244.91	244.92	244.92	244.92	244.97
543.766	248.24	248.44	248.49	248.57	248.66	248.70	248.73	248.78	249.43
542.605	253.56	253.68	253.68	253.76	253.87	253.87	253.87	254.13	254.25
540.226	259.11	259.12	259.13	259.14	259.15	259.16	259.16	259.16	259.20
539.707	256.79	256.80	256.81	256.82	256.83	256.84	256.84	256.84	256.84
539.013	251.90	251.91	251.92	251.93	251.94	251.95	251.95	251.95	251.95
538.563	250.28	250.29	250.30	250.31	250.32	250.33	250.33	250.33	250.35
537.993	245.78	245.79	245.80	245.81	245.82	245.83	245.83	245.83	245.83
537.571	244.10	244.11	244.12	244.13	244.14	244.15	244.15	244.15	244.15
536.891	243.03	243.19	243.21	243.27	243.33	243.37	243.40	243.44	243.93
536.539	242.70	243.18	243.18	243.26	243.32	243.35	243.37	243.41	243.87
536.243	242.70	242.82	242.86	242.94	243.04	243.11	243.15	243.22	243.85
535.106	242.38	242.46	242.51	242.61	242.76	242.87	242.93	243.03	243.82
534.776	242.34	242.39	242.42	242.47	242.55	242.61	242.63	242.69	243.67
533.611	242.07	242.08	242.09	242.10	242.11	242.14	242.17	242.23	243.43
533.149	242.07	242.08	242.09	242.10	242.11	242.12	242.12	242.12	243.09
532.351	242.36	242.44	242.49	242.53	242.54	242.55	242.55	242.55	243.09
531.906	241.25	241.45	241.52	241.57	241.64	241.70	241.74	241.81	242.86
531.757	241.25	241.45	241.52	241.57	241.64	241.70	241.74	241.81	242.86
531.543	241.25	241.45	241.52	241.57	241.64	241.70	241.74	241.81	242.86
531.132	241.25	241.45	241.52	241.57	241.64	241.70	241.74	241.81	242.86
530.705	241.32	241.47	241.52	241.57	241.65	241.70	241.75	241.81	242.90
529.768	241.43	241.47	241.53	241.57	241.65	241.70	241.75	241.82	242.95
529.274	241.33	241.48	241.53	241.58	241.66	241.72	241.77	241.84	243.04
528.741	241.72	241.73	241.74	241.79	241.89	241.96	242.03	242.13	243.44
528.668	241.97	242.04	242.16	242.28	242.41	242.53	242.64	242.75	244.14
528.540	241.79	242.10	242.34	242.57	242.79	242.90	243.03	243.11	244.55
528.371	241.92	242.18	242.41	242.72	242.95	243.06	243.18	243.26	244.77
525.984	247.55	247.56	247.57	247.58	247.59	247.60	247.60	247.60	247.60
524.906	250.01	250.02	250.03	250.04	250.05	250.06	250.06	250.06	250.06
524.180	250.61	250.62	250.63	250.64	250.65	250.66	250.66	250.66	250.66
523.223	251.80	251.81	252.33	252.53	252.78	252.79	252.79	252.79	252.79
521.918	253.24	253.25	253.26	253.27	253.28	253.38	253.38	253.38	253.38
520.339	253.33	253.34	253.35	253.36	253.37	253.38	253.38	253.38	253.38
519.224	252.98	253.16	253.32	253.51	253.64	253.65	253.65	253.65	253.84
518.556	253.46	253.47	253.48	253.49	253.64	253.65	253.65	253.66	254.27
517.428	253.09	253.13	253.17	253.21	253.28	253.33	253.35	253.40	254.30
516.980	253.09	253.13	253.17	253.21	253.28	253.33	253.35	253.40	254.30
516.484	253.35	253.36	253.37	253.38	253.41	253.46	253.48	253.53	254.30
516.313	253.35	253.36	253.37	253.38	253.41	253.46	253.48	253.53	254.30
515.601	253.20	253.45	253.55	253.55	253.76	253.91	253.91	253.91	254.30
515.084	253.92	253.93	253.94	253.95	253.96	253.97	253.97	253.97	254.02
515.011	254.09	254.42	254.42	254.62	254.63	254.64	254.64	254.64	254.64
514.218	253.93	253.94	253.95	253.96	254.39	254.40	254.40	254.40	254.40
513.671	253.77	253.78	253.79	253.80	253.81	253.82	253.82	253.82	253.82
512.108	251.31	251.32	251.33	251.34	251.35	251.36	251.36	251.36	252.34
510.815	250.15	250.29	250.36	250.44	250.57	250.65	250.73	250.82	252.27

Track Lift:	Existing
Structures:	Existing

	Modelled Flood Level (mAHD)								
Kilometerage	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
509.640	250.15	250.33	250.39	250.47	250.61	250.70	250.79	250.88	252.42
508.164	251.77	251.78	251.79	251.80	251.81	251.82	251.82	251.82	252.50
507.025	253.92	253.93	253.94	253.95	253.96	253.97	253.97	253.97	253.97
506.676	254.30	254.31	254.32	254.33	254.34	254.35	254.35	254.35	254.70
505.502	254.65	254.66	254.67	254.68	254.69	254.70	254.70	254.70	254.70
504.798	254.10	254.11	254.12	254.13	254.14	254.15	254.15	254.15	254.86
504.707	254.10	254.25	254.34	254.41	254.47	254.51	254.56	254.61	255.99
503.720	254.90	254.90	254.91	254.91	255.05	255.12	255.23	255.33	256.48
503.599	254.78	254.94	254.95	254.98	255.32	255.40	255.60	255.68	256.57
502.974	255.23	255.24	255.25	255.26	255.55	255.56	255.76	255.84	256.61
502.456	255.23	255.24	255.25	255.26	255.64	255.64	255.83	255.90	256.63
501.167	257.72	257.73	257.74	257.75	258.05	258.36	258.36	258.36	258.36
500.663	258.06	258.11	258.12	258.13	258.14	258.15	258.15	258.15	258.15
500.558	257.55	257.56	257.57	257.58	257.59	257.60	257.60	257.60	257.60
500.482	257.43	257.43	257.43	257.43	257.46	257.50	257.58	257.59	257.60
500.138	258.43	258.43	258.43	258.49	258.50	258.51	258.53	258.54	258.74
499.577	260.77	260.77	260.77	260.79	260.84	260.85	260.85	260.85	260.85
499.545	261.39	261.48	261.61	261.80	261.80	261.80	262.78	262.78	262.78
498.870	264.51	264.64	264.65	264.70	264.71	264.72	264.72	264.72	264.72
498.625	263.97	264.06	264.13	264.26	264.51	264.70	264.88	265.10	265.40
498.061	265.40	265.41	265.42	265.43	265.44	265.45	265.45	265.45	265.45
497.760	264.39	264.50	264.56	264.69	264.70	264.71	264.71	264.71	264.71
497.613	264.47	264.76	264.83	264.89	264.93	264.96	264.97	265.00	265.32
496.885	266.46	266.47	266.48	266.49	266.50	266.51	266.51	266.51	266.51
496.067	267.68	267.69	267.70	267.71	267.72	267.73	267.73	267.73	267.73
495.535	268.77	268.78	268.79	268.80	268.81	268.82	268.82	268.82	268.82
494.815	272.01	272.02	272.03	272.04	272.05	272.06	272.06	272.06	272.06
493.749	276.98	277.11	277.22	277.28	277.64	277.64	277.64	277.64	277.64
493.293	278.09	278.10	278.11	278.12	278.13	278.14	278.14	278.14	278.14
492.947	278.11	278.12	278.13	278.14	278.15	278.16	278.16	278.16	278.16
492.079	280.70	280.91	280.92	280.93	280.94	280.95	280.95	280.95	280.95
491.834	281.10	281.11	281.12	281.13	281.14	281.15	281.15	281.15	281.15
490.553	285.52	285.95	286.29	286.51	286.52	286.53	286.53	286.53	286.53
490.189	286.24	286.25	286.26	286.27	286.28	286.29	286.29	286.29	286.29
489.844	285.11	285.49	285.78	286.21	286.28	286.29	286.29	286.29	286.29
488.908	290.83	290.84	290.85	290.86	290.87	290.88	290.88	290.88	290.88
487.960	296.41	296.42	296.43	296.54	296.85	296.92	296.95	296.99	297.49
484.829	316.75	316.89	317.00	317.19	317.45	317.67	317.77	317.89	318.08
484.581	318.03	318.04	318.05	318.06	318.07	318.08	318.08	318.08	318.08
483.940	315.07	315.08	315.09	315.10	315.11	315.12	315.12	315.12	315.12
483.549	310.89	310.90	310.91	310.92	310.93	310.94	310.94	310.94	310.94
482.947	305.47	305.57	305.63	305.64	305.65	305.66	305.66	305.66	305.66
482.824	305.15	305.16	305.17	305.18	305.19	305.20	305.20	305.20	305.20
481.921	298.72	298.73	298.74	298.75	298.76	298.77	298.77	298.77	298.77
480.350	292.61	292.88	293.01	293.07	293.08	293.09	293.09	293.09	294.73
479.300	290.74	291.44	291.97	292.55	292.56	292.57	292.70	292.83	294.74
478.796	291.37	291.39	291.40	291.41	292.30	292.54	292.70	292.83	294.69
478.262	291.08	291.39	291.40	291.41	292.30	292.53	292.70	292.83	294.64
477.703	293.98	294.19	294.20	294.21	294.22	294.23	294.23	294.23	294.69
476.796	296.85	296.86	296.87	297.24	297.31	297.32	297.32	297.32	297.32
476.771	296.52	296.53	296.54	296.55	296.56	296.57	296.57	296.57	296.57
473.938	313.33	313.39	313.40	313.41	313.46	313.49	313.56	313.62	314.07
473.905	314.22	314.23	314.24	314.25	314.26	314.27	314.27	314.27	314.27
472.030	312.47	312.88	313.19	313.73	314.48	314.70	314.76	316.49	316.49
470.467	321.82	321.83	321.84	321.85	321.86	321.87	321.87	321.87	321.87
469.524	318.02	318.03	318.04	318.05	318.06	318.26	318.28	318.32	318.74
468.565	313.93	314.25	314.34	314.35	314.36	314.37	314.37	314.37	314.73
468.366	313.87	313.87	313.87	313.87	313.87	313.87	313.87	313.87	314.59
468.176	314.03	314.04	314.05	314.06	314.07	314.08	314.08	314.08	314.59
466.824	313.27	313.28	313.29	313.30	313.35	313.59	313.59	313.65	314.13
465.859	315.87	315.88	315.89	315.90	315.91	315.92	315.92	315.92	315.92
465.366	314.43	314.44	314.45	314.46	314.47	314.48	314.48	314.48	314.48
465.310	314.43	314.44	314.45	314.46	314.47	314.48	314.48	314.48	314.48
465.265	314.67	314.82	314.83	314.84	314.85	314.86	314.86	314.86	314.86

Track Lift:	Existing
Structures:	Existing

	Modelled Flood Level (mAHD)								
Kilometerage	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
464.746	309.63	309.64	309.65	309.66	309.67	309.68	309.68	309.82	310.82
464.694	307.87	308.18	308.40	308.77	309.38	309.68	309.68	309.79	310.80
463.224	319.63	319.66	319.70	319.78	319.92	320.02	320.07	320.09	320.33
463.019	319.98	320.01	320.05	320.13	320.27	320.39	320.58	320.65	320.66
462.814	319.21	319.26	319.31	319.38	319.53	319.64	319.78	319.88	320.66
461.980	315.50	315.75	315.94	316.01	316.02	316.03	316.03	316.03	316.03
461.252	308.49	308.60	308.74	308.94	309.25	309.34	309.38	309.44	310.17
461.157	307.38	307.78	307.79	307.80	308.09	308.27	308.33	308.42	309.67
460.698	306.23	306.37	306.48	306.68	307.03	307.25	307.37	307.53	309.63
460.127	309.40	309.50	309.51	309.52	309.53	309.54	309.54	309.54	309.57
459.676	310.48	310.49	310.50	310.51	310.52	310.53	310.53	310.53	310.53
458.648	310.36	310.37	310.38	310.39	310.40	310.41	310.41	310.41	310.41
458.323	309.98	310.16	310.30	310.39	310.40	310.41	310.41	310.41	310.41
458.285	309.99	310.00	310.01	310.02	310.03	310.04	310.04	310.04	310.04
457.486	305.40	305.41	305.42	305.43	305.44	305.45	305.45	305.45	305.45
456.992	304.67	304.80	304.81	304.82	304.83	304.84	304.84	304.84	304.84
456.184	302.76	302.90	303.01	303.13	303.30	303.31	303.31	303.31	303.31
455.228	297.94	297.95	297.96	297.97	298.44	298.90	298.90	299.02	300.26
454.844	297.23	297.31	297.38	297.49	297.71	297.86	297.93	298.95	300.26
454.353	299.66	299.67	299.76	299.96	300.18	300.30	300.30	300.30	300.30
453.642	300.86	301.00	301.12	301.24	301.25	301.26	301.26	301.26	301.26
453.403	300.16	300.47	300.69	301.01	301.25	301.26	301.26	301.26	301.26
452.721	300.56	301.03	301.40	301.41	301.42	301.43	301.43	301.43	301.43
451.332	307.36	307.49	307.60	307.79	308.14	308.38	308.51	308.78	309.71
450.204	317.21	317.28	317.30	317.33	317.39	317.42	317.44	317.47	317.80
449.852	321.20	321.21	321.22	321.23	321.24	321.25	321.25	321.25	321.25
449.765	322.59	322.61	322.61	322.71	322.81	322.87	322.90	322.93	323.05
449.350	325.50	325.65	325.77	325.96	325.97	325.98	325.98	325.98	325.98

Appendix C – Registered groundwater bores

Table C-1 Licenced groundwater bores (Department of Primary Industries, Water, 2016a) accessed 1 June 2016

ID	License No.		Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised purpose	Strata
GW030752	80WA703150		Bore	Local Govt	42.3	Good	-	-	-	-32.2556	148.2203	Town water supply	Sand, gravel
GW013357	80WA703398		Bore	Private	24.4	Good	-	24.4	-	-32.2562	148.2145	Stock	Unknown
GW014268	80WA703399		Well	Private	27.4	(Unknown)	-	-	-	-32.2521	148.2192	Stock	Unknown
GW066807	-		Bore	Mines	132	-	-	-	-	-32.4771	148.1323	Test Bore	Unknown
GW026475	-		Bore	Private	68.3	(Unknown)	53.05	21.3	29	-32.2518	148.2190	Irrigation	Gravel
GW062210	80WA703150		Bore	Local Govt	43	0-500 ppm	18.87	18.5	-	-32.2557	148.2202	Town water supply	Sand, gravel
GW015879	80BL007213		Bore	Private	91.4	3001-7000 ppm	-	-	-	-32.7629	148.1937	Stock, domestic, irrigation	Unknown
GW800082	80BL237162		Bore	Private	32	-	-	-	-	-32.2557	148.2156	Stock, domestic	Unknown
GW801040	80BL236789		Bore	Private	84	Good	3	16.7	-	-32.2400	148.2307	Stock, domestic	Sand
GW052940	70BL112492		Bore	Private	83.8	1001-3000 ppm	-	-	-	-33.0932	148.1165	Domestic	Granite
GW013352	80WA703397		Bore	Private	38.4	Good	-	-	-	-32.2418	148.2273	Stock, domestic	Unknown
GW042259	-		Well	Private	24.4	(Unknown)	-	-	-	-32.2573	148.2131	Unknown	Unknown
GW062195	-		Bore	Private	79.3	(Unknown)	-	-	-	-32.2523	148.2220	Domestic, stock, irrigation	Sand, gravel
GW005572	-		Bore	Private	84.7	Salty	-	-	-	-32.3807	148.1612	Unknown	Clay
GW023048	80WA703401		Bore	Private	28.3	Good	-	-	-	-32.2423	148.2267	Stock, domestic	Sand, Gravel
GW701611	70BL227792		Bore	Private	77.724	(Unknown)	-	45.72	-	-33.0806	148.1117	Stock, domestic	Unknown

ID	License No.		Type	Owner	Final depth	Salinity	Yield	SWL	Drawdown	Latitude	Longitude	Authorised purpose	Strata
GW060152	80CA703171		Bore	Private	69.4	Good	-	-	-	-32.2522	148.2177	Stock, domestic, irrigation	Sand, gravel
GW803117	-		Bore	Private	80	-	1.5	25.3	25.7	-32.2515	148.2224	Stock, domestic	Gravel, Sand
GW703472	70BL229161		Bore	Private	30	-	-	-	-	-33.1190	148.1257	Stock, domestic	Unknown

Appendix D – Surface water licences

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

Access Licence Category	No. of WAL's	Total Share Component (ML or units)	Water made Available (ML)	Usage YTD (ML)
Macquarie Bogan Unregulated and Alluvial Water Sources 2012				
Backwater Boggy Cowal Water Source				
Domestic and stock	1	6	6	0
Domestic and stock [stock]	3	12	16	0
Unregulated river	11	2609	2609	0
Upper Bogan River Water Source				
Domestic and stock	6	36	42	0
Domestic and stock [stock]	4	16	16	0
Domestic and stock [town water supply]	2	32	32	0
Unregulated river	13	1463	1463	0
Unregulated river [special additional high flow]	1	182	182	0
Lachlan Unregulated and Alluvial Water Sources 2012				
Goobang and Billabong Creeks Water Source				
Domestic and stock	3	8	8	0
Domestic and stock [domestic]	1	2	2	0
Domestic and stock [stock]	2	8	8	0
Local water utility	1	1500	1500	0
Unregulated river	14	2200	2200	0

Note: WAL: Water Access Licence

YTD: Year to date

Appendix E – Overtopping information for existing formation

This appendix provides a summary of length of existing track that is overtopped during the modelled design flood events.

Track overtopping occurs when the modelled local catchment flood level is higher than the existing top of rail level.

Section:	P2N
Track Lift:	Existing
Structures:	Existing

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
449.350	-	0.0	0.0	0.0	0.0	0.0	0.0
449.765	449.771	0.5	3.0	3.0	10.0	19.0	24.0
449.852	-	0.0	0.0	0.0	0.0	0.0	0.0
450.204	450.335	22.4	30.1	32.1	36.0	41.8	44.7
451.332	-	0.0	0.0	0.0	0.0	0.0	0.0
452.721	-	0.0	0.0	0.0	0.0	0.0	0.0
453.403	-	0.0	0.0	0.0	0.0	0.0	0.0
453.642	-	0.0	0.0	0.0	0.0	0.0	0.0
454.353	454.498	0.0	0.0	0.0	0.0	0.0	19.3
454.844	-	0.0	0.0	0.0	0.0	0.0	0.0
455.228	454.922	0.0	0.0	0.0	0.0	0.0	35.4
456.184	-	0.0	0.0	0.0	0.0	0.0	0.0
456.992	-	0.0	0.0	0.0	0.0	0.0	0.0
457.486	-	0.0	0.0	0.0	0.0	0.0	0.0
458.285	-	0.0	0.0	0.0	0.0	0.0	0.0
458.323	-	0.0	0.0	0.0	0.0	0.0	0.0
458.648	-	0.0	0.0	0.0	0.0	0.0	0.0
459.676	-	0.0	0.0	0.0	0.0	0.0	0.0
460.127	-	0.0	0.0	0.0	0.0	0.0	0.0
460.698	-	0.0	0.0	0.0	0.0	0.0	0.0
461.157	-	0.0	0.0	0.0	0.0	0.0	0.0
461.252	461.246	0.0	0.0	0.0	0.0	38.3	47.3
461.980	-	0.0	0.0	0.0	0.0	0.0	0.0
462.814	-	0.0	0.0	0.0	0.0	0.0	0.0
463.019	-	0.0	0.0	0.0	0.0	0.0	0.0
463.224	463.256	0.0	0.0	0.0	0.0	5.6	18.3
464.694	464.653	0.0	0.0	0.0	0.0	0.0	51.0
465.265	465.251	7.9	18.7	18.7	18.7	18.7	18.7
465.310	-	0.0	0.0	0.0	0.0	0.0	0.0
465.366	-	0.0	0.0	0.0	0.0	0.0	0.0
465.859	-	0.0	0.0	0.0	0.0	0.0	0.0
466.824	466.822	0.0	0.0	0.0	0.0	0.0	103.0
468.176	-	0.0	0.0	0.0	0.0	0.0	0.0
468.366	-	0.0	0.0	0.0	0.0	0.0	0.0
468.565	-	0.0	0.0	0.0	0.0	0.0	0.0
469.524	469.601	0.0	0.0	0.0	0.0	0.0	105.0
470.467	-	0.0	0.0	0.0	0.0	0.0	0.0
472.030	471.857	0.0	0.0	0.0	0.0	0.0	301.7
473.905	-	0.0	0.0	0.0	0.0	0.0	0.0
473.938	-	0.0	0.0	0.0	0.0	0.0	0.0
476.771	-	0.0	0.0	0.0	0.0	0.0	0.0
476.796	-	0.0	0.0	0.0	0.0	0.0	0.0
477.703	-	0.0	0.0	0.0	0.0	0.0	0.0
478.262	478.268	0.0	0.0	0.0	0.0	204.0	613.9

Section:	P2N
Track Lift:	Existing
Structures:	Existing

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
478.796	-	0.0	0.0	0.0	0.0	0.0	0.0
479.300	-	0.0	0.0	0.0	0.0	0.0	0.0
480.350	-	0.0	0.0	0.0	0.0	0.0	0.0
481.921	-	0.0	0.0	0.0	0.0	0.0	0.0
482.824	-	0.0	0.0	0.0	0.0	0.0	0.0
482.947	-	0.0	0.0	0.0	0.0	0.0	0.0
483.549	-	0.0	0.0	0.0	0.0	0.0	0.0
483.940	-	0.0	0.0	0.0	0.0	0.0	0.0
484.581	-	0.0	0.0	0.0	0.0	0.0	0.0
484.829	-	0.0	0.0	0.0	0.0	0.0	0.0
487.960	487.977	0.0	0.0	0.0	0.0	14.1	21.1
488.908	-	0.0	0.0	0.0	0.0	0.0	0.0
489.844	-	0.0	0.0	0.0	0.0	0.0	0.0
490.189	-	0.0	0.0	0.0	0.0	0.0	0.0
490.553	-	0.0	0.0	0.0	0.0	0.0	0.0
491.834	-	0.0	0.0	0.0	0.0	0.0	0.0
492.079	-	0.0	0.0	0.0	0.0	0.0	0.0
492.947	492.992	0.0	0.0	0.0	0.0	18.0	45.0
493.293	-	0.0	0.0	0.0	0.0	0.0	0.0
493.749	493.935	0.0	0.0	0.0	49.3	302.3	302.3
494.815	-	0.0	0.0	0.0	0.0	0.0	0.0
495.535	-	0.0	0.0	0.0	0.0	0.0	0.0
496.067	-	0.0	0.0	0.0	0.0	0.0	0.0
496.885	-	0.0	0.0	0.0	0.0	0.0	0.0
497.613	497.313	0.0	0.0	0.0	49.7	69.3	76.2
497.760	-	0.0	0.0	0.0	0.0	0.0	0.0
498.061	-	0.0	0.0	0.0	0.0	0.0	0.0
498.625	-	0.0	0.0	0.0	0.0	0.0	0.0
498.870	-	0.0	0.0	0.0	0.0	0.0	0.0
499.545	499.562	0.0	0.0	0.0	5.3	5.3	5.3
500.138	-	0.0	0.0	0.0	0.0	0.0	0.0
500.482	-	0.0	0.0	0.0	0.0	0.0	0.0
500.558	-	0.0	0.0	0.0	0.0	0.0	0.0
500.663	-	0.0	0.0	0.0	0.0	0.0	0.0
501.167	-	0.0	0.0	0.0	0.0	0.0	0.0
502.456	-	0.0	0.0	0.0	0.0	0.0	0.0
502.974	-	0.0	0.0	0.0	0.0	0.0	0.0
503.599	-	0.0	0.0	0.0	0.0	0.0	0.0
504.707	-	0.0	0.0	0.0	0.0	0.0	0.0
504.798	-	0.0	0.0	0.0	0.0	0.0	0.0
505.502	-	0.0	0.0	0.0	0.0	0.0	0.0
506.676	-	0.0	0.0	0.0	0.0	0.0	0.0
507.025	-	0.0	0.0	0.0	0.0	0.0	0.0
508.164	-	0.0	0.0	0.0	0.0	0.0	0.0

Section:	P2N
Track Lift:	Existing
Structures:	Existing

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
509.640	509.697	0.0	14.0	71.0	143.0	322.0	387.0
510.815	510.849	0.0	474.5	569.2	656.8	789.6	863.4
512.108	-	0.0	0.0	0.0	0.0	0.0	0.0
513.671	-	0.0	0.0	0.0	0.0	0.0	0.0
514.218	-	0.0	0.0	0.0	0.0	0.0	0.0
515.011	-	0.0	0.0	0.0	0.0	0.0	0.0
515.601	-	0.0	0.0	0.0	0.0	0.0	0.0
516.313	-	0.0	0.0	0.0	0.0	0.0	0.0
516.484	-	0.0	0.0	0.0	0.0	0.0	0.0
516.980	-	0.0	0.0	0.0	0.0	0.0	0.0
517.428	-	0.0	0.0	0.0	0.0	0.0	0.0
518.556	-	0.0	0.0	0.0	0.0	0.0	0.0
519.224	-	0.0	0.0	0.0	0.0	0.0	0.0
520.339	-	0.0	0.0	0.0	0.0	0.0	0.0
521.918	-	0.0	0.0	0.0	0.0	0.0	0.0
523.223	-	0.0	0.0	0.0	0.0	0.0	0.0
524.180	-	0.0	0.0	0.0	0.0	0.0	0.0
524.906	-	0.0	0.0	0.0	0.0	0.0	0.0
525.984	-	0.0	0.0	0.0	0.0	0.0	0.0
528.371	528.337	0.0	0.0	0.0	0.0	11.7	52.7
528.540	528.512	0.0	0.0	0.0	0.0	62.2	126.2
528.668	-	0.0	0.0	0.0	0.0	0.0	0.0
528.741	-	0.0	0.0	0.0	0.0	0.0	0.0
529.274	-	0.0	0.0	0.0	0.0	0.0	0.0
529.768	-	0.0	0.0	0.0	0.0	0.0	0.0
531.132	531.453	0.0	147.0	892.0	1199.7	1337.7	1378.8
531.543	531.646	0.0	0.0	204.2	204.2	204.2	204.2
531.757	531.848	0.0	0.0	2.0	63.6	102.6	132.6
532.351	532.281	12.2	150.0	173.0	199.0	205.0	210.0
533.149	-	0.0	0.0	0.0	0.0	0.0	0.0
533.611	-	0.0	0.0	0.0	0.0	0.0	0.0
534.776	-	0.0	0.0	0.0	0.0	0.0	0.0
535.106	-	0.0	0.0	0.0	0.0	0.0	0.0
536.243	-	0.0	0.0	0.0	0.0	0.0	0.0
536.539	536.825	0.0	113.9	113.9	284.8	367.7	387.7
536.891	-	0.0	0.0	0.0	0.0	0.0	0.0
537.571	-	0.0	0.0	0.0	0.0	0.0	0.0
537.993	-	0.0	0.0	0.0	0.0	0.0	0.0
539.013	-	0.0	0.0	0.0	0.0	0.0	0.0
539.707	-	0.0	0.0	0.0	0.0	0.0	0.0
540.226	-	0.0	0.0	0.0	0.0	0.0	0.0
542.605	-	0.0	0.0	0.0	0.0	0.0	0.0
543.766	543.770	26.4	84.4	97.4	119.4	149.3	162.7
545.968	-	0.0	0.0	0.0	0.0	0.0	0.0

Section:	P2N
Track Lift:	Existing
Structures:	Existing

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
546.542	-	0.0	0.0	0.0	0.0	0.0	0.0
546.812	-	0.0	0.0	0.0	0.0	0.0	0.0
547.282	547.259	0.0	0.0	0.0	0.0	4.0	136.0
547.559	547.600	0.0	0.0	0.0	0.0	82.7	341.1
547.739	547.713	0.0	0.0	0.0	0.0	94.8	119.7
547.841	548.267	0.0	0.0	0.0	0.0	212.5	449.8
548.064	-	0.0	0.0	0.0	0.0	0.0	0.0
549.027	-	0.0	0.0	0.0	0.0	0.0	0.0
549.072	-	0.0	0.0	0.0	0.0	0.0	0.0
550.835	-	0.0	0.0	0.0	0.0	0.0	0.0
551.146	-	0.0	0.0	0.0	0.0	0.0	0.0
551.571	-	0.0	0.0	0.0	0.0	0.0	0.0
552.631	552.619	0.0	0.0	0.0	0.0	76.0	390.9

Total:	69.3	1035.6	2176.6	3039.4	4758.3	7174.7

Appendix F – Compliance to ETD-10-02 for existing formation

ETD-10-02 requires that the ballast of the upgraded track be above the modelled one per cent AEP local catchment flood level.

This appendix provides a summary of length of existing track which does not meet the design requirements of ETD-10-02. This appendix also provides a summary of the length of existing ballast that is flooded by a range of modelled local flood events.

It should be noted that the depth of ballast of the existing track is not accurately known and varies significantly. In lieu of a measured depth of ballast, a range of ballast depths (measured from the top of the existing rail) are used in the estimation of non-compliance with ETD-10-02. As such, at some locations the assumed base of the existing ballast may be below the surrounding ground level. The compliance of the existing track conditions to ETD-10-02 is used for comparative purposes only, therefore the potential for a small overestimate of the length of flooded ballast is considered to be of minimal impact.

Section:	P2N
Track Lift:	Existing
Culverts:	Existing

Catchment	Length of non-compliance with ETD-10-02 (m)		
	400 mm Ballast	600 mm Ballast	720 mm Ballast
449.350	1	30	49
449.765	59	76	89
449.852	-	20	30
450.204	92	110	123
451.332	-	194	252
452.721	-	-	-
453.403	461	565	626
453.642	6	82	109
454.353	115	158	172
454.844	-	-	-
455.228	276	461	535
456.184	570	626	686
456.992	41	89	125
457.486	-	-	7
458.285	-	10	22
458.323	32	97	182
458.648	-	-	158
459.676	-	-	135
460.127	-	108	197
460.698	-	-	-
461.157	75	125	148
461.252	94	115	126
461.980	38	59	72
462.814	-	-	-
463.019	-	-	-
463.224	63	82	94
464.694	289	360	412
465.265	19	19	19
465.310	34	74	80
465.366	-	-	17
465.859	146	247	356
466.824	225	276	303
468.176	-	-	46
468.366	-	-	-
468.565	-	66	132
469.524	303	341	364
470.467	125	317	533
472.030	551	621	659
473.905	65	90	104
473.938	-	-	-
476.771	-	-	-
476.796	30	30	65
477.703	117	223	262
478.262	729	776	807

Section:	P2N
Track Lift:	Existing
Culverts:	Existing

Catchment	Length of non-compliance with ETD-10-02 (m)		
	400 mm Ballast	600 mm Ballast	720 mm Ballast
478.796	171	296	338
479.300	-	-	200
480.350	-	-	-
481.921	-	-	-
482.824	-	-	12
482.947	-	-	-
483.549	-	-	-
483.940	-	3	8
484.581	227	402	421
484.829	-	3	219
487.960	64	85	99
488.908	5	39	69
489.844	192	263	307
490.189	-	-	-
490.553	-	3	4
491.834	-	-	-
492.079	-	-	2
492.947	437	493	542
493.293	123	180	180
493.749	365	412	433
494.815	43	340	422
495.535	-	-	-
496.067	-	-	-
496.885	-	247	366
497.613	350	433	454
497.760	109	185	234
498.061	68	145	239
498.625	-	-	-
498.870	103	207	236
499.545	119	182	207
500.138	-	-	-
500.482	-	-	-
500.558	-	-	-
500.663	35	201	291
501.167	-	101	421
502.456	-	138	182
502.974	-	604	604
503.599	-	-	334
504.707	-	-	-
504.798	-	-	-
505.502	138	240	295
506.676	211	267	298
507.025	144	513	563
508.164	-	-	-

Section:	P2N
Track Lift:	Existing
Culverts:	Existing

Catchment	Length of non-compliance with ETD-10-02 (m)		
	400 mm Ballast	600 mm Ballast	720 mm Ballast
509.640	789	860	892
510.815	1118	1143	1164
512.108	715	851	947
513.671	-	126	160
514.218	-	143	326
515.011	-	300	361
515.601	226	314	353
516.313	-	-	132
516.484	-	-	-
516.980	-	-	-
517.428	-	-	-
518.556	-	10	292
519.224	-	27	437
520.339	1141	1211	1244
521.918	511	551	581
523.223	526	669	707
524.180	-	-	183
524.906	-	97	179
525.984	-	6	114
528.371	189	221	221
528.540	141	141	141
528.668	173	173	173
528.741	-	-	-
529.274	-	-	39
529.768	332	484	556
531.132	1723	1723	1723
531.543	204	204	204
531.757	317	431	495
532.351	409	620	714
533.149	-	-	-
533.611	-	-	-
534.776	-	-	-
535.106	-	-	72
536.243	296	404	430
536.539	497	531	559
536.891	-	-	-
537.571	-	-	-
537.993	-	-	9
539.013	8	67	105
539.707	64	97	120
540.226	66	106	125
542.605	-	101	144
543.766	248	279	292
545.968	-	-	-

Section:	P2N
Track Lift:	Existing
Culverts:	Existing

Catchment	Length of non-compliance with ETD-10-02 (m)		
	400 mm Ballast	600 mm Ballast	720 mm Ballast
546.542	210	324	464
546.812	92	138	138
547.282	368	368	368
547.559	341	341	341
547.739	120	120	120
547.841	684	684	684
548.064	137	137	137
549.027	204	481	481
549.072	183	256	328
550.835	-	-	-
551.146	-	-	-
551.571	616	631	631
552.631	517	574	611

Total:	**20620**	**28366**	**34564**

Appendix G – Proposed structure details and flood levels

This appendix provides a summary of the proposed structures between Parkes and Narromine that have been identified, using the methods outlined in Appendix A, and the modelled local upstream catchment flood levels for a range of design flood events.

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Proposed Culvert			Structure Invert (as modelled) (mAHD)	Design Rail Low Point (as modelled) (mAHD)
	Type	# Units	# Barrels		
449.350	B500	2	2	325.27	325.28
449.765	B700	2	2	322.59	322.66
449.852	B700	1	1	321.20	321.21
450.204	B700	2	2	316.94	317.00
451.332	B1300	10	10	307.38	307.52
452.721	C1800	3	3	300.33	300.67
453.403	C1800	3	3	300.02	300.26
453.642	B900	2	2	300.71	300.84
454.353	B700	4	4	299.66	299.76
454.844	B1300	12	12	297.24	297.33
455.228	C1800	8	8	297.68	297.95
456.184	B1100	4	4	302.63	302.75
456.992	B1100	1	1	304.62	304.77
457.486	B900	2	2	305.38	305.41
458.285	B900	1	1	309.99	310.00
458.323	B700	1	1	309.79	309.91
458.648	B900	2	2	310.36	310.37
459.676	B500	2	2	310.44	310.49
460.127	B1300	1	1	309.41	309.50
460.698	C1500	2	2	306.20	306.33
461.157	B1300	10	10	307.30	307.66
461.252	B700	4	4	308.40	308.60
461.980	B900	1	1	315.30	315.44
462.814	B1100	1	1	319.20	319.23
463.019	B1100	1	1	319.97	319.97
463.224	B700	1	1	319.62	319.62
464.694	B1100	5	5	307.86	308.15
464.746	B1300	1	1	309.63	309.64
465.265	B700	1	1	314.58	314.78
465.310	A300	1	2	314.43	314.44
465.366	B500	1	1	314.43	314.44
465.859	B1100	1	1	315.87	315.88
466.824	C1800	8	8	313.27	313.28
468.176	B1100	2	2	314.03	314.04
468.366	B1100	2	2	313.70	313.75
468.565	C1800	6	6	313.80	314.07
469.524	B1500	12	12	318.02	318.03
470.467	B1300	1	1	321.82	321.83
472.030	C2100	7	7	312.28	312.57
473.905	A400	1	2	313.96	314.23
473.938	A400	1	2	313.33	313.37
476.771	B700	1	1	296.52	296.53
476.796	B700	1	1	296.85	297.05
477.703	B1100	3	3	293.81	294.06
478.262	B1500	10	10	290.63	290.83
478.796	B900	2	2	291.37	291.39
479.300	C3000	10	10	290.86	291.64
480.350	C1500	6	6	292.46	292.69
481.921	B1100	2	2	298.72	298.73
482.824	B900	2	2	305.15	305.16

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Proposed Culvert			Structure Invert (as modelled) (mAHD)	Design Rail Low Point (as modelled) (mAHD)
	Type	# Units	# Barrels		
482.947	B1300	2	2	305.43	305.51
483.549	B900	2	2	310.89	310.90
483.940	B900	3	3	315.07	315.08
484.581	B700	2	2	318.03	318.04
484.829	B1300	2	2	316.72	316.84
487.960	B700	4	4	296.41	296.44
488.908	B900	2	2	290.83	290.84
489.844	B1300	10	10	285.00	285.32
490.189	B1300	2	2	286.24	286.25
490.553	B1300	10	10	285.55	286.01
491.834	C1500	4	4	281.10	281.11
492.079	B1500	4	4	280.52	280.85
492.947	B900	3	3	278.11	278.12
493.293	B700	1	1	278.09	278.10
493.749	B700	4	4	276.86	276.90
494.815	B900	2	2	272.01	272.02
495.535	B700	3	3	268.77	268.78
496.067	B500	2	2	267.68	267.69
496.885	B900	2	2	266.46	266.47
497.613	B900	4	4	264.22	264.36
497.760	B900	1	1	264.26	264.31
498.061	B900	1	1	265.29	265.41
498.625	B500	3	3	263.90	263.92
498.870	A300	1	2	264.18	264.24
499.545	B900	4	4	260.99	261.09
499.577	B1100	2	2	260.76	260.76
500.138	B900	1	1	258.42	258.42
500.482	B500	2	2	257.37	257.38
500.558	A400	2	4	257.55	257.56
500.663	B900	1	1	257.90	258.11
501.167	B900	2	2	257.72	257.73
502.456	B1100	3	3	255.23	255.24
502.974	B900	2	2	255.23	255.24
503.599	C1500	4	4	254.53	254.94
503.720	B700	1	1	254.90	254.90
504.707	B1100	4	4	254.10	254.18
504.798	B900	5	5	254.10	254.11
505.502	C1500	5	5	254.61	254.66
506.676	B900	4	4	254.30	254.31
507.025	B500	2	2	253.92	253.93
508.164	B700	12	12	251.71	251.78
509.640	C2400	12	12	249.16	249.56
510.815	B1300	12	12	249.19	249.28
512.108	C1800	9	9	250.58	251.20
513.671	B500	2	2	253.77	253.78
514.218	B700	2	2	253.93	254.25
515.011	B1100	4	4	254.11	254.48
515.084	B1100	2	2	253.92	253.93
515.601	B900	2	2	253.18	253.48
516.313	B700	4	4	253.18	253.36

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Proposed Culvert			Structure Invert (as modelled) (mAHD)	Design Rail Low Point (as modelled) (mAHD)
	Type	# Units	# Barrels		
516.484	B700	2	2	253.35	253.36
516.980	B1100	2	2	253.09	253.10
517.428	B1100	10	10	253.09	253.10
518.556	B1300	4	4	253.46	253.47
519.224	B1300	5	5	252.97	253.22
520.339	B1300	2	2	253.33	253.34
521.918	B1300	1	1	253.24	253.25
523.223	B1300	3	3	251.80	252.20
524.180	B1300	1	1	250.61	250.62
524.906	B500	1	1	250.01	250.02
525.984	B1100	2	2	247.49	247.56
528.371	B900	12	12	241.78	241.80
528.540	B700	8	8	241.74	241.89
528.668	B700	4	4	241.97	241.98
528.741	B700	2	2	241.72	241.73
529.274	B500	8	8	240.19	240.20
529.768	B1300	12	12	241.43	241.44
530.705	B900	12	12	240.85	241.19
531.132	B1100	13	13	241.24	241.40
531.543	B700	13	13	241.24	241.40
531.757	B700	12	12	240.98	241.28
531.906	B900	8	8	241.18	241.39
532.351	B1300	10	10	242.35	242.51
533.149	B1300	2	2	242.07	242.08
533.611	B1300	2	2	242.07	242.08
534.776	B1300	2	2	242.32	242.33
535.106	C1500	1	1	242.32	242.49
536.243	C1500	8	8	242.58	242.85
536.539	C1500	9	9	242.58	243.05
536.891	C1500	1	1	242.91	243.06
537.571	B1300	2	2	244.10	244.11
537.993	B700	1	1	245.78	245.79
538.563	B700	1	1	250.28	250.29
539.013	B900	12	12	251.90	251.91
539.707	B1300	1	1	256.79	256.80
540.226	A300	2	4	259.11	259.12
542.605	B500	2	2	253.56	253.66
543.766	B900	6	6	247.85	248.00
544.452	B900	2	2	244.87	244.88
545.968	B1100	7	7	239.72	239.73
546.542	C1500	6	6	238.98	239.51
546.812	B700	2	2	239.26	239.27
547.282	B700	7	7	238.47	238.58
547.559	B900	8	8	238.40	238.57
547.739	B900	7	7	238.27	238.39
547.841	B900	7	7	238.16	238.22
548.064	B900	1	1	238.16	238.21
548.581	B700	2	2	238.32	238.33
549.027	B700	2	2	237.99	238.13
549.072	B900	4	4	237.81	237.90

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Proposed Culvert			Structure Invert (as modelled) (mAHD)	Design Rail Low Point (as modelled) (mAHD)
	Type	# Units	# Barrels		
549.090	B700	1	1	237.66	237.67
550.835	B1100	1	1	239.01	239.02
551.146	B1100	1	1	239.01	239.02
551.571	B1100	1	1	240.18	240.19
552.631	C2400	9	9	235.33	235.69
554.243	B1100	1	1	239.21	239.22

NW Link 1 (approx. 450)	C2400	2	2	299.33	299.53
NW Link 2 (approx. 448)	B1300	15	15	284.45	284.6
NW Link 3 (approx. 448)	B500	4	4	283.08	283.11

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	**Local Catchment Area (ha)**	**Local Catchment Probablistic Ration Method Peak Flow Rate (m^3/s)**								
		50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
449.350	54.2	0.394	0.808	1.2	2.01	3.88	5.53	6.64	8.86	74.3
449.765	4	0.0482	0.0989	0.147	0.247	0.478	0.68	0.964	1.29	9.96
449.852	16.2	0.151	0.31	0.459	0.774	1.5	2.13	2.71	3.62	29.3
450.204	11.3	0.113	0.233	0.345	0.58	1.12	1.6	2.08	2.78	22.2
451.332	492	2.1	4.29	6.32	10.6	20.4	29	34	45.3	407
452.721	792	3	6.08	8.95	15.1	28.9	41.1	48.4	64.4	587
453.403	333	1.58	3.21	4.74	7.98	15.4	21.8	25.5	34	301
453.642	40.5	0.313	0.643	0.952	1.6	3.09	4.4	5.35	7.14	59.3
454.353	40.5	0.313	0.642	0.952	1.6	3.09	4.4	5.35	7.13	59.3
454.844	270	1.34	2.74	4.06	6.81	13.1	18.7	21.8	29	256
455.228	2010	5.9	11.9	17.6	29.4	56.2	79.9	96.1	128	1200
456.184	91.9	0.593	1.21	1.8	3.02	5.83	8.3	9.81	13.1	112
456.992	22.3	0.195	0.401	0.593	1	1.93	2.75	3.44	4.59	37.4
457.486	238	1.22	2.5	3.7	6.22	12	17.1	19.9	26.5	233
458.285	0.0264	0.000727	0.0015	0.00219	0.00371	0.00698	0.00999	0.0234	0.0313	0.208
458.323	16.1	0.151	0.309	0.458	0.772	1.49	2.12	2.71	3.61	29.2
458.648	87	0.569	1.16	1.72	2.9	5.59	7.96	9.43	12.6	107
459.676	70.2	0.482	0.986	1.46	2.46	4.74	6.76	8.03	10.7	90.6
460.127	67.5	0.467	0.957	1.42	2.38	4.6	6.55	7.81	10.4	87.9
460.698	58.7	0.419	0.859	1.27	2.14	4.13	5.88	7.04	9.39	78.9
461.157	3030	7.96	16.1	23.6	39.3	75.5	107	130	174	1650
461.252	212	1.12	2.29	3.39	5.7	11	15.6	18.2	24.3	213
461.980	19.5	0.175	0.36	0.532	0.897	1.73	2.47	3.11	4.15	33.7
462.814	2.65	0.0341	0.0701	0.104	0.175	0.339	0.482	0.709	0.947	7.24
463.019	1.22	0.0177	0.0365	0.0541	0.0912	0.176	0.251	0.399	0.533	3.98
463.224	1.17	0.0171	0.0352	0.0523	0.088	0.17	0.243	0.387	0.517	3.85
464.694	2450	6.8	13.8	20.2	33.8	65	92.1	111	149	1400
464.746	0.00792	0.000291	0.000598	0.000842	0.00144	0.00258	0.0037	0.00959	0.0128	0.082
465.265	19.4	0.175	0.359	0.532	0.896	1.73	2.47	3.11	4.15	33.7
465.310	0.496	0.0083	0.0171	0.0253	0.0427	0.0826	0.118	0.205	0.274	1.99
465.366	23.4	0.203	0.416	0.616	1.04	2	2.85	3.56	4.75	38.8
465.859	0.429	0.00733	0.0151	0.0224	0.0377	0.073	0.104	0.184	0.246	1.78
466.824	127	0.761	1.55	2.3	3.87	7.47	10.6	12.5	16.6	143
468.176	56.8	0.408	0.837	1.24	2.09	4.02	5.73	6.87	9.17	77
468.366	0.0626	0.00146	0.003	0.00443	0.0075	0.0144	0.0205	0.0444	0.0593	0.404
468.565	1210	4.08	8.29	12.2	20.5	39.4	55.8	66.3	88.4	816
469.524	150	0.865	1.76	2.61	4.39	8.47	12.1	14.1	18.8	163
470.467	31.5	0.257	0.527	0.781	1.31	2.54	3.61	4.44	5.92	48.8
472.030	1880	5.6	11.4	16.7	27.9	53.7	76.1	91.4	122	1140
473.905	45.8	0.346	0.708	1.05	1.77	3.41	4.85	5.86	7.82	65.2
473.938	0.073	0.00165	0.00341	0.00504	0.00852	0.0163	0.0233	0.0497	0.0665	0.455
476.771	0.348	0.00615	0.0126	0.0188	0.0316	0.0612	0.0873	0.158	0.211	1.52
476.796	189	1.03	2.1	3.1	5.22	10.1	14.3	16.7	22.3	194
477.703	503	2.13	4.35	6.43	10.8	20.8	29.5	34.5	46	413
478.262	2850	7.62	15.3	22.6	37.7	72.4	103	125	166	1580
478.796	0.75	0.0118	0.0242	0.036	0.0605	0.117	0.167	0.279	0.373	2.74
479.300	24400	35.5	71.6	104	173	330	465	614	815	8250
480.350	859	3.18	6.45	9.49	16	30.6	43.5	51.3	68.4	625
481.921	135	0.797	1.63	2.42	4.07	7.83	11.2	13.1	17.4	150
482.824	137	0.807	1.65	2.44	4.1	7.91	11.3	13.2	17.6	152
482.947	20.3	0.181	0.372	0.551	0.927	1.79	2.55	3.21	4.28	34.8
483.549	5.6	0.0636	0.131	0.193	0.326	0.63	0.898	1.24	1.65	12.9
483.940	32.3	0.262	0.538	0.796	1.34	2.59	3.69	4.53	6.04	49.8
484.581	54.1	0.393	0.805	1.19	2.01	3.88	5.52	6.62	8.83	74.1
484.829	42.4	0.325	0.666	0.987	1.66	3.21	4.57	5.53	7.39	61.5
487.960	26.9	0.227	0.466	0.689	1.16	2.24	3.19	3.95	5.27	43.3
488.908	164	0.923	1.89	2.79	4.69	9.05	12.9	15.1	20.1	174
489.844	2600	7.1	14.4	21.1	35.3	67.7	95.8	116	155	1470
490.189	63	0.444	0.908	1.34	2.26	4.36	6.22	7.42	9.9	83.4
490.553	5300	11.9	24	35.1	58.7	112	159	198	263	2540
491.834	264	1.32	2.7	3.99	6.71	12.9	18.4	21.5	28.6	252

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	**Local Catchment Area (ha)**	**Local Catchment Probablistic Ration Method Peak Flow Rate (m³/s)**								
		50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
492.079	734	2.82	5.76	8.48	14.2	27.4	38.9	45.8	60.9	554
492.947	135	0.797	1.63	2.41	4.05	7.82	11.1	13	17.4	150
493.293	3.1	0.0389	0.0799	0.119	0.2	0.386	0.55	0.797	1.06	8.17
493.749	17.7	0.162	0.333	0.493	0.831	1.6	2.28	2.9	3.87	31.3
494.815	110	0.683	1.4	2.07	3.48	6.71	9.56	11.2	15	129
495.535	401	1.8	3.68	5.44	9.15	17.6	25	29.2	38.9	347
496.067	52.3	0.383	0.784	1.16	1.95	3.77	5.37	6.46	8.62	72.2
496.885	411	1.84	3.75	5.54	9.31	17.9	25.5	29.8	39.7	354
497.613	129	0.77	1.57	2.33	3.92	7.56	10.7	12.6	16.8	145
497.760	4.66	0.0547	0.112	0.166	0.28	0.542	0.772	1.08	1.44	11.2
498.061	16.8	0.156	0.32	0.474	0.798	1.54	2.19	2.79	3.72	30.1
498.625	9.34	0.0968	0.199	0.295	0.496	0.959	1.37	1.81	2.41	19.1
498.870	2.64	0.034	0.0698	0.104	0.174	0.337	0.481	0.708	0.945	7.22
499.545	64.5	0.452	0.923	1.37	2.3	4.44	6.33	7.55	10.1	84.9
499.577	0.00244	0.00013	0.000266	0.00035	0.000601	0.000989	0.00141	0.00401	0.00537	0.0331
500.138	1.55	0.0218	0.0448	0.0665	0.112	0.216	0.309	0.478	0.638	4.8
500.482	0.538	0.0089	0.0183	0.0271	0.0458	0.0886	0.126	0.218	0.292	2.12
500.558	10.7	0.108	0.221	0.328	0.552	1.07	1.52	1.99	2.66	21.2
500.663	148	0.853	1.74	2.58	4.33	8.37	11.9	13.9	18.6	161
501.167	328	1.56	3.17	4.69	7.87	15.2	21.6	25.2	33.6	297
502.456	115	0.704	1.44	2.13	3.58	6.9	9.83	11.6	15.4	132
502.974	170	0.948	1.94	2.87	4.83	9.31	13.3	15.5	20.7	179
503.599	3510	8.86	17.8	26.2	43.7	83.8	119	145	194	1850
503.720	0.00179	0.000108	0.00022	0.00028	0.000483	0.000769	0.0011	0.00319	0.00427	0.0261
504.707	93.3	0.6	1.23	1.82	3.05	5.9	8.4	9.91	13.2	113
504.798	67.8	0.468	0.959	1.42	2.39	4.61	6.57	7.83	10.4	88.2
505.502	15000	25.2	50.1	73.6	122	233	329	426	566	5650
506.676	28.3	0.236	0.483	0.716	1.21	2.33	3.32	4.1	5.47	44.9
507.025	189	1.03	2.1	3.11	5.24	10.1	14.4	16.8	22.4	195
508.164	137	0.806	1.64	2.43	4.1	7.91	11.2	13.2	17.6	152
509.640	7300	14.9	30.2	44.1	73.5	141	199	251	334	3250
510.815	72.4	0.493	1.01	1.49	2.52	4.86	6.92	8.23	11	92.8
512.108	13000	22.6	45.1	66.5	110	211	298	384	509	5060
513.671	50	0.37	0.758	1.12	1.89	3.65	5.19	6.25	8.34	69.7
514.218	73.2	0.497	1.02	1.51	2.54	4.9	6.98	8.29	11.1	93.6
515.011	560	2.32	4.72	6.96	11.7	22.5	31.9	37.4	49.9	449
515.084	0.0105	0.000357	0.000736	0.00105	0.00179	0.00326	0.00466	0.0118	0.0158	0.102
515.601	188	1.02	2.09	3.1	5.2	10	14.3	16.7	22.2	194
516.313	236	1.22	2.48	3.67	6.18	11.9	16.9	19.7	26.3	231
516.484	22.9	0.2	0.41	0.606	1.02	1.97	2.81	3.51	4.68	38.2
516.980	0.353	0.00622	0.0128	0.019	0.032	0.062	0.0884	0.16	0.214	1.53
517.428	10500	19.4	38.9	56.8	94.9	181	257	327	435	4300
518.556	250	1.27	2.59	3.83	6.43	12.4	17.6	20.6	27.4	241
519.224	417	1.86	3.79	5.6	9.41	18.1	25.8	30.1	40.1	358
520.339	854	3.16	6.42	9.47	15.9	30.5	43.4	51.1	68.2	622
521.918	128	0.765	1.57	2.31	3.89	7.51	10.7	12.5	16.7	144
523.223	159	0.903	1.84	2.73	4.59	8.86	12.6	14.7	19.7	170
524.180	585	2.39	4.87	7.18	12.1	23.2	33	38.6	51.5	465
524.906	429	1.9	3.87	5.73	9.61	18.5	26.3	30.7	41	366
525.984	110	0.683	1.4	2.07	3.48	6.71	9.56	11.2	15	129
528.371	0.377	0.00657	0.0135	0.0201	0.0338	0.0654	0.0933	0.168	0.224	1.61
528.540	0.685	0.0109	0.0224	0.0333	0.0561	0.109	0.155	0.261	0.348	2.55
528.668	7050	14.5	29.4	42.9	71.8	137	194	244	325	3170
528.741	1.24	0.018	0.037	0.055	0.0926	0.179	0.256	0.405	0.541	4.04
529.274	0.176	0.00344	0.00708	0.0105	0.0177	0.0343	0.0489	0.0952	0.127	0.894
529.768	8590	16.8	33.8	49.4	82.3	158	223	282	376	3690
530.705	0.00222	0.000123	0.000251	0.000327	0.000563	0.000918	0.00131	0.00375	0.00502	0.0308
531.132	857	3.17	6.44	9.51	15.9	30.6	43.4	51.3	68.3	624
531.543	27.6	0.231	0.474	0.702	1.18	2.28	3.25	4.02	5.37	44.1
531.757	685	2.69	5.46	8.05	13.5	26	37	43.4	57.9	525
531.906	0.0117	0.000387	0.000797	0.00114	0.00194	0.00355	0.00508	0.0128	0.0171	0.111
532.351	3690	9.16	18.5	27.1	45.3	86.7	123	151	202	1920

Track Lift:	Design, Existing
Structures:	100 year ARI, Existing

Kilometerage	**Local Catchment Area (ha)**	**Local Catchment Probablistic Ration Method Peak Flow Rate (m^3/s)**								
		50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
533.149	2.33	0.0306	0.0629	0.0933	0.157	0.304	0.433	0.645	0.861	6.56
533.611	99.8	0.631	1.29	1.91	3.22	6.21	8.85	10.4	13.9	119
534.776	531	2.22	4.53	6.69	11.2	21.6	30.7	36	48	431
535.106	60.6	0.429	0.881	1.3	2.19	4.23	6.03	7.2	9.61	80.9
536.243	913	3.32	6.74	9.93	16.6	32	45.5	53.7	71.6	655
536.539	395	1.78	3.65	5.38	9.02	17.4	24.7	28.9	38.5	343
536.891	69.8	0.48	0.983	1.45	2.45	4.72	6.72	8	10.7	90.2
537.571	458	1.99	4.07	6	10.1	19.4	27.6	32.2	43	385
537.993	0.525	0.00871	0.0179	0.0266	0.0448	0.0867	0.124	0.214	0.286	2.08
538.563	0.00205	0.000117	0.000239	0.000309	0.000531	0.000859	0.00123	0.00353	0.00472	0.0289
539.013	293	1.43	2.92	4.31	7.24	14	19.8	23.2	30.9	273
539.707	1.09	0.0162	0.0332	0.0493	0.0831	0.161	0.229	0.368	0.492	3.66
540.226	2.16	0.0288	0.0591	0.0878	0.148	0.286	0.407	0.61	0.816	6.19
542.605	6.52	0.0721	0.148	0.22	0.369	0.715	1.02	1.38	1.85	14.5
543.766	256	1.29	2.64	3.9	6.56	12.6	18	21	28	246
544.452	0.00332	0.000159	0.000326	0.000437	0.000751	0.00127	0.00182	0.00504	0.00674	0.042
545.968	433	1.91	3.9	5.75	9.66	18.6	26.5	30.9	41.2	368
546.542	5090	11.6	23.2	34.2	57	109	154	191	256	2460
546.812	0.284	0.00518	0.0106	0.0158	0.0267	0.0515	0.0735	0.136	0.182	1.3
547.282	2.23	0.0296	0.0607	0.0901	0.152	0.294	0.418	0.625	0.835	6.35
547.559	0.526	0.00872	0.0179	0.0266	0.0448	0.0868	0.124	0.214	0.287	2.08
547.739	0.191	0.0037	0.00761	0.0113	0.019	0.0368	0.0525	0.101	0.135	0.955
547.841	525	2.21	4.49	6.64	11.1	21.4	30.5	35.7	47.5	428
548.064	0.279	0.00509	0.0105	0.0156	0.0262	0.0507	0.0724	0.134	0.179	1.28
548.581	0.0184	0.000547	0.00113	0.00163	0.00278	0.00517	0.0074	0.0179	0.024	0.157
549.027	25.9	0.22	0.452	0.669	1.13	2.18	3.1	3.84	5.13	42
549.072	568	2.34	4.77	7.03	11.8	22.7	32.2	37.8	50.4	454
549.090	0.00393	0.000178	0.000365	0.000496	0.00085	0.00146	0.00209	0.00571	0.00765	0.0478
550.835	444	1.95	3.97	5.87	9.84	19	27	31.5	42	376
551.146	77.8	0.522	1.07	1.58	2.66	5.13	7.31	8.67	11.6	98.1
551.571	1.23	0.0179	0.0368	0.0546	0.092	0.178	0.254	0.402	0.538	4.01
552.631	15000	25.3	50.4	74	123	234	331	426	569	5670
554.243	0.000722	6.54E-05	0.000131	0.000151	0.000261	0.000365	0.000517	0.00163	0.00218	0.013

NW Link 1 (approx. 450)	157	0.894	1.83	2.7	4.54	8.76	12.5	14.6	19.5	169
NW Link 2 (approx. 448)	1340	4.4	8.91	13.2	22	42.3	59.9	71.5	95.3	882
NW Link 3 (approx. 448)	10	0.102	0.21	0.311	0.524	1.01	1.44	1.9	2.54	20.2

Note: The above table includes the local catchment areas only and does not include the interaction of some adjacent catchments.

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	**Modelled Flood Level (mAHD)**								
	50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
449.350	325.27	325.28	325.29	325.30	325.31	325.32	325.99	326.00	326.01
449.765	322.59	322.66	322.68	322.74	322.83	322.89	322.89	322.92	323.08
449.852	321.20	321.21	321.22	321.23	321.24	321.25	321.26	321.27	321.28
450.204	316.94	317.00	317.05	317.14	317.31	317.43	317.55	317.68	318.19
451.332	307.38	307.52	307.64	307.85	308.24	308.53	308.61	308.87	309.80
452.721	300.33	300.67	300.94	301.41	301.42	301.43	301.44	301.45	301.46
453.403	300.02	300.26	300.43	300.75	301.25	301.26	301.27	301.28	301.29
453.642	300.71	300.84	300.94	301.11	301.25	301.26	301.27	301.28	301.29
454.353	299.66	299.76	299.83	299.96	300.18	300.30	300.30	300.32	300.55
454.844	297.24	297.33	297.40	297.53	297.78	298.73	298.73	298.94	300.54
455.228	297.68	297.95	297.96	297.97	298.14	298.73	298.73	298.94	300.54
456.184	302.63	302.75	302.85	303.01	303.30	303.31	303.32	303.33	303.34
456.992	304.62	304.77	304.81	304.82	304.83	304.84	304.85	304.86	304.87
457.486	305.38	305.41	305.42	305.43	305.44	305.45	305.46	305.47	305.48
458.285	309.99	310.00	310.01	310.02	310.03	310.04	310.05	310.06	310.07
458.323	309.79	309.91	310.00	310.18	310.40	310.41	310.42	310.43	310.44
458.648	310.36	310.37	310.38	310.39	310.40	310.41	310.42	310.43	310.44
459.676	310.44	310.49	310.50	310.51	310.52	310.53	310.54	310.55	310.56
460.127	309.41	309.50	309.51	309.52	309.53	309.54	309.55	309.56	309.73
460.698	306.20	306.33	306.42	306.60	306.93	307.18	307.25	307.42	309.91
461.157	307.30	307.66	307.79	307.80	308.20	308.53	308.53	308.67	309.93
461.252	308.40	308.60	308.75	309.01	309.28	309.37	309.37	309.39	310.23
461.980	315.30	315.44	315.54	315.73	316.02	316.03	316.04	316.05	316.06
462.814	319.20	319.23	319.27	319.33	319.45	319.54	319.64	319.73	320.69
463.019	319.97	319.97	319.97	320.00	320.07	320.13	320.23	320.31	320.69
463.224	319.62	319.62	319.62	319.66	319.73	319.79	319.88	319.96	320.36
464.694	307.86	308.15	308.38	308.79	309.57	309.68	309.69	309.84	310.88
464.746	309.63	309.64	309.65	309.66	309.67	309.68	309.69	309.86	310.91
465.265	314.58	314.78	314.83	314.84	314.85	314.86	314.87	314.88	314.89
465.310	314.43	314.44	314.45	314.46	314.47	314.48	314.49	314.50	314.51
465.366	314.43	314.44	314.45	314.46	314.47	314.48	314.49	314.50	314.51
465.859	315.87	315.88	315.89	315.90	315.91	315.92	315.93	315.94	315.95
466.824	313.27	313.28	313.29	313.40	313.66	313.82	313.82	313.82	314.42
468.176	314.03	314.04	314.05	314.06	314.07	314.08	314.09	314.10	314.47
468.366	313.70	313.75	313.82	313.82	313.83	313.83	313.83	313.83	313.92
468.565	313.80	314.07	314.28	314.35	314.36	314.37	314.38	314.39	314.61
469.524	318.02	318.03	318.04	318.11	318.36	318.53	318.53	318.53	319.11
470.467	321.82	321.83	321.84	321.85	321.86	321.87	321.88	321.89	321.90
472.030	312.28	312.57	312.81	313.22	314.00	314.58	314.67	314.98	316.03
473.905	313.96	314.23	314.24	314.25	314.26	314.27	314.28	314.29	314.30
473.938	313.33	313.37	313.45	313.45	313.45	313.45	313.45	313.47	313.78
476.771	296.52	296.53	296.54	296.55	296.56	296.57	296.58	296.59	296.81
476.796	296.85	297.05	297.23	297.30	297.31	297.32	297.33	297.34	297.35
477.703	293.81	294.06	294.20	294.21	294.22	294.23	294.24	294.25	294.97
478.262	290.63	290.83	290.98	291.25	291.79	292.52	292.90	293.06	294.92
478.796	291.37	291.39	291.40	291.41	291.79	292.52	292.90	293.06	294.97
479.300	290.86	291.64	292.24	292.55	292.56	292.79	292.90	293.06	295.02
480.350	292.46	292.69	292.86	293.07	293.08	293.09	293.10	293.11	295.01
481.921	298.72	298.73	298.74	298.75	298.76	298.77	298.78	298.79	298.80
482.824	305.15	305.16	305.17	305.18	305.19	305.20	305.21	305.22	305.23
482.947	305.43	305.51	305.58	305.64	305.65	305.66	305.67	305.68	305.69
483.549	310.89	310.90	310.91	310.92	310.93	310.94	310.95	310.96	310.97
483.940	315.07	315.08	315.09	315.10	315.11	315.12	315.13	315.14	315.15
484.581	318.03	318.04	318.05	318.06	318.07	318.08	318.09	318.10	318.11
484.829	316.72	316.84	316.94	317.12	317.45	317.70	317.70	317.84	318.11
487.960	296.41	296.44	296.51	296.62	296.81	296.94	296.94	297.02	297.71
488.908	290.83	290.84	290.85	290.86	290.87	290.88	290.89	290.90	290.91
489.844	285.00	285.32	285.57	286.03	286.28	286.29	286.30	286.31	286.32
490.189	286.24	286.25	286.26	286.27	286.28	286.29	286.30	286.31	286.32
490.553	285.55	286.01	286.37	286.51	286.52	286.53	286.54	286.55	286.56
491.834	281.10	281.11	281.12	281.13	281.14	281.15	281.16	281.17	281.18
492.079	280.52	280.85	280.92	280.93	280.94	280.95	280.96	280.97	280.98
492.947	278.11	278.12	278.13	278.14	278.15	278.16	278.17	278.18	278.19
493.293	278.09	278.10	278.11	278.12	278.13	278.14	278.15	278.16	278.17
493.749	276.86	276.90	276.94	277.01	277.15	277.25	277.33	277.45	277.68
494.815	272.01	272.02	272.03	272.04	272.05	272.06	272.07	272.08	272.09
495.535	268.77	268.78	268.79	268.80	268.81	268.82	268.83	268.84	268.85
496.067	267.68	267.69	267.70	267.71	267.72	267.73	267.74	267.75	267.76

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Modelled Flood Level (mAHD)								
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
496.885	266.46	266.47	266.48	266.49	266.50	266.51	266.52	266.53	266.54
497.613	264.22	264.36	264.47	264.71	265.01	265.02	265.07	265.11	265.52
497.760	264.26	264.31	264.36	264.45	264.61	264.71	264.72	264.73	264.74
498.061	265.29	265.41	265.42	265.43	265.44	265.45	265.46	265.47	265.48
498.625	263.90	263.92	263.94	263.99	264.09	264.17	264.25	264.34	265.43
498.870	264.18	264.24	264.29	264.37	264.54	264.72	264.73	264.74	264.75
499.545	260.99	261.09	261.16	261.30	261.57	261.76	261.76	261.96	262.69
499.577	260.76	260.76	260.76	260.77	260.77	260.78	260.86	260.87	260.88
500.138	258.42	258.42	258.44	258.49	258.50	258.52	258.52	258.56	258.85
500.482	257.37	257.38	257.38	257.40	257.41	257.42	257.46	257.49	257.63
500.558	257.55	257.56	257.57	257.58	257.59	257.60	257.61	257.62	257.63
500.663	257.90	258.11	258.12	258.13	258.14	258.15	258.16	258.17	258.18
501.167	257.72	257.73	257.74	258.24	258.35	258.36	258.37	258.38	258.39
502.456	255.23	255.24	255.25	255.26	255.62	255.91	256.00	256.10	256.92
502.974	255.23	255.24	255.25	255.26	255.43	255.87	255.92	256.03	256.89
503.599	254.53	254.94	254.95	254.96	255.30	255.67	255.79	255.90	256.86
503.720	254.90	254.90	254.90	254.91	254.92	255.26	255.48	255.59	256.78
504.707	254.10	254.18	254.29	254.41	254.53	254.59	254.71	254.77	256.25
504.798	254.10	254.11	254.12	254.13	254.14	254.15	254.16	254.17	254.99
505.502	254.61	254.66	254.67	254.68	254.69	254.70	254.71	254.72	254.73
506.676	254.30	254.31	254.32	254.33	254.34	254.35	254.36	254.37	254.73
507.025	253.92	253.93	253.94	253.95	253.96	253.97	253.98	253.99	254.00
508.164	251.71	251.78	251.79	251.80	251.81	251.82	251.83	251.84	252.91
509.640	249.16	249.56	249.77	250.17	251.07	251.22	251.27	251.36	252.86
510.815	249.19	249.28	249.32	249.40	249.54	249.64	251.27	251.35	252.74
512.108	250.58	251.20	251.33	251.34	251.35	251.36	251.37	251.38	252.78
513.671	253.77	253.78	253.79	253.80	253.81	253.82	253.83	253.84	253.85
514.218	253.93	254.25	254.37	254.38	254.39	254.40	254.41	254.42	254.43
515.011	254.11	254.48	254.61	254.62	254.63	254.64	254.65	254.66	254.67
515.084	253.92	253.93	253.94	253.95	253.96	253.97	253.98	253.99	254.16
515.601	253.18	253.48	253.69	253.89	253.90	253.91	253.92	253.97	254.56
516.313	253.18	253.36	253.37	253.42	253.50	253.55	253.67	253.71	254.56
516.484	253.35	253.36	253.37	253.42	253.50	253.55	253.67	253.71	254.56
516.980	253.09	253.10	253.21	253.29	253.37	253.42	253.53	253.58	254.56
517.428	253.09	253.10	253.21	253.29	253.37	253.42	253.53	253.58	254.56
518.556	253.46	253.47	253.60	253.63	253.64	253.68	253.79	253.84	254.55
519.224	252.97	253.22	253.39	253.63	253.64	253.65	253.66	253.67	254.00
520.339	253.33	253.34	253.35	253.36	253.37	253.38	253.39	253.40	253.45
521.918	253.24	253.25	253.26	253.27	253.37	253.38	253.38	253.40	253.41
523.223	251.80	252.20	252.36	252.64	252.78	252.79	252.79	252.79	252.82
524.180	250.61	250.62	250.63	250.64	250.65	250.66	250.67	250.68	250.69
524.906	250.01	250.02	250.03	250.04	250.05	250.06	250.07	250.08	250.09
525.984	247.49	247.56	247.57	247.58	247.59	247.60	247.61	247.62	247.63
528.371	241.78	241.80	241.84	241.97	241.97	241.97	243.12	243.45	245.14
528.540	241.74	241.89	241.89	241.89	241.89	241.89	242.96	243.21	244.93
528.668	241.97	241.98	241.99	242.00	242.33	242.59	242.61	242.82	244.49
528.741	241.72	241.73	241.74	241.75	241.81	241.85	242.30	242.41	243.84
529.274	240.19	240.20	240.23	240.32	240.32	240.32	242.23	242.30	243.51
529.768	241.43	241.44	241.45	241.69	242.14	242.21	242.21	242.27	243.42
530.705	240.85	241.19	241.38	241.69	242.10	242.19	242.20	242.26	243.36
531.132	241.24	241.40	241.50	241.63	242.02	242.11	242.17	242.24	243.30
531.543	241.24	241.40	241.50	241.63	242.02	242.11	242.17	242.24	243.30
531.757	240.98	241.28	241.47	241.69	242.10	242.17	242.17	242.24	243.30
531.906	241.18	241.39	241.50	241.71	242.10	242.17	242.17	242.24	243.30
532.351	242.35	242.51	242.52	242.53	242.54	242.55	242.56	242.57	243.44
533.149	242.07	242.08	242.09	242.10	242.14	242.23	242.24	242.31	243.44
533.611	242.07	242.08	242.09	242.11	242.25	242.37	242.44	242.52	243.72
534.776	242.32	242.33	242.36	242.51	242.60	242.69	242.85	242.91	243.98
535.106	242.32	242.49	242.57	242.82	242.94	243.01	243.18	243.26	244.16
536.243	242.58	242.85	242.93	243.10	243.25	243.33	243.39	243.48	244.20
536.539	242.58	243.05	243.12	243.25	243.47	243.58	243.58	243.63	244.24
536.891	242.91	243.06	243.13	243.27	243.51	243.69	243.69	243.73	244.33
537.571	244.10	244.11	244.12	244.13	244.14	244.15	244.16	244.17	244.33
537.993	245.78	245.79	245.80	245.81	245.82	245.83	245.84	245.85	245.86
538.563	250.28	250.29	250.30	250.31	250.32	250.33	250.34	250.35	250.41
539.013	251.90	251.91	251.92	251.93	251.94	251.95	251.96	251.97	251.98
539.707	256.79	256.80	256.81	256.82	256.83	256.84	256.85	256.86	256.87
540.226	259.11	259.12	259.13	259.14	259.15	259.16	259.17	259.18	259.23

Track Lift:	Design
Structures:	100 year ARI

Kilometerage	Modelled Flood Level (mAHD)								
	50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
542.605	253.56	253.66	253.69	253.76	253.89	253.99	253.99	254.01	254.28
543.766	247.85	248.00	248.12	248.34	248.74	248.88	248.88	248.97	249.78
544.452	244.87	244.88	244.89	244.90	244.91	244.92	244.93	244.94	244.94
545.968	239.72	239.73	239.74	239.75	239.76	239.80	239.82	239.93	241.25
546.542	238.98	239.51	239.74	239.75	239.76	239.77	239.78	239.83	240.95
546.812	239.26	239.27	239.28	239.29	239.39	239.63	239.63	239.66	240.65
547.282	238.47	238.58	238.71	238.90	239.39	239.62	239.62	239.65	240.62
547.559	238.40	238.57	238.69	238.88	239.33	239.57	239.57	239.59	240.50
547.739	238.27	238.39	238.60	238.81	239.21	239.45	239.45	239.48	240.39
547.841	238.16	238.22	238.42	238.61	238.93	239.30	239.30	239.38	240.39
548.064	238.16	238.21	238.33	238.46	238.65	239.05	239.09	239.21	240.39
548.581	238.32	238.33	238.34	238.46	238.58	238.82	238.91	239.10	240.39
549.027	237.99	238.13	238.28	238.44	238.54	238.79	238.91	239.09	240.39
549.072	237.81	237.90	237.96	238.06	238.34	238.79	238.91	239.09	240.42
549.090	237.66	237.67	237.68	237.69	238.23	238.79	238.91	239.09	240.65
550.835	239.01	239.02	239.03	239.04	239.05	239.06	239.07	239.09	240.86
551.146	239.01	239.02	239.03	239.04	239.05	239.06	239.07	239.09	240.86
551.571	240.18	240.19	240.20	240.21	240.22	240.23	240.24	240.25	240.86
552.631	235.33	235.69	236.01	236.41	237.16	237.73	237.73	238.64	241.66
554.243	239.21	239.22	239.23	239.24	239.25	239.26	239.27	239.28	240.86

NW Link 1 (approx. 450)	299.33	299.53	299.69	299.97	300.51	300.91	301.11	301.55	302.53
NW Link 2 (approx. 448)	284.45	284.6	284.72	284.94	285.35	285.65	285.82	286.16	287.74
NW Link 3 (approx. 448)	283.08	283.11	283.13	283.18	283.28	283.35	283.42	283.51	286.06

Track Lift:	Design vs Existing
Structures:	100 year ARI vs Existing

Kilometerage	Change in Modelled Flood Level (mAHD)								
	50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
449.350	-0.24	-0.37	-0.48	-0.66	-0.66	-0.66	0.01	0.02	0.03
449.765	0.00	0.05	0.07	0.03	0.02	0.02	-0.01	0.00	0.03
449.852	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
450.204	-0.27	-0.28	-0.26	-0.20	-0.08	0.02	0.11	0.21	0.39
451.332	0.02	0.03	0.04	0.06	0.10	0.15	0.10	0.09	0.09
452.721	-0.23	-0.36	-0.46	0.00	0.00	0.00	0.01	0.02	0.03
453.403	-0.14	-0.21	-0.26	-0.25	0.00	0.00	0.01	0.02	0.03
453.642	-0.15	-0.17	-0.18	-0.13	0.00	0.00	0.01	0.02	0.03
454.353	0.00	0.10	0.07	0.00	0.00	0.00	0.00	0.02	0.25
454.844	0.01	0.02	0.03	0.04	0.06	0.87	0.81	-0.02	0.29
455.228	-0.26	0.00	0.00	0.00	-0.30	-0.16	-0.16	-0.08	0.29
456.184	-0.13	-0.14	-0.16	-0.12	0.00	0.00	0.01	0.02	0.03
456.992	-0.05	-0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.03
457.486	-0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
458.285	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
458.323	-0.19	-0.25	-0.29	-0.21	0.00	0.00	0.01	0.02	0.03
458.648	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
459.676	-0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
460.127	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.16
460.698	-0.03	-0.05	-0.06	-0.09	-0.10	-0.08	-0.12	-0.10	0.28
461.157	-0.08	-0.13	0.00	0.00	0.11	0.26	0.19	0.25	0.26
461.252	-0.09	0.01	0.01	0.07	0.02	0.03	-0.01	-0.06	0.06
461.980	-0.20	-0.31	-0.40	-0.28	0.00	0.00	0.01	0.02	0.03
462.814	0.00	-0.03	-0.04	-0.05	-0.08	-0.11	-0.13	-0.16	0.03
463.019	-0.01	-0.04	-0.08	-0.13	-0.20	-0.25	-0.34	-0.34	0.03
463.224	-0.01	-0.04	-0.08	-0.12	-0.19	-0.24	-0.19	-0.13	0.03
464.694	-0.02	-0.03	-0.02	0.02	0.19	0.00	0.01	0.06	0.08
464.746	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.09
465.265	-0.09	-0.04	0.00	0.00	0.00	0.00	0.01	0.02	0.03
465.310	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
465.366	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
465.859	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
466.824	0.00	0.00	0.00	0.10	0.31	0.23	0.23	0.17	0.28
468.176	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	-0.12
468.366	-0.16	-0.12	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.67
468.565	-0.12	-0.18	-0.06	0.00	0.00	0.00	0.01	0.02	-0.12
469.524	0.00	0.00	0.00	0.05	0.30	0.27	0.25	0.21	0.37
470.467	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
472.030	-0.19	-0.30	-0.39	-0.51	-0.48	-0.13	-0.09	-1.50	-0.46
473.905	-0.26	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
473.938	0.00	-0.02	0.05	0.04	0.00	-0.04	-0.11	-0.16	-0.29
476.771	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.24
476.796	0.00	0.20	0.37	0.06	0.00	0.00	0.01	0.02	0.03
477.703	-0.17	-0.12	0.00	0.00	0.00	0.00	0.01	0.02	0.28
478.262	-0.44	-0.57	-0.43	-0.17	-0.51	-0.01	0.20	0.23	0.28
478.796	0.00	0.00	0.00	0.00	-0.51	-0.01	0.20	0.23	0.28
479.300	0.12	0.20	0.26	0.00	0.00	0.22	0.20	0.23	0.28
480.350	-0.15	-0.20	-0.15	0.00	0.00	0.00	0.01	0.02	0.28
481.921	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
482.824	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
482.947	-0.04	-0.06	-0.05	0.00	0.00	0.00	0.01	0.02	0.03
483.549	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
483.940	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
484.581	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
484.829	-0.03	-0.04	-0.05	-0.07	0.01	0.04	-0.07	-0.05	0.03
487.960	0.00	0.02	0.08	0.08	-0.04	0.02	-0.01	0.02	0.22
488.908	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
489.844	-0.11	-0.17	-0.21	-0.19	0.00	0.00	0.01	0.02	0.03
490.189	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
490.553	0.03	0.06	0.08	0.00	0.00	0.00	0.01	0.02	0.03
491.834	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
492.079	-0.18	-0.06	0.00	0.00	0.00	0.00	0.01	0.02	0.03
492.947	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
493.293	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
493.749	-0.12	-0.21	-0.28	-0.27	-0.49	-0.39	-0.31	-0.19	0.04
494.815	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
495.535	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
496.067	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03

Track Lift:	Design vs Existing
Structures:	100 year ARI vs Existing

	Change in Modelled Flood Level (mAHD)								
Kilometerage	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
496.885	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
497.613	-0.25	-0.40	-0.36	-0.18	0.08	0.06	0.10	0.11	0.20
497.760	-0.12	-0.19	-0.20	-0.25	-0.09	0.00	0.01	0.02	0.03
498.061	-0.10	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
498.625	-0.07	-0.13	-0.19	-0.27	-0.42	-0.53	-0.63	-0.76	0.03
498.870	-0.33	-0.40	-0.37	-0.32	-0.17	0.00	0.01	0.02	0.03
499.545	-0.40	-0.39	-0.44	-0.50	-0.23	-0.04	-1.02	-0.83	-0.09
499.577	0.00	-0.01	-0.01	-0.03	-0.07	-0.07	0.01	0.02	0.03
500.138	-0.01	-0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.11
500.482	-0.06	-0.05	-0.05	-0.02	-0.05	-0.08	-0.12	-0.10	0.03
500.558	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
500.663	-0.16	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
501.167	0.00	0.00	0.00	0.49	0.31	0.00	0.01	0.02	0.03
502.456	0.00	0.00	0.00	0.00	-0.02	0.26	0.17	0.20	0.29
502.974	0.00	0.00	0.00	0.00	-0.12	0.31	0.16	0.20	0.28
503.599	-0.25	0.00	0.00	-0.02	-0.01	0.27	0.19	0.22	0.29
503.720	0.00	0.00	0.00	0.00	-0.13	0.14	0.25	0.26	0.29
504.707	0.00	-0.07	-0.05	0.00	0.06	0.08	0.15	0.15	0.27
504.798	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.14
505.502	-0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
506.676	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
507.025	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
508.164	-0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.41
509.640	-0.99	-0.78	-0.62	-0.30	0.46	0.52	0.48	0.48	0.44
510.815	-0.96	-1.01	-1.04	-1.04	-1.03	-1.01	0.54	0.54	0.47
512.108	-0.73	-0.12	0.00	0.00	0.00	0.00	0.01	0.02	0.44
513.671	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
514.218	0.00	0.30	0.42	0.42	0.00	0.00	0.01	0.02	0.03
515.011	0.02	0.06	0.19	0.00	0.00	0.00	0.01	0.02	0.03
515.084	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.14
515.601	-0.02	0.03	0.14	0.34	0.14	0.00	0.01	0.06	0.25
516.313	-0.17	0.00	0.00	0.04	0.09	0.09	0.18	0.18	0.25
516.484	0.00	0.00	0.00	0.04	0.09	0.09	0.18	0.18	0.25
516.980	0.00	-0.03	0.04	0.08	0.09	0.09	0.18	0.18	0.25
517.428	0.00	-0.03	0.04	0.08	0.09	0.09	0.18	0.18	0.25
518.556	0.00	0.00	0.12	0.14	0.00	0.03	0.14	0.18	0.29
519.224	-0.01	0.05	0.07	0.12	0.00	0.00	0.01	0.02	0.16
520.339	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07
521.918	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.03
523.223	0.00	0.38	0.02	0.11	0.00	0.00	0.00	0.00	0.03
524.180	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
524.906	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
525.984	-0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
528.371	-0.15	-0.38	-0.57	-0.75	-0.98	-1.09	-0.05	0.19	0.37
528.540	-0.05	-0.21	-0.45	-0.68	-0.90	-1.00	-0.06	0.10	0.38
528.668	0.00	-0.06	-0.17	-0.28	-0.07	0.07	-0.04	0.07	0.35
528.741	0.00	0.00	0.00	-0.04	-0.08	-0.12	0.27	0.28	0.40
529.274	-1.14	-1.27	-1.30	-1.26	-1.35	-1.40	0.46	0.46	0.47
529.768	0.00	-0.03	-0.08	0.13	0.49	0.51	0.46	0.46	0.47
530.705	-0.48	-0.27	-0.14	0.12	0.45	0.49	0.45	0.45	0.46
531.132	-0.02	-0.05	-0.02	0.06	0.37	0.41	0.43	0.43	0.44
531.543	-0.02	-0.05	-0.02	0.06	0.37	0.41	0.43	0.43	0.44
531.757	-0.27	-0.17	-0.05	0.12	0.46	0.47	0.43	0.43	0.44
531.906	-0.07	-0.06	-0.01	0.14	0.46	0.47	0.43	0.43	0.44
532.351	-0.01	0.07	0.03	0.00	0.00	0.00	0.01	0.02	0.35
533.149	0.00	0.00	0.00	0.00	0.02	0.11	0.12	0.19	0.35
533.611	0.00	0.00	0.00	0.01	0.14	0.23	0.27	0.29	0.28
534.776	-0.02	-0.06	-0.07	0.04	0.05	0.08	0.21	0.22	0.31
535.106	-0.06	0.03	0.05	0.21	0.18	0.15	0.25	0.23	0.33
536.243	-0.12	0.03	0.07	0.16	0.20	0.22	0.24	0.26	0.36
536.539	-0.12	-0.13	-0.06	-0.01	0.16	0.22	0.20	0.23	0.37
536.891	-0.13	-0.13	-0.08	0.01	0.18	0.32	0.29	0.30	0.40
537.571	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.19
537.993	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
538.563	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07
539.013	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
539.707	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03
540.226	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03

Track Lift:	Design vs Existing
Structures:	100 year ARI vs Existing

Kilometerage	**Change in Modelled Flood Level (mAHD)**								
	50% AEP	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
542.605	0.00	-0.03	0.01	0.00	0.02	0.12	0.12	-0.12	0.03
543.766	-0.39	-0.44	-0.37	-0.23	0.08	0.17	0.15	0.19	0.35
544.452	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	-0.03
545.968	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.12	0.32
546.542	-0.06	0.04	0.00	0.00	0.00	0.00	0.01	0.06	0.30
546.812	0.00	0.00	0.00	0.00	0.09	0.22	0.14	0.12	0.29
547.282	-0.11	-0.11	-0.16	-0.25	0.18	0.21	0.14	0.12	0.27
547.559	-0.17	-0.11	-0.17	-0.21	0.14	0.21	0.14	0.12	0.27
547.739	-0.20	-0.29	-0.24	-0.20	0.04	0.17	0.09	0.08	0.27
547.841	-0.22	-0.44	-0.36	-0.36	-0.19	0.12	0.07	0.09	0.27
548.064	-0.19	-0.19	-0.14	-0.12	0.01	0.20	-0.01	0.03	0.27
548.581	-0.01	0.00	0.00	0.11	0.22	0.26	-0.10	-0.05	0.27
549.027	-0.30	-0.16	-0.01	0.15	0.25	0.23	-0.03	0.04	0.27
549.072	-0.15	-0.07	0.00	0.09	0.38	0.23	-0.03	0.04	0.27
549.090	0.00	0.00	0.00	0.00	0.52	0.23	0.14	0.16	0.28
550.835	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.28
551.146	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.28
551.571	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.28
552.631	-0.58	-0.69	-0.73	-0.98	-1.22	-0.97	-1.14	-0.41	0.27
554.243	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.28

NW Link 1 (approx. 450)	NA	NA	NA	NA	NA	NA	NA	NA	NA
NW Link 2 (approx. 448)	NA	NA	NA	NA	NA	NA	NA	NA	NA
NW Link 3 (approx. 448)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix H – Overtopping for design conditions

This appendix provides a summary of length of the design track that is overtopped during the modelled design flood events.

Track overtopping occurs when the modelled local catchment flood level is higher than the design top of rail level.

Section:	P2N
Track Lift:	Design
Structures:	1% AEP

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
449.350		0.0	0.0	0.0	0.0	0.0	0.0
449.765	449.771	8.0	16.0	17.0	20.3	32.0	37.0
449.852		0.0	0.0	0.0	0.0	0.0	0.0
450.204		0.0	0.0	0.0	0.0	0.0	0.0
451.332		0.0	0.0	0.0	0.0	0.0	0.0
452.721		0.0	0.0	0.0	0.0	0.0	0.0
453.403		0.0	0.0	0.0	0.0	0.0	0.0
453.642		0.0	0.0	0.0	0.0	0.0	0.0
454.353	454.504	0.0	0.0	0.0	0.0	29.3	52.5
454.844		0.0	0.0	0.0	0.0	0.0	0.0
455.228		0.0	0.0	0.0	0.0	0.0	0.0
456.184		0.0	0.0	0.0	0.0	0.0	0.0
456.992		0.0	0.0	0.0	0.0	0.0	0.0
457.486		0.0	0.0	0.0	0.0	0.0	0.0
458.285		0.0	0.0	0.0	0.0	0.0	0.0
458.323		0.0	0.0	0.0	0.0	0.0	0.0
458.648		0.0	0.0	0.0	0.0	0.0	0.0
459.676		0.0	0.0	0.0	0.0	0.0	0.0
460.127		0.0	0.0	0.0	0.0	0.0	0.0
460.698		0.0	0.0	0.0	0.0	0.0	0.0
461.157		0.0	0.0	0.0	0.0	0.0	0.0
461.252	461.252	0.0	0.0	0.0	28.3	50.3	62.3
461.980		0.0	0.0	0.0	0.0	0.0	0.0
462.814		0.0	0.0	0.0	0.0	0.0	0.0
463.019		0.0	0.0	0.0	0.0	0.0	0.0
463.224		0.0	0.0	0.0	0.0	0.0	0.0
464.694	464.677	0.0	0.0	0.0	0.0	64.6	158.2
465.265	465.253	7.9	18.7	18.7	18.7	18.7	18.7
465.310		0.0	0.0	0.0	0.0	0.0	0.0
465.366		0.0	0.0	0.0	0.0	0.0	0.0
465.859		0.0	0.0	0.0	0.0	0.0	0.0
466.824		0.0	0.0	0.0	0.0	0.0	0.0
468.176		0.0	0.0	0.0	0.0	0.0	0.0
468.366		0.0	0.0	0.0	0.0	0.0	0.0
468.565		0.0	0.0	0.0	0.0	0.0	0.0
469.524		0.0	0.0	0.0	0.0	0.0	0.0
470.467		0.0	0.0	0.0	0.0	0.0	0.0
472.030		0.0	0.0	0.0	0.0	0.0	0.0
473.905	473.919	0.0	0.0	0.0	0.0	1.0	3.0
473.938		0.0	0.0	0.0	0.0	0.0	0.0
476.771		0.0	0.0	0.0	0.0	0.0	0.0
476.796		0.0	0.0	0.0	0.0	0.0	0.0
477.703		0.0	0.0	0.0	0.0	0.0	0.0
478.262		0.0	0.0	0.0	0.0	0.0	0.0

Section:	P2N
Track Lift:	Design
Structures:	1% AEP

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
478.796		0.0	0.0	0.0	0.0	0.0	0.0
479.300		0.0	0.0	0.0	0.0	0.0	0.0
480.350		0.0	0.0	0.0	0.0	0.0	0.0
481.921		0.0	0.0	0.0	0.0	0.0	0.0
482.824		0.0	0.0	0.0	0.0	0.0	0.0
482.947		0.0	0.0	0.0	0.0	0.0	0.0
483.549		0.0	0.0	0.0	0.0	0.0	0.0
483.940		0.0	0.0	0.0	0.0	0.0	0.0
484.581		0.0	0.0	0.0	0.0	0.0	0.0
484.829		0.0	0.0	0.0	0.0	0.0	0.0
487.960		0.0	0.0	0.0	0.0	0.0	0.0
488.908		0.0	0.0	0.0	0.0	0.0	0.0
489.844		0.0	0.0	0.0	0.0	0.0	0.0
490.189		0.0	0.0	0.0	0.0	0.0	0.0
490.553		0.0	0.0	0.0	0.0	0.0	0.0
491.834		0.0	0.0	0.0	0.0	0.0	0.0
492.079		0.0	0.0	0.0	0.0	0.0	0.0
492.947		0.0	0.0	0.0	0.0	0.0	0.0
493.293		0.0	0.0	0.0	0.0	0.0	0.0
493.749		0.0	0.0	0.0	0.0	0.0	0.0
494.815		0.0	0.0	0.0	0.0	0.0	0.0
495.535		0.0	0.0	0.0	0.0	0.0	0.0
496.067		0.0	0.0	0.0	0.0	0.0	0.0
496.885		0.0	0.0	0.0	0.0	0.0	0.0
497.613		0.0	0.0	0.0	0.0	0.0	0.0
497.760		0.0	0.0	0.0	0.0	0.0	0.0
498.061		0.0	0.0	0.0	0.0	0.0	0.0
498.625		0.0	0.0	0.0	0.0	0.0	0.0
498.870		0.0	0.0	0.0	0.0	0.0	0.0
499.545		0.0	0.0	0.0	0.0	0.0	0.0
500.138		0.0	0.0	0.0	0.0	0.0	0.0
500.482		0.0	0.0	0.0	0.0	0.0	0.0
500.558		0.0	0.0	0.0	0.0	0.0	0.0
500.663		0.0	0.0	0.0	0.0	0.0	0.0
501.167		0.0	0.0	0.0	0.0	0.0	0.0
502.456		0.0	0.0	0.0	0.0	0.0	0.0
502.974		0.0	0.0	0.0	0.0	0.0	0.0
503.599		0.0	0.0	0.0	0.0	0.0	0.0
504.707		0.0	0.0	0.0	0.0	0.0	0.0
504.798		0.0	0.0	0.0	0.0	0.0	0.0
505.502		0.0	0.0	0.0	0.0	0.0	0.0
506.676		0.0	0.0	0.0	0.0	0.0	0.0
507.025		0.0	0.0	0.0	0.0	0.0	0.0
508.164		0.0	0.0	0.0	0.0	0.0	0.0

Section:	P2N
Track Lift:	Design
Structures:	1% AEP

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
509.640		0.0	0.0	0.0	0.0	0.0	0.0
510.815		0.0	0.0	0.0	0.0	0.0	0.0
512.108		0.0	0.0	0.0	0.0	0.0	0.0
513.671		0.0	0.0	0.0	0.0	0.0	0.0
514.218		0.0	0.0	0.0	0.0	0.0	0.0
515.011		0.0	0.0	0.0	0.0	0.0	0.0
515.601		0.0	0.0	0.0	0.0	0.0	0.0
516.313		0.0	0.0	0.0	0.0	0.0	0.0
516.484		0.0	0.0	0.0	0.0	0.0	0.0
516.980		0.0	0.0	0.0	0.0	0.0	0.0
517.428		0.0	0.0	0.0	0.0	0.0	0.0
518.556		0.0	0.0	0.0	0.0	0.0	0.0
519.224		0.0	0.0	0.0	0.0	0.0	0.0
520.339		0.0	0.0	0.0	0.0	0.0	0.0
521.918		0.0	0.0	0.0	0.0	0.0	0.0
523.223		0.0	0.0	0.0	0.0	0.0	0.0
524.180		0.0	0.0	0.0	0.0	0.0	0.0
524.906		0.0	0.0	0.0	0.0	0.0	0.0
525.984		0.0	0.0	0.0	0.0	0.0	0.0
528.371		0.0	0.0	0.0	0.0	0.0	0.0
528.540		0.0	0.0	0.0	0.0	0.0	0.0
528.668		0.0	0.0	0.0	0.0	0.0	0.0
528.741		0.0	0.0	0.0	0.0	0.0	0.0
529.274		0.0	0.0	0.0	0.0	0.0	0.0
529.768	529.330	0.0	0.0	0.0	0.0	42.3	73.7
531.132		0.0	0.0	0.0	0.0	0.0	0.0
531.543		0.0	0.0	0.0	0.0	0.0	0.0
531.757		0.0	0.0	0.0	0.0	0.0	0.0
532.351		0.0	0.0	0.0	0.0	0.0	0.0
533.149		0.0	0.0	0.0	0.0	0.0	0.0
533.611		0.0	0.0	0.0	0.0	0.0	0.0
534.776		0.0	0.0	0.0	0.0	0.0	0.0
535.106		0.0	0.0	0.0	0.0	0.0	0.0
536.243		0.0	0.0	0.0	0.0	0.0	0.0
536.539		0.0	0.0	0.0	0.0	0.0	0.0
536.891		0.0	0.0	0.0	0.0	0.0	0.0
537.571		0.0	0.0	0.0	0.0	0.0	0.0
537.993		0.0	0.0	0.0	0.0	0.0	0.0
539.013		0.0	0.0	0.0	0.0	0.0	0.0
539.707		0.0	0.0	0.0	0.0	0.0	0.0
540.226		0.0	0.0	0.0	0.0	0.0	0.0
542.605		0.0	0.0	0.0	0.0	0.0	0.0
543.766		0.0	0.0	0.0	0.0	0.0	0.0
545.968		0.0	0.0	0.0	0.0	0.0	0.0

Section:	P2N
Track Lift:	Design
Structures:	1% AEP

Catchment	Kilometerage (at mid point)	Length of rail overtopping (m)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
546.542		0.0	0.0	0.0	0.0	0.0	0.0
546.812		0.0	0.0	0.0	0.0	0.0	0.0
547.282		0.0	0.0	0.0	0.0	0.0	0.0
547.559		0.0	0.0	0.0	0.0	0.0	0.0
547.739		0.0	0.0	0.0	0.0	0.0	0.0
547.841		0.0	0.0	0.0	0.0	0.0	0.0
548.064		0.0	0.0	0.0	0.0	0.0	0.0
549.027		0.0	0.0	0.0	0.0	0.0	0.0
549.072		0.0	0.0	0.0	0.0	0.0	0.0
550.835		0.0	0.0	0.0	0.0	0.0	0.0
551.146		0.0	0.0	0.0	0.0	0.0	0.0
551.571		0.0	0.0	0.0	0.0	0.0	0.0
552.631		0.0	0.0	0.0	0.0	0.0	0.0
Total:		15.9	34.7	35.7	67.3	238.2	405.4

Appendix I – Compliance to ETD-10-02 – design conditions

ETD-10-02 requires that the ballast of the upgraded track be above the modelled one per cent AEP local catchment flood level.

This appendix provides a summary of length of design track which does not meet the design requirements of ETD-10-02. This appendix also provides a summary of the length of design ballast that is flooded by a range of modelled local flood events.

Section:	P2N
Track Lift:	Design
Culverts:	1% AEP

Catchment	Length of non-compliance with ETD-10-02 (m)
449.350	-
449.765	116
449.852	43
450.204	61
451.332	22
452.721	-
453.403	45
453.642	-
454.353	163
454.844	159
455.228	53
456.184	278
456.992	-
457.486	-
458.285	23
458.323	137
458.648	-
459.676	-
460.127	-
460.698	-
461.157	160
461.252	141
461.980	19
462.814	-
463.019	-
463.224	15
464.694	398
465.265	18
465.310	77
465.366	14
465.859	-
466.824	142
468.176	-
468.366	-
468.565	-
469.524	372
470.467	-
472.030	523
473.905	86
473.938	13
476.771	-
476.796	29
477.703	108
478.262	724

Section:	P2N
Track Lift:	Design
Culverts:	1% AEP

Catchment	Length of non-compliance with ETD-10-02 (m)
478.796	106
479.300	524
480.350	-
481.921	-
482.824	-
482.947	-
483.549	-
483.940	149
484.581	156
484.829	-
487.960	64
488.908	33
489.844	197
490.189	-
490.553	137
491.834	12
492.079	36
492.947	402
493.293	69
493.749	285
494.815	-
495.535	-
496.067	-
496.885	-
497.613	475
497.760	-
498.061	-
498.625	-
498.870	236
499.545	21
500.138	-
500.482	-
500.558	84
500.663	251
501.167	214
502.456	85
502.974	603
503.599	47
504.707	-
504.798	-
505.502	-
506.676	9
507.025	382
508.164	-

Section:	P2N
Track Lift:	Design
Culverts:	1% AEP

Catchment	Length of non-compliance with ETD-10-02 (m)
509.640	836
510.815	-
512.108	-
513.671	2
514.218	6
515.011	83
515.601	233
516.313	114
516.484	-
516.980	-
517.428	-
518.556	-
519.224	-
520.339	89
521.918	310
523.223	-
524.180	-
524.906	84
525.984	-
528.371	-
528.540	-
528.668	1
528.741	-
529.274	-
529.768	635
531.132	1721
531.543	203
531.757	493
532.351	416
533.149	-
533.611	-
534.776	-
535.106	3
536.243	15
536.539	11
536.891	-
537.571	-
537.993	38
539.013	-
539.707	-
540.226	98
542.605	122
543.766	251
545.968	-

Section:	P2N
Track Lift:	Design
Culverts:	1% AEP

Catchment	Length of non-compliance with ETD-10-02 (m)
546.542	151
546.812	128
547.282	367
547.559	342
547.739	120
547.841	684
548.064	128
549.027	253
549.072	210
550.835	-
551.146	-
551.571	289
552.631	148

Total:	**17097**

Appendix J – Detailed flood impacts

This appendix contains a summary table of the maximum modelled flood levels for the one per cent AEP flood events for the existing and proposed (C100) conditions, as well as detailed views of the one per cent AEP flood impact areas for the length of the proposal site.

Kilometerage	1% AEP Modelled Flood Level (mAHD)	
	Existing	C100
449.350	325.98	325.32
449.765	322.87	322.89
449.852	321.25	321.25
450.204	317.42	317.43
451.332	308.38	308.53
452.721	301.43	301.43
453.403	301.26	301.26
453.642	301.26	301.26
454.353	300.30	300.30
454.844	297.86	298.73
455.228	298.90	298.73
456.184	303.31	303.31
456.992	304.84	304.84
457.486	305.45	305.45
458.285	310.04	310.04
458.323	310.41	310.41
458.648	310.41	310.41
459.676	310.53	310.53
460.127	309.54	309.54
460.698	307.25	307.18
461.157	308.27	308.53
461.252	309.34	309.37
461.980	316.03	316.03
462.814	319.64	319.54
463.019	320.39	320.13
463.224	320.02	319.79
464.694	309.68	309.68
464.746	309.68	309.68
465.265	314.86	314.86
465.310	314.48	314.48
465.366	314.48	314.48
465.859	315.92	315.92
466.824	313.59	313.82
468.176	314.08	314.08
468.366	313.87	313.83
468.565	314.37	314.37
469.524	318.26	318.53
470.467	321.87	321.87
472.030	314.70	314.58
473.905	314.27	314.27
473.938	313.49	313.45
476.771	296.57	296.57
476.796	297.32	297.32
477.703	294.23	294.23
478.262	292.53	292.52
478.796	292.54	292.52

Kilometerage	1% AEP Modelled Flood Level (mAHD)	
	Existing	C100
479.300	292.57	292.79
480.350	293.09	293.09
481.921	298.77	298.77
482.824	305.20	305.20
482.947	305.66	305.66
483.549	310.94	310.94
483.940	315.12	315.12
484.581	318.08	318.08
484.829	317.67	317.70
487.960	296.92	296.94
488.908	290.88	290.88
489.844	286.29	286.29
490.189	286.29	286.29
490.553	286.53	286.53
491.834	281.15	281.15
492.079	280.95	280.95
492.947	278.16	278.16
493.293	278.14	278.14
493.749	277.64	277.25
494.815	272.06	272.06
495.535	268.82	268.82
496.067	267.73	267.73
496.885	266.51	266.51
497.613	264.96	265.02
497.760	264.71	264.71
498.061	265.45	265.45
498.625	264.70	264.17
498.870	264.72	264.72
499.545	261.80	261.76
499.577	260.85	260.78
500.138	258.51	258.52
500.482	257.50	257.42
500.558	257.60	257.60
500.663	258.15	258.15
501.167	258.36	258.36
502.456	255.64	255.91
502.974	255.56	255.87
503.599	255.40	255.67
503.720	255.12	255.26
504.707	254.51	254.59
504.798	254.15	254.15
505.502	254.70	254.70
506.676	254.35	254.35
507.025	253.97	253.97
508.164	251.82	251.82
509.640	250.70	251.22

Kilometerage	1% AEP Modelled Flood Level (mAHD)	
	Existing	C100
510.815	250.65	249.64
512.108	251.36	251.36
513.671	253.82	253.82
514.218	254.40	254.40
515.011	254.64	254.64
515.084	253.97	253.97
515.601	253.91	253.91
516.313	253.46	253.55
516.484	253.46	253.55
516.980	253.33	253.42
517.428	253.33	253.42
518.556	253.65	253.68
519.224	253.65	253.65
520.339	253.38	253.38
521.918	253.38	253.38
523.223	252.79	252.79
524.180	250.66	250.66
524.906	250.06	250.06
525.984	247.60	247.60
528.371	243.06	241.97
528.540	242.90	241.89
528.668	242.53	242.59
528.741	241.96	241.85
529.274	241.72	240.32
529.768	241.70	242.21
530.705	241.70	242.19
531.132	241.70	242.11
531.543	241.70	242.11
531.757	241.70	242.17
531.906	241.70	242.17
532.351	242.55	242.55
533.149	242.12	242.23
533.611	242.14	242.37
534.776	242.61	242.69
535.106	242.87	243.01
536.243	243.11	243.33
536.539	243.35	243.58
536.891	243.37	243.69
537.571	244.15	244.15
537.993	245.83	245.83
538.563	250.33	250.33
539.013	251.95	251.95
539.707	256.84	256.84
540.226	259.16	259.16
542.605	253.87	253.99
543.766	248.70	248.88

Kilometerage	1% AEP Modelled Flood Level (mAHD)	
	Existing	C100
544.452	244.92	244.92
545.968	239.77	239.80
546.542	239.77	239.77
546.812	239.41	239.63
547.282	239.41	239.62
547.559	239.36	239.57
547.739	239.27	239.45
547.841	239.18	239.30
548.064	238.84	239.05
548.581	238.56	238.82
549.027	238.56	238.79
549.072	238.56	238.79
549.090	238.56	238.79
550.835	239.06	239.06
551.146	239.06	239.06
551.571	240.23	240.23
552.631	238.70	237.73
554.243	239.26	239.26

NW Link 1 (approx. 450)	-	300.91
NW Link 2 (approx. 448)	-	285.65
NW Link 3 (approx. 448)	-	283.35

Paper Size A3

0 100 200 400 600 800

Metres

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

LEGEND

- Culvert / underbridge location
- Existing 100 year flood extent
- Increase in flood extent
- Reduction in flood extent
- Cadastre

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

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Detailed Changes to 1% AEP Flood Level Impact Extents

Figure J-1

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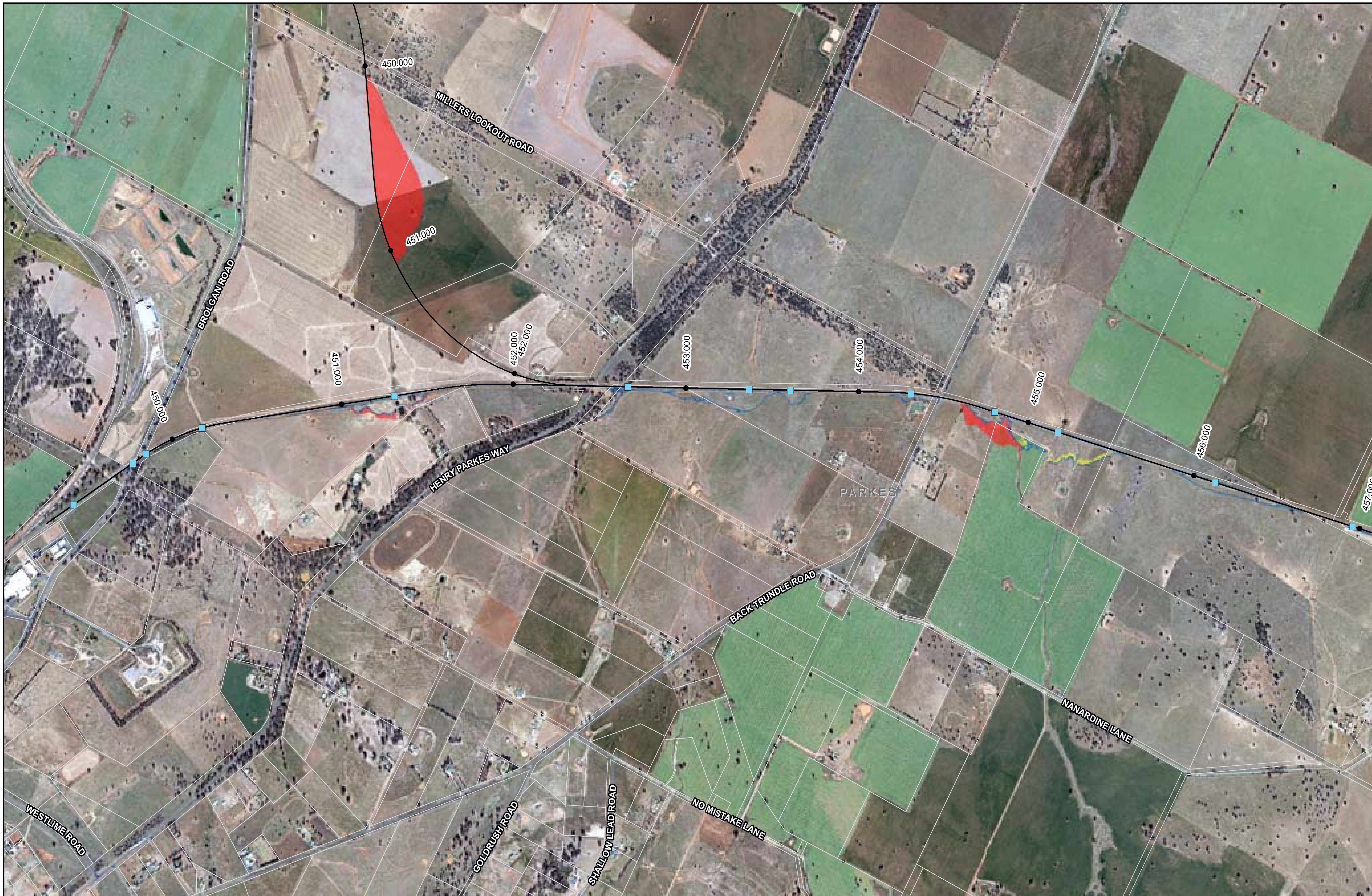
Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid



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

LEGEND

- Culvert / underbridge location
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- Increase in flood extent
- Reduction in flood extent
- Cadastre

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Figure J-2

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Figure J-3

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Figure J-5

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

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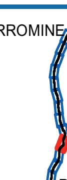

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Figure J-6

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LEGEND

- Culvert / underbridge location
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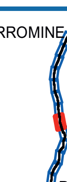

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Grid: GDA 1994 MGA Zone 55

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LEGEND
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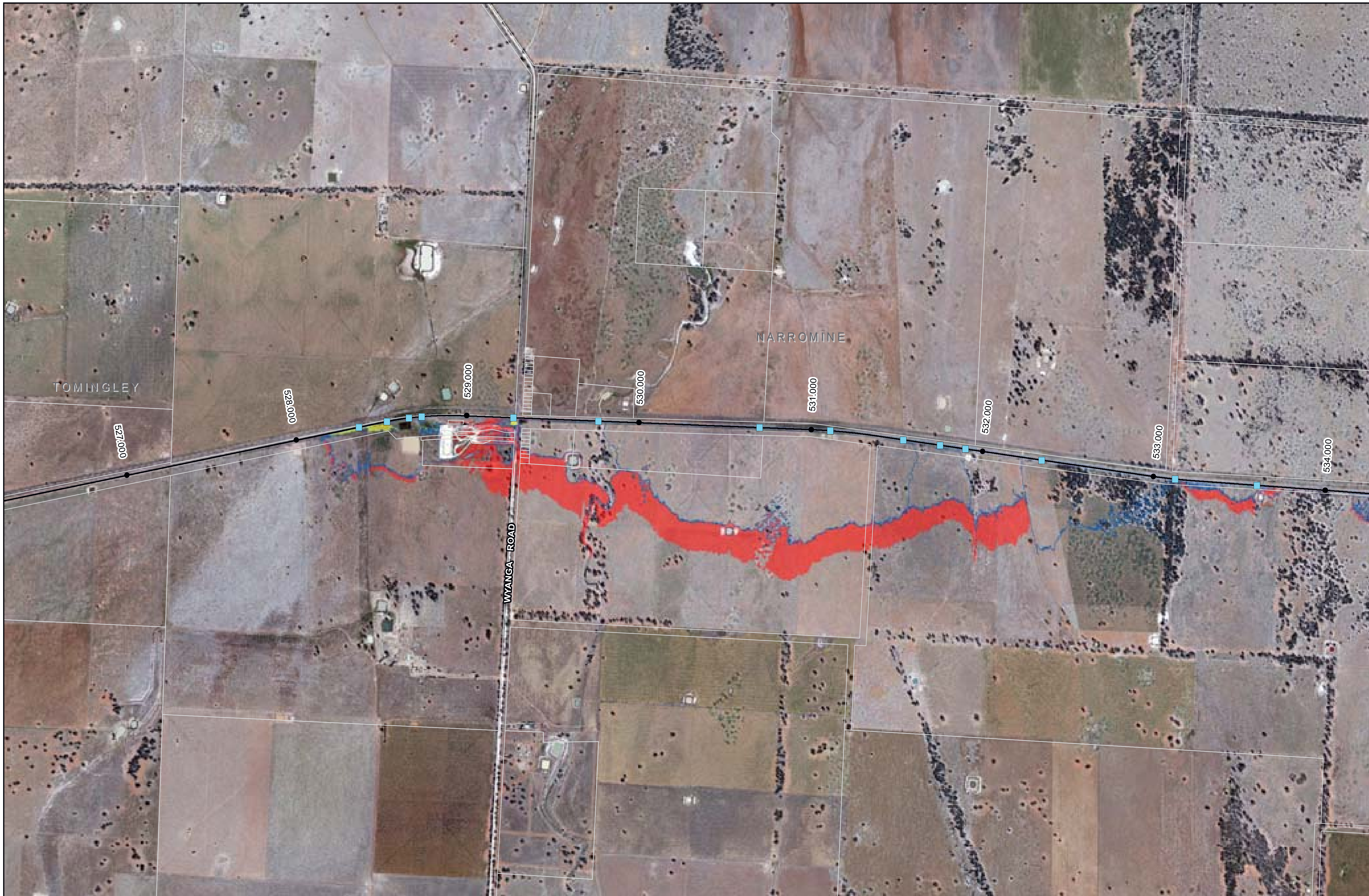

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LEGEND

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LEGEND
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LEGEND

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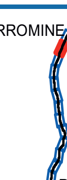

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Detailed Changes to 1% AEP Flood Level Impact Extents **Figure J-14**

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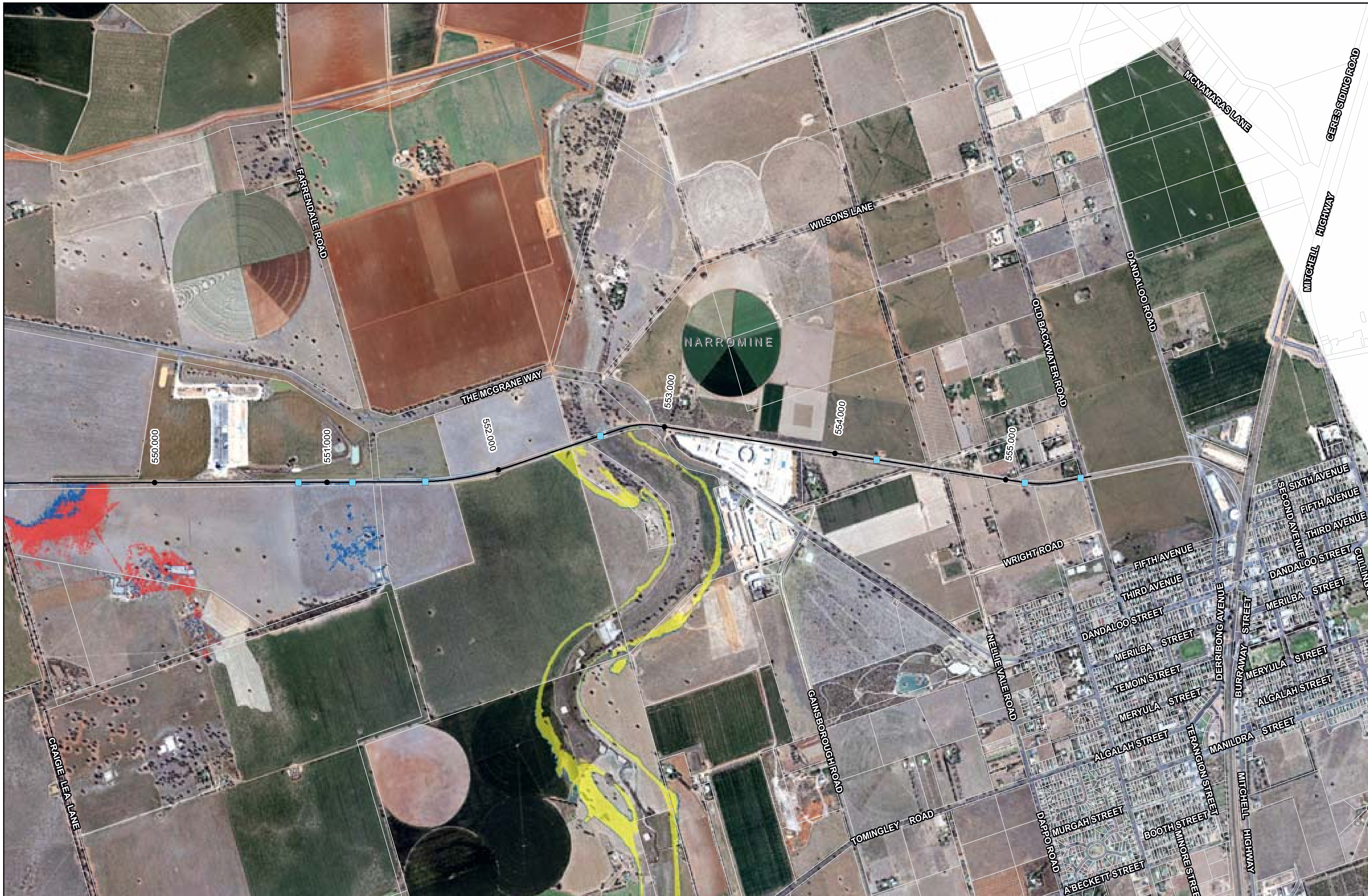

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LEGEND
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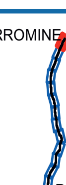

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GHD

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	I Joliffe	A Wyatt		S Page		21/06/2017

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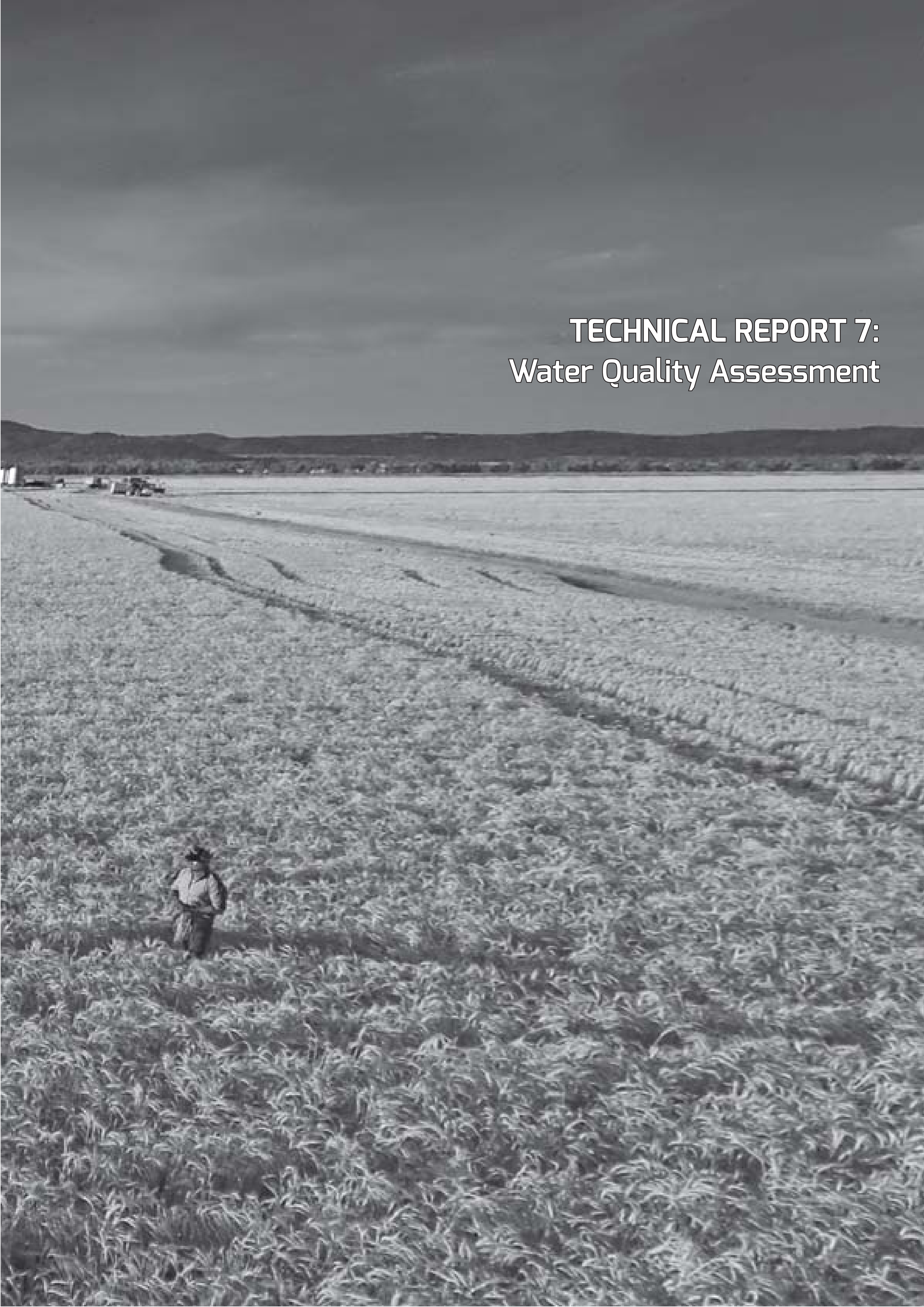
TECHNICAL REPORT 7:
Water Quality Assessment



Australian Rail Track Corporation

Inland Rail - Parkes to Narromine
Water Quality Assessment

June 2017

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

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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
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
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
Existing rail corridor	The area of land that is identified for the continued operation of the rail line between Parkes and Narromine
Flood	Relatively high river, creek or water way flow which overtop the natural or artificial banks to inundate surrounding areas in an uncontrolled manner

Term	Explanation
Flood depth	The depth of floodwater above ground level
Flood plain	Land adjacent to a river, creek or water way 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
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 m3/s – design for 1 per cent AEP event
Minor structure	Has a design flow less than 50 m3/s – design for 2 per cent AEP event
Morphology	A particular form, shape or structure
Mulitcell	Multiple number of openings within a structure
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 Parkes to Narromine 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

Term	Explanation
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
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 Parkes to Narromine section of Inland Rail ('the proposal').

The proposal would involve upgrading the existing rail line between Parkes and Narromine for a distance of 106 kilometres, including new crossing loops, some track realignment and replacement of culverts. The proposal also includes a new north to west connection between Inland Rail and the Broken Hill line (Parkes north west connection).

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

The proposal site is located within the Lachlan and Macquarie-Bogan river catchments and crosses several named watercourses. The majority of the watercourses are ephemeral and there is a minimal amount of water quality data to describe the existing conditions along the corridor. Soils are generally identified as being highly erodible.

Water quality objectives for the Lachlan and Macquarie-Bogan river catchments have been reviewed. For water quality parameters that are commonly reported, the water quality objectives are similar to the ANZECC water quality targets.

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.

These recommended mitigation measures are described below. 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 impact 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 demand for construction period water demand.
- The proposed provision of rock rip rap 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 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 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 controlled to not exceed the design value.
- Track inspections would be undertaken after significant flood events to identify any required repairs or maintenance prior to recommencing services.

Application of appropriate environmental protection measures 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. The Inland Rail programme (Inland Rail) involves the design and construction of a new inland rail connection, about 1,700 kilometres long, between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail would enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) has sought approval to construct and operate the proposal.

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) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

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 address the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs), issued on 8 November 2016 and the terms of the assessment bilateral agreement between the Commonwealth and the State of New South Wales under the EPBC Act.

1.2 The proposal

1.2.1 Location

The proposal is generally located in the existing rail corridor between the towns of Parkes and Narromine, via Peak Hill. In addition, a new connection to the Broken Hill rail line ('the Parkes north west connection') is proposed outside the existing rail corridor at the southern end of the proposal site near Parkes. The location of the proposal is shown in Figure 1-1.

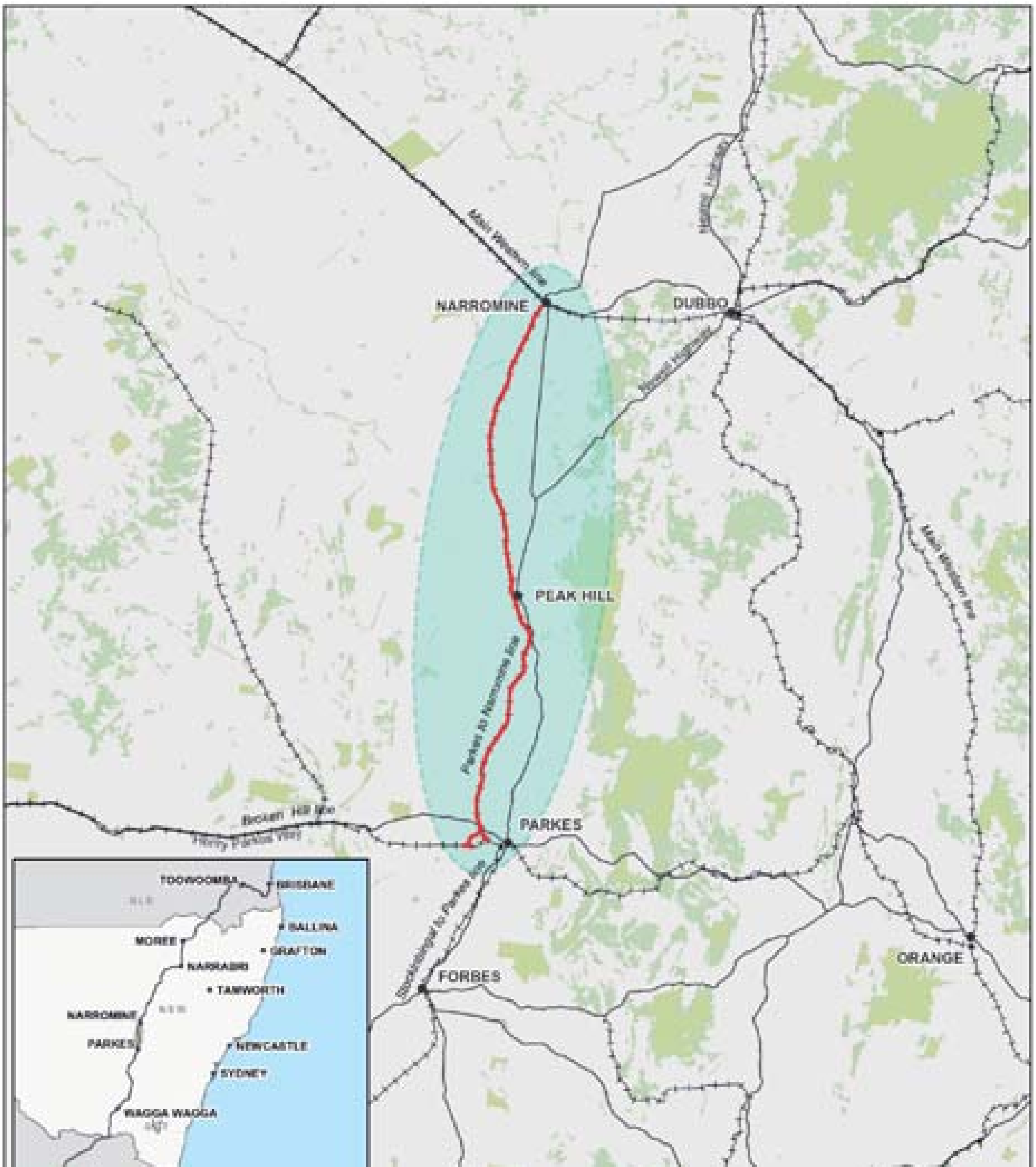
1.2.2 Key features

The key features of the proposal involve:

- Upgrading the track, track formation, and culverts within the existing rail corridor for a distance of 106 kilometres between Parkes and Narromine
- Realigning the track where required within the existing rail corridor to minimise the radius of tight curves
- Providing three new crossing loops within the existing rail corridor, at Goonumbla, Peak Hill, and Timjelly
- Providing a new 5.3 kilometre long rail connection to the Broken Hill Line to the west of Parkes ('the Parkes north west connection'), including a road bridge over the existing rail corridor at Brolgan Road ('the Brolgan Road 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.



LEGEND

Proposal site

Proposal location

Rail lines

Main roads

Paper Size A4

0 5 10 20 30

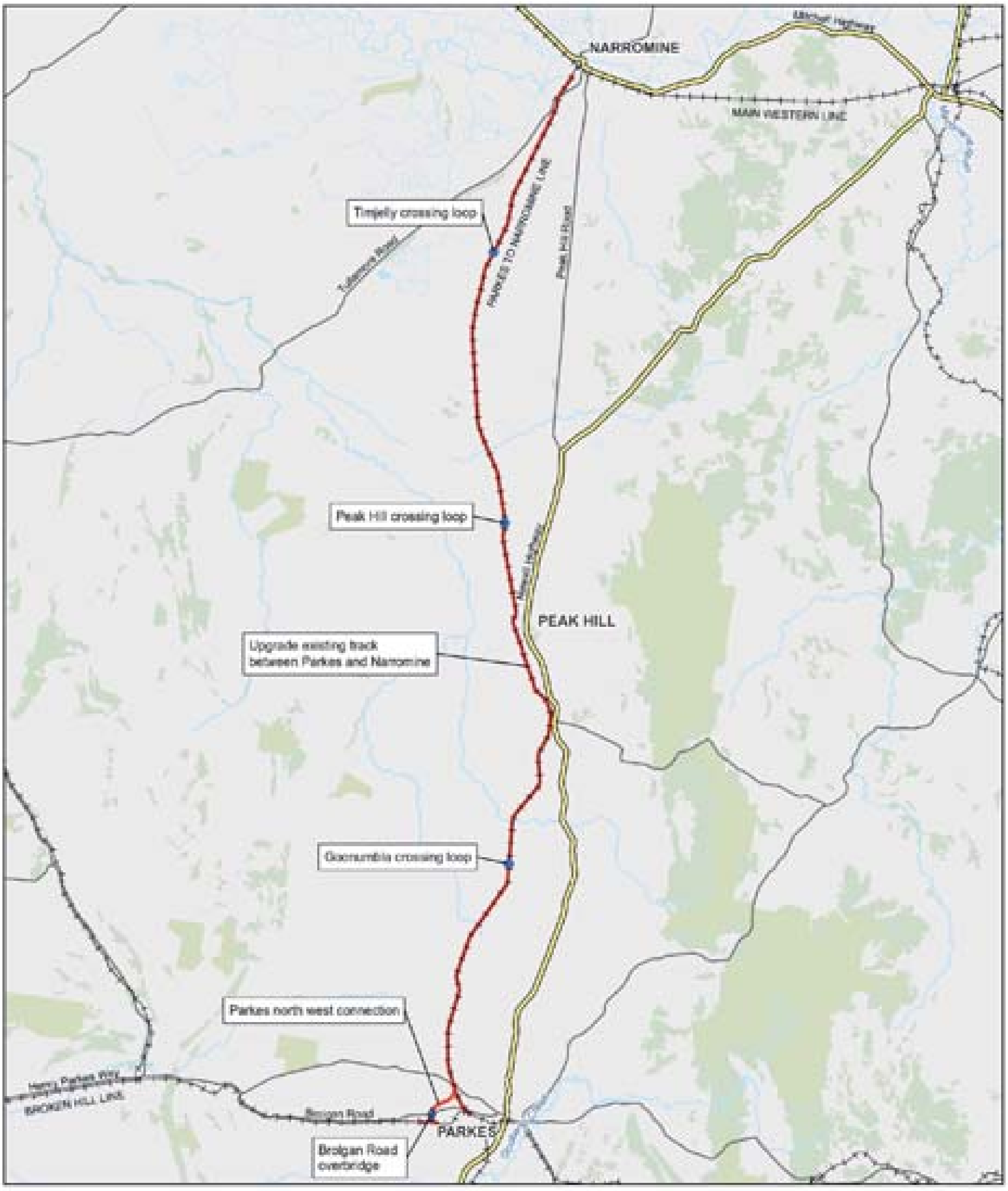
Kilometers

Australian Rail Track Corporation
Inland Rail Track Alignment

Job Number | 2217…
Revision | 0
Date | 30 Nov 2016

Location of the proposal

Figure 1-1



LEGEND

- New bridge
- Crossing loop
- The proposal
- Railway
- Highway
- Road

Paper Size A4

0 2.5 5 10 15

Kilometers

Australian Rail Track Corporation
Inland Rail Track Alignment

Job Number 2217116
Revision 0
Date 19 Jun 2017

Key features of the proposal

Figure 1-2

Data source: Commonwealth of Australia (Geoscience Australia), 2006, Topographic Data Series 3, 2006

Further information on the proposal is provided in the EIS.

1.2.3 Operation

Prior to the opening of Inland Rail as a whole, the proposal would be used by existing rail traffic, which includes trains carrying grain and ore 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 8.5 trains per day in 2025, increasing to 15 trains per day in 2040. The trains would be a mix of grain, intermodal (freight), and other general transport trains.

1.2.4 Timing

Subject to approval of the proposal, construction is planned to start in early to mid 2018, and is expected to take about 18 months. Existing train operations along the Parkes to Narromine line would continue prior to, during, and following construction. Inland Rail as a whole would be operational once all 13 sections are complete, which is estimated to be 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 *ARTC Inland Rail – Parkes to Narromine Hydrologic and Flooding Report* (GHD 2016).
- 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.

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 directly or indirectly affected by the proposal in a significant way. Additional downstream areas could potentially be impacted as a result of a regional flood in either the broader Lachlan River basin or the Macquarie-Bogan River basin, as detailed in Section 3.7.1.

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 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 Parkes through to Narromine 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
- Building new sidings.

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 Adopted drainage performance 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 Macquarie, Bogan or Lachlan 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 impact 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 floodplain. The embankment and upgraded structures would be required to permit an appropriate flow to minimise adverse flooding impacts.

The upgraded structures are designed to pass all flows up to the one per cent AEP magnitude and thus restrict the rail line from overtopping in all but extreme rainfall local catchment events. Regional flood events could still be expected to overtop the rail line in at the northern end near Narromine.

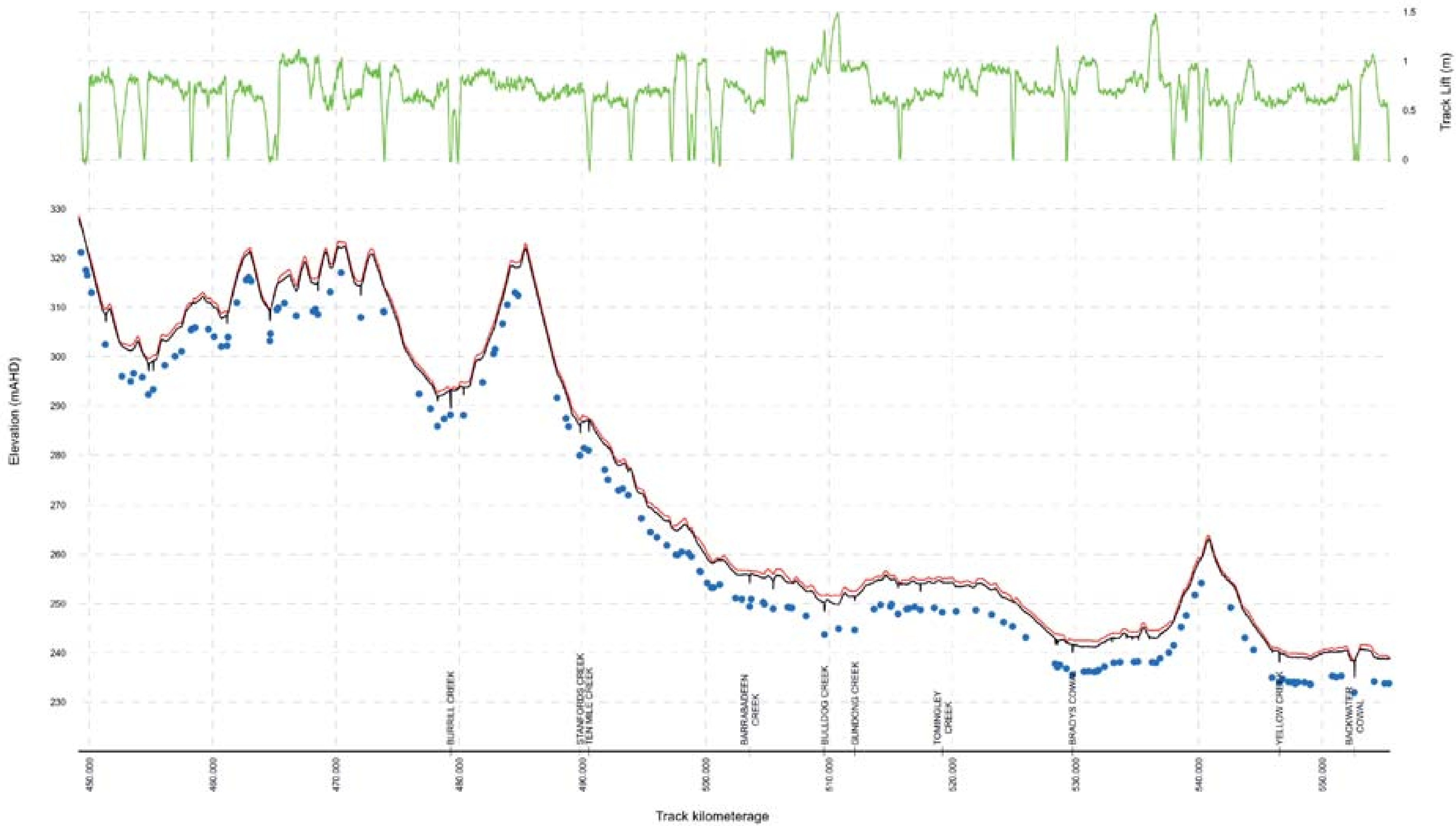
Changes to the hydrological and hydraulic regime could impact the water quality during both construction and operation of the proposal.

Details of the process used to select structure sizes for the proposal are described in accompanying *ARTC Inland Rail – Parkes to Narromine 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 Parkes and Narromine 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 and, over the majority of the proposal, the track lift would generally be between 0.3 metres and 1.0 metres, with a number of locations being raised up to about 1.5 metres..

The proposed locations of structures (culverts and underbridges) along the length of the proposal between Parkes and Narromine are shown in Figure 2-1. The structures are offset eight metres below their invert level for clarity of presentation. A plan view of the proposed culvert locations for the same portion of track are shown in Figure 2-2. Culverts proposed for the Parkes north west connection will be placed in natural low points to maintain existing flow paths.

The proposed Parkes north west connection would include three structures sized to match the corresponding main line culvert.



Paper Size A3

LEGEND
- Design
- Natural Surface
- Track Lift
- Culvert

GHD

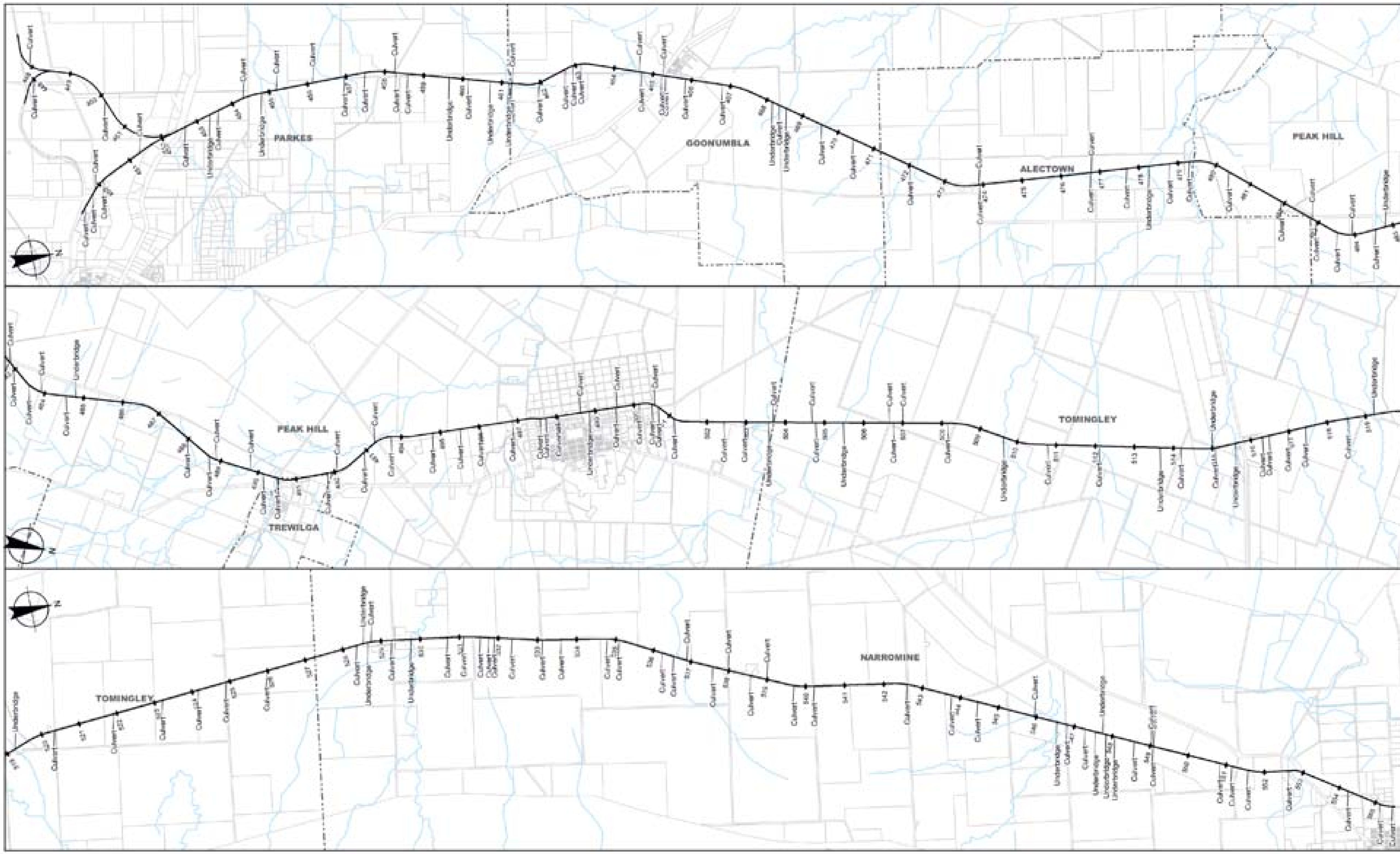
Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Design Track Alignment

Figure 2-1

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



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
- Lot boundary
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Proposed Culvert Locations

Figure 2-2

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

Data source: ARTC: imagery, 2014.

2.3.2 Proposal end points

The local catchment flooding and water quality assessment extends from near Parkes (about chainage 484 to near Narromine (about chainage 550).

2.4 Hydrologic and hydraulic assessment

2.4.1 Surface water hydrologic impacts – overview

An assessment of the surface water hydrologic impacts of the proposal are provided in the Technical Report 5. This assessment predicts that the proposal would have the following impacts on surface water hydrology as:

- The existing low-flow culvert crossing locations along the existing rail corridor would be retained because of replacing or retaining culverts at, or very close to, their existing location.
- There would be a concentration of flows with all flows crossing the existing rail line only at culverts, without track overtopping for events up to the one per cent AEP local catchment event, except for a minimal number of level crossings. In larger events, there could be flow through ballast and in extreme events, there could also potentially be track overtopping at locations away from culverts.
- There would be a concentration of flows downstream of the existing culverts between Parkes and Narromine, since flows would not overtop the rail for events up to the one percent AEP local catchment event.
- There would be an increase in the duration of flow through culverts for local catchment storm events.
- Figure 2-1 shows the proposed culvert and underbridge locations along the proposal.

2.4.2 Groundwater hydrologic impacts – overview

A groundwater hydrologic assessment is provided in the *ARTC Inland Rail – Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017). The assessment indicates that the proposal is unlikely to have any significant impact on the long-term groundwater hydrology.

2.4.3 Hydraulic and flooding impacts – overview

A comprehensive assessment of the hydraulic and flooding impacts of the proposal are provided in the *ARTC Inland Rail –Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017). This assessment predicts that the proposal would have the following hydraulic impacts:

- The proposal would reduce the extent of track length that currently overtops during flood events. This would be achieved through a combination of raising the track level and increasing culvert capacity for events up to the local catchment one per cent AEP local catchment event magnitude, except at a few level crossing locations.
- The proposal would create a slightly larger flood affected area upstream of the proposal.
- The proposal would lead to an increase in the flood levels and flooding duration upstream of the existing rail corridor.

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:
  - Lachlan River Water Quality and River Flow Objectives (DECCW 2006a)
  - Macquarie-Bogan River Water Quality and River Flow Objectives (DECCW 2006b)
- 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).

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, and – 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 2.6.1 Section 5.2 Section 6.2.1 Sections 2.6.2, 5 and 6 Sections 2.6.1 and 5.2.2 Section 6 Sections 5 and 6 Sections 4 and 5 Section 7
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 3.10 and Section 5 Section 5.2 Section 4.4 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:	Sections 3.5, 3.7 and 3.8

Agency	Desired performance outcome	Requirements	Where Addressed
		– 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	Sections 2.6.1, 4.2 and 4.4
		• 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 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	Sections 5.2.2 and 6
		• 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 (eg 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 Hydrology and Flooding Assessment (Technical Report 6)

2.6 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

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 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 – Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017).

Following the introduction of the *Water Management Act* 2000 water sharing plans have been developed for the Lower Macquarie Groundwater Sources; Lachlan Regulated River; Lachlan Unregulated and Alluvial Water Sources; Macquarie Bogan Unregulated and Alluvial Water Sources; Macquarie and Cudgegong Regulated Rivers. All of these cover part or the entire 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 2015) 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.

2.6.1 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. 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 Lachlan and Macquarie-Bogan Rivers have been extracted from the NSW Environment Protection Authority (EPA) website and are provided in Table 2-2. Table 2-2 also includes an assessment of the proposal against water quality objectives for the Lachlan and Macquarie-Bogan catchments to determine impacts to water quality due to construction and operation. The drinking water objectives for the Lachlan and Macquarie-Bogan Rivers 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 2-2 Water quality objectives for lowland rivers

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River 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	50 µg/L	Construction of the proposal would comply with the construction EPL for the proposal and operation would comply with 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	500 µg/L	
	Chlorophyll-a	5 µg/L	5 µg/L	
	turbidity	6–50 NTU	6–50 NTU	
	Salinity (Electrical conductivity) (µS/cm)	125–2200 µS/cm	125–2200 µS/cm	
	Dissolved oxygen	85–100%	85–100%	
	pH	6.5–8.5	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%.	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. 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.
	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.	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,	Macrophytes, phytoplankton scums,	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
		filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	
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).	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).	Construction activities would be managed to minimise the potential for contaminated runoff to enter surface waterbodies. Construction of the proposal would comply with the construction EPL for the proposal and operation would comply with ARTC's existing EPL and standard operating procedures. This would result in the proposal having minimal impacts on surface water receivers.
	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).	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).	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 study area are ephemeral. The discharge water quality would enable the potential for secondary contact recreation to be undertaken downstream of the proposal.
	Algae & blue-green algae	<15 000 cells/mL.	<15 000 cells/mL	
	Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.	
	Surface films	Use visual amenity guidelines.	Use visual amenity guidelines.	
Primary contact recreation				
Maintaining or improving water quality for activities	Turbidity	A 200 mm diameter black disc should be able to be	A 200 mm diameter black disc should be able to be	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
such as swimming in which there is a high probability of water being swallowed		sighted horizontally from a distance of more than 1.6 m (about 6 NTU).	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 of the proposal would comply with the construction EPL for the proposal and operation would comply with 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. The immediate receiving watercourses are not currently used for primary contact recreation as the majority of watercourses within the study 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).	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).	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).	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	<15 000 cells/Ml	
	Nuisance organisms	Use visual amenity guidelines.	Use visual amenity guidelines.	
	pH	5.0–9.0	5.0–9.0	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
	Temperature	15°–35°C for prolonged exposure.	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.	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.	Use visual amenitguidelines.	
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.	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 of the proposal would comply with the construction EPL for the proposal and operation would comply with 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, 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).	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	Drinking water for livestock should contain less than 100 thermotolerant coliforms	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
		per 100 mL (median value).	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.	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.	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 of the proposal would comply with the construction EPL for the proposal and operation would comply with 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.	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	Trigger values for thermotolerant coliforms	Trigger values for thermotolerant coliforms	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
	(faecal coliforms)	in irrigation water used for food and non-food crops are provided in Table 4.2.2 of the ANZECC Guidelines.	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.	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.	
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.	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 of the proposal would comply with the construction EPL for the proposal and operation would comply with 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. 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	5 NTU; <1 NTU desirable for effective disinfection; >1 NTU may shield some	

Water quality objective	Indicator	Lachlan River Trigger value or criteria	Macquarie-Bogan River Trigger value or criteria	Relevance to the proposal
		micro-organisms from disinfection. (see supporting information).	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.	<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.	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	6.5–8.5	
	Chemical contaminants	See Guidelines for Inorganic Chemicals in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004).	See Guidelines for Inorganic Chemicals in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004).	

3. Physical characteristics of the proposal site

3.1 Local government areas

The proposal is located within the Parkes Shire Council and Narromine Shire Council local government areas.

3.2 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 3-1.

The mean annual rainfall recorded at these stations, as reported by the BOM, varies along the rail corridor, with the annual average rainfall about 540 millimetres, with the rainfall occurring relatively uniformly throughout the year.

Table 3-1 Long term meteorological recording stations

Region	Name	Number	Latitude	Longitude	Starting year
Parkes	Goonumbla (Coradgery)	050016	32.97	148.06	1882
Parkes	Parkes Airport AWS	065068	33.13	148.24	1941
Parkes	Alectown (Cawdor)	065100	32.99	148.23	1992
Narromine	Bowling Club	054120	30.32	149.78	1870
Narromine	Alagalah Street	051037	32.24	148.24	1886
Narromine	Mumble Peg	051005	32.06	148.24	1881

3.2.1 Design rainfall data

Design rainfall data was obtained from the BoM Intensity Frequency Duration (IFD) generation process based on Australian Rainfall and Runoff (Pilgrim (Ed) 1987). A comparison between the resulting IFD rainfall pattern developed for Parkes and for Narromine indicates that the rainfall IFD patterns were effectively the same for both end points of the proposal site. Therefore, the proposal site could be adequately represented by a single rainfall IFD pattern.

Updated design rainfall data has been provided as part of the revision to Australian Rainfall and Runoff (Ball et al., 2016). A comparison of the 1987 IFD data and the 2013 IFD data showed only minor and insignificant differences in intensity.

3.2.2 Climate change impacts

The NSW and ACT Regional Climate Model (NARCLiM) provides recent projections for the potential climate change impacts for the greater Central West and Orara regions, 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 3-2.

Table 3-2 NARCLiM data summary

Parameter	Projected change (%) to 2020–2039	Projected change (%) to 2060– 2079
Annual mean rainfall change	-5 to 0	5 to 10
Summer rainfall	5 to 10 through -5 to 0	10 to 20
Autumn rainfall	5 to 10	10 to 20
Winter rainfall	-5 to 0 through -10 to -5	5 to 10
Spring rainfall	-20 to -10 through -10 to -5	-10 to -5

From the available NARCLiM modelling, climate change has been assessed by adopting an increase in adopted rainfall IFD intensity varying from 10 to 30 per cent design suitably accounts for estimated rainfall changes.

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

The 0.5 per cent and 0.2 per cent ARI events were used as a surrogate for the specific evaluation of climate change impacts.

3.3 Terrain

The topographic data used for the preparation of the design and the associated hydrologic and hydraulic analysis is described in detail in the *ARTC Inland Rail – Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017).

In summary, three sets of topographical data covering the study area have been obtained:

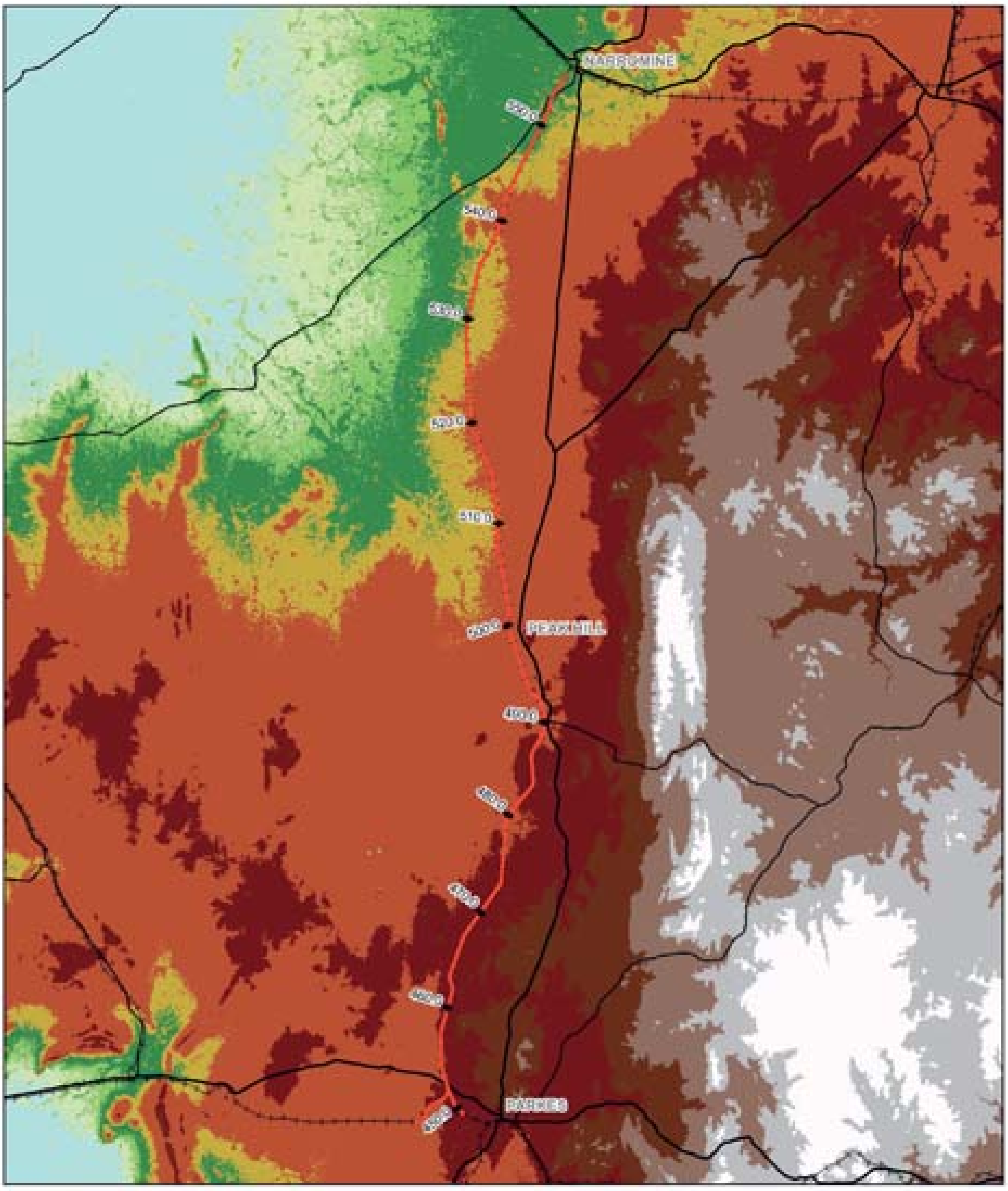
- Survey model obtained through LiDAR survey and aerial imaging.
- Digital Elevation Model (DEM) obtained through Shuttle Radar Topography Mission (SRTM).
- Localised site survey was available for a limited number of culvert locations.
- The adopted terrain model is presented in Figure 3-1. It shows the general landform adjacent to the study area. This was formed from LiDAR (where available) and SRTM outside the LiDAR corridor. The terrain is higher toward the southern end of the proposal site.

3.4 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 3-2.



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway

< 220; 220 - 225; 225 - 230; 230 - 240; 240 - 250; 250 - 300; 300 - 350; 350 - 400; 400 - 500; 500 - 600; > 600

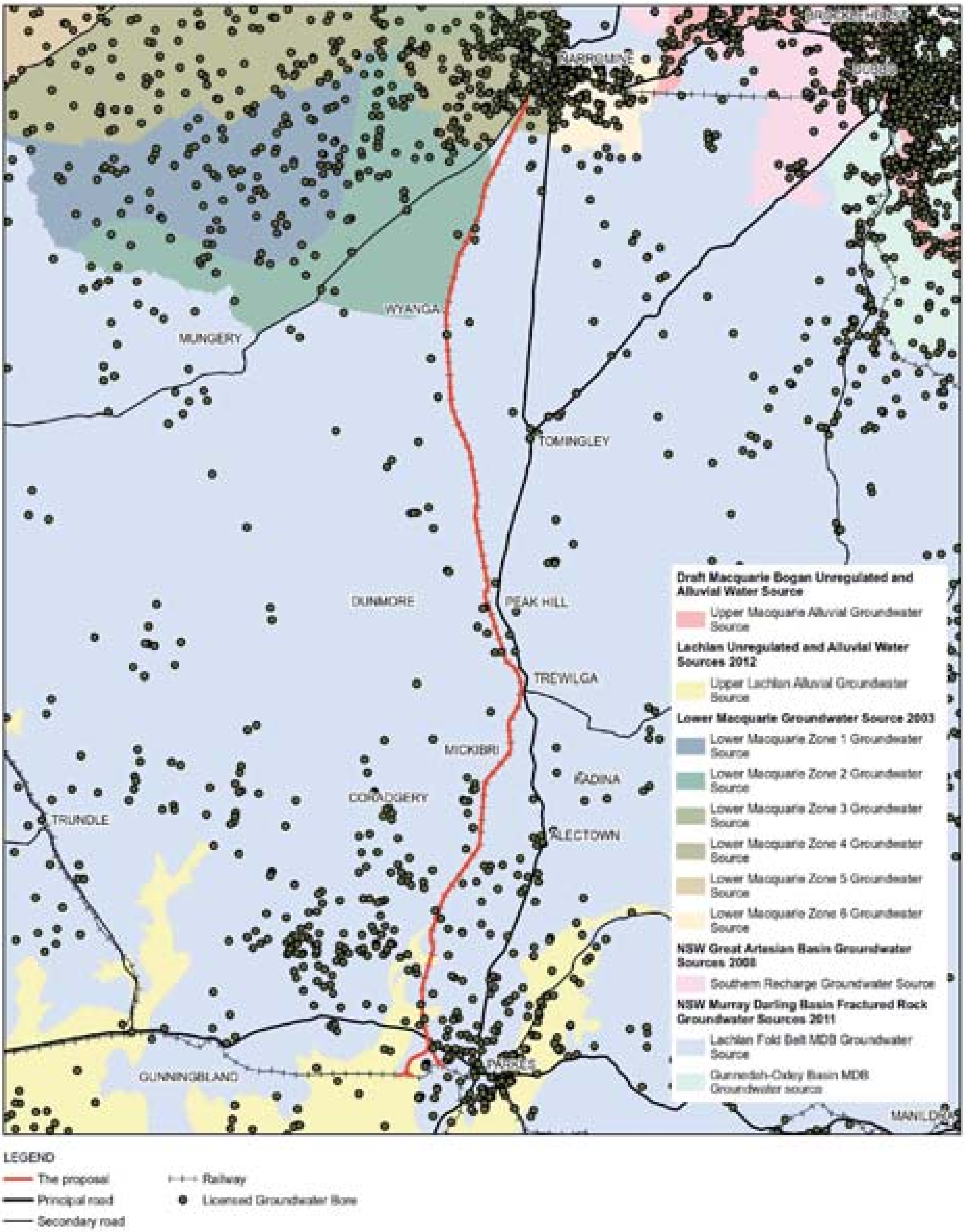
Paper Size A4

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17316
Revision 0
Date 23 Nov 2016

Corridor and Catchment Topography

Figure 3-1



Paper Size A4

Kilometres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17916
Revision 0
Date 23 Nov 2016

Licensed Groundwater Bores

Figure 3-2

3.5 Geology and soils

3.5.1 General

The study area is located generally within the Central Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary aged red silty alluvium over folded and faulted Silurian and Ordovician aged sedimentary and minor metamorphic sequences, which outcrop intermittently along the rail corridor.

Thick reactive brown and grey clay soils are predominantly associated with the near level terrain north of Peak Hill, while moderately thick red and brown sandy and silty clay soils are typically associated with the undulating terrain south of Peak Hill.

3.5.2 Soil groups and characteristics

Soil characteristics within the proposal site have been determined from the eSpade database. The dominant Great Soil Groups along the length of the proposal are shown in Figure 3-3.

Table 3-3 provides a summary of the soil landscape groups along the proposal area while Table 3-4 provides information on dominant soil groups along length of the proposal.

3.5.3 Acid sulfate soils

No acid sulfate soils are expected to be encountered in the proposal site.

3.6 Land uses

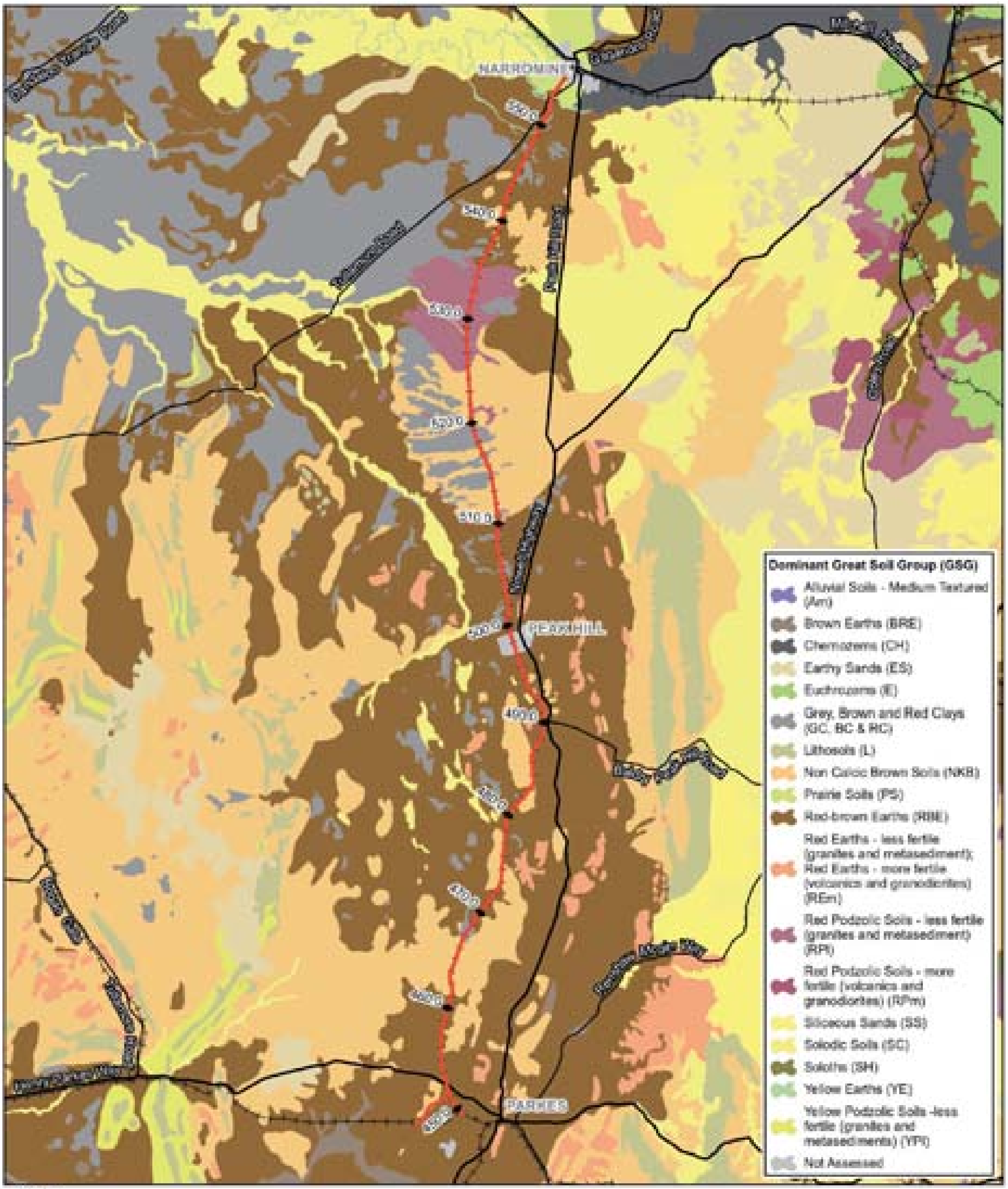
The majority of construction activities for the proposal would occur within the existing rail corridor of the Parkes to Narromine line, with the exception of the Parkes north west connection.

Beyond the rail corridor, the study area and surrounding land is dominated by agricultural industries, with significant cotton, wheat, and livestock industries. These industries have 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 Parkes, Peak Hill and Narromine. There are also some mine and quarry sites within the contributing catchments. The urban, mining and quarrying land uses are well cleared.

Figure 3-4 shows the land uses along the rail corridor along with forestry reserves, conservation reserves and national parks.



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway

Paper Size A4

0 2 4 8 12 16

Kilometres

Map Projection: Transverse Mercator

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

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Soil Landscape

Figure 3-3

Table 3-3 Soil landscape groups

Range Soil Type Occurs	Classification / Profile No.	Location	Soil types	Soil Landscape	Erosion / Salinity
450–455	Parkes	Parkes and Forbes	Shallow to moderately deep (<60 cm), moderately well drained Red Earths, and Red Podzolic Soils on side slopes. Lower slopes have moderately deep (>80 cm) imperfectly drained Red Brown Earths. Narrow drainage lines have deep (>150 cm) poorly drained Brown Solodic Soils.	• Stoniness • Sodicity / dispersibility • Hardsetting surfaces (localised) • Low permeability	• High water erosion hazard • Salinity (localised) • Moderate to high erodibility
450–460	Brolgan Plain	Plains west of Parkes, including Brolgan Plain	Deep (>100 cm) imperfectly drained Red Brown Earths and Non-calcic Brown Soils. Deep (>100 cm) moderately well drained Red Podzolic. Soils and Red Earths also occur on some plains.	• Sodicity / dispersibility • Hardsetting surface (localised) • Flood hazard • Foundation hazard • Seasonal waterlogging (localised)	• Low to moderate erosion hazard • Topsoils have high erodibility • Clay-rich subsoils have moderate erodibility
450–465	Goonumbla	Vicinity of Goonumbla and Cooks Myalls	Shallow (<10 cm) well drained Lithosols and shallow (<50 cm) moderately well drained Red Podozlic Soils occur on crests. Shallow (<50 cm) moderately well drained Red Earths / Euchronsems and Red Podzolic Soils occur on upper and mid-slopes Moderately deep (>80 cm) moderately well drained Non-calcic Brown Soils occur on lower slopes.	• Stoniness • Hardsetting surfaces (localised) • Rock outcrop	• Moderate to high water erosion hazard • Moderate topsoil erodibility • Very low subsoil erodibility
460–480	Cooks Myalls	Between Parkes and Bogan Gate	Soils are moderately deep (>50 cm), moderately well drained Red Podzolic Soils, deep (>100 cm) poorly drained Red Solodic Soils along drainage lines and lower slopes. Shallow to moderately deep (<80 cm) well-drained Terra Rossa Soils, Red Podzolic Soils and Red Earths / calcareous Red Earth intergrades occur on limestone and sandstone/chert/siltstone bedrock. Moderately deep (>60 cm), moderately well drained Non-calcic Brown Soils occur on some slopes. Small areas of gilgai soils.	• Alkalinity (localised) • Sodicity / dispersibility (localised) • Hardsetting surfaces (localised) • Seasonal waterlogging (localised)	• High water erosion hazard • Salinity (localised) • High erodibility (localised)

Table 3-4 Major soil groups

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
465–470	North of Goonumbla	Shallow (<40 cm) imperfectly drained Red Clays occur on flat alluvial plains.	• Low permeability • Seasonal cracking when dry • Low runoff	• High erosion hazard • No salting evident • Moderate soil erodibility
470–480	North of Goonumbla	Shallow (<40 cm) moderately well drained Red Podzolic Soils occur on lower and upper hillslopes.	• Slowly permeable • Hardsetting when dry • Moderate runoff	• Moderate erosion hazard • Moderate soil erodibility • No salting evident
475–485	Between Trewilga and Parkes	Moderately deep (<105 cm) reddish brown sand acts as topsoil on flat topography. Very deep (>170 cm) moderately well drained Red Clay and Red Podzolic Soils occur on flats and hillslope depressions.	• Moderate to high soil erodibility • Permeability varies • Moderate to high runoff	• Very high to high erosion hazard • Minor (<150 cm) active gully erosion • No salting evident
480–490		Shallow (<5 cm) sandy loam topsoils, and shallow (<40 cm) imperfectly drained Red Podzolic Soils occur on upper and lower hillslopes.	• Moderate soil erodibility • Hardsetting when dry • Moderate to high runoff	• High erosion hazard • No salting evident
485–490		Shallow (<20 cm) sandy loam topsoil occur on upper slopes, and silty loam and sandy clay loams occur on lower slopes. Shallow to moderate depth (<60 cm) poorly drained Non-calcic Brown Soils and moderately drained Red Podzolic Soils occur on lower slopes, and moderately well drained Grey-brown Podzolic Soils occur on upper slopes.	• Moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• Slight–moderate erosion hazard • No salting evident
490–500	Between Trewilga and Peak Hill	Moderately shallow (<35 cm) moderately well drained brown clay loam topsoils occur on batters and within gullies. Moderately deep(<80 cm) brown medium to heavy clay Red Podzolic Soils occur on batters and within gullies. On lower slopes, moderate (<50 cm) moderately well drained Non-calcic Brown Soils	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Very high to high erosion hazard on batters and within gullys • Moderate erosion hazard on lower slopes • Moderate (<1.5m) active gully erosion

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
		and moderately deep (<95 cm) Yellow Podzolic Soils.		• No salting evident
500–510	North of Peak Hill	Shallow (<20 cm) topsoil layers of silty clay loam and sandy clay loam. Moderately deep (<90 cm) moderately well drained Non-calcic Brown Soils, and moderate depth (<40 cm) moderately well drained Red and Brown Podzolic Soils occur on hillslopes and flat plains.	• Moderate soil erodibility • Hardsetting when dry • High to moderate runoff on hillslopes • Low runoff on flat plains	• High erosion hazard near Peak Hill (CH 500), moving to moderate erosion hazard • No salting evident
510–520	South west of Tomingley	Shallow (<15 cm) layers of fine sandy loam topsoil. Moderate (<50 cm) layers of moderately well drained Non-calcic Brown Soils and Red Brown Earth.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Slight erosion hazard • No salting evident
510–520	South west of Tomingley	Moderately deep (<70 cm) very poorly drained Grey Clay occurs within depressions (gilgai) on flat plains.	• Moderate soil erodibility • Seasonal cracking • No runoff	• Moderate erosion hazard • No salting evident
520–525	West of Tomingley	Moderately shallow (<40 cm) moderately well drained loamy sand top soils. Moderately deep (<95 cm) moderately well drained Earthy Sands and Red Podzolic Soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate to low runoff	• Earthy sands have high erosion hazard • Moderate erosion hazard for Red Podzolic Soils • No salting evident
525–535	North west of Tomingley	Shallow (<25 cm) poorly drained sandy clay and silty clay loam topsoil on flat plains. Moderately deep (<90 cm) imperfectly drained Yellow Podzolic Soils occur in depressions. Poorly drained deep (<150 cm) brown chromosol and moderately deep (<90 cm) solodic soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • High to moderate runoff	• Solodic soils on flat plains have high erosion hazard • Moderate erosion hazard for Brown Chromosol and Yellow Podzolic Soils • No salting evident
535–545	South of Narromine	Shallow (<30 cm) silty loam topsoil on lower slopes and shallow (<10 cm) clay loam topsoil on flat plains.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
		Moderately deep (<110 cm) moderately well drained Red Brown Earth on lower slopes and flat plains.		
540–550	South of Narromine	Shallow (<10 cm) topsoil layer of poorly drained Red Brown Earth occurring on plains. Deep (<120 cm) layers of moderately well drained Brown Clay and imperfectly drained Grey Clay occur on flat plains and floodplains. Moderately deep (<95 cm) poorly drained Grey Clay occurs in depressions (such as Backwater Cowal).	• High to moderate soil erodibility on flat plains and floodplains • Low soil erodibility in depressions • Hardsetting when dry • Low to moderate runoff	• Slight erosion hazard • No salting evident
550–555	Narromine	Shallow (<28 cm) topsoil layer of silty clay loam occur on flat plains. Moderately deep (<65 cm) imperfectly drained Red Brown Earth and deep (<100 cm) layers of Non-calcic Brown Soils. Drainage of Non-calcic Soils varies from poorly drained to moderately well drained.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident
465–470	North of Goonumbla	Shallow (<40 cm) imperfectly drained Red Clays occur on flat alluvial plains.	• Low permeability • Seasonal cracking when dry • Low runoff	• High erosion hazard • No salting evident • Moderate soil erodibility
470–480	North of Goonumbla	Shallow (<40cm) moderately well drained Red Podzolic Soils occur on lower and upper hillslopes.	• Slowly permeable • Hardsetting when dry • Moderate runoff	• Moderate erosion hazard • Moderate soil erodibility • No salting evident
475–485	Between Trewilga and Parkes	Moderately deep (<105cm) reddish brown sand acts as topsoil on flat topography. Very deep (>170cm) moderately well drained Red Clay and Red Podzolic Soils occur on flats and hillslope depressions.	• Moderate to high soil erodibility • Permeability varies • Moderate to high runoff	• Very high to high erosion hazard • Minor (<150cm) active gully erosion • No salting evident
480–490		Shallow (<5cm) sandy loam topsoils, and shallow (<40cm) imperfectly drained Red Podzolic Soils occur on upper and lower hillslopes.	• Moderate soil erodibility • Hardsetting when dry • Moderate to high runoff	• High erosion hazard • No salting evident

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
485–490		Shallow (<20 cm) sandy loam topsoil occur on upper slopes, and silty loam and sandy clay loams occur on lower slopes. Shallow to moderate depth (<60 cm) poorly drained Non-calcic Brown Soils and moderately drained Red Podzolic Soils occur on lower slopes, and moderately well drained Grey-brown Podzolic Soils occur on upper slopes.	• Moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• Slight to moderate erosion hazard • No salting evident
490–500	Between Trewilga and Peak Hill	Moderately shallow (<35 cm) moderately well drained brown clay loam topsoils occur on batters and within gullies. Moderately deep(<80 cm) brown medium to heavy clay Red Podzolic Soils occur on batters and within gullies. On lower slopes, moderate (<50 cm) moderately well drained Non-calcic Brown Soils and moderately deep (<95 cm) Yellow Podzolic Soils.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Very high to high erosion hazard on batters and within gullys • Moderate erosion hazard on lower slopes • Moderate (<1.5m) active gully erosion • No salting evident
500–510	North of Peak Hill	Shallow (<20 cm) topsoil layers of silty clay loam and sandy clay loam. Moderately deep (<90 cm) moderately well drained Non-calcic Brown Soils, and moderate depth (<40 cm) moderately well drained Red and Brown Podzolic Soils occur on hillslopes and flat plains.	• Moderate soil erodibility • Hardsetting when dry • High to moderate runoff on hillslopes • Low runoff on flat plains	• High erosion hazard near Peak Hill (CH 500), moving to moderate erosion hazard • No salting evident
510–520	South west of Tomingley	Shallow (<15 cm) layers of fine sandy loam topsoil. Moderate (<50 cm) layers of moderately well drained Non-calcic Brown Soils and Red Brown Earth.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate runoff	• Slight erosion hazard • No salting evident
510–520	South west of Tomingley	Moderately deep (<70 cm) very poorly drained Grey Clay occurs within depressions (gilgai) on flat plains.	• Moderate soil erodibility • Seasonal cracking • No runoff	• Moderate erosion hazard • No salting evident
520–525	West of Tomingley	Moderately shallow (<40 cm) moderately well drained loamy sand top soils. Moderately deep (<95 cm) moderately well drained Earthy Sands and Red Podzolic Soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • Moderate to low runoff	• Earthy sands have high erosion hazard

Chainage	Location	Soil types	Soil Characteristics	Erosion / Salinity
				• Moderate erosion hazard for Red Podzolic Soils • No salting evident
525–535	North west of Tomingley	Shallow (<25 cm) poorly drained sandy clay and silty clay loam topsoil on flat plains. Moderately deep (<90 cm) imperfectly drained Yellow Podzolic Soils occur in depressions. Poorly drained deep (<150 cm) brown chromosol and moderately deep (<90 cm) solodic soils occur on flat plains.	• Moderate to high soil erodibility • Hardsetting when dry • High to moderate runoff	• Solodic soils on flat plains have high erosion hazard • Moderate erosion hazard for Brown Chromosol and Yellow Podzolic Soils • No salting evident
535–545	South of Narromine	Shallow (<30 cm) silty loam topsoil on lower slopes and shallow (<10 cm) clay loam topsoil on flat plains. Moderately deep (<110 cm) moderately well drained Red Brown Earth on lower slopes and flat plains.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident
540–550	South of Narromine	Shallow (<10 cm) topsoil layer of poorly drained Red Brown Earth occurring on plains. Deep (<120 cm) layers of moderately well drained Brown Clay and imperfectly drained Grey Clay occur on flat plains and floodplains. Moderately deep (<95 cm) poorly drained Grey Clay occurs in depressions (such as Backwater Cowal).	• High to moderate soil erodibility on flat plains and floodplains • Low soil erodibility in depressions • Hardsetting when dry • Low to moderate runoff	• Slight erosion hazard • No salting evident
550–555	Narromine	Shallow (<28 cm) topsoil layer of silty clay loam occur on flat plains. Moderately deep (<65 cm) imperfectly drained Red Brown Earth and deep (<100 cm) layers of Non-calcic Brown Soils. Drainage of Non-calcic Soils varies from poorly drained to moderately well drained.	• High to moderate soil erodibility • Hardsetting when dry • Low to moderate runoff	• High erosion hazard • No salting evident

LEGEND

- The proposal
- Local Government Area
- Principal road
- Secondary road
- Railway
- Watercourse
- Forestry reserve
- Conservation reserve

Paper Size A4

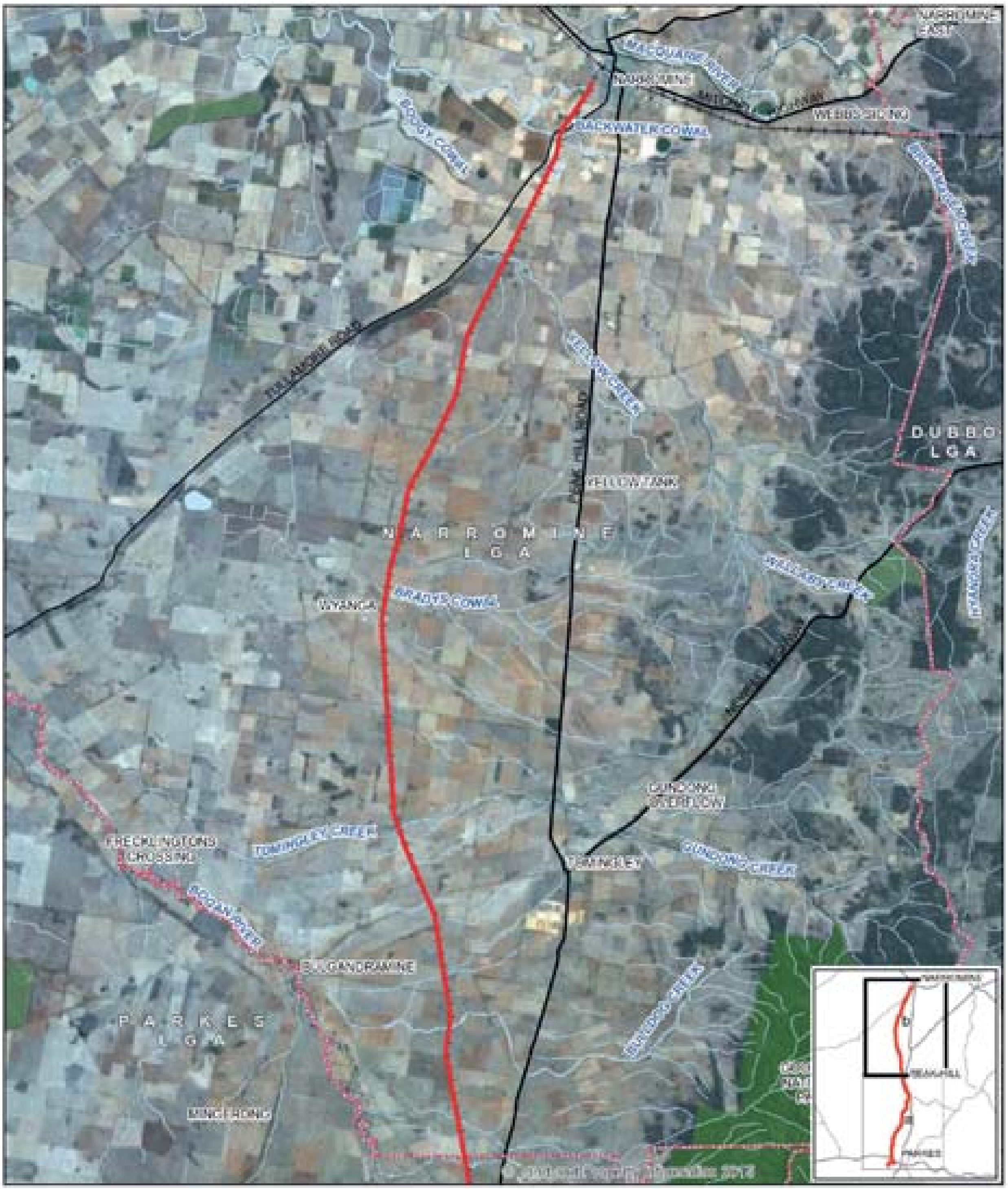
Kilometres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17016
Revision 0
Date 23 Nov 2016

Land Use - Sheet 1

Figure 3-4a



LEGEND

- The proposal
- Local Government Area
- Principal road
- Secondary road
- Railway
- Watercourse
- Forestry reserve
- Conservation reserve

Paper Size A4

0 1 2 4 6 8

Kilometres

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number 22-17916
Revision 0
Date 23 Nov 2016

Land Use - Sheet 2

Figure 3-4b

3.7 Watercourses

3.7.1 Major river and basin systems

The proposal is located within the major water catchments of the Lachlan River Basin and the Macquarie-Bogan River Basin (formed by the Macquarie and the Bogan rivers).

The Lachlan River starts in the east as a chain of lakes formed by the confluence of the Hannans Creek and Mutmutbilly Creek catchments. Heading west, the river system passes south of Parkes and the proposed rail corridor. Ridgey Creek, one kilometre east of the proposal, is the closest of the significant Lachlan River tributaries. The Lachlan River, while a tributary of the Murrumbidgee River and a contributor to the Murray-Darling Basin (MDB), effectively terminates in the west as a large, expansive system of wetlands known as the Great Cumbung Swamp. The Lachlan River Basin therefore connects only to the MDB during periods of major flood (NSW Fisheries Scientific Committee 2005).

The Macquarie River starts in the east at the confluence of the Cambells River and Davies Creek, within Bathurst and travels north west past the towns of Wellington, Dubbo and Narromine (passing 900 metres north of the proposal site) to the Macquarie Marshes. The Macquarie Marshes drain via the lower Barwon River into the Darling River and the broader MDB. The waters of the Macquarie River and its tributaries are impounded for flood control and irrigation by Burrendong Dam, a large reservoir with a capacity of 1,188 gigalitres near Wellington and the Cudgegong Dam.

The Bogan River lies within the Macquarie-Bogan River Basin and is located west of the proposal, making it a receiving environment rather than a potential contributor to flooding. The Bogan River drains via the Lower Barwon River into the Darling River and the broader MDB.

3.7.2 Watercourses

Surface water within the study area is predominately comprised of ephemeral watercourses, excluding the major perennial river systems identified in Section 3.7.1. This is due to the relative size of the contributing catchment areas, the regional rainfall pattern, and the lack of base flow. Minor rivers (those less than 1,000 square kilometres along the existing rail corridor include:

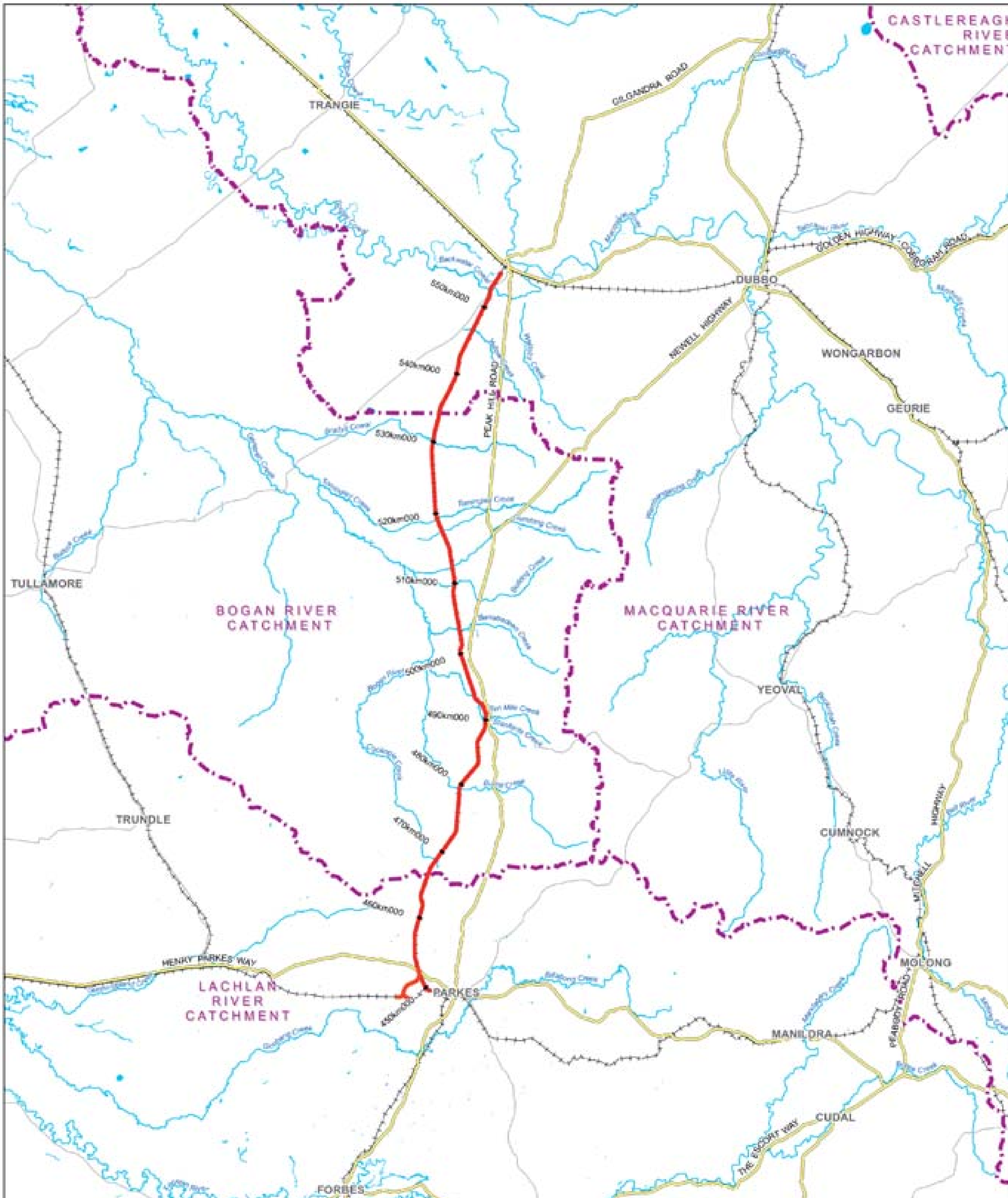
- Burrill Creek
- Stanfords creek
- Ten Mile Creek
- Barrabadeen Creek
- Bulldog Creek
- Gundong Creek
- Tomingley Creek
- Bradys Cowal
- Yellow Creek

Figure 3-5 shows the locations of the named watercourses that are crossed by the proposal.

Table 3-5 provides details on the main watercourses 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).

The watercourses assessed include all named watercourses and all un-named watercourses with stream order greater than third order.



LEGEND

- Parkes to Narromine Rail Line
- Major Road
- Secondary Road
- Railway
- Watercourse
- Waterbody
- Major river catchment

Paper Size A3

0 2,500 5,000 10,000 15,000 20,000

Metres

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

Australian Rail Track Corporation
Inland Rail - Parkes to Narromine

Job Number	22-17916
Revision	0
Date	23 Nov 2016

Major Watercourses

Figure 3-5

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

Table 3-5 Details of third order and higher watercourses crossed by the proposal

Catchment	Chainage (km)	Watercourse	Flow regime	Stream order	River style	Condition	Comments
Lachlan	455.2	Un-named	Ephemeral	3	Valley fill	Poor	Stable although modified to flow within floodway.
Lachlan	461.15	Un-named	Ephemeral	3	Channelised fill	Moderate	Stable, grass lined trapezoidal channel.
Bogan	472.05	Un-named	Ephemeral	3	Channelised fill	Moderate	Stable, grass lined trapezoidal channel.
Bogan	478.25	Un-named	Ephemeral	3	Valley fill	Moderate	Some channelisation downstream.
Bogan	479.3	Burrill Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable channel with near permanent ponds.
Bogan	489.8	Stanfords Creek	Ephemeral	4	Channelised fill	Poor	Incised channel with minor levels of bank erosion downstream.
Bogan	490.55	Ten Mile Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Stable, grass lined trapezoidal channel.
Bogan	503.6	Barrabadeen Creek	Ephemeral	5	Low sinuosity fine grained	Poor	Incised system with unvegetated upper banks, although relatively stable. Near permanent pools.
Bogan	509.65	Bulldog Creek	Ephemeral	4	Valley fill	Moderate	Large pool immediately downstream of existing rail corridor. Mound to the south indicates the pool was likely excavated.
Bogan	512.1	Gundong Creek	Ephemeral	4	Channelised fill	Poor	Excavated straight channel downstream with moderate levels of bank erosion. Upstream valley fill in moderate condition.
Bogan	517.43	Unnamed	Ephemeral	4	Valley fill	Poor	Relatively stable, minimal vegetation and watercourse shape converts to floodplain downstream of culvert
Bogan	519.2	Tomingley Creek	Ephemeral	4	Valley fill	Good	Stable, well vegetated creek in narrow valley set within a Gilgai landscape.
Bogan	529.8	Brady's Cowal	Ephemeral	4	Low sinuosity fine grained	Moderate	Stable, grassed channel. Large excavated pond on downstream side of existing rail corridor.

Catchment	Chainage (km)	Watercourse	Flow regime	Stream order	River style	Condition	Comments
Macquarie	546.55	Yellow Creek	Ephemeral	3	Valley fill	Moderate	Stable, well vegetated system. Online dams.
Macquarie	552.65	Backwater Cowal	Ephemeral	5	Valley fill	Moderate	Stable, broad depression – infilled paleo-channel – well vegetated with ground cover species. Receives flow from Wallaby Creek catchment and flood flows from the Macquarie River.

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 as a result 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.

3.7.3 Watercourses at crossings of the proposal

An inspection of the watercourses that would be crossed by the proposal was undertaken. The form of the watercourses at these crossing locations is discussed in more detail in Table 3-5.

3.8 Groundwater sharing plan

The proposal lies within the following Water Sharing Plans:

- The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources (NSW Government 2012a). This commenced in September 2012 and regulates the interception and extraction of water from unregulated rivers and alluvium within the defined Water Sharing Plan area. The proposal lies within the Upper Lachlan Alluvial Groundwater Source of this Water Sharing Plan as shown in Figure 3-2.
- The Water Sharing Plan for the NSW Macquarie-Darling Basin Groundwater Source (NSW Government 2011). This commenced in January 2012 and regulates the interception and extraction of water from fractured rock groundwater sources and from unmapped alluvial sediments that overlay outcropping fractured rock within the defined Water Sharing Plan area. The proposal lies within the Lachlan Fold Belt Macquarie-Darling Basin Groundwater Source of this Water Sharing Plan as shown in Figure 3-2.
- The Water Sharing Plan for the Lower Macquarie Groundwater Source (NSW Government 2003). This commenced in October 2006 and is due for extension/replacement in July 2017 and is currently undergoing a formal review (DPI – Water 2016b). This Water Sharing Plan regulates the interception and extraction of water from the alluvium and Great Artesian Basin within the defined Water Sharing Plan area. The proposal lies within the Lower Macquarie Zone 4 groundwater source and lies on the boundary of the Lower Macquarie Zone 2 groundwater source of this Water Sharing Plan as also shown in Figure 3-2.

- The Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Government 2012b). This commenced in October 2012 and regulates the interception and extraction of water from unregulated rivers and alluvium within the defined Water Sharing Plan area.

3.9 Sensitive ecological areas

Wetlands

The Macquarie Marshes are on the Macquarie River, between Warren and Carinda. The upstream end is about 100 kilometres downstream of Narromine. They are one of the State's most sensitive inland watercourses.

The marshes have been subjected to extensive hydrological and ecological studies over the last few decades. Some of the more recent studies have included MDBA (2012) and Hogendyk (2007). These studies and the national importance of the wetlands have led to the development of an adaptive management plan for the area (DECCW 2010) that provides a synthesis of information from prior projects and action plans.

Vegetation

A detailed ecologic assessment of the proposal route is reported in the *Aquatic Ecology Assessment* (Umwelt 2017) and *Biodiversity Assessment Report* (Umwelt 2017b). The following is extracted from those reports

Umwelt (2017) indicates that Burrill Creek includes stands of native sedges and river red gums, whilst Backwater Cowal consists of cleared / non-native vegetation on the banks with weed dominated vegetation characterising both the bed and banks.

Aquatic ecology

Key areas of fish habitat have previously been identified and mapped within local government areas traversed by the proposal. The habitat areas, mapped by DPI (undated a, undated b) show the extents of the respective habitat areas.

Goobang Creek, Ridgey Creek, Burrill Creek, Ten Mile Creek, Barrabadeen Creek, Bogan River Bulldog Creek, Gundong Creek, Tomingley Creek, Fiddlers Creek, Bradys Cowal and the Macquarie River have all been identified as being between Class 2 (moderate) and Class 4 (unlikely) *key fish habitat* (Umwelt 2017), in accordance with the *Policy and guidelines for fish habitat conservation and managemen*t (DPI 2013).

Groundwater dependent ecosystems

A review of the Australian Government's National Atlas of Groundwater Dependent Ecosystems identified the watercourses and riparian vegetation either side of the proposal site along Burrill Creek, Tomingley Creek and Wallaby Creek as potentially including groundwater dependent ecosystems in the study area.

A detailed evaluation of the ecology of the area and ecological impacts is being provided in a separate report (Umwelt, 2017).

3.10 Water demands

Estimated water demands for construction of the proposal have been provided by ARTC as being in the order of 75 to 100 ML, or about 60 ML per year, for earthworks and dust control. Likely water sources have been provided as being, subject to the gaining of applicable approvals and access agreements and there being sufficient water at each site:

- Parkes Shire Council – 5 ML.
- Private bores near chainages 708, 716, 724, 738, 748 and 778 – 3 ML per bore. Each bore is within 5 km of the proposal alignment.
- Parkes North and Peak Hill mines – 10 to 15 ML for each mine.
- Private dams near chainages 730, 782 and 798 – 10 ML at each site.
- Macquarie River – 10 ML.
- Narromine Shire Council – 5 ML.

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

4. Existing environment

4.1 Regional context

4.1.1 Catchments

The study area includes numerous watercourses within portions of the Lachlan River and Macquarie-Bogan River basins. Both river basins eventually drain to the Murray River.

Watercourse catchments crossed by the proposal range in size from small unnamed tributaries of less than a square kilometre to large rivers. These large river catchments (regional catchments) extend in some instances to the Great Dividing Range and encompass large areas.

As discussed in Chapter 3, land use within the catchment areas has undergone significant change, with a progressive move to more intensive cropping, general development and construction of major water storage dams.

Catchments for the major river systems (Lachlan River and Macquarie River) extend east to the Great Dividing Range while most of the small catchments draining under the rail line are located nearer to the rail corridor and have a modest topographic relief.

4.1.2 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 4-1, which provides a diagrammatic representation of the years with complete rainfall records for Narromine between 1886 and 2013. The minimum annual rainfall recorded in that period was 217 millimetres while the maximum was about 1,386 millimetres and the average was about 527 millimetres. As shown in Figure 4-1 there have been a number of periods with consecutive years of below average rainfall.

The Narromine site has reported a relatively uniform monthly distribution of the mean rainfalls varying from a high of 56.7 millimetres in January to a low of 36.3 millimetres in September.

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.

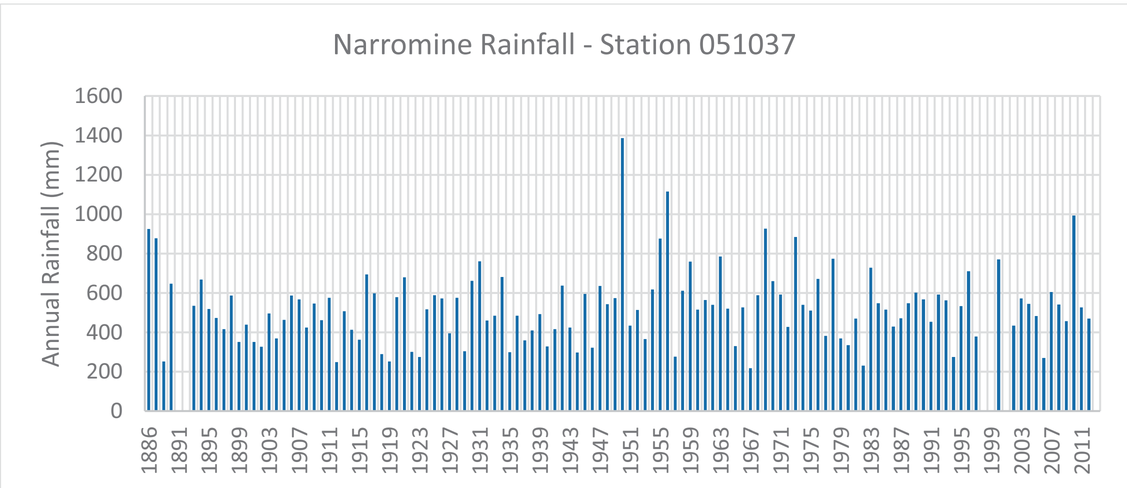


Figure 4-1 Narromine rainfall

4.1.3 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 fall from Parkes to Narromine from about 330 metres AHD to about 240 metres AHD with regional valleys located along the corridor. The steepest portion of the rail corridor occurs just after the Mickibiri Bridge with a one per cent longitudinal grade, which indicates the generally flat nature of the locality.

Most catchments include cleared areas used for agriculture, grazing and rural residential land uses. Urbanised areas occupy a minor proportion of the overall catchment area, and are mostly located in the vicinity of Parkes, Peak Hill and Narromine.

4.2 Hydrology

4.2.1 Surface water

The major rivers north of Narromine – the Macquarie and Bogan rivers – are perennial watercourses. The Lachlan River, south of Parkes, is also a perennial watercourse. 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 Parkes to Narromine rail corridor.

4.2.2 Groundwater

The results of a bore search and a review of groundwater sharing plans are summarised in Section 3.9. These results indicate that:

- Groundwater sources in the proposal site include alluvial sediments near Narromine, associated with the Macquarie River.
- The alluvial sediments extend up to 80 metres below ground level.
- Alluvial groundwater associated with the Macquarie 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.
- To the south of Narromine, the proposal site is underlain by fractured rock associated with the Lachlan Fold Belt. Groundwater bores intercepting the fractured siltstone and sandstone rock aquifer are deeper than 70 metres below ground level. Groundwater in the fractured rock aquifer is not expected to be present near the ground surface.

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.

4.2.3 Groundwater hydrology

Within the alluvial sediments in the vicinity of Narromine, associated with the Macquarie River, flow direction in the alluvial aquifer would correspond with the flow direction in the Macquarie River; that is, east to west in the vicinity of 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.

Within the fractured sandstone and siltstone aquifer of the Lachlan Fold Belt groundwater, flow directions are expected to correspond with the dip of the strata and surface elevation from east to west and south to north. Based on typical hydraulic conductivities for sandstone and fractured or weathered rock (as reported by Kruseman and de Ridder 1994), the hydraulic conductivity of the sandstone and siltstone of the Lachlan Fold Belt may vary from 0.001 to one metre per day.

4.3 Flooding

4.3.1 Culvert locations and levels

Proposed culverts and underbridges would be located as close as practical to the existing locations of culverts and underbridges, which are shown in Figure 2-1.

4.3.2 Flood level analysis

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 – Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017).

4.3.3 Adjacent land impacts

The predicted flood levels for the existing conditions were examined for a range of design events from the 50 per cent AEP through to 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.

Upstream flood effects

Flood levels

Flood levels for the existing conditions were assessed using the method summarised in Section 4.3.2.

The assessment indicated that the existing rail line overtops at several locations between Parkes and Narromine 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 flooded areas upstream of the proposal have the potential to impact the surface water quality through the mobilisation of pollutants. Changes to flood affected 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 4-1 for local catchment flooding for flood events up to the Probable Maximum Flood (PMF). Table 4-1 shows that the area of inundation would decrease for events up to and including the two per cent local catchment event, while the area of inundation would increase for events greater than this.

Table 4-1 Areas of upstream flooding

Design event (% AEP)	Area of inundation (ha)		
	Existing	Design	Change (design – existing)
50	355.9	242.0	-113.9 (-32%)
20	480.1	363.9	-116.1 (-24%)
10	553.3	454.8	-98.5 (-18%)
5	648.2	579.9	-68.3 (-11%)
2	840.0	821.9	-18.1 (-2%)
1	938.0	1,036.5	+98.5 (+11%)
0.5	1,044.8	1,146.2	+101.3 (+10%)
0.2	1,146.5	1,283.3	+136.8 (+12%)
PMF	2,720.8	3,162.1	+441.3 (+16%)

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 generally be less than two metres per second except in very 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.

Downstream flood effects

Flood levels

Design flood levels downstream of the rail corridor have not been assessed, as other impacts such as conditions further downstream of the proposal site would affect the flood levels.

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, but these are expected to be generally confined to within the existing rail corridor.

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.

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.

4.4 Water quality

4.4.1 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. Table 4-2 indicates that in both the Lachlan and Macquarie-Bogan River catchments the water quality was relatively poor quality.

The assessment considered data from 15 sites in the Lachlan River catchment and from 17 sites in the Macquarie Bogan river catchment. Some sites in the Macquarie-Bogan river system did not have data for all parameters.

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 in 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 data was collected as part of this assessment due to the ephemeral nature of the watercourses that cross the proposal site.

Table 4-2 Assessed water quality

Parameter	Lachlan River catchment	Macquarie-Bogan River catchment
Turbidity	Fair 31% of samples exceeded guideline values	Good 76% of samples complied with ANZECC / ARMCAM guideline values
Salinity	Fair 50% of samples exceeded guideline values	Poor Median values at sites ranged from 92–1,140 μS/cm
pH	Good 85% of samples within catchment were within guideline values	Fair A significant variability in the observations was observed.
Total Nitrogen	Very poor 96% of samples did not meet guideline values Median values at sites ranged from 456–860 μg/L	Very poor Median values at sites ranged from 370–1,200 μg/L
Total Phosphorus	Poor 72% of samples did not meet guideline values Median values at sites ranged from 12–83 μg/L	Very poor Median values at sites ranged from 21–154 μg/L

4.4.2 Macquarie River

While limited, electrical conductivity data was obtained for the Macquarie River between 27 November 1998 and 26 September 2009 from the NSW Government Waterinfo website. The data shows the electrical conductivity at Dubbo (station 421001) as varying between 120 and 860 micro-siemens per centimetre (μS/cm) corrected for 25^{o} Celsius.

5. Water quality risks from proposal

5.1 Background

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:

- Nationally Important Wetlands.
- National parks, nature reserves and State conservations areas – an example being the Macquarie Marshes Nature Reserve downstream of Warren, which is also listed as a Ramsar Wetlands site.
- 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.

The *ARTC Inland Rail – Parkes to Narromine Aquatic Ecology Assessment* (Umwelt 2017) details the threatened ecological communities and key fish habitats relevant to the proposal. The Ramsar listed Macquarie Marshes is an important ecological site located about 200 kilometres downstream of Narromine, within the Macquarie-Bogan River catchment. In addition, the Lachlan River catchment contain the following environmental values (DPI (Water), 2017):

- Nine wetlands which are featured in the Directory of Important Wetlands In Australia, including Lake Cowal, Lake Brewster, Booligal wetlands and Great Cumbung Swamp (Lachlan River catchment). None of these wetlands is located within 100 kilometres of the proposal site.

5.2 Water quality risks

Table 5-1 identifies the main construction phase risks that are likely to affect 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 downstream watercourses 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
Oils and grease exported off proposal area	• Potential transport of spilt oils and grease off site into downstream watercourses or the groundwater	• Undertake plant maintenance and refuelling activities within appropriately bunded areas in construction compounds • Undertake vehicle and equipment maintenance in accordance with manufacturers 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
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 • As part of routine train inspections and maintenance specifically consider inspections for wear or damage to elements that contain any potentially contaminating material
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 as a result 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

5.2.1 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 downstream watercourses, 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 downstream watercourses at locations where water is extracted for any potable purpose
- Increased sediment loads from discharge of sediment-laden water from dewatering of excavations.
- Increased levels of nutrients, metals and other pollutants transported via sediment to downstream watercourses or via discharge of water to watercourses.
- Chemicals, oils, grease and petroleum hydrocarbon spills from construction machinery directly polluting downstream watercourses.
- Increased levels of litter from construction activities polluting downstream watercourses.
- 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 *ARTC Inland Rail – Parkes to Narromine Hydrology and Flooding Assessment* (GHD 2017) can impact 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 and bridges, 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 3.5).

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, 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 downstream watercourse 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 4.2.2 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. 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.

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 from unpaved surfaces.
- 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 downstream watercourses 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.

5.2.2 Water quality objectives and existing water quality

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 leaks and spills during construction and operation.

The water quality objectives and their relevance to the proposal are defined in Table 2-2 for the Lachlan and Macquarie-Bogan river systems. Objectives are summarised in Table 5-3 for those pollutants that the proposal may introduce into the water cycle. The objectives are based upon the default trigger values for chemical and physical trigger values for the protection of aquatic ecosystems in slightly disturbed river ecosystems in south eastern Australia (ANZECC / ARMCANZ 2000).

Table 5-3 Selected water quality objectives

Water quality parameter	Trigger value
Turbidity	6-50 NTU
Total nitrogen	50 μg/L
Total phosphorous	5 μg/L
Dissolved oxygen (per cent saturation)	85–110% saturation
Electrical conductivity	125–2,200 (μS/cm)
pH	6.5–8.0
Oils and petroleum hydrocarbons	Insufficient data to give trigger value although the EPL is likely to require no visible oils or sheen in discharge water

As described in Section 4.4 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 2-2. The poor quality is likely to reflect existing soil conditions and agricultural land use practices (described in sections 3.5 and 3.6).

The majority of watercourses in the study area are ephemeral and agricultural land uses dominate the study area. Therefore, it is considered unlikely that construction and operation of the proposal would have a significant influence on water quality in surrounding watercourses.

However, as described in Table 2-2, the proposal would be constructed and operated in accordance with the relevant EPLs. This would mean that any discharge water would meet the water quality objectives provided in Table 2-2 and would be of better quality than that within the surrounding watercourses.

Construction and operation would also be undertaken in accordance with the management measures provided in sections 5 and 6, which would minimise the potential for the proposal to reduce the quality of water in 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 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. This would have a beneficial impact on water quality in the study area, with the quality of water more likely to meet the relevant objectives. Further details of the beneficial impacts associated with the proposed design control measures is provided in section 6.

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 flood free for the predicted 100 year ARI local catchment flood level (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 at least half of the potential flood events, when compared to the existing conditions, hence decreasing the potential for mobilisation of pollutants (refer to section 4.3.3).

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 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.

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 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 watercourses immediately downstream of some culverts to increased flow rates, flow volumes and flow velocities. This would occur when a replacement culvert locally increases the velocity relative to that for the existing culvert due to its more efficient conveyance of water, or where the replacement culvert is wider than the existing culvert. This effect would be localised and would only occur at a small number of culverts due to the proposed “like for like” replacement of culverts. The rock energy dissipation layer discussed in section 6.1.5 would reduce the velocity immediately downstream of these culverts, thereby mitigating downstream impacts.

Since the rail is not intended to overtop (except at a minimal number of level crossing locations), there will be an increase in the flow volume passing through each culvert for flood events, relative to that which would occur for the same rainfall event under existing conditions. These effects would occur because of:

- A 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 peak runoff rate. This effect directs an increased total volume of water through the collective group of culverts.
- An increased flooding level upstream, 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. However, there would be a greater amount of flow passing along the relatively small incised watercourses downstream of culverts and this could lead to erosion of those watercourses.

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 against water quality objectives

The assessment has indicated a residual erosion risk at about 12 culvert locations (of the 145 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.

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

6.1.7 Removed culverts

The concept design has allowed for the replacement of all existing culverts.

A very limited number of the existing culverts are relatedly new and comprise reinforced concrete box culvert units (RCBC). Should it be possible during the construction of the proposal to recover any of the RCBCs in a sound condition they would be stored for potential reuse.

Some of the existing culverts comprise segments of reinforced concrete pipes or corrugated steel pipes. Should any segments of these culverts be recovered in a sound condition they would be stored for potential reuse.

Benefits

This measure would potentially provide some waste minimisation through the reuse of any recovered sound RCBCs or lengths of pipes from the existing culverts.

Residual impacts of measure against water quality objectives

This measure would only have a minimal benefit on the water quality objectives.

6.1.8 Precast culvert segments

It is proposed to construct culverts using pre-cast concrete segments where practical.

Benefits

This measure would:

- Reduce the construction time undertaken on and over ephemeral and perennial flowing waterbodies and, hence, reduce both the potential for spills and disturbance of the watercourses, and floods impacting on construction activities.
- Minimise the number of concrete pours at each site.

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 6.2.1).

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 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 and culvert 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.

Benefits

These measures would:

- Provide broad environmental benefits.
- Reduce the potential for litter to be transported off site by water in an uncontrolled manner.

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.

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
- 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 project area. 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 with the objectives of not adversely impacting the water quality in the watercourses.

6.2.5 Vehicle washdown

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 compounds would meet the criteria outlined in section 6.2.6.

All wastewater from vehicle washdown areas 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 2-2 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

The location of these compounds 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 would minimise the probability of the construction compounds being located in areas that could potentially flood and hence minimise the probability of the construction compounds 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 detect immediately 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 during construction. Instead, an opportunistic event-based sampling program is recommended.

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 2-2 and Table 5-3.

It is recommended that the objective for water quality is to cause no net change to receiving watercourses quality because of construction or operation of the proposal.

7.1.2 Sampling sites and regime

Sampling sites would be selected based on the agreed objectives. Potential locations include any permanent 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 because 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.

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	Construction Phase
pH	Yes, when flow is occurring
Total Suspended Solids (TSS)	Yes, when flow is occurring
Oils and grease	Yes, when flow is occurring
Electrical conductivity (EC)	Yes, when flow is occurring
Dissolved Oxygen (DO)	Yes, when flow is occurring
Total Phosphorous (TP)	-
Total Nitrogen (TN)	-

8. Conclusions

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 effects 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 a CEMP 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.
- 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 construction compounds and tracks that may affect the protection of the downstream water quality.

8.3 Operational life of the proposal

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

- Controlling train speed not to 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.

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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

Access Licence Category	No. of WAL's	Total Share Component (ML or units)	Water made Available (ML)	Usage YTD (ML)
Macquarie Bogan Unregulated and Alluvial Water Sources 2012				
Backwater Boggy Cowal Water Source				
Domestic and stock	1	6	6	0
Domestic and stock [stock]	3	12	16	0
Unregulated river	11	2609	2609	0
Upper Bogan River Water Source				
Domestic and stock	6	36	42	0
Domestic and stock [stock]	4	16	16	0
Domestic and stock [town water supply]	2	32	32	0
Unregulated river	13	1463	1463	0
Unregulated river [special additional high flow]	1	182	182	0
Lachlan Unregulated and Alluvial Water Sources 2012				
Goobang and Billabong Creeks Water Source				
Domestic and stock	3	8	8	0
Domestic and stock [domestic]	1	2	2	0
Domestic and stock [stock]	2	8	8	0
Local water utility	1	1500	1500	0
Unregulated river	14	2200	2200	0

Note:

WAL: Water Access Licence

YTD: Year to date

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