TECHNICAL REPORT

3

Flooding and hydrology assessment

PART 1 OF 12

Main Report

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

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

TECHNICAL REPORT

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NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

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

ARTC Inland Rail

Narromine to Narrabri Project

Flooding and Hydrology Assessment

Technical Report 3

2-0001-250-EAP-00-RP-0010

Table of contents

Table index

Figure index

Appendices

Executive summary

The proposal

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

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

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

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

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

This report

This Flooding and Hydrology Assessment has been prepared on behalf of ARTC for the proposal to support the environmental impact statement (EIS) for the proposal and responds to the Secretary's Environmental Assessment Requirements (SEARs) for water - flooding.

The assessment presented in this report has included a review of relevant legislation, consideration of the existing conditions, an impact assessment to determine the significance of hydrology, geomorphology and flooding impacts as a direct result of the construction and operation of the proposal, and a cumulative impact assessment. Recommended mitigation and management measures have been identified in response to the impact assessment findings.

In accordance with the SEARs, extensive consultation has been undertaken and is ongoing with landowners, the broader community, councils, State Government agencies and Narrabri Floodplain Risk Management Committee. As relevant, feedback from this consultation was used to inform and validate the flood models. ARTC has and will continue to consult with all relevant stakeholders in order to mitigate flooding and hydrology impacts.

The findings in this report have also been independently peer reviewed by BMT, and the peer review is provided in Appendix B to this report. The independent review found that generally the hydrological modelling undertaken for the proposal is consistent with the relevant guidelines and is appropriate for the reference design phase of the proposal. Recommendations have been provided in relation to refinements of the hydrological and hydraulics models and these would be undertaken during detailed design.

Existing flooding and hydrology context

The proposal site is located within the major regional water catchments of the Macquarie River Basin, Castlereagh River Basin, and Namoi River Basin, all of which are located within the Murray-Darling Basin. The majority of watercourses crossed by the proposal comprise minor watercourses with non-perennial (ephemeral / intermittent) flow conditions. Only two major perennial watercourses (Macquarie River and Namoi River) are intersected by the proposal.

Existing flood behaviour across the study area varies considerably according to the size of waterway and contributing catchment area. Flooding of the Macquarie River and Namoi River spills onto the floodplains affecting the majority of the Narromine and Narrabri townships respectively, with durations of flooding typically a few days. While flooding in some smaller, unnamed tributaries, on the other hand, is typically confined to the channels and may last less than a few hours.

There are about 6,110 buildings within the study area subject to above floor flooding in the 1% Annual Exceedance Probability (AEP) event. 3,508 of those buildings are located within Narrabri followed by buildings (2,250) located at Narromine. Five highways within the study area are affected by flooding. The Mitchell Highway, Newell Highway and Oxley Highway are affected most frequently, being inundated in the 20% AEP event and greater. All the existing rail lines located within the study area are subject to flooding in the 20% AEP event and greater, except for the Main Western Railway (Dubbo to Narromine and Narromine to Cobar Lines) and the Narrabri West Walgett Railway. Cropping areas are the predominant land use inundated within the study area, followed by grazing areas, and forested areas.

The majority of watercourses within the study area have a moderate geomorphic condition, with localised degradation of river character and behaviour. Patchy vegetation coverage contributes to some localised accelerated erosion. A number of watercourses are in poor geomorphic condition where reaches are typically degraded through intense land use and vegetation removal and significant erosion of the bed and banks. Watercourses in good geomorphic condition where the river character and behaviour is similar to the pre-development state include the Macquarie River, Ewenmar Creek and Tinegie Creek.

Impacts from the proposal during construction

Without the implementation of appropriate management measures, the inundation of the construction sites by floodwater has the potential to:

- cause damage to the construction works and delays in construction programming
- pose a safety risk to construction workers
- detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- obstruct the passage of floodwater and overland flow through the provision of temporary measures such as site compounds and stockpiles, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint.

Flood modelling of the construction phase was carried out to assess flood impacts. While the findings of this initial assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be carried out during detailed design, as layouts and construction staging strategies are further developed. The location and layout of construction work sites and compounds would be prepared with consideration of overland flow paths, avoiding flood liable land where practicable to avoid detrimental impacts.

It should also be noted that all construction infrastructure is temporary, and the assessment should be read in context of the likelihood of a flood of a given AEP occurring during the construction period. In addition, given the short duration of construction relative to the operational life of the proposal, these impacts should be considered in context of the predicted operational impacts.

The construction of the proposal has the potential to impact on the geomorphological condition and stability of the waterways. The activities which pose the greatest risk and could result in channel and floodplain instabilities are:

- Instream structures – direct disturbance to bed and banks of the waterway and its floodplain, hydraulic changes associated with flow through instream structures increase risk of erosion and sedimentation.
- Vegetation removal – vegetation removal will reduce hydraulic roughness and resistance of surfaces to scour, thereby increasing the risk of erosion and sedimentation.
- Construction of access roads – where orientated parallel to direction of in-channel or out of channel floodplain flows, these will tend to function as preferred flow paths, potentially triggering further incision and migration of flow paths away from their existing alignment.

The key activities during construction that can directly or indirectly result in channel and floodplain instabilities include:

- Construction of waterway crossings – the construction of waterway crossings comprises of culverts and bridges, both of which can require instream works. Piling is required at the larger bridge structures crossing the Macquarie River and Naomi River/Narrabri Creek which can result in moderate impact to substrates due to disturbance. Additionally, installation of culverts would require some bed levelling and instream disturbance of substrates.
- Construction of railway line, access and haulage roads – clearing of vegetation and soil compaction during construction of these features and from movement of heavy machinery changes the roughness and resistance of surfaces, potentially triggering erosion and migration of flow paths.

Impacts from the proposal during operation

The operational phase of the proposal would result in some minor changes to existing flood behaviour that have the potential to impact flooding to existing buildings, roads, railways, and agricultural cropping and grazing areas.

Afflux upstream of the proposal is typically between 0.05 to 0.2 metres, while localised increases in flood levels immediately downstream of drainage structures typically range between about 0.05 to 0.1 metres. Adverse changes in flood hazard are typically constrained to areas immediately adjacent to the operational footprint, and changes in duration of flooding are typically negligible.

The impact of the proposal on flooding to existing buildings is most apparent at Narromine and Narrabri. There are 51 buildings located near or in Narrabri and 14 buildings at Narromine that are subject to above floor flooding and impacted more than 10 millimetres due to the proposal in the 1% AEP event. This represents about one per cent of buildings within the study area already affected by 1% AEP flooding.

For the purposes of this assessment:

- Buildings include residences, educational facilities, health facilities, community facilities, commercial / industrial premises and other structures (such as garages).
- Sensitive buildings include all of the above buildings but do not include other structures.

In the case of buildings without surveyed floor levels, ground levels at the centroid of buildings have been extracted from the best available DEM to define floor levels of buildings on the assumption that floor levels are located 0.3 metres above ground level. This was checked against surveyed floor level data provided by Narrabri Shire Council and found to provide a good estimation of floor levels.

Further analysis of above floor flooding for the 1% AEP flood event by building type predicts that for:

- All buildings – 6,100 would be subject to above floor flooding, of which 1,329 (22 per cent) have surveyed floor levels. This is nine less than existing conditions.
- Sensitive buildings – 2,567 would be subject to above floor flooding, of which 1,316 (51 per cent) have surveyed floor levels. This is six less than existing conditions and is comprised of nine that would no longer be subject to above floor flooding and three that are not currently subject to above floor flooding would experience above floor flooding.

The majority of impacted buildings are located near or within Narromine and Narrabri.

Of the 2,567 sensitive buildings subject to above floor flooding, the majority are predicted to experience a negligible change (ie less than 10 millimetre increase or decrease) to existing conditions.

A total of 71 buildings are predicted to be subject to above floor flooding and experience an afflux of greater than 10 millimetres. Of these 71 buildings, 22 are sensitive buildings that are predicted to experience an increase of between 10 and 100 millimetres, of which all but one experience above floor flooding under existing conditions.

Additional assessment and modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings and determine if the proposal could be modified so that flooding characteristics are not worsened or minimised as far as practicable, up to and including the 1% AEP event. Where localised impacts are unavoidable further consultation with the affected property owners would be undertaken to identify measures that could be implemented to minimise the impacts as far as practicable.

The impact of the proposal on flooding to highways, roads, railways, and agricultural land uses are generally negligible. There are some minor increases in the length of rail line overtopped by floodwaters for the Parkes to Narromine Line, Dubbo to Coonamble Line, Narrabri to Walgett Line and Mungindi Line. While these lines are already subject to extensive flooding during these events, further refinement would be undertaken during detailed design to minimise these increases where practicable in order to limit impacts to train operations.

The operational phase of the proposal has the potential impact on the geomorphological conditions and stability of the waterways. The activities which pose the greatest risk and could result in channel and floodplain instabilities are:

- Scour at railway culvert and bridge crossings – faster flows at railway crossing, at piles or edges of rail embankments could lead to potential scouring of waterways.
- Maintenance/repair of instream structures – removal of sediment, vegetation and wood from instream structures has the potential to change hydraulics upstream and downstream which may impact on condition and stability of the waterway.
- Use of and maintenance of access roads – erosion and sedimentation arising from increased runoff from roads and transport downstream.

Recommended mitigation measures

Measures to avoid, minimise or manage impacts to flooding and hydrology, and geomorphology proposed for future stages of the proposal are as follows:

- The proposal would continue to be refined during detailed design to not worsen existing flooding characteristics, where practicable, up to and including the 1% AEP event.
- Further modelling would be undertaken during detailed design to confirm the locations downstream of culverts that require erosion protection, and confirm the extent and type of protection required.
- Construction planning and the layout of construction work sites and compounds would be carried out with consideration of overland flow paths and flood risk, avoiding flood liable land and flood events where practicable.
- A flood and emergency response plan would be prepared and implemented as part of the CEMP. The plan would include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It would also include measures to manage flood risks during construction and address flood recovery during construction.
- A geomorphology monitoring program would be implemented in accordance with the soil and water management plan as part of the CEMP.

Glossary and abbreviations

Acronym/term	Definition
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% AEP flood event is equivalent to the 100 year ARI flood event.
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff
ARTC	Australian Rail Track Corporation
ASS	Acid Sulfate Soils
ASRIS	Australian Soil Resource Information System
BCD	Biodiversity Conservation Division
BoM	Bureau of Meteorology
CC	Climate change
CEMP	Construction environmental management plan
DECC	Department of Environment and Climate Change (former)
DECCW	Department of Environment Climate Change and Water (former)
DEM	Digital Elevation Model
DIPNR	Department of Infrastructure, Planning and Natural Resources (former)
DPI	Department of Primary Industries (former)
DPIE	Department of Planning, Industry and Environment
DTM	Digital terrain model
EIS	Environmental Impact Statement
ELVIS	Elevation Information System - Elevation and Depth – Foundation Spatial Data available from http://elevation.fsdf.org.au/
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ETD	ARTC's technical note which provides the design requirements for greenfield and brownfield rail developments.
FFA	Flood frequency analysis
FLIKE	A computer program used for flood frequency analysis
FM	Flexible mesh
FPL	Flood Planning Level
GIS	Geographical Information System
HPC	Heavily Parallelised Compute used by TUFLOW
JacobsGHD	JacobsGHD IR Joint Venture
LEP	Local environmental plan
LGA	Local government area
LWD	Large Woody Debris

Acronym/term	Definition
MIKE	A range of software products released by Danish Hydraulic Institute to analyse, model and simulate movement of water. MIKE11 is a one dimensional hydrodynamic computer model and MIKE FLOOD includes a wide selection of specialised one dimensional and two dimensional flood simulation engines to model flood behaviour in channels, floodplains and coastal areas.
NFM	Narromine flood model
NSW	New South Wales
OEH	Office of Environment and Heritage (former)
The proposal	Defined as the construction and operation of the Narromine to Narrabri section of Inland Rail.
the proposal site	Defined as the area that would be directly affected by construction of the proposal (also known as the construction footprint). It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the compounds and laydown areas that would be used during construction.
PMF	Probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions.
Rail corridor	The corridor within which the rail tracks and associated infrastructure would be located.
RAFTS	RAFTS (xpratfs) is a runoff routing model that is used for hydrologic and hydraulic analysis of storm water drainage and conveyance systems.
RCP	Representative concentration pathways
RFFE	A computer based Regional Flood Frequency Estimation model developed at the Western Sydney University for Australian Rainfall and Runoff project.
RORB	RORB is a rainfall runoff and streamflow routing computer program that calculates catchment losses and streamflow hydrographs resulting from rainfall events.
SEARs	Secretary’s Environmental Assessment Requirements
SES	State Emergency Service
SRTM	Shuttle Radar Topography Mission
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled one dimensional and two dimensional hydraulic solutions using a powerful and robust computation.

1. Introduction

1.1 Overview

1.1.1 Inland Rail and the proposal

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

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

- Using the existing interstate rail line through Victoria and southern NSW
- Upgrading about 400 kilometres of existing track, mainly in western NSW
- Providing about 600 kilometres of new track in NSW and south-east Queensland

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

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

1.1.2 Approval and assessment requirements

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

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

1.2 The proposal

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

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

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

1.2.1 Location

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

The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key design features of the proposal include:

Rail infrastructure

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

Road infrastructure

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

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

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

Further information on the proposal is provided in the EIS.

Figure 1.1 **Location of the proposal**

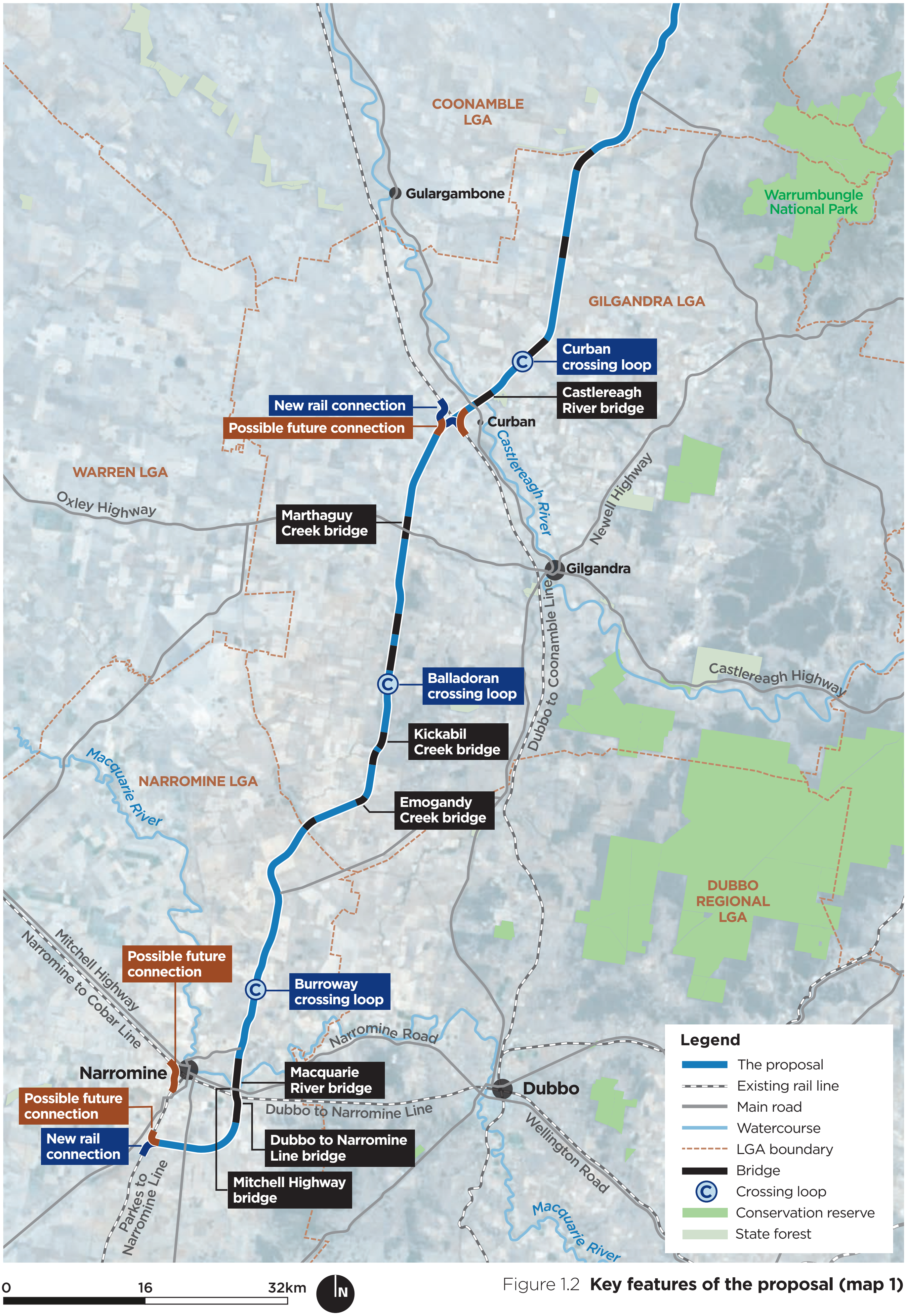


Figure 1.2 **Key features of the proposal (map 1)**

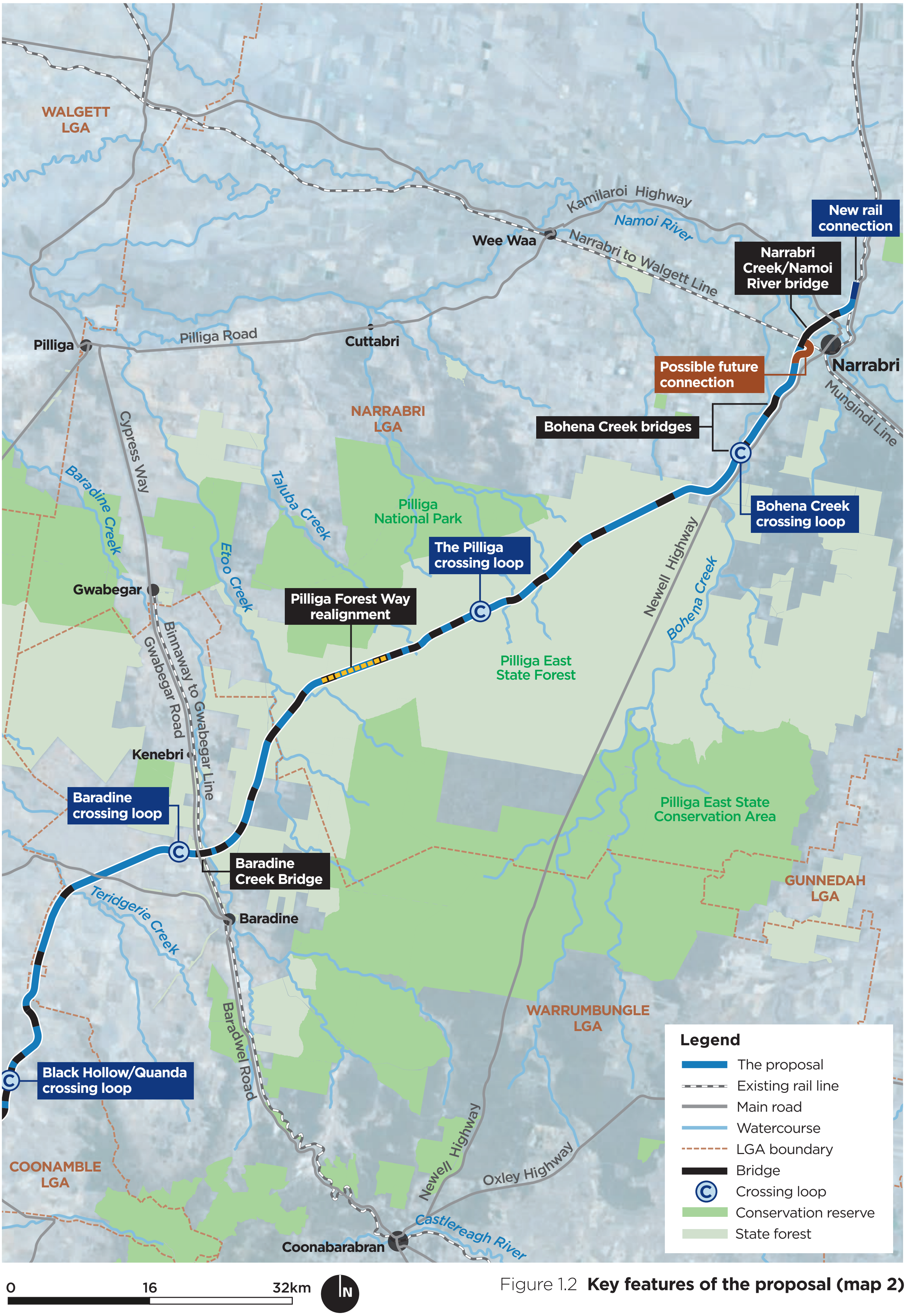


Figure 1.2 **Key features of the proposal (map 2)**

1.2.3 Construction overview

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

Timing and work phases

Construction of the proposal would involve five main phases of work as outlined in Figure 1.3. It is anticipated that the first phase would commence in late 2021, and construction would be completed in 2025.

Table 1.1 Main construction phases and indicative activities

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

Key construction infrastructure

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

- Borrow pits:
  - Borrow pit A – Tantitha Road, Narromine
  - Borrow pit B – Tomingley Road, Narromine
  - Borrow pit C – Euromedah Road, Narromine
  - Borrow pit D – Perimeter Road, Narrabri
- Three main compounds, which would include a range of facilities to support construction (‘multi-function compounds’), located at:
  - Narromine South
  - Curban
  - Narrabri West
- Temporary workforce accommodation for the construction workforce:
  - Within the Narromine South multi-function compound
  - Narromine North
  - Gilgandra
  - Baradine
  - Within the Narrabri West multi-function compound

The key construction infrastructure are shown in Figure 1.3.

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

1.2.4 Operation

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

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

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

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

1.3 Purpose and scope of this report

The purpose of this report is to assess the potential impacts to hydrology, flooding and geomorphology from the operation and construction of the proposal. The report:

- Addresses the relevant SEARs outlined in Table 1.2.
- Describes the existing environment with respect to hydrology, flooding and geomorphology.
- Assesses the impacts of constructing and operating the proposal on hydrology, flooding, and geomorphology conditions within the vicinity of the proposal.
- Recommends measures to mitigate and manage the impacts identified.

The methodology for the assessment is described in Section 3.

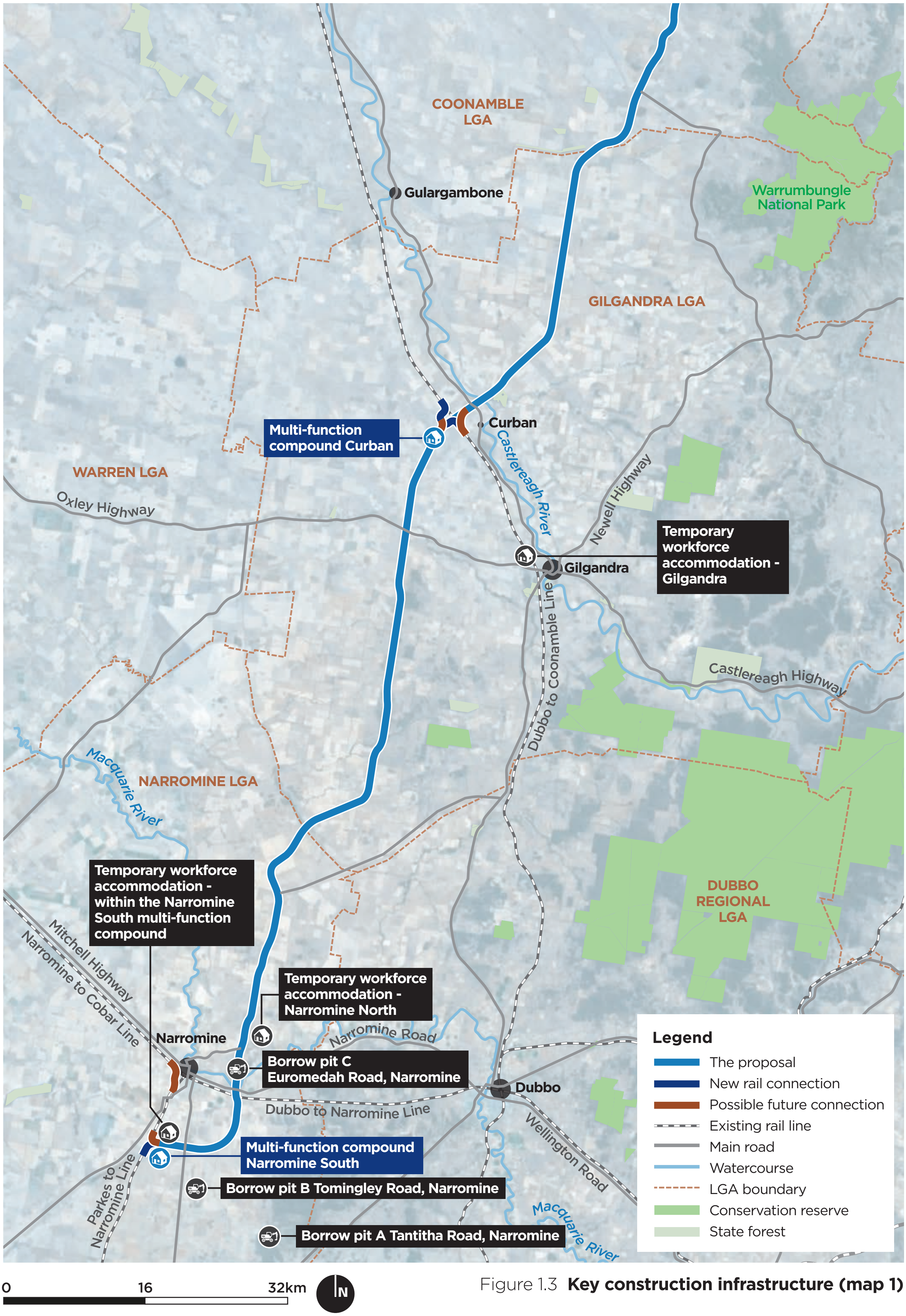


Figure 1.3 **Key construction infrastructure (map 1)**

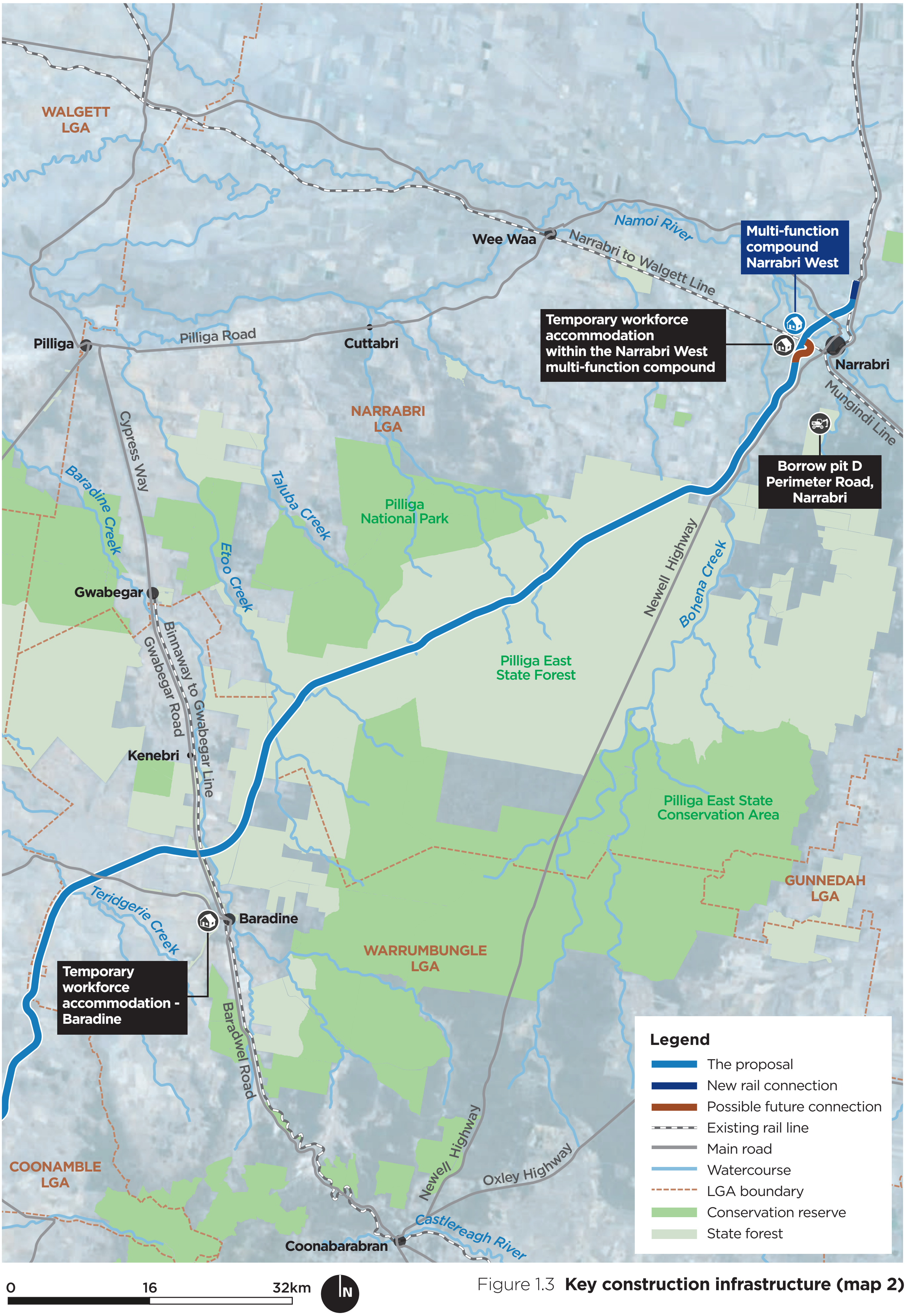


Figure 1.3 **Key construction infrastructure (map 2)**

Table 1.2 SEARs relevant to this assessment

SEAR number	Requirements	Where addressed in this report
9.1	The Proponent must describe the existing flooding characteristics and assess flooding impacts on property and public safety. The assessment must include, but not necessarily be limited to:	Section 5.2 describes the existing flooding characteristics. Section 6.1 and section 7.1 provide assessments of flooding impacts during construction and operation, respectively.
	a. The location and size of all existing and proposed pipes, culverts, viaducts and bridges, and the locations and annual exceedance probabilities (AEPs) of flows that overtop the existing formation and rail;	Section 3.5.2 provides figures showing the location of all proposed culverts and bridges. Appendix A provides details of the proposed culvert and bridge sizes.
	b. The existing and proposed topography in all flood prone areas, including the indicative locations, and typical horizontal and vertical dimensions of spoil mounds. Where there is uncertainty about the total spoil volume, upper and lower bounds must be estimated;	Section 3.3.3 describes the existing topography and data used to define the existing terrain in the flood models. Section 3.5.1 describes the proposed topography.
	c. Describe and justify the proposed flood planning level (FPL) for the project including the AEP of the flood which will overtop the formation and rail. The FPL must consider adjacent infrastructure such as road crossings whose flood immunity is determined by the project's FPL;	Section 3.2.1 describes the flood immunity, ie flood planning level, adopted for the proposal.
	d. Assess the existing hydrology, geomorphology and flooding characteristics of all watercourses within and adjacent to the project area. This includes locating and assessing flowpaths emanating from existing culverts, pipes and bridges under the rail formation, or from overtopping of the existing formation in large storms;	Section 5.2 provides an assessment of the existing hydrology and flooding characteristics. Section 5.3 provides an assessment of the existing watercourse geomorphology.
	e. Develop and justify quantitative design limits on potential adverse flooding, hydrological and geomorphological impacts resulting from the project. These are to consider land use and include afflux, velocity, extent, duration, hazard, scour potential, etc;	Section 3.2.2 identifies the design objectives adopted for the proposal.
	f. Carry out geotechnical and geomorphological investigations to assess the propensity for scour, erosion and geomorphological changes to occur within any watercourses or overland flowpaths affected by the project;	Section 3.9 describes the methodology for assessing geomorphology impacts. Section 6.2 and section 7.2 outline the geomorphological investigations and assessment for construction and operation respectively.
	g. Consider the impacts of floods up to the probable maximum flood including consideration of flood risks to people and property resulting from failure of the rail formation or washouts of ballast;	Section 7.1.13 provides an assessment of the risk of overtopping and failure of the rail formation.

SEAR number	Requirements	Where addressed in this report
	h. Prepare preliminary engineering designs of the velocity dissipation or other mitigation works that are proposed to avoid adverse offsite scouring or geomorphological impacts on the adjoining land downstream of the project area, adjacent to locations where pipes, culverts or bridges are proposed or where the rail formation may be overtopped;	Section 7.1.7 provides typical engineering designs of culvert and bridge scour protection measures to avoid adverse scour impacts.
	i. At locations along the rail route, identify the width of land between the toe of the formation and the downstream boundary of the project area, that is available for the construction of these mitigation works; and	Section 7.1.7 identifies the width of rail corridor available for construction, including scour protection works.
	j. Where there is insufficient width of project land available for these works, clearly identify the extent of additional land beyond the project boundary that may be required, including the locations where easements over land or acquisition of land may be required.	Section 7.1.7 identifies that the available corridor would be of sufficient width to accommodate the culvert and bridge scour protection.
9.2	The Proponent must model the impacts of the project on flood behaviour, including the existing, during construction and post construction (ie Operational) flooding conditions for a full range of flood events up to and including the probable maximum flood. The assessment must include consideration of the impacts of climate change and differing storm durations, and include but not necessarily be limited to:	Section 6.1 describes the flood modelling and impact assessment for the construction phase. Section 7.1 describes the flood modelling and impact assessment for the operational phase.
	a. Utilising hydrologic and hydraulic models that are consistent with current best practice and utilise topographic and infrastructure data that is of sufficient spatial coverage and accuracy to ensure the resultant models can accurately assess existing and proposed water flow characteristics;	Section 3.4.1 describes the hydrology models utilised for the assessment. Section 3.4.2 describes the hydraulic models developed and used for the flooding assessment.
	b. Having these models independently peer-reviewed with the review findings published in the EIS;	Section 3.8 and Appendix B describe the independent review of the flood models.
	c. Assessing any detrimental increases in the potential flood affectation, scouring or geomorphological changes to other properties, assets and infrastructure, over a full range of flood durations and flood frequencies;	Section 7.1 assesses potential flood impacts to properties and infrastructure in the operational phase. Section 7.2 assesses the potential geomorphology impacts in the operational phase.
	d. The extent to which the project alleviates or exacerbates the flood impact the existing rail infrastructure has on property or people;	Section 7.1 assesses the flood impact the proposal has on property and people. Section 7.1.5 specifically assesses flood impacts to existing rail infrastructure.

SEAR number	Requirements	Where addressed in this report
	e. An assessment of the consistency (or inconsistency) with the applicable Council or OEH floodplain management plans. The requirements of these plans must be discussed with OEH and the Council:	Section 7.1.8 describes the consistency with relevant floodplain management plans.
	f. Assessing whether each component of the project is compatible with the flood hazard of the land and the hydraulic functions of flow conveyance, floodway and flood storage;	Section 7.1.9 assesses the compatibility with the flood hazard and hydraulic functions.
	g. Assessing existing upstream and downstream flow, level, velocity, hazard and scour potential, and changes following the decommissioning of the borrow pits and downstream flowpaths (location, discharges and velocities);	Section 6.1.1 describes the proposed borrow pits and their rehabilitation strategy. Section 7.1 assesses flood impacts during the operational phase once the borrow pits are decommissioned.
	h. Quantifying and evaluating changes in flood safety risks on private and public land including roads and pathways;	Section 7.1 provides a quantitative assessment flood impacts including assessment of flood hazard, and changes to flooding of existing roads, highways and rail lines.
	i. Assessing any impacts that the project may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Service and applicable Council; and	Section 7.1.10 assesses potential impacts the proposal may have on existing emergency management arrangements for flooding.
	j. Evaluating any social and economic impacts that the project may have on the community as a consequence of changes to flooding, hydrology and geomorphology.	Section 7.1.11 provides an evaluation of potential social and economic impacts of the proposal as a result of changes to flooding.

1.4 Structure of this report

The structure of the report is outlined below:

- Section 1 – provides an introduction to the report
- Section 2 – provides an overview legislation, policies and guidelines application to this assessment
- Section 3 – describes the methodology and approach for the assessment
- Section 4 – provides a summary of community consultation carried out for the hydrology and flooding assessment
- Section 5 – provides a summary of the existing flooding and hydrological conditions
- Section 6 – presents a summary of the potential impacts associated with construction of the proposal
- Section 7 – presents a summary of the potential impacts associated with operation of the proposal
- Section 8 – presents a summary of the potential cumulative impacts associated with the proposal
- Section 9 – provides recommended mitigation and management measures
- Section 10 – concludes the key findings and recommendations from the investigation

2. Legislation and policy 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.

2.1 Legislation

2.1.1 Water Management Act 2000 and Water Act 1912

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 replace the *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, which are made under the *Water Management Act 2000*.

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 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, such as the proposal. 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 now managed under the *Water Management Act 2000,* having previously been managed under Part 8 of the *Water Act 1912.* The floodplain management provisions under the *Water Act 1912* have transitioned to the *Water Management Act 2000*, including the provisions of floodplain management plans and 'flood works' i.e. works that affect, or are likely to affect, flooding and/or floodplain functions.

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

- *Water Sharing Plan for the Castlereagh River Unregulated and Alluvial Water Sources 2011.*
- *Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012.*
- *Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2011.*
- *Water Sharing Plan for the Murray-Darling Basin Porous Rock Groundwater Sources 2011.*
- *Water Sharing Plan for the Lower Macquarie Groundwater Sources 2003.*
- *Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2016.*
- *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012.*

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 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). The relevant requirements of these Acts have been considered in this assessment.

2.1.2 Dams Safety Act 2015

Safety of dams has been administered under the *Dams Safety Act 1978* (1978 Act) for the last forty years. In the absence of regulations, the Dams Safety Committee administered the 1978 Act by publishing guidance material for dam owners. The 1978 Act also had very limited penalty provisions.

In 2015, the *Dams Safety Act 2015* (2015 Act) replaced the 1978 Act. The 2015 Act requires a dams safety regulation to be enacted for dam owners to follow. The 2015 Act and Dams Safety Regulation 2019 commenced on 1 November 2019. The 2015 Act and Regulation include provisions to ensure that any risks to public safety, environment and assets relating to dams are of a level that is acceptable to the community. The Regulation identifies that a dam or proposed dam that is a prescribed dam within the meaning of the 1978 Act immediately before the repeal of that Act is a declared dam.

For the purposes of the 2015 Act, a dam or proposed dam may be declared to be a declared dam if:

- The dam has a dam wall that is more than 15 metres high.
- Is a dam that, if there were to be a failure of the dam, would cause major or catastrophic level of severity of damage or loss, or endanger the life of a person.

The 2015 Act would be applicable if works associated with the proposal function like a dam and any potential failure of the works would result in unacceptable risks to public safety, environment and assets. The relevant requirements of the 2015 Act have been considered in this assessment.

2.2 Policies and planning controls

2.2.1 NSW Flood Prone Land Policy

The NSW Flood Prone Land Policy is produced within section 1.1 of the *Floodplain Development Manual* (DIPNR, 2005). 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 manual “*promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable*”.

2.2.2 Flood Planning Guideline

On 31 January 2007 the NSW Planning Minister announced a guideline for development control on floodplains (the “Flood Planning Guideline”). An overview of the Flood Planning Guideline and associated changes to the EP&A Act and Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) was issued by the then Department of Planning in a Planning Circular dated 31 January 2007 (Reference PS 07-003). The Flood Planning Guideline issued by the Minister in effect relates to a package of directions and changes to the EPA Act, EP&A Regulation and *Floodplain Development Manual* (DIPNR, 2005).

This Flood Planning Guideline confirms that unless there are “exceptional circumstances”, councils are to adopt the 100 year flood (ie 1% AEP flood) as the flood planning level for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Flood Planning Guideline does provide that controls on residential development above the 100 year flood may be imposed subject to an “exceptional circumstance” justification being agreed to by the Department of Natural Resources and the Department of Planning (both now incorporated into the Department of Planning, Industry and Environment (DPIE)) prior to the exhibition of a draft local environmental plan or draft development control plan.

DPIE are currently proposing to provide an updated Flood Prone Land Package to provide land use planning advice to councils, however this has not yet been implemented at the time of finalising this report.

2.2.3 NSW Climate Change Policy Framework

The *NSW Climate Change Policy Framework* (OEH, 2016) summarises how the NSW Government intends to support the reduction of emissions to reduce the effects of climate change, and measures to adapt to the risks associated with climate change.

One of the policy directions is to reduce risks and damage to public and private assets in NSW arising from climate change. This has been considered in the design and assessment of the proposal by considering the projected climate for the year 2090 when carrying out the flood modelling (refer Section 3.6.3).

2.2.4 Local environmental plans

Local environmental plans (LEPs) are the principal planning controls for local councils, summarising permissible land uses throughout the local government area (LGA). The proposal is located within the Narromine Shire, Gilgandra Shire, Coonamble Shire, Warrumbungle Shire and Narrabri Shire Council LGAs and the current LEPs that are relevant to the proposal.

The LEPs include a clause on flood planning. The objectives of this clause are to:

- Minimise the flood risk to life and property associated with the use of land.
- Allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change.
- To avoid significant adverse impacts on flood behaviour and the environment.

The flood planning clause applies to:

- Land identified as "flood planning area" on the Flood Planning Map.
- Other land at or below the flood planning level which is defined as the level of a 1:100 average recurrent interval (ie 1% AEP) flood event plus 0.5 metres freeboard.

The flood planning clause identifies that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- Is compatible with the flood hazard of the land.
- Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties.
- Incorporates appropriate measures to manage risk to life from flood.
- Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.
- Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

While the provisions of these LEPs does not apply to State significant infrastructure projects, such as the proposal, the relevant matters have been considered in this assessment.

2.2.5 Development control plans

Development control plans (DCPs) summarise the design guidelines that should be followed by developments within an LGA. DCPs typically include specific requirements for different land uses (eg rural, residential, and commercial), with respect to building envelopes, boundary offsets, stormwater management, driveway and road geometry, and other development features. DCPs also often contain controls for development on flood prone land, such as minimum floor levels for new buildings and flood effects caused by the development on other properties.

DCPs for the Narromine Shire, Gilgandra Shire, Coonamble Shire, Warrumbungle Shire and Narrabri Shire Council LGAs are applicable to the proposal. While the provisions of these DCPs do not apply to State significant infrastructure projects, such as the proposal, the relevant matters have been considered in this assessment.

2.2.6 Floodplain management plans

Floodplain management plans, prepared under the *Water Management Act 2000* and *Water Act 1912* (Section 2.1.1) describe the mechanisms of flooding, benefits and risks associated with flood events, and provide guidance for the assessment of works within the flood affected area.

Existing flood management plans near the proposal include the following:

- *Draft Floodplain Management Plan for the Macquarie Valley Floodplain 2018* (Department of Industry, 2018) under the *Water Management Act 2000*: the proposal is located several kilometres upstream of the designated floodplain for the plan.
- *Floodplain Management Plan for the Upper Namoi Valley Floodplain 2019* (NSW Government, 2019) under the *Water Management Act 2000*: the downstream boundary of designated plan is located upstream of the proposal.
- *Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020* (NSW Government, 2020) under the *Water Management Act 2000*: The Plan applies to construction and demolition of existing or proposed flood works including an access road, a supply channel, a stock refuge, an infrastructure protection work, an ecological enhancement work, an Aboriginal cultural value enhancement work and a heritage site enhancement work within the Lower Namoi Valley Floodplain.

  A review of the available mapping for the Plan indicates that the proposed Narrabri bridge crosses the Lower Namoi Valley Floodplain which is classified under Lower Namoi Management Zone AD and Lower Namoi Management Zone B. The proposed bridge is not a flood work. However, temporary infrastructure required to construct the bridge such as access tracks, crane pads, barges, scaffolding etc. have the potential to impact on flood behaviour in Lower Namoi Management Zone AD and Lower Namoi Management Zone B.

  Lower Namoi Management Zone AD includes areas of the floodplain where a significant discharge of floodwater occurs during floods, with relatively high flood flow velocity and depth. These areas are generally characterised by defined channels and banks. Lower Namoi Management Zone B includes areas of the floodplain that are important for the conveyance of floodwater during large flood events and for the temporary pondage of floodwaters during the passage of a flood.

  Different rules and assessment criteria apply for approval of flood works in each Management Zone. Approval of flood works within Management Zone AD is based on complex criteria of products of flood depths and velocities. Approval of flood works within Lower Namoi Management Zone B needs to ensure that changes in flow distribution are less than five per cent, afflux is less than 0.2 metres, changes in velocity are less than 50 per cent and the proposed flood works have minimal impact on soil erodibility. However, no approvals are required for flood works for State significant infrastructure projects, such as the proposal (https://www.industry.nsw.gov.au/water/licensing-trade/approvals/flood-work-approvals accessed on 1 November 2020).

2.2.7 Floodplain risk management plans

Floodplain risk management plans are generally prepared for urban floodplains to address the existing, continuing and future flood risk in accordance with NSW Government's Flood Prone Land Policy (Section 2.2.1) and Flood Planning Guideline (Section 2.2.2).

The *Narromine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2009) for Narromine is relevant to this proposal. Narromine Shire Council, through its floodplain management committee undertook a floodplain risk management study and a floodplain risk management plan for the township of Narromine in accordance with the NSW Government's flood prone land policy and using procedures set out in the *Floodplain Development Manual* (DIPNR, 2005). Key works and measures recommended in the floodplain risk management plan for Narromine include the following:

- Implementation of development controls based on the draft flood policy (the flood planning level for residential development is set at 1% AEP flood level with a 0.5 metre freeboard).
- Implementation of flood awareness and education program for residents and owners of commercial and industrial developments.
- A feasibility study of river bank levee for Narromine which includes upgrading of the existing levee and extending the levee upstream of the town.
- A feasibility study for upgrading the hydraulic capacity of culverts under the Parkes to Narromine railway (prior to Inland Rail – Parkes to Narromine).

The 2009 floodplain risk management study for Narromine is currently under review (https://www.narrominenewsonline.com.au/story/6313404/flood-risk-management-plan-under-review/ accessed 28/02/2020).

While the Narromine study has been considered in relation to the proposal, there are no existing floodplain risk management plans that cover the floodplains crossed by the proposal. A floodplain risk management plan for Narrabri is currently being prepared and apart from the supplementary flood study report (Section 3.3.5) (http://www.narrabri.nsw.gov.au/files/uploaded/file/Planning%20and%20Development/Strategic%20Documents/Supplemenntary%20flood%20study%20report%20RS.pdf accessed 20/08/2020), no further information is available on the plan.

2.2.8 Local flood plans

Local flood plans, prepared by the State Emergency Service (SES) as part of broader local disaster plans, outline the preparations, responses and recovery actions that are to be undertaken prior to, during and following a major flood event. A number of local flood plans have been prepared for the area within the vicinity of the proposal:

- *Gilgandra Shire Local Flood Plan* (SES, 2008)
- *Warrumbungle Shire Flood Emergency Sub Plan* (SES, 2013)
- *Narromine Shire Flood Emergency Sub Plan* (SES, 2014)
- *Narrabri Shire Flood Emergency Sub Plan* (SES, 2015)

2.3 Guidelines

2.3.1 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Ball et al., 2019) (ARR 2019) is a national guideline for the estimation of design flood characteristics in Australia. The approaches presented in ARR 2019 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 ARR 2019 in developing the methodological framework for assessing potential impacts of the proposal on hydrology, flooding and water quality.

2.3.2 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

Australian Disaster Resilience Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Institute for Disaster Resilience, 2017) provides guidance on best practice in flood risk management in Australia. This handbook aims to encourage practice that works towards the vision that *floodplains are strategically managed for the sustainable long-term benefit of the community and the environment, and to improve community resilience to floods*.

The handbook promotes the consideration and management of flood impacts to existing and future development within the community and it aims to improve community flood resilience using a broad risk management hierarchy of avoidance, minimisation and mitigation to:

- Limit the health, social and financial costs of occupying the floodplain
- Increase the sustainable benefits of using the floodplain
- Improve or maintain floodplain ecosystems dependent on flood inundation

The handbook emphasises the need for understanding flood behaviour so that the full range of flood risk to the community can be understood, effectively communicated and, where practical and justifiable, mitigated. The handbook facilitates informed decisions on the management of this risk, and economic investment in development and infrastructure on the floodplain.

2.3.3 Flood hazard

Flood preparedness, flood hazard and emergency management guidelines have been developed and are available from the SES local flood plans (Section 2.2.8) (2008, 2013, 2014 and 2015). The *Australian Disaster Resilience Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute for Disaster Resilience, 2017) and ARR 2019 also provide guidelines in respect to hazard categorisation (Figure 2.1) and management.

These guidelines were considered in defining existing flood hazard (H1 to H6 identified in Figure 2.1) for the full range of flood events. In order to provide a consistent and simplified commentary on impacts of the proposal on flood hazard, flood hazard categories H1 and H2 are referred to as “low” hazard and flood hazard categories H3 to H6 are referred to as “high” hazard.

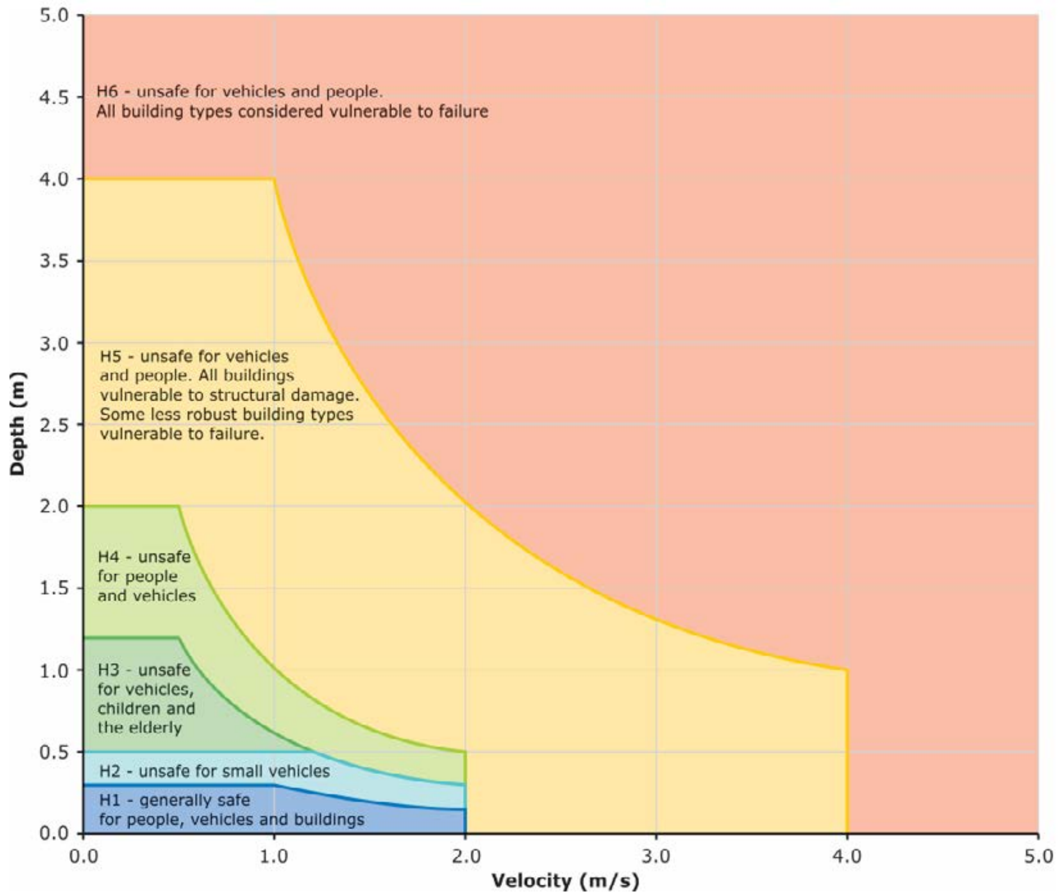


Figure 2.1 Combined flood hazard curves (ARR 2019)

2.3.4 ARTC guidelines

ARTC's *Engineering Practices Manual, Civil Engineering, Track Drainage - Design and Construction* (ARTC, 2013) details minimum design criteria and construction practices prescribed by ARTC throughout the planning, design, construction and operation of the rail line.

The Inland Rail *Climate Change Risk Assessment Framework* (ARTC, 2019) provides a standard approach to climate change risk assessment and mitigation across all Inland Rail projects. In accordance with the framework a specific climate change risk assessment was undertaken for the proposal. The framework is consistent with a number of other guidelines including:

- *AS 5334-2013 Climate change adaptation for settlements and infrastructure – a risk-based approach and satisfy climate risk.*
- *AS/NZS ISO 31000-2009 Risk management – principles and guidelines.*
- The climate adaptation requirements of the ISCA infrastructure sustainability rating tool.
- ARTC's Inland Rail Project Risk Management Framework.
- *Floodplain Risk Management Guidelines – Practical Consideration of Climate Change* (DECC, 2007).

It has also taken into consideration state specific guidance documents, such as Transport for NSW's *Climate Risk Assessment Guidelines* (TfNSW, 2018), which in turn, has been informed by *Climate Change Impacts & Risk Management A Guide for Business and Government* (Australian Greenhouse Office, 2006).

3. Assessment methodology

3.1 Definitions

3.1.1 Study area

The study area for the hydrology and flooding investigation is considered the area that may be affected (directly or indirectly) by the proposal (Figure 3.1). 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 three river basin catchments in the study area – the Macquarie River, Castlereagh River and Namoi River basins as detailed in Section 5.1.1.

3.1.2 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 area, 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 the regulated Macquarie and Namoi rivers.

Hydraulics

Hydraulics is the term given to the study of water flow in waterways. In particular, the evaluation of flow parameters such as water level and velocity.

Flood event

A flood event can be either:

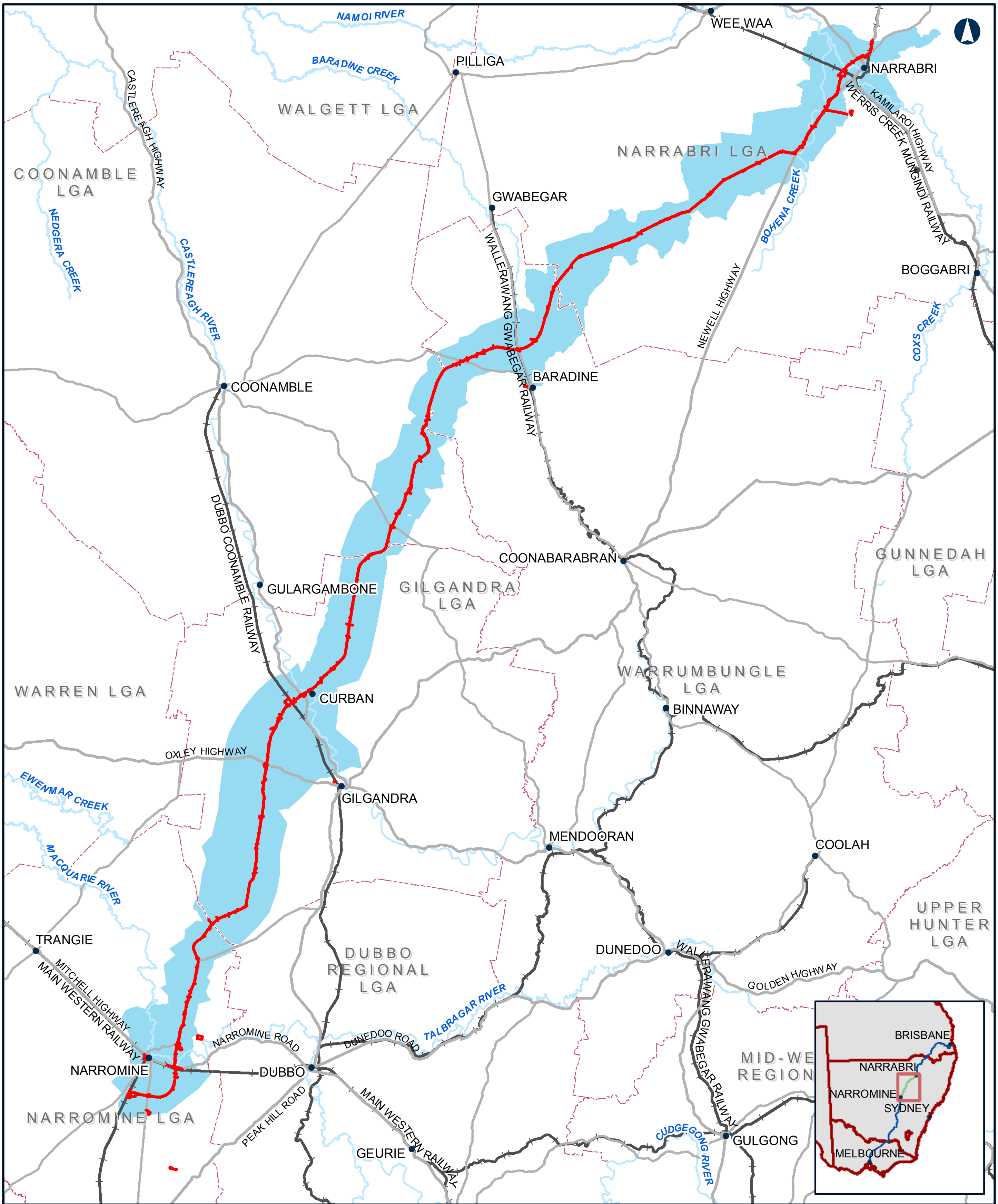
- A historical flood event for which information on rainfall, flood extent, flood levels, stream flow data is available.
- A design flood, based on a statistical analysis of long-term flow records from stream gauges or modelling of the flood response to design (synthetic) rainfall events.

The relative magnitude of a design flood event is generally described in terms of an annual exceedance probability (AEP), which relates to the likelihood of a flood of a given size (or larger) occurring in any given year. For example, a 5% AEP flood event has a five per cent (one in 20) chance of occurring in any given year. Historical flood events may be compared with a design flood event to obtain an estimate of the likelihood (in terms of AEP) of that specific event occurring.

Average recurrence interval (ARI) was a term used previously to define the probability of design flood events. It was defined as the average period between occurrences equalling or exceeding a given value. The use of terms such as "recurrence interval" and "return period" are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years.

Structure

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



NARROMINE TO NARRABRI Study Area

Figure 3.1

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 30/07/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Flood Study Area
- LGA Boundary
- Railway

INLAND RAIL ARTC

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

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3.2 Flood planning level and quantitative design objectives

3.2.1 Flood planning level

The flood planning level for the proposal has been determined based on achieving a minimum flood immunity for the 1% AEP event with due consideration of adjacent infrastructure. This is consistent with the *Floodplain Development Manual* (DIPNR, 2005), the Flood Planning Guideline, AS/RISSB 7637:2014 Railway Infrastructure – Hydrology and Hydraulics and ARTC Code of Practice – Track and Civil Section 10 Flooding (Technical Note ETD-10-02). In addition, in order for the proposal to meet the Inland Rail *Programme Business Case* (ARTC, 2015) and Service Offering it needs to achieve a high level of reliability so that it is a competitive freight transport solution. The proposed flood planning level is essential in order for the proposal to meet these requirements.

3.2.2 Quantitative design objectives

ARTC proposes the quantitative design objectives detailed in Table 3.1 as the proposal's quantitative design limits. These quantitative design objectives apply outside the rail corridor, for events up to and including the 1% AEP flood event. These objectives would be further refined during detailed design in consultation with relevant stakeholders with consideration to location specific land use risks.

These have been established based on, as relevant, policies, planning controls and guidelines (see Section 2) and similar infrastructure projects in NSW. Adoption of these minimises the risk to public safety, buildings, existing highways and roads, existing rail lines and land uses.

Based on the current design, in certain circumstances these quantitative design objectives cannot be achieved at specific locations. During detailed design, the design would continue to be refined and further flood modelling undertaken to try and achieve these objectives, but where this is not possible or practical, ARTC will:

- Document the extent of the non-compliance with the quantitative design objectives and justify why it is not possible or practical to achieve compliance through design changes.
- In instances of non-compliance with the quantitative design objectives, consult with and obtain agreement from the affected land or property owners to either:
  - The non-compliance, or
  - Establish an alternative level of mitigation of impacts for that location through alternative design measures
- Where an alternative level of mitigation of impacts is required for a location, achieve a level of mitigation through design measures beyond the rail corridor.

Table 3.1 Quantitative design objectives

Parameter	Location or land use	Quantitative design objective	Justification/description
Afflux ie increase in flood level resulting from implementation of the proposal	Habitable floors [1]	10 mm	For the proposal, the increase in flood level (afflux) should be minimal. A target maximum afflux of 10 mm has been adopted for habitable floors where there is above floor flooding. This target is unlikely to result in a significant impact to land use and hazard. Afflux being the relative difference between the modelled existing flood levels and the predicted flood level after construction of the proposal. This is reported against surveyed floor levels (where available) or assumed floor levels where existing surveys have not been carried out for both habitable and non-habitable buildings. For the remaining areas (excluding forestry and unimproved agricultural areas) a target of 200 mm afflux at the rail corridor boundary has been generally adopted. For forestry and unimproved agricultural areas, a target of 400 mm afflux has been applied in some circumstances due to the lower human exposure and infrastructure in these areas.
	Sensitive infrastructure, assumed to include: • Emergency services (eg hospitals, ambulance, fire, police stations) • Flood evacuation routes • Electricity substations • Water treatment plants.	10 mm	
	Other urban and recreational	200 mm	
	Agricultural	200 mm	
	Forest and unimproved grazing land	400 mm	
	Highways and sealed roads greater than 80 km/hr	Less than 10 mm at sensitive infrastructure. Less than 10% change in length of overtopping.	Target has been adopted to minimise as far as practicable impacts to transport routes.
	Unsealed roads and sealed roads less than 80 km/hr		
Scour/ erosion potential ie increase in flood velocity resulting from implementation of the proposal	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads and most urban, commercial, industrial, recreational and forested land. Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	Outlet velocities from the rail corridor to be in accordance with site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is to be in accordance with the requirements of the NSW Blue Book (DECC, 2008a and 2008b).	In all areas a target of minimising any increases in velocities has been adopted. Scour protection provided downstream of new drainage culverts within the rail corridor where outlet velocities are greater than 0.5 m/s and/or as required in accordance with the NSW Blue Book (DECC, 2008a and 2008b). For bridges in water courses, scour protection provided at piers and abutments as required. Energy dissipaters would be provided downstream of structures where increased velocities may result in scour to adjacent land.

Parameter	Location or land use	Quantitative design objective	Justification/description
Flood hazard i.e. increase in flood hazard resulting from implementation of the proposal	Urban, commercial, industrial, highways and sealed roads	Minimise changes based on an assessment of risk with a focus on land use and flood sensitive receptors	Minimising increases in flood hazard for sensitive land uses, buildings and key infrastructure such as highways is important for public safety. The proposal has been developed with a target of minimising increases in flood hazard where practical.
Flood duration i.e. increase in duration of inundation resulting from implementation of the proposal	Habitable floors [1]	Less than 10% change in duration of inundation where there is above floor flooding.	Minimising increases in duration of flood inundation will mitigate potential impacts to residents that may be isolated within houses, or may have evacuated and wish to return within a reasonably similar timeframe as is currently possible. It is also important in order to minimise impacts to agricultural and forested lands. The proposal has been developed with a target of minimising increases in duration of flood inundation where practical.
	Highways and sealed roads >80 km/hr	Minimise changes to accessibility during flood events.	
	Elsewhere	Minimise changes based on an assessment of risk with a focus on land use and flood sensitive receptors.	

1 Habitable floors/rooms are defined consistent with the use of this term in the *Floodplain Development Manual* (DIPNR, 2005). In a residential situation this comprises a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial, commercial or other building, this comprises an area used for an office or to store valuable possessions, goods or equipment susceptible to flood damage in the event of a flood.

3.3 Review of available data

3.3.1 Local government areas

The proposal is located within the Narromine, Gilgandra, Warrumbungle, Coonamble and Narrabri LGAs.

3.3.2 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 (refer to Figure 3.2), as listed in Table 3.2.

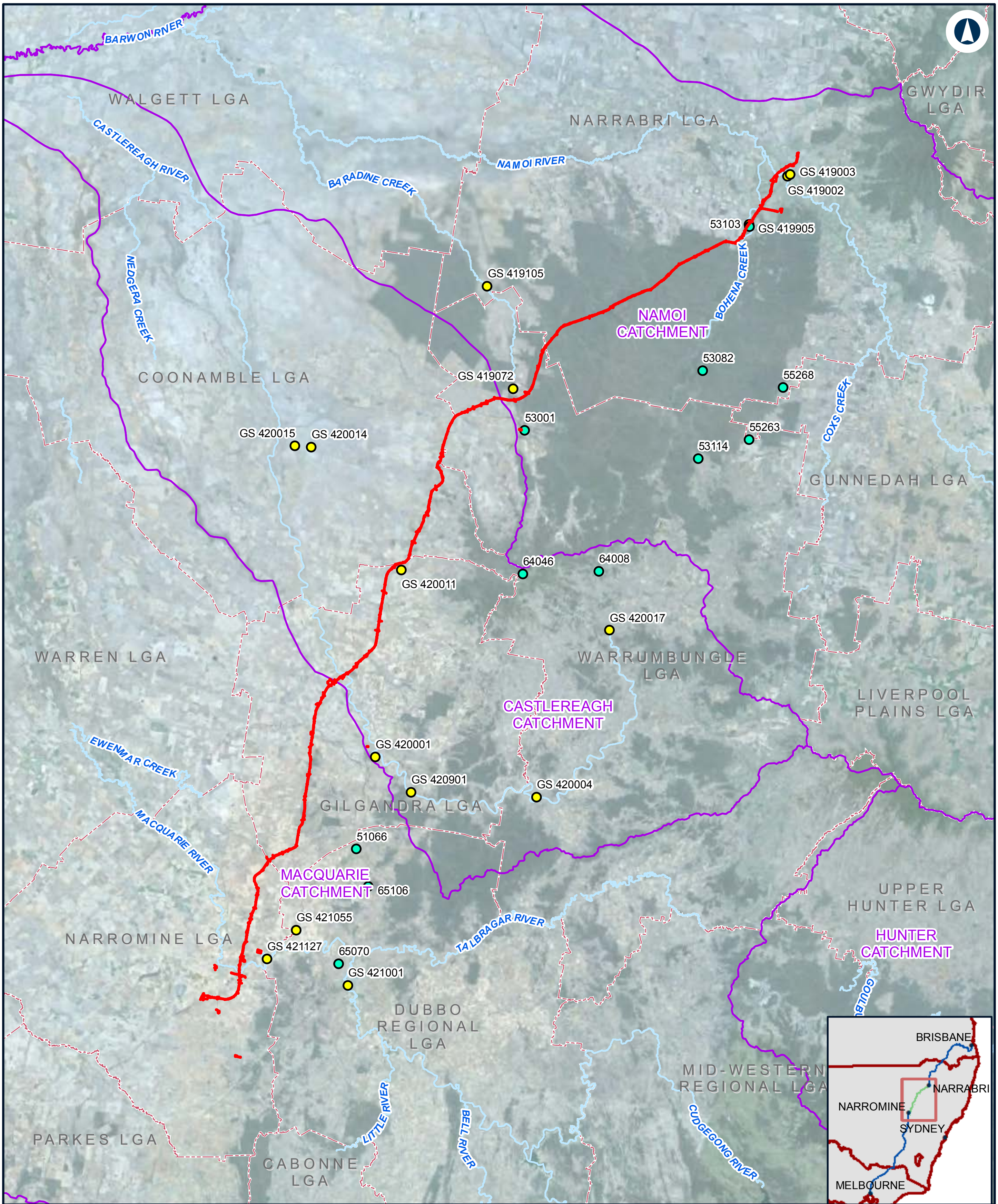
Table 3.2 Meteorological recording stations

Station ID	Station name	Historical reporting period
420003	Belar Creek at Warkton	1951 to present
421078	Macquarie River at Burrendong Dam	1967 to present
421146	Gum Cowal at bifurcation	1987 to present
421148	Cudgegong River at Windamere Dam	1986 to present
421178	Molong Creek at downstream Borenore Creek	2002 to present
421198	DPI-Orange auto weather station	2017 to present
064015	Mendooran Post Office	1886 to present
064024	Gilgandra	1902 to present

The mean annual rainfall recorded at these stations varies along the proposal site. The average annual rainfall is about 640 millimetres. Rainfall occurs relatively uniformly throughout the year, with higher variability during summer and autumn due, in part, to the influence of the *El Nino Southern Oscillation* (ie the El Nino – La Nina cycle).

Design rainfalls

Rainfall depths for the design events between 50% AEP and 0.05% AEP were extracted from BoM's 2016 Design Rainfall Dataset for each catchment. Probable maximum precipitation depths were estimated based on the *Generalised Short- Duration Method* (BoM, 2003). Rainfall depths for the 0.01% AEP event were estimated based on log-normal interpolation technique presented in ARR 2019.



NARROMINE TO NARRABRI Rainfall and streamflow gauging stations Figure 3.2

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 30/07/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,372,730
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Major river catchment
- Watercourse
- Rainfall Gauge
- Stream Gauge

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3.3.3 Terrain

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

- Survey model obtained through Light Detection and Ranging (LiDAR) survey and aerial imaging
- Elevation Information System (ELVIS)
- Digital Elevation Model (DEM) obtained through Shuttle Radar Topography Mission (SRTM)
- Localised site survey

The adopted terrain model is presented in Figure 3.3, which shows the general landform adjacent to the study area. This was formed from LiDAR (where available) and SRTM outside the LiDAR corridor.

LiDAR

A topographic survey model was obtained through LiDAR imaging provided by ARTC. The LiDAR data provided by ARTC was captured by AAM Pty Ltd in 2015, 2017 and 2018. Data validation showed a vertical accuracy (root mean square error) of 0.079 metres and a standard deviation of 0.078 metres.

ELVIS

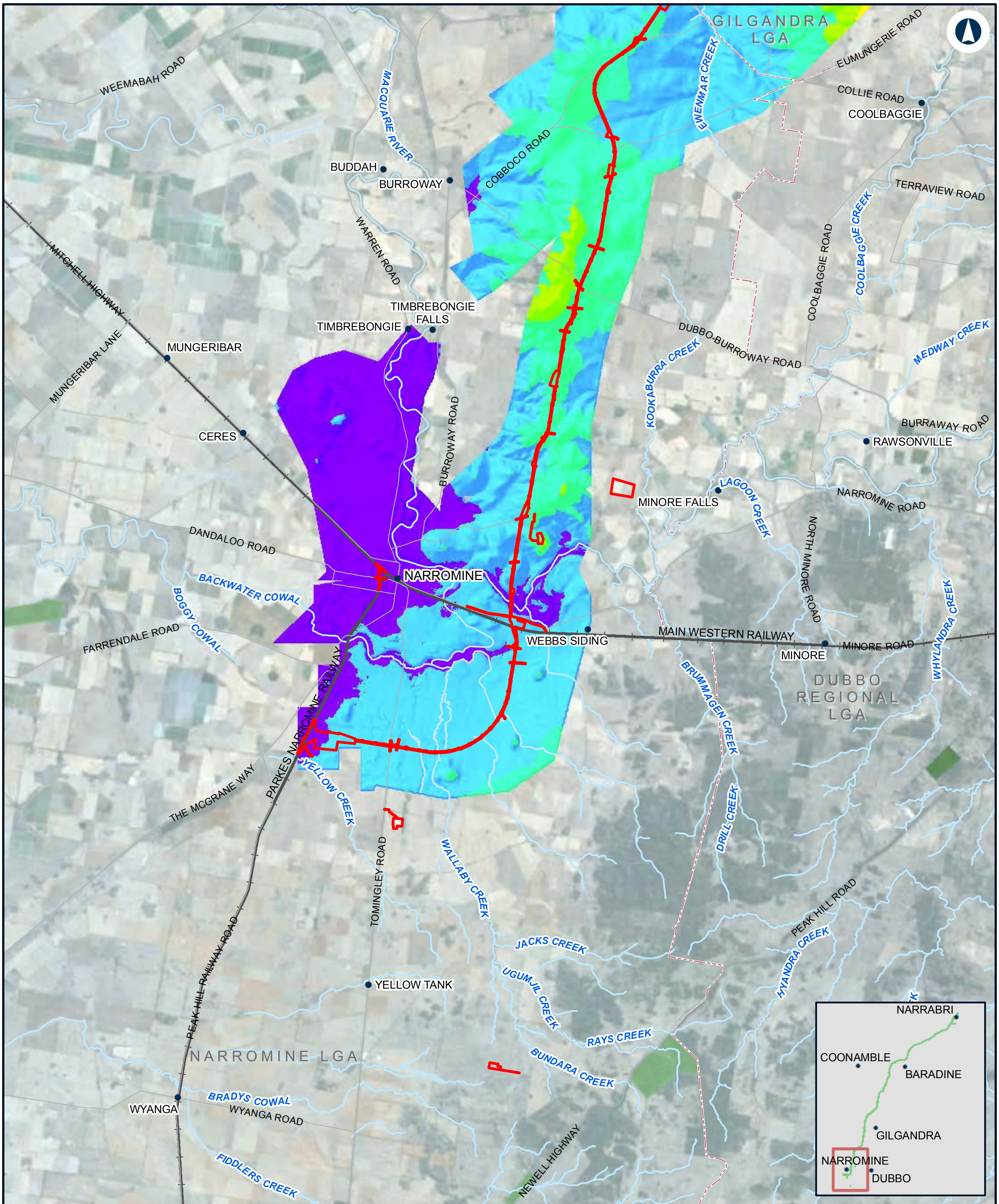
The Geoscience Australia provides processed one metre and five metre DEMs for most of NSW through ELVIS (www.elevation.fsdf.org.au). These DEMs are based on LiDAR and other surveys undertaken on behalf of state and federal governments. These DEMs were used to supplement LiDAR data provided by ARTC to represent terrains for the hydraulics models.

Shuttle radar

Topographic data generated by the SRTM program was used for terrain outside the LiDAR corridor where necessary to define broader catchment boundaries. The resolution of the Digital Elevation Model is about 30 metres. The reported vertical accuracy of the data is plus or minus 10 metres

Site survey

As part of investigations for the proposal, existing culverts, bridges, channel cross sections and historic flood marks identified by landowners were surveyed in May 2019. The surveyed features are located on Crown land, road reserves and private properties with land access was available. In total, 46 culverts were surveyed and geographical coordinates, basic dimensions, field notes and photographs were captured for each culvert. Geographical coordinates, basic dimensions, field notes and photographs were also collected for eight bridges. Twenty channel cross sections were surveyed. Landowners provided information on historic flood levels for two locations. One historic flood mark is located in Narromine and the other historic flood mark is located in Narrabri. It is to be noted that the survey was based on the NSW CORS / SmartNet network, where the typical expected horizontal accuracy is plus or minus 50 metres.



NARROMINE TO NARRABRI Corridor and catchment topography Figure 3.3a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

The proposal
300.1 - 320

Elevation (m AHD)

200.1 - 220
220.1 - 240
240.1 - 260
260.1 - 280
280.1 - 300

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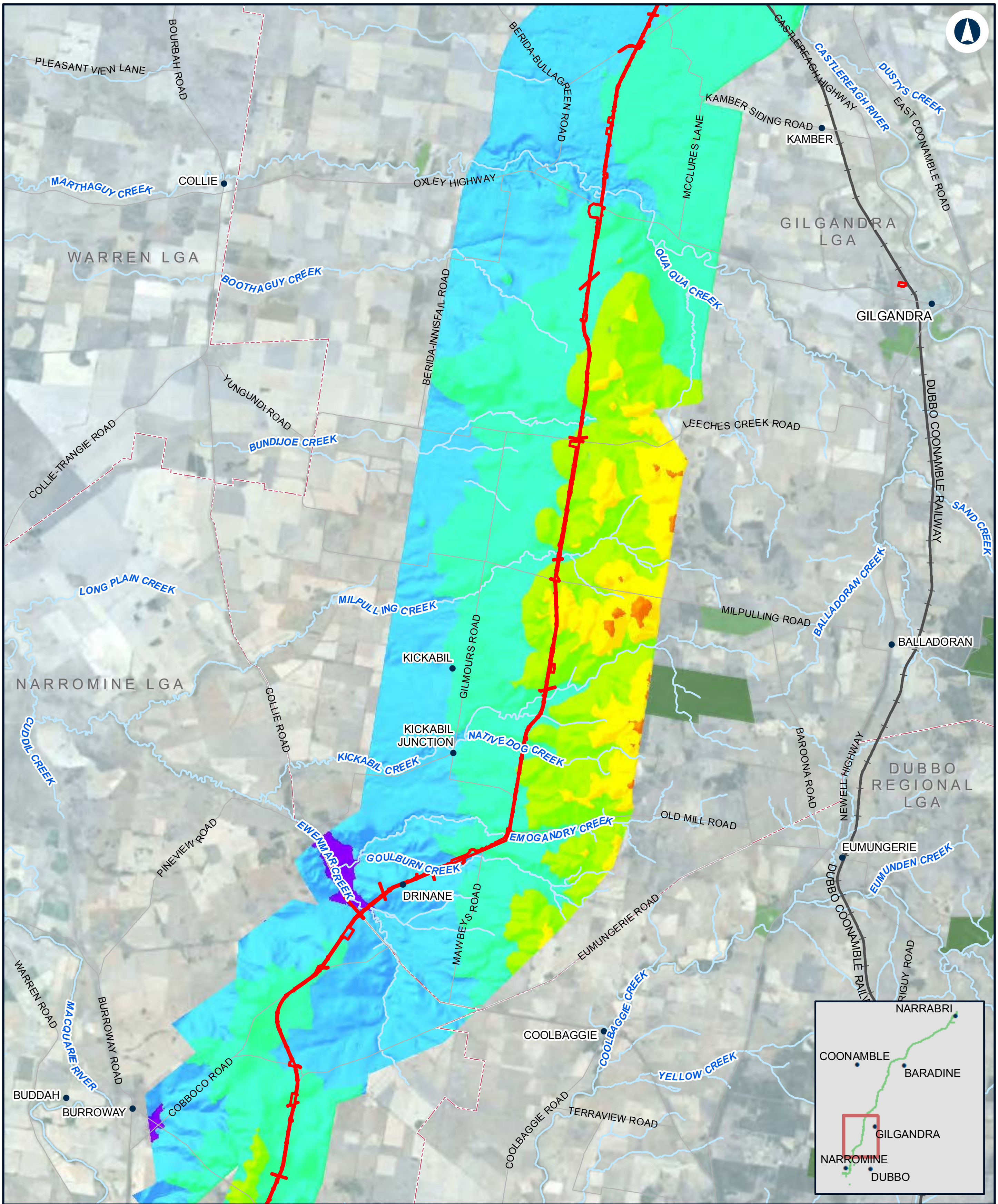

NARROMINE TO NARRABRI Corridor and catchment topography

Figure 3.3b

0 3.5 7 Km

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Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Elevation (m AHD)
  - 200.1 - 220
  - 220.1 - 240
  - 240.1 - 260
  - 260.1 - 280
  - 280.1 - 300
  - 300.1 - 320
  - 320.1 - 340

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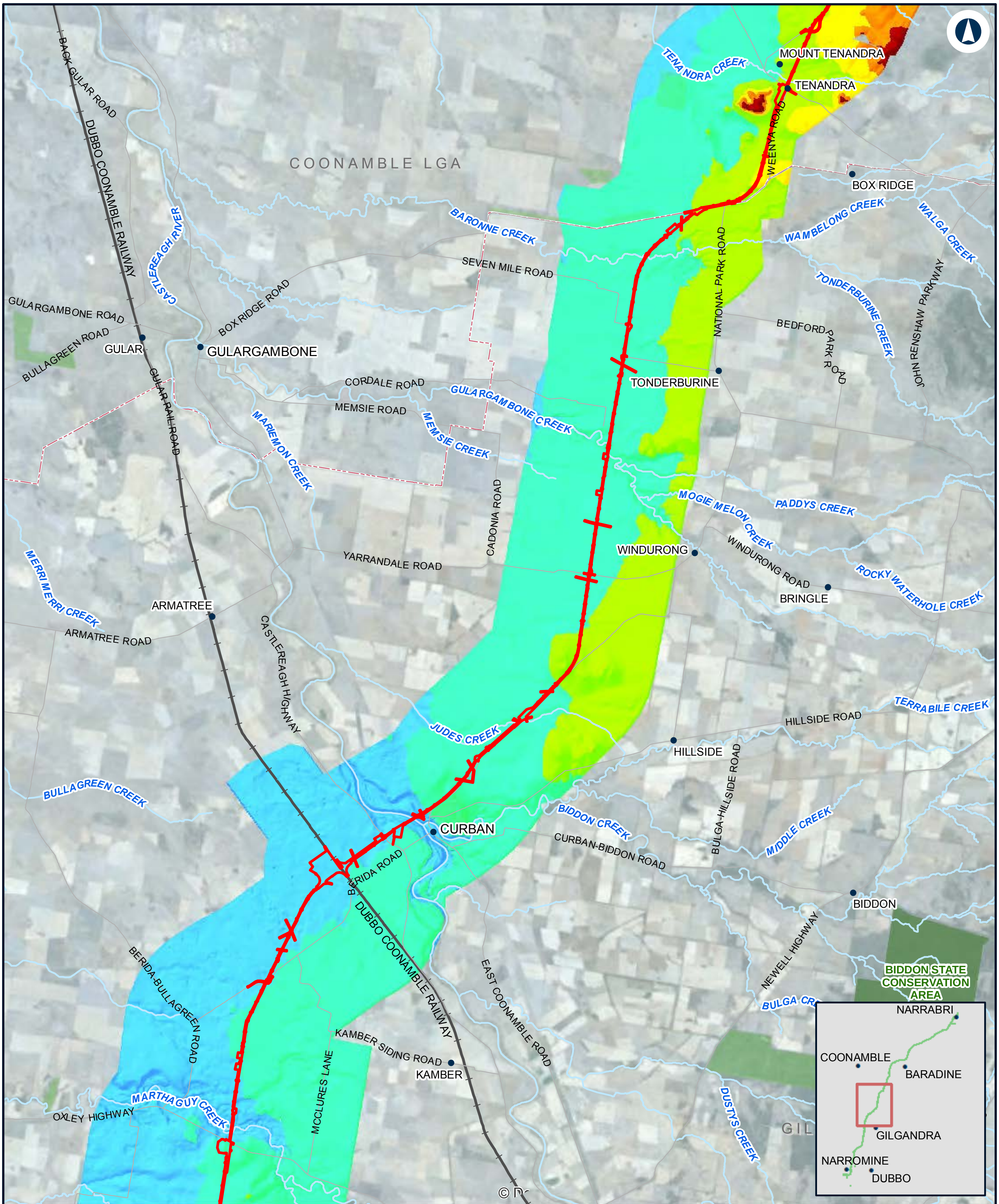

NARROMINE TO NARRABRI Corridor and catchment topography Figure 3.3c

0 3.5 7 Km

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LEGEND

The proposal

Elevation (m AHD)
- 200.1 - 220
- 220.1 - 240
- 240.1 - 260
- 260.1 - 280
- 280.1 - 300
- 300.1 - 320
- 320.1 - 340
- 340.1 - 420

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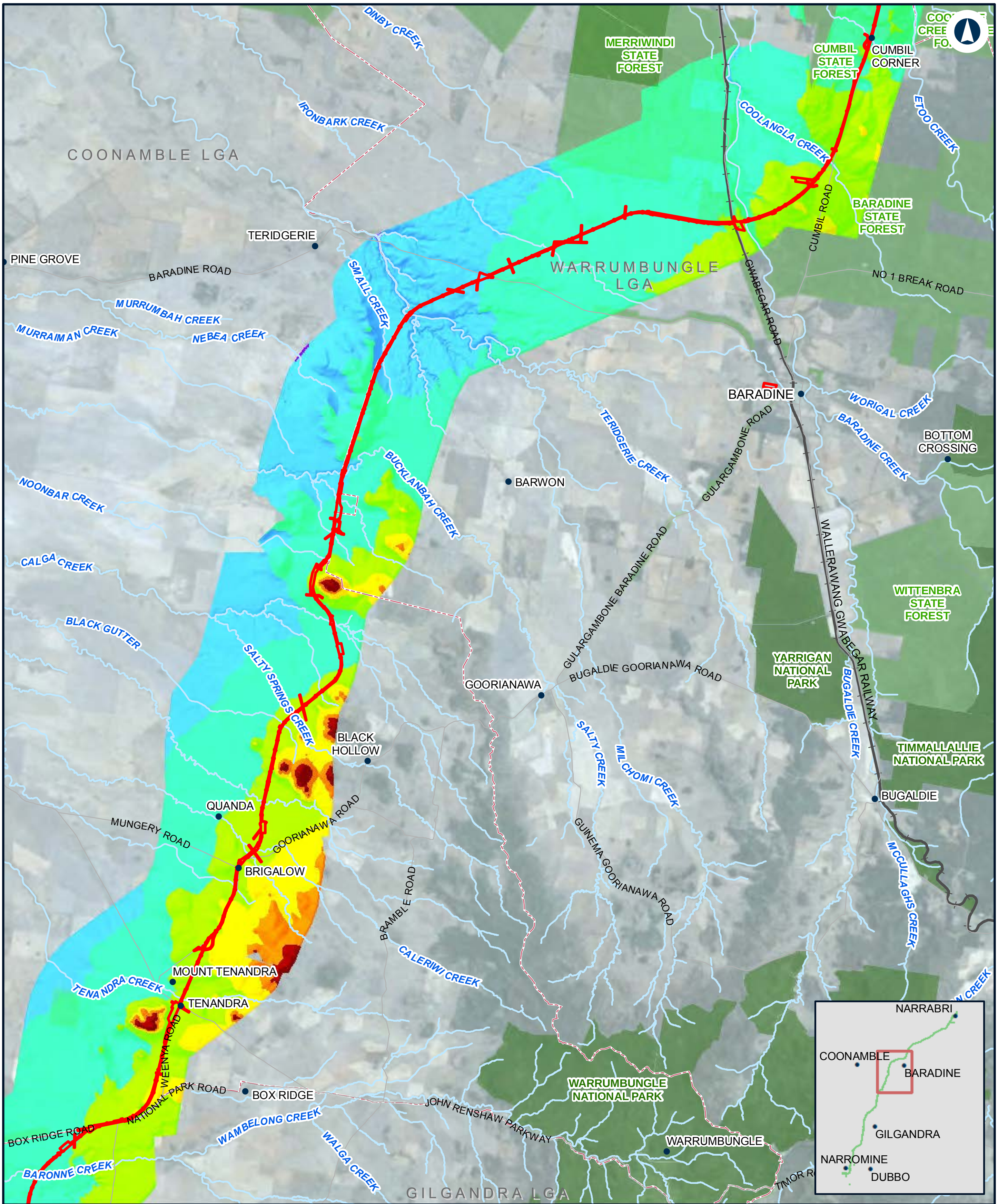

NARROMINE TO NARRABRI

Corridor and catchment topography

Figure 3.3d

0 3.5 7 Km

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LEGEND

The proposal

Elevation (m AHD)

- 220.1 - 240
- 240.1 - 260
- 260.1 - 280
- 280.1 - 300
- 300.1 - 320
- 320.1 - 340
- 340.1 - 420

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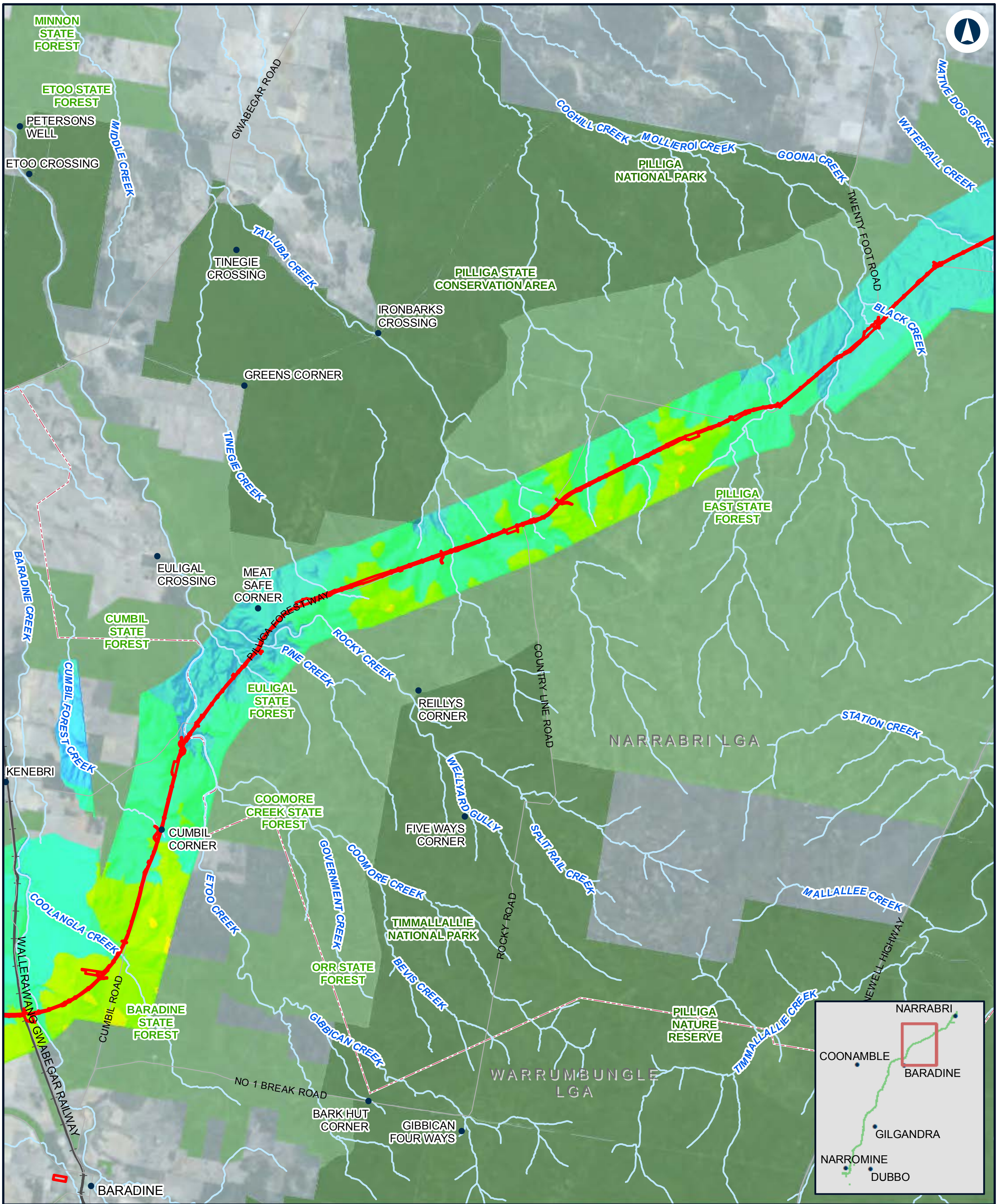

NARROMINE TO NARRABRI Corridor and catchment topography

Figure 3.3e

0 3.5 7 Km

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LEGEND

The proposal

Elevation (m AHD)

- 184.1 - 200
- 200.1 - 220
- 220.1 - 240
- 240.1 - 260
- 260.1 - 280
- 280.1 - 300
- 300.1 - 320

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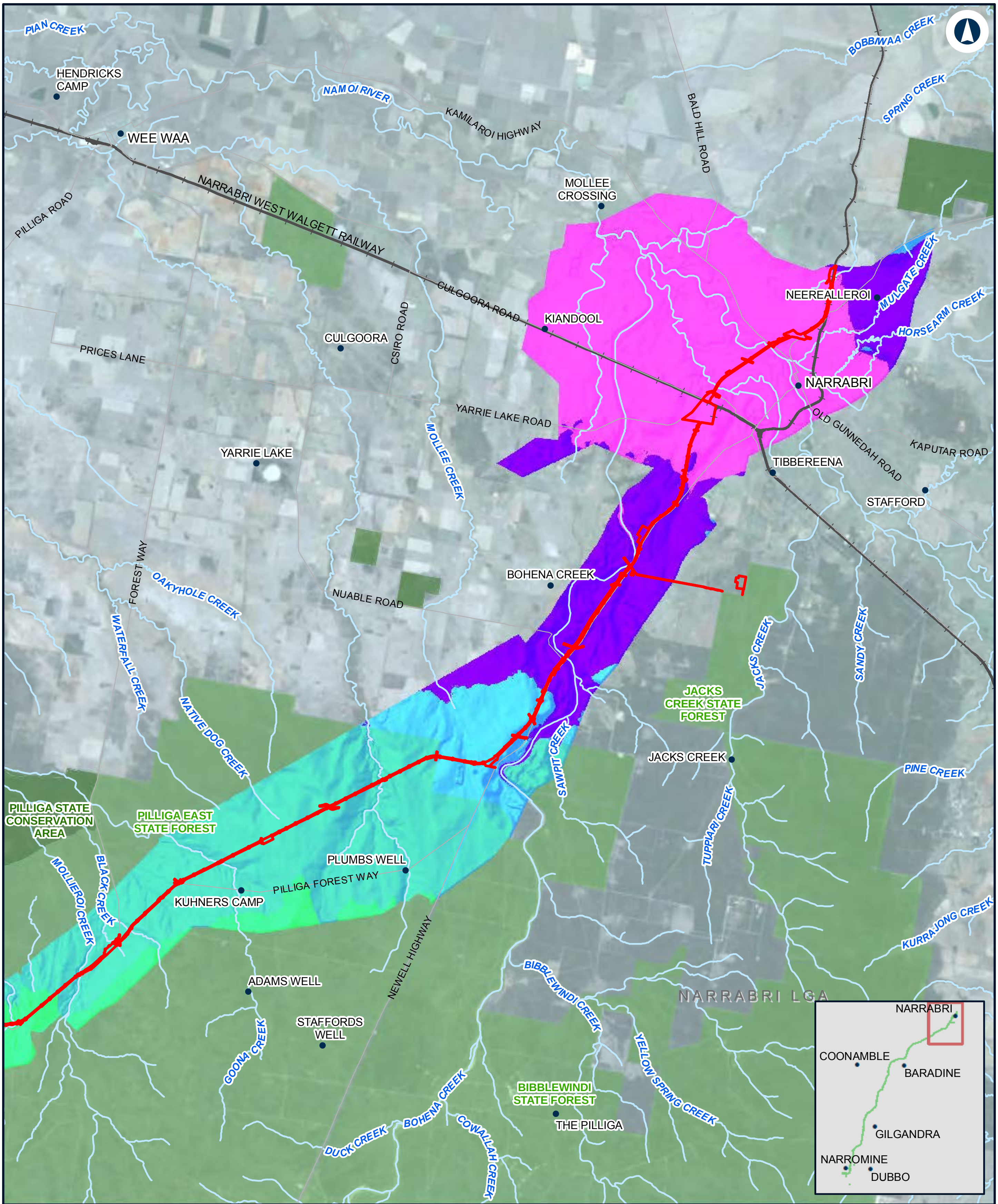

NARROMINE TO NARRABRI Corridor and catchment topography Figure 3.3f

0 3.5 7 Km

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Elevation (m AHD)
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3.3.4 Stream gauge data

Historical flood level and flow data was extracted from publicly available databases (http://waterinfo.nsw.gov.au/, https://realtimedata.waternsw.com.au/ and PINNEENA (a surface and groundwater monitoring database released by NSW Government). The extracted data was then subject to a flood frequency analysis to determine the magnitude of design floods based on the historical data.

The gauging stations (refer to Figure 3.2) considered in the analysis are listed in Table 3.3.

Table 3.3 Flow gauging station considered in assessment

Station No	Station Name	Gauging period	Catchment area (km^2)
419002	Namoi River at Narrabri	1890 to 2015	25,400
419003	Narrabri Creek at Narrabri	1891 to present	24,400
419905	Bohena Creek at Narrabri	1995 to present	2,180
419072	Baradine Creek at Kenebri No. 2	1995 to 2011	995
419105	Baradine Creek at Gwabegar	2011 to present	-
421001	Macquarie River at Dubbo	1966 to present	19,600
421127	Macquarie River at Baroona	1986 to present	25,700
420001	Castlereagh River at Gilgandra	1909 to 2000	6,350
420004	Castlereagh River at Mendooran	1968 to present	3600
420011	Baronne Creek at near Gulargambone	1983 to 1999	398
420014	Magometon Creek (Site 3) at near Coonamble	1969 to 2002	540
420015	Warrana Creek at Warrana	1969 to 2002	583
420017	Castlereagh River at Hidden Valley	1980 to present	1166
420901	Castlereagh River at Lucas Bridge	1999 to present	-
421055	Coolbaggie Creek at Rawsonville	1980 to present	626

3.3.5 Previous flood studies and models

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.

Below is a summary of the publicly available recent flood studies relevant to the proposal.

Narrabri Floodplain Risk Management Study and Plan, Volume I: Supplementary Flood Study - Namoi River, Mulgate Creek and Long Gully

The Supplementary *Flood Study – Namoi River, Mulgate Creek and Long Gully* (WRM, 2019) updated the *Narrabri Flood Study - Namoi River, Mulgate Creek and Long Gully* (WRM, 2016) which examined the regional flooding from the Namoi River (catchment area 25,400 square kilometres and local catchment flooding from Mulgate Creek (catchment area 202 square kilometres) and Long Gully (catchment area 28 square kilometres) at Narrabri.

The stage discharge rating curve was reviewed in detail and the rating curve was updated through hydraulic modelling (WRM, 2016). The regional design discharges at Narrabri were estimated from an annual series flood frequency analysis of the combined recorded flows at the two stream gauges (Namoi River at Narrabri (GS419002) and Narrabri Creek at Narrabri (GS419003)). All available flood information for Narrabri dating back to 1890 (126 years from 1890 to 2015) was included in the analysis. A Log-Pearson Type III distribution was fitted to the annual series of recorded (and inferred) peak flood discharges at Narrabri using the Bayesian inference methodology recommended in ARR 2019 using the TUFLOW FLIKE software. The 1% AEP design discharge at Narrabri was estimated at 4,860 m^3/s, which was slightly lower than the historical 1955 flood of the Namoi River. The estimated AEP of the 1955 flood is between 1% and 0.5%.

The design discharges from the catchment areas of Mulgate Creek and Long Gully were updated (WRM, 2019) using a XP-RAFTS model and guidelines presented in ARR 2019. XP-RAFTS design discharge estimates for the local catchments were validated against results from Regional Flood Frequency Estimate (RFFE) program (Ball et al, 2019).

A ground surface digital terrain model (DTM) of the floodplain around Narrabri was provided by NSW Government Land and Property Information. The DTM was based on LiDAR data captured in January 2014. The DTM and surveyed topographic data were used to develop a computer based MIKE-FLOOD FM (flexible mesh) hydrodynamic model to simulate the flow behaviour of the Namoi River, Narrabri Creek and local creeks within the study area. The MIKE-FLOOD FM model was calibrated against three regional flood events of February 1955, February 1971 and July 1998 and two local flood events of December 2004 and February 2012.

Hydraulic modelling of the study area was undertaken to derive design flood levels, depths and extents for the 20%, 10%, 5%, 2% and 1% AEP flood events and an extreme flood. Preliminary flood hazard mapping and flood emergency response classifications were also prepared.

This flood modelling data (WRM, 2016) and the report were available for this assessment. Review of the MIKE-FLOOD FM hydraulics model indicated significant updates would be needed to make the model suitable for assessing flood behaviour for the proposal. Hence, a new TUFLOW hydraulics model was developed for Narrabri, consistent with other hydraulic models developed for the entire proposal. Details on the hydraulic model development are provided in Section 3.4.2.

Baradine

The *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2012) defines flood behaviour of Teridgerie Creek for the township of Baradine. The study area includes the upper reach of the creek and includes the western parts of the township.

The extents of this study are not within the study area for the proposal.

Gulargambone

The *Gulargambone Flood Study Report* (Jacobs, 2016) defines flood behaviour for the township of Gulargambone due to flooding from the Castlereagh River and Gulargambone Creek.

The extents of this study are not within the study area for the proposal.

Gilgandra

The *Gilgandra Floodplain Management Study* (Lyall & Associates, 1996) provides a summary of the flood behaviour of the Castlereagh River, within the vicinity of Gilgandra. The largest historical flood occurred in 1955, reaching a height of 10.05 metres at the local river gauge. Lyall & Associates (1996) estimates that this event was about equivalent to the 1% AEP flood event. The 1955 flood resulted in significant flooding of the township, damaging commercial and residential properties.

The study presents a number of options for the management of future flood events, ranging from the installation of a flood warning system to the construction of a levee. These options were reviewed by the *Review of Gilgandra Floodplain Risk Management Study* (URS, 2012) (as discussed above), who recommended a scoping study to investigate the feasibility of various levee options, including temporary flood levees, and adoption of flood planning levels within the township.

Flood models and data from this study were not available for use in this assessment.

Narromine

The *Narromine River Bank Levee Feasibility Study* (Lyall & Associates, 2013) examined flood events around Narromine. 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 1% AEP event.

Flood models developed by Lyall & Associates for the 2013 feasibility study were provided by Narromine Shire Council for use in this study. The TUFLOW hydraulics model provided by Council has been extended, principally to include the Backwater Cowal within the two-dimensional model domain, and the updated TUFLOW model has been re- calibrated to the historical events.

Macquarie River Floodplain Management Plan

The *Draft Floodplain Management Plan for the Macquarie Valley Floodplain 2018* (Department of Industry, 2018) assessed flood behaviour in the lower reaches of Ewenmar Creek and Marthaguy Creek. The study area for the proposal is located upstream of the floodplain management area for the Macquarie Valley and the hydrology and hydraulics models utilised in the assessment of flood behaviour for Ewenmar Creek and Marthaguy Creek were not available for use in this assessment.

3.4 Flood modelling

Hydrologic and hydraulic computer models were used to simulate flows and flood behaviour in all watercourses crossed by the proposal. Hydrologic models are used to represent the upstream catchment areas and simulate the rainfall and runoff processes to derive flood hydrographs. Hydraulic models are then used to translate these flood hydrographs into flood levels, flow velocities and the extent of flood inundation.

3.4.1 Hydrologic modelling

Hydrological modelling and analysis provide a means for identifying contributing catchment areas and estimation of runoff and streamflow generated by the catchment areas upslope of the study area. The length of the proposal site meant that the rainfall runoff response of hundreds of ungauged catchments needed to be estimated.

A tiered method for the estimation of runoff response of each sub- catchment area was adopted utilising the available topographic data as follows:

- Rainfall-runoff models and hydrological analyses provided by local councils were reviewed and where practical updated and used to estimate the local catchment hydrology based on the methods outlined in ARR 2019. An XP- RAFTS model representing the catchment areas of Mulgate Creek and Long Gully was provided by Narrabri Shire Council (WRM, 2016). This XP-RAFTS model was reviewed and considered suitable for use in this study.
- For the major watercourses, where sufficient historical streamflow data is available, at-site flood frequency analyses (FFA) were undertaken, based on the methods outlined in ARR 2019 to estimate peak flows for flood events up to and including the 0.5% AEP event.
- For the remaining catchment areas, new rainfall-runoff hydrology models were developed.

Model selection

The runoff- routing model RORB developed by Laurenson and Mein (2010) was selected for developing new hydrology models for this study. RORB is identified as one of the suitable hydrology models in ARR 2019. RORB is one of the most widely used models of its type in Australia, and consequently there is a good deal of information available on the value of model parameters for a wide range of catchments. RORB is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non- linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal distribution of rainfall as well as losses, and can model flows at any number of points throughout the catchment.

Model configuration

RORB hydrology models were developed for the catchment areas of waterways crossed by the proposal excluding the catchment areas of Mulgate Creek and Long Gully Creek for which XP-RAFTS hydrology models were provided by Narrabri Shire Council.

Sub-areas for the RORB model were delineated using the SRTM data combined with a GIS layer of watercourses and satellite imagery. The sub-areas within each RORB model are defined to coincide with watershed boundaries and stream junctions. At the catchment scale, the proportion of imperviousness represented by houses and roads are considered negligible and therefore are not included in the models. All links are defined as natural channel type. Sub-areas for the RORB model and channel lengths were measured in GIS.

Model calibration

In the case of gauged catchments, excluding the catchment areas of the Macquarie, Castlereagh and Namoi river basins, RORB hydrology models for Baradine Creek, Bohena Creek and Coolbaggie Creek, an intended donor catchment which is not crossed by the proposal, were calibrated and verified against recorded stream flow data. Generally, at least, three historical flood events were selected for calibration and verification of the RORB models for gauged catchments. The events were selected though a review of the available stream flow and sub-daily rainfall data.

Estimation of runoff hydrographs for design storm events

Design hydrographs for a range of flood events from the 50% AEP to the probable maximum flood (PMF) event were estimated using the methods provided in ARR 2019.

Based on calibration and verification results, and in consideration of recommendations in ARR 2019, the hydrology models were parameterised as follows:

- Calibrated models – median rainfall losses and median model parameter values from calibration results and rainfall losses for the PMF event based on ARR 2019.
- Uncalibrated models – a conservative approach was adopted in selecting rainfall losses based on calibration results from adjacent catchment (where available) and ARR 2019 Data hub losses. RORB model parameter values were based on ARR 2019. The same XP- RAFTS model parameter values used in the council flood study for Narrabri (WRM, 2016) were adopted in this assessment.

The ensemble event method of peak discharge estimation, as detailed in Chapter 3.3.2 of Book 4 of ARR 2019, was adopted for selecting peak discharges, critical storm durations and temporal patterns for all points of interest. Points of interest include inflow locations defined in the TUFLOW hydraulics models and watercourses crossed by the proposal.

In the case of the Macquarie, Castlereagh and Namoi river basins, the following approach was adopted to estimate runoff hydrographs for the full range of flood events up to and including the PMF:

- Peak flows for flood events up to and including the 0.5% AEP event were based on at-site FFA. Hydrographs simulated by the RORB models were scaled based on the FFA.
- Peak flows for the PMF event were estimated based on PMF estimates for South Eastern Australia and maximum observed floods in the world (Nathan et al, 1994) for similar sized catchments. Peak flows for flood events between the 0.5% AEP and the PMF event were estimated through interpolation.
- Peak flows for intermediate events between 0.5% AEP and the PMF event were estimated through log-normal interpolation.
- Hydrographs simulated by the RORB models were scaled based on the adopted peak flows.

Validation of design discharge estimates

Calibrated RORB models

Estimated peak discharges for the full range of flood events between 50% AEP and the 1% AEP event were compared against at-site FFA results and the RFFE tool, provided by ARR 2019.

Uncalibrated RORB models

Estimated peak discharges for the full range of flood events between 50% AEP and the 1% AEP event were compared against the RFFE tool, provided by ARR 2019.

3.4.2 Hydraulics modelling

Rainfall runoff hydrographs simulated by hydrology models were input into hydraulics models to define flood levels, flood depths and velocities in the channels and on the floodplains which are traversed by the proposal.

Model selection

TUFLOW (BMT, 2018), which is a combined one-dimensional (1D) and two-dimensional (2D) hydraulics model, was used in this assessment for developing new hydraulics computer models. TUFLOW is an industry-standard flood modelling platform identified in ARR 2019.

Model development

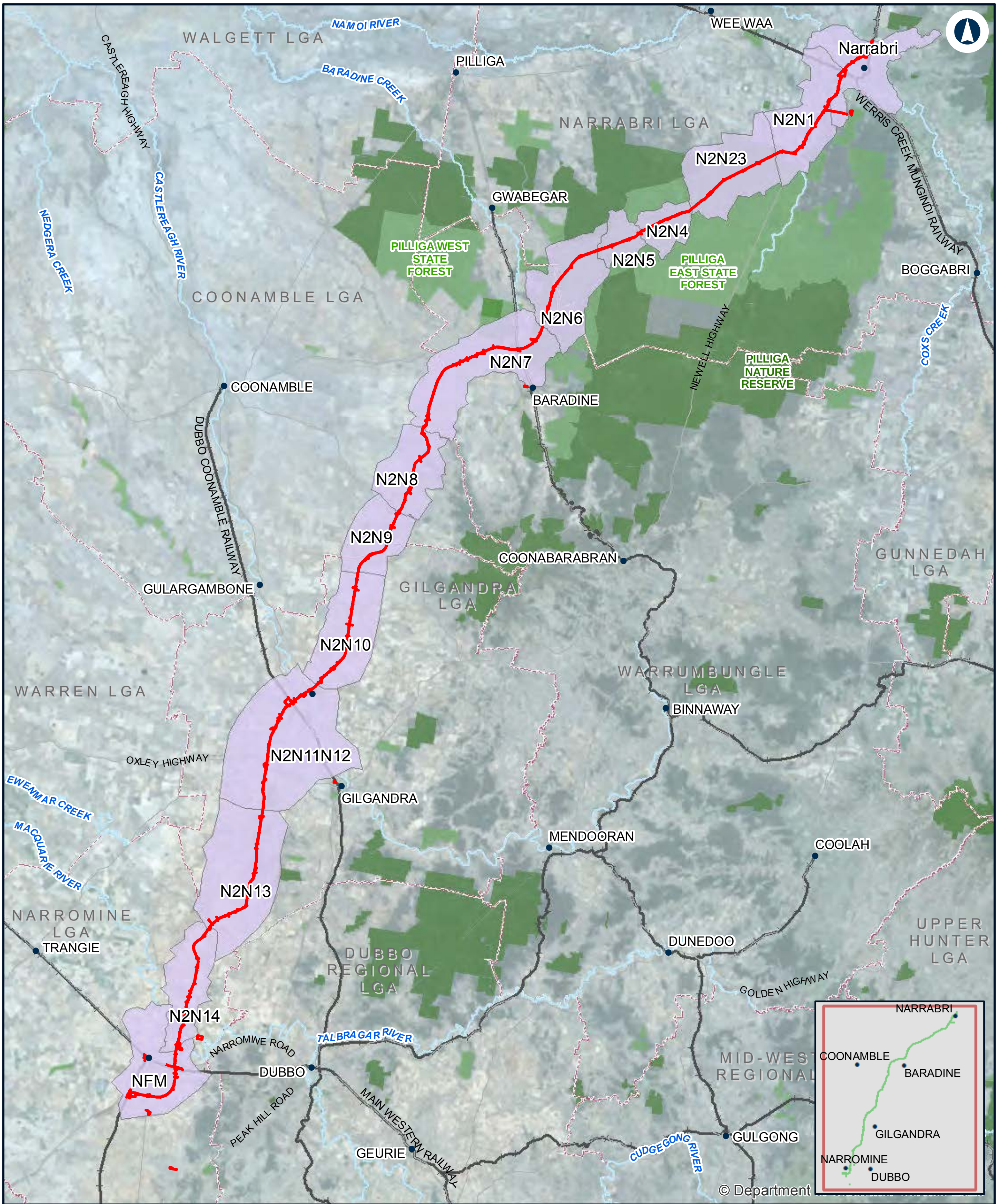
Fourteen TUFLOW hydraulics models were developed using the available topographic and land use data to define flood behaviour along the proposal. Extents of the hydraulics models are shown in Figure 3.4 and the extent of the proposal covered by each hydraulics model is shown in Table 3.4. Each hydraulics model covers a portion of the proposal site and an area of the floodplain upslope and downslope sufficient to capture any potential upstream breakouts, changes in flood behaviour due to the proposal and relatively free from backwater influences.

Table 3.4 Extent of the proposal represented in each hydraulics model

TUFLOW model	Description	Start chainage (km)	End chainage (km)
Narromine Flood Model (NFM)	Macquarie River and Wallaby Creek	547.00	569.40
N2N14	Minor watercourses	566.39	594.88
N2N13	Ewenmar Creek to Bundijoe Creek	593.34	624.82
N2N11-12	Boothaguy Creek to Castlereagh River	623.91	657.63
N2N10	Judes Creek to Gulargambone Creek	654.34	681.24
N2N9	Baronne Creek to Tenandra Creek	677.64	697.45
N2N8	Mungery Creek to Calga Creek	696.95	717.56
N2N7	Noonbar Creek to Coolangla Creek	717.56	754.75
N2N6	Cumbil Forest Creek to Tinegie Creek	754.75	775.67
N2N5	Talluba Creek	775.67	785.82
N2N4	Rocky Creek to Coghill Creek	785.82	797.54
N2N23	Mollieroi Creek to Bundock Creek	797.54	818.86
N2N1	Bohena Creek	818.86	843.89
Narrabri	Namoi River and Narrabri Creek	833.70	853.00

The adopted grid size for all TUFLOW models is 10 metres. The hydraulics model topography was defined from DEMs provided by ARTC (refer Section 3.3.3) and DEMs extracted from ELVIS (refer Section 3.3.3). Surface roughness was based on typical industry standard values for different land use types identified from GIS layers (eg land use and planning layers for NSW) and aerial photography, and was adjusted through the model calibration process.

Bridges were generally modelled in two dimensions as flow constrictions. In general, a generic approach in combination with blockage due to piers at the new bridges was adopted for all but NFM and Narrabri TUFLOW models. A detailed analysis was undertaken to define energy loss coefficients for the proposed Macquarie River and Narrabri bridges. Typically, culverts were modelled as one-dimensional elements to capture the hydraulic response of each culvert and to allow for the simple modification of the number of culverts and dimensions. Details on the existing culverts and bridges were sourced from the hydraulics models for Narrabri and Narromine provided by councils, topographic survey undertaken for the proposal, information from Transport for NSW and identified based on a review of terrain data and aerial imagery.



NARROMINE TO NARRABRI Hydraulic model extents Figure 3.4

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

- The proposal
- Hydraulic model extent

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Model calibration and verification

Five TUFLOW hydraulics models were calibrated against observed stream data as follows:

- Narromine (NFM) was calibrated against flood events of August 1990, August 1998, November 2000 and November 2010.
- Baronne Creek (N2N9) was checked against the flood events of January 1995 and July 1998.
- Baradine Creek (N2N7) was calibrated against flood events of July 1998 and December 2007.
- Bohena Creek (N2N1) was calibrated against flood events of July and September 1998.
- Narrabri (Narrabri) was calibrated against regional flood events of February 1995, February 1971 and July 1998, and the local catchment flood events of December 2004 and February 2012.

In general, acceptable calibration results were achieved for all five TUFLOW models.

Limited stream data was available to verify three TUFLOW models. The models for Narromine (NFM) and Narrabri (Narrabri) were verified against flood behaviour modelled in council flood studies for design flood events. The Bohena Creek (N2N1) model was verified against the current stage and discharge rating curve adopted by WaterNSW for the stream gauge located at Newell Highway bridge (gauging station number 419905). Satisfactory verification results were obtained for the three TUFLOW models.

3.4.3 Design flood event simulation

The TUFLOW hydraulic models were used to define existing flood behaviour for the range of design flood events using flood hydrographs simulated by the RORB hydrology models (Section 3.4.1). Model results were processed to define peak flood depths, peak flood levels, peak velocities, flood hazard categories and duration of inundation above 0.5 metres depth of flooding for all channels and floodplains crossed by the proposal at 10 metre grids. The 0.5 metres depth of flooding was selected for duration of inundation analysis on the basis of the following considerations:

- A typical depth of flooding likely to impact on land uses such as crops, pastures and grazing.
- Buildings with slab on ground are likely to be impacted by flooding.
- A 0.5 metres freeboard above the 1% AEP event is typically adopted by local councils for defining flood planning level for residential development.

A geo-database was created in GIS for each selected design flood event to identify peak flood depths, peak flood levels, peak velocities, flood hazard categories and duration of inundation above 0.5 metres depth of flooding for further analysis. The geo-databases were used to generate flood maps and define flood behaviour along the proposal site.

3.4.4 Landowner validation of modelled flood behaviour

As part of consultation activities with landowners (refer Section 4.2), flood maps prepared for the existing 1% AEP event were presented to 117 landowners to confirm acceptance of modelled flood behaviour. Eighty landowners confirmed reasonable accuracy of the flood mapping, seven landowners identified the need for partial updating of flood mapping and eleven landowners requested revision/ updating of flood mapping. Nineteen landowners had no comments or declined to comment on the acceptability of flood mapping.

A review of responses provided by two landowners identifies that local flood behaviour in minor water courses and localised obstructions (eg banks, vegetation etc.) need to be represented in detail to update flood mapping in two localised areas. Five landowners did not provide any information to explain the reasons for partial updating of the maps. Differences between observed and modelled flood behaviour in localised areas were also identified as the main reason for revision/updating of flood mapping by two landowners.

The owner of a property in Narromine identified that the property was flooded during the flood event of 1955 which was equivalent to about a 1% AEP event. However, the property is not impacted in the modelled 1% AEP event. A review of the available information (Bewsher, 1998) suggests that floodwaters broke out from the Macquarie River near Webbs Siding in the 1955 flood event due to failure of the railway embankment. These floodwaters moved through the railway culvert and over the washed out section of the railway line and joined with Backwater Cowal. Differences between the 1955 observed flood behaviour and modelled flood behaviour are likely to be due to how the existing rail embankments are represented in the flood model. The flood modelling for the proposal is based on the existing embankment at Webbs Siding remaining during a flood and would not be washed out due to overtopping of the embankment. This is considered an appropriate assumption as it is understood the rail embankment at Webbs Siding was reconstructed following the 1955 flood event and has not failed as a result of flooding since then. In addition, all other embankments within the study area are assumed to remain standing during a flood which is considered the most appropriate approach given the high degree of uncertainty in trying to predict or simulate the failure of embankments due to flooding.

3.5 Design process

3.5.1 Bridge and culvert sizing

The TUFLOW hydraulic models representing the existing developed conditions were updated to represent all proposed works for the operational phase of the proposal. In particular, the rail formation, culverts, bridges, roads and other works which have the potential to impact on flood behaviour were represented in the TUFLOW models. It is not proposed to construct any permanent spoil mounds within the proposal site. The management of excess spoil from the proposal, including reuse in rehabilitation of borrow pits, is discussed further in the EIS.

An iterative approach was used to identify the size of each structure required to minimise the flood impacts associated with the proposal. The TUFLOW models representing the operational phase of the proposal were initially run for the selected design flood events to satisfy the flood immunity requirement for the proposal and then several iterations were undertaken to minimise flooding impacts in the 1% AEP event. A schematic summarising the design process for the identification of the required culverts and bridges is included Figure 3.5. The term ‘exit’ used in the figure refers to the completion of the design process once afflux values were within the target range, or minimised as far as practical, using feasible structure sizes.

Bridges and culverts were assumed clear of blockages when sizing the structures and assessing construction phase and operational phase flood impacts. Blockage of structures was considered by undertaking a blockage sensitivity assessment for the operational phase as discussed in Section 3.6.4.

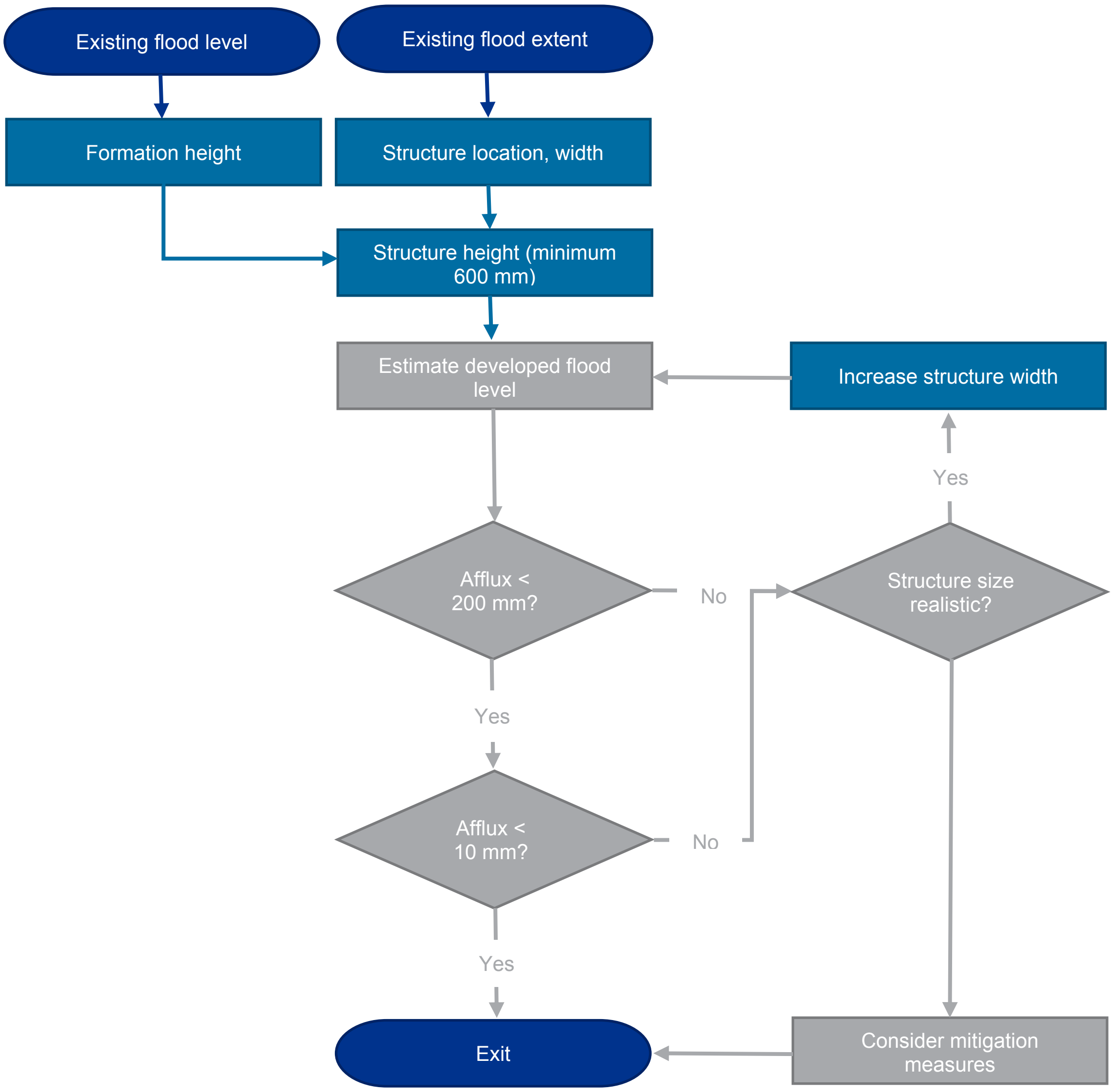


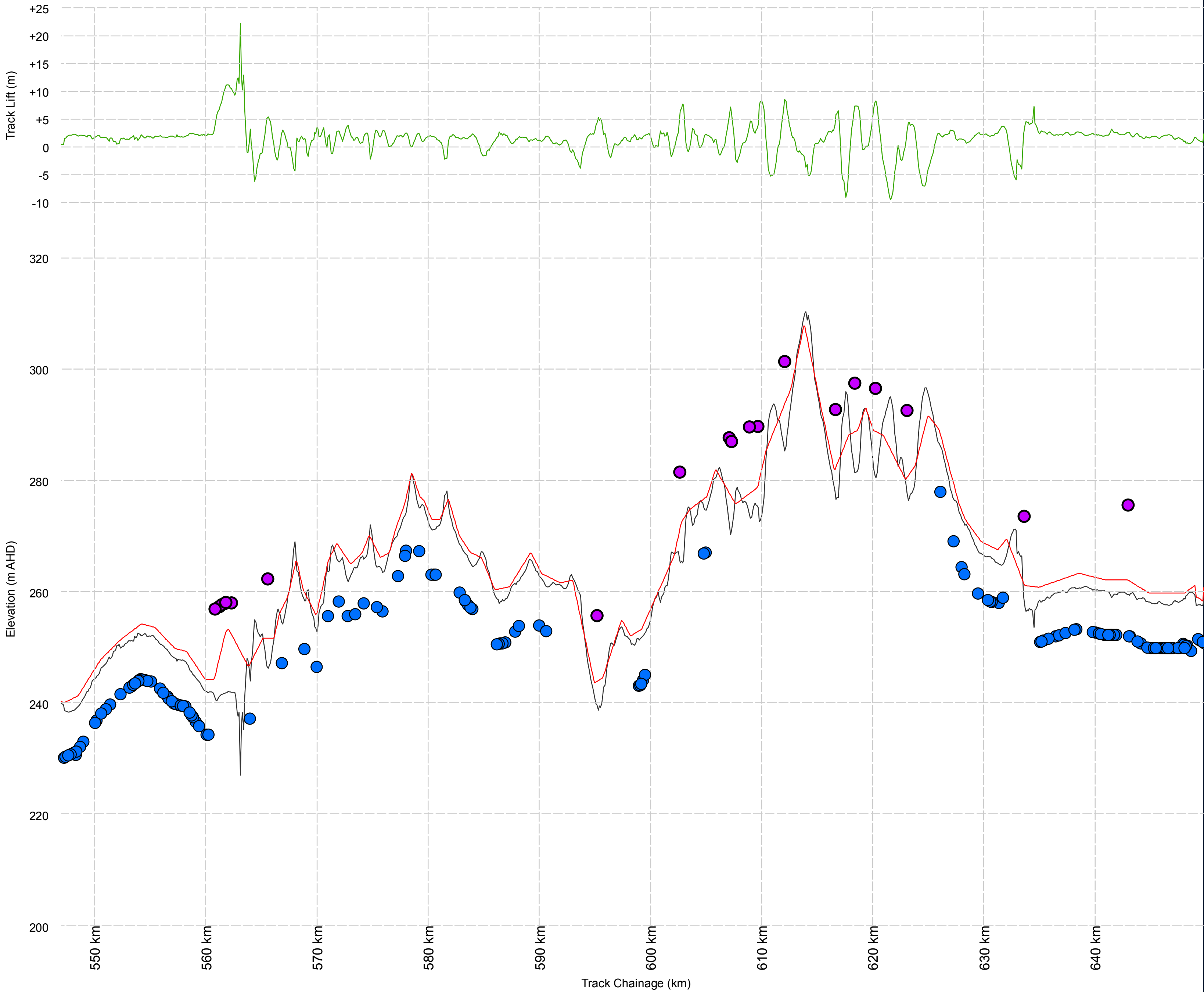
Figure 3.5 Indicative design process

3.5.2 Proposed bridges and culverts

The proposal includes about 630 banks of culverts of varying types and sizes and 73 bridges along the proposal site.

Figure 3.6 provides the existing natural surface along the proposed alignment, and the design track long section and associated structures (offset eight metres below the track level for clarity).

Figure 3.7 shows the locations of proposed culverts and bridges for the proposal while details of the proposed culverts and bridges are provided in Appendix A.



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NARROMINE TO NARRABRI

Design track alignment

Figure 3.6a

LEGEND

- Bridges (Elevation not shown)
- Culverts (Elevation not shown)
- Design
- Natural Surface
- Track Lift

Coordinate System: GDA 1994 MGA Zone 55

Date: 10/09/2020 Paper: A4
Author: JacobsGHD Scale: 1:500,000
Data Sources: Track alignment: ARTC;

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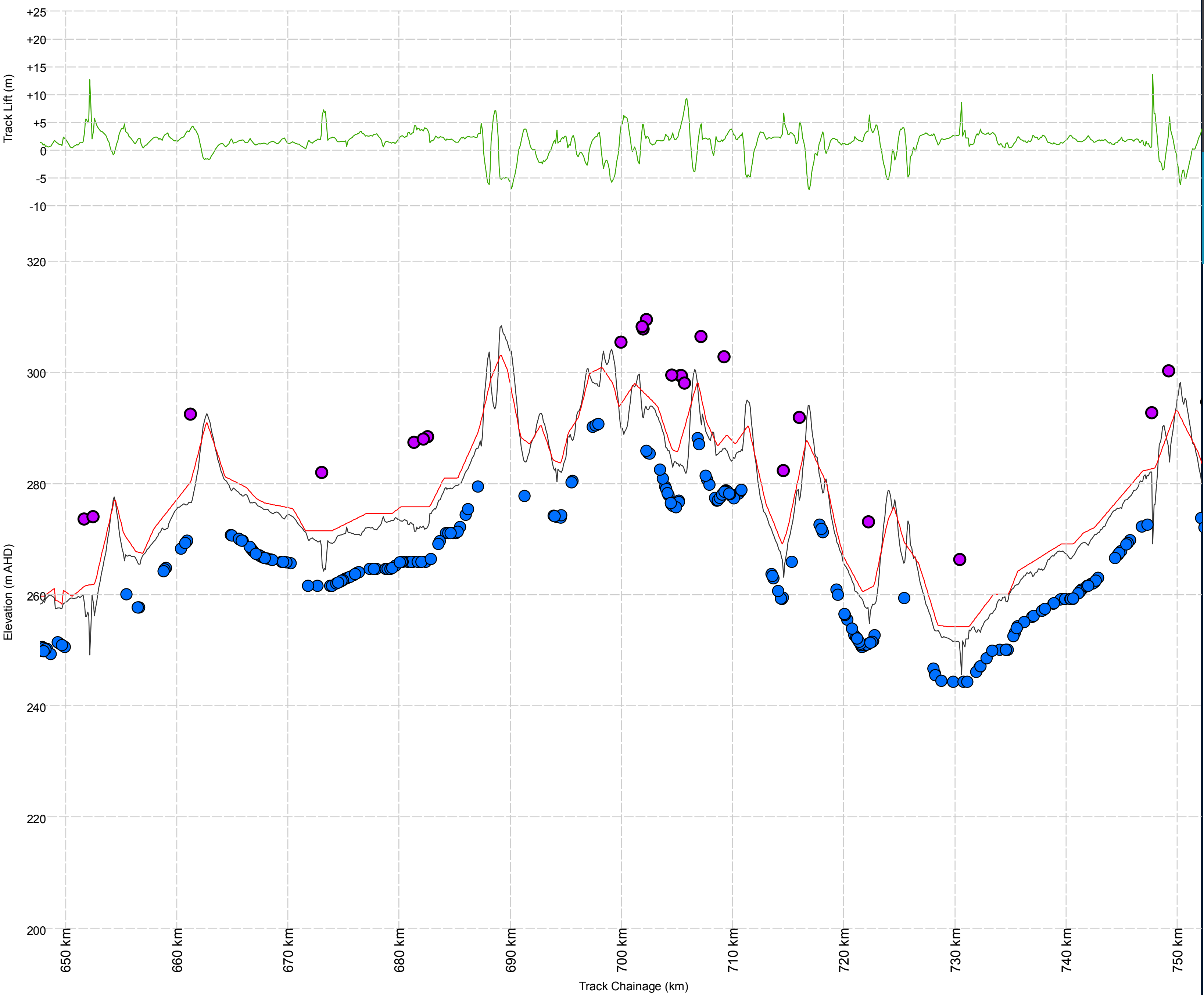

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NARROMINE TO NARRABRI

Design track alignment

Figure 3.6b

LEGEND

- Bridges (Elevation not shown)
- Culverts (Elevation not shown)
- Design
- Natural Surface
- Track Lift

Coordinate System: GDA 1994 MGA Zone 55

Date: 10/09/2020
Paper: A4
Author: JacobsGHD
Scale: 1:500,000
Data Sources: Track alignment: ARTC;

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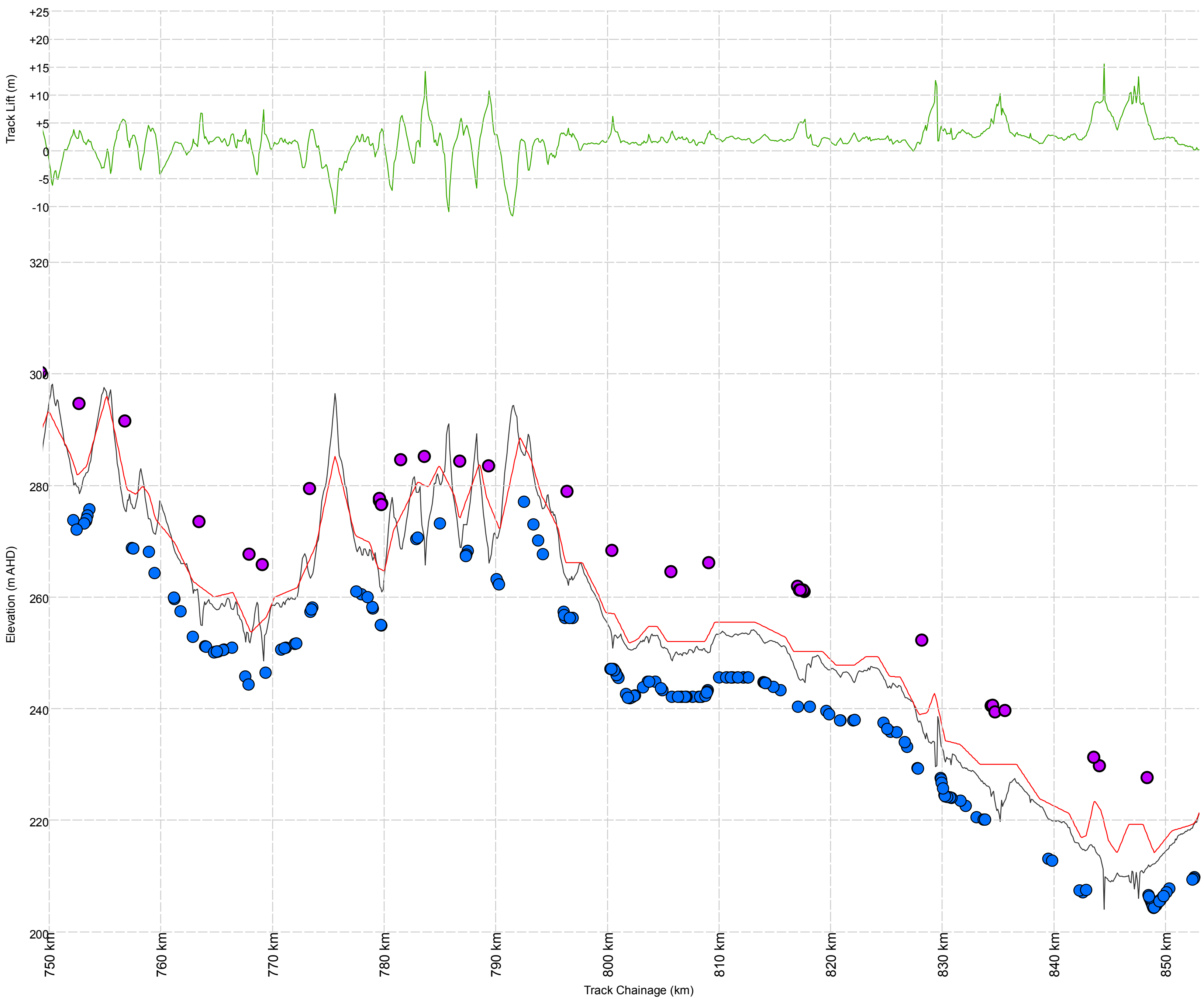

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NARROMINE TO NARRABRI
Design track alignment

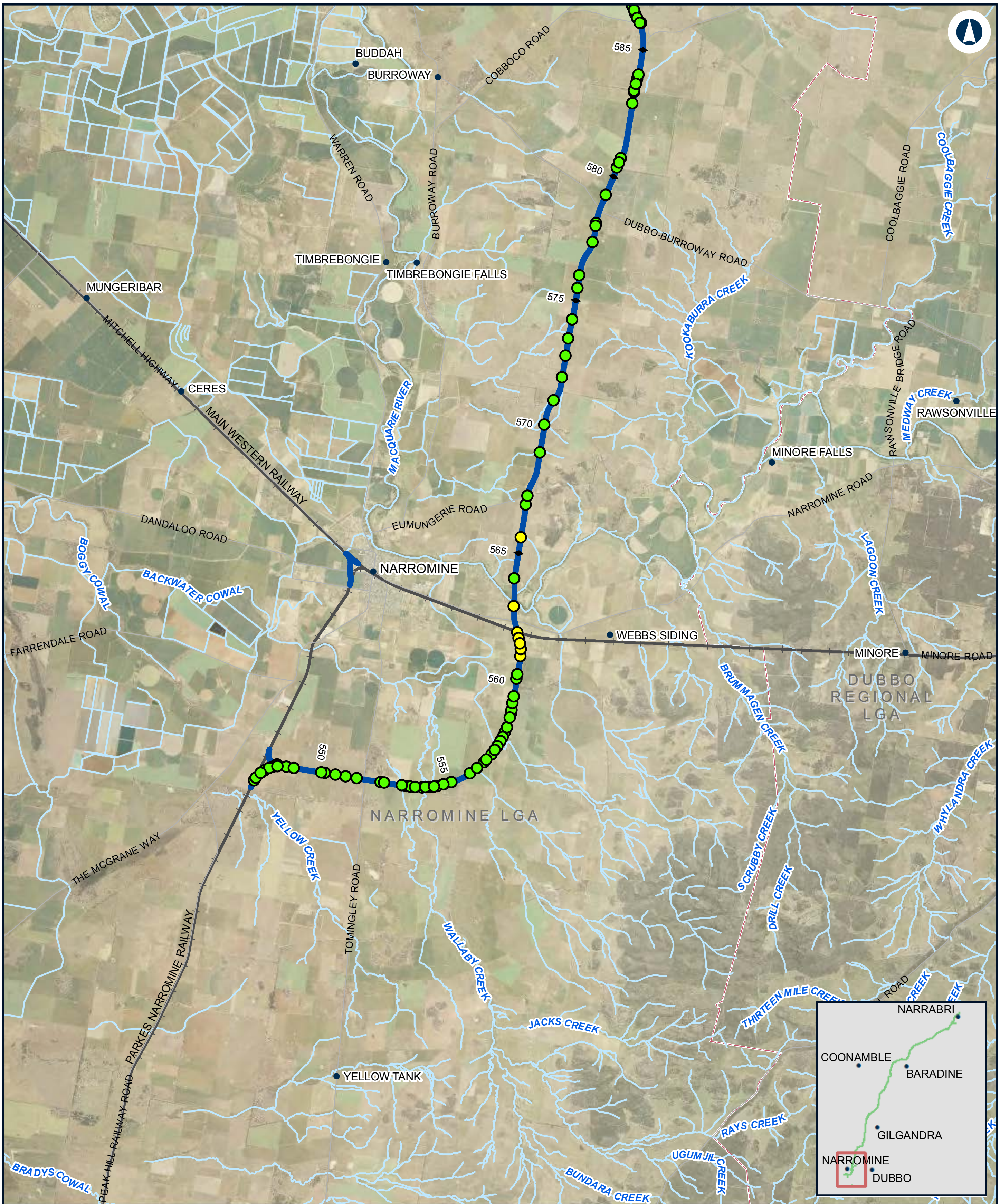
Figure 3.6c

LEGEND

- Bridges (Elevation not shown)
- Culverts (Elevation not shown)
- Design
- Natural Surface
- Track Lift

Coordinate System: GDA 1994 MGA Zone 55

Date: 10/09/2020 Paper: A4
Author: JacobsGHD Scale: 1:500,000
Data Sources: Track alignment: ARTC;



NARROMINE TO NARRABRI Proposed structure locations

Figure 3.7a

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 55

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Data Sources: Basemap layers: NSWSS;

LEGEND

- Bridge
- Culvert
- Alignment
- Watercourse
- Railway
- Road

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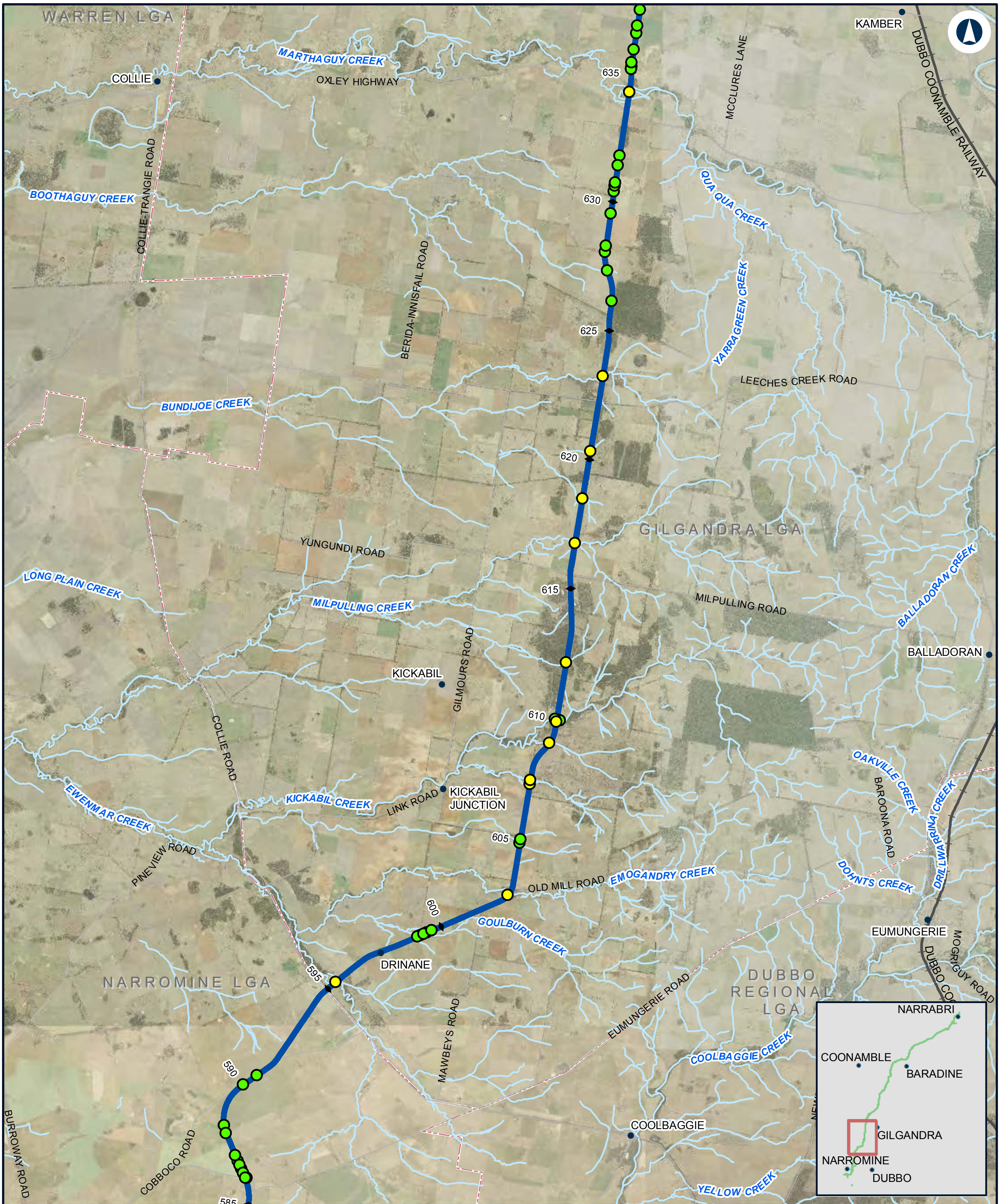

NARROMINE TO NARRABRI

Proposed structure locations

Figure 3.7b

0 4 8 Km

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LEGEND

- Bridge
- Culvert
- Alignment
- Watercourse
- Railway
- Road

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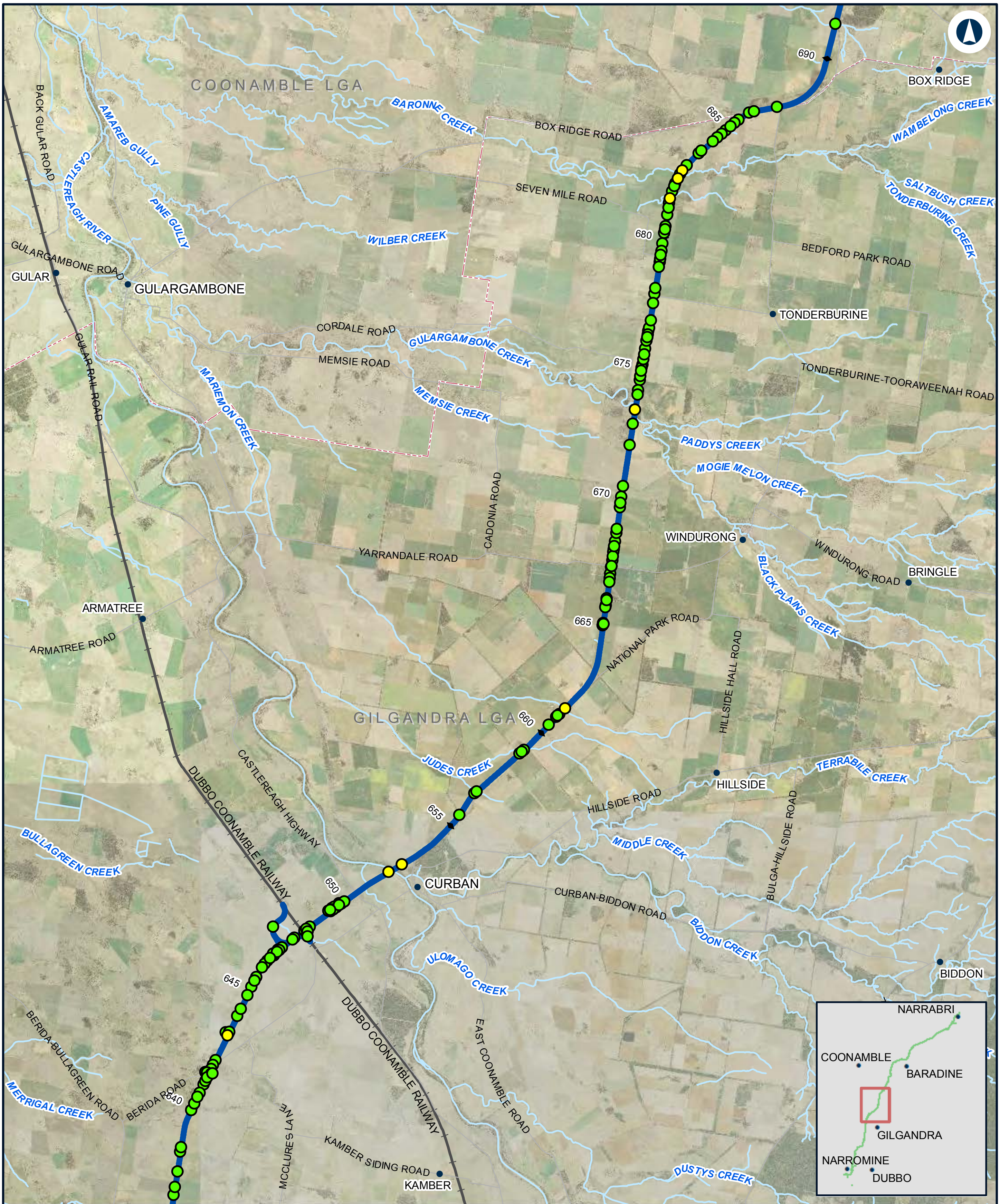

NARROMINE TO NARRABRI Proposed structure locations Figure 3.7c

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 55

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Data Sources: Basemap layers: NSWSS;

LEGEND

- Bridge
- Culvert
- Alignment
- Watercourse
- Railway
- Road

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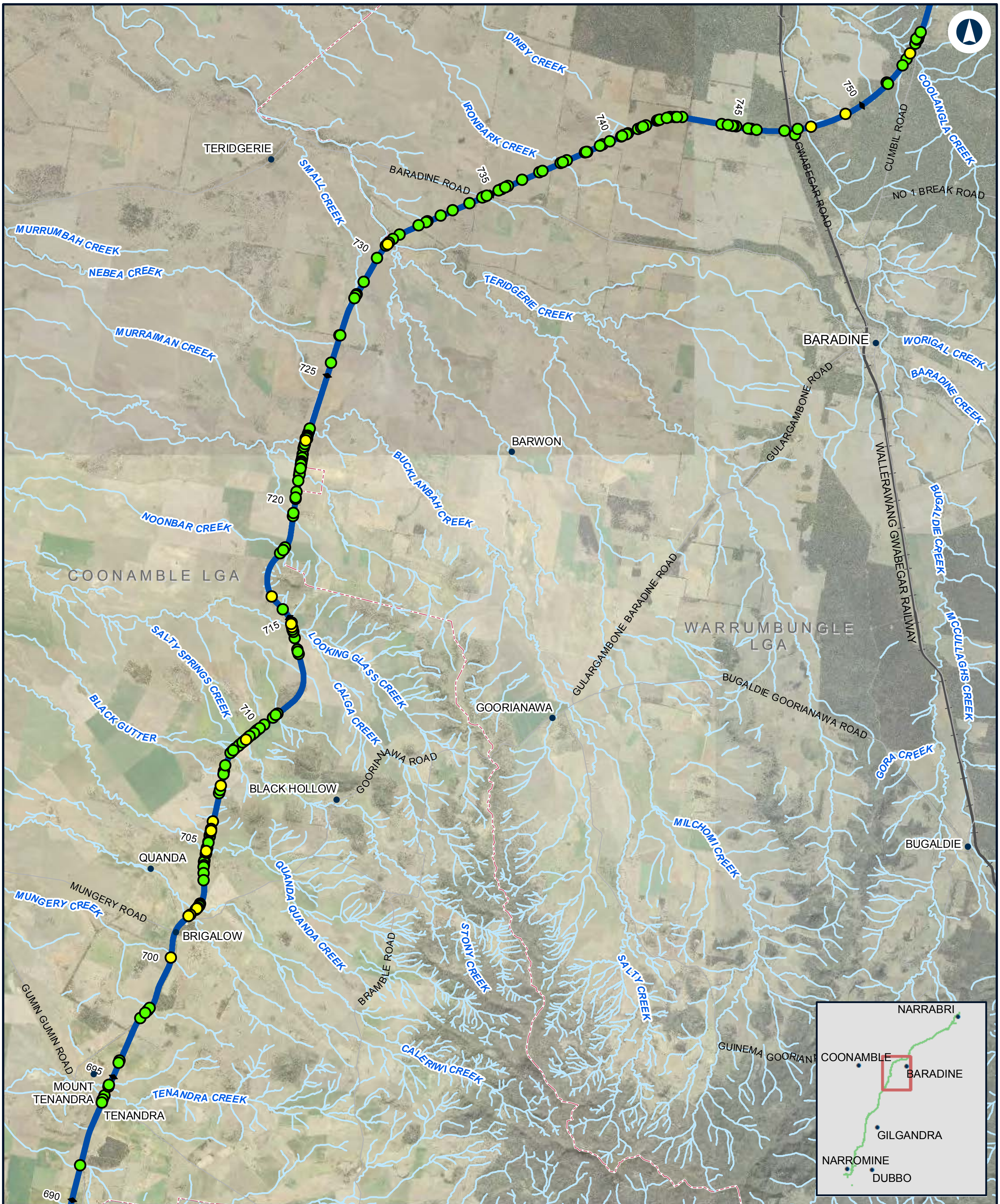

NARROMINE TO NARRABRI

Proposed structure locations

Figure 3.7d

0 4 8 Km

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Data Sources: Basemap layers: NSWSS;

LEGEND

- Bridge
- Culvert
- Alignment
- Railway

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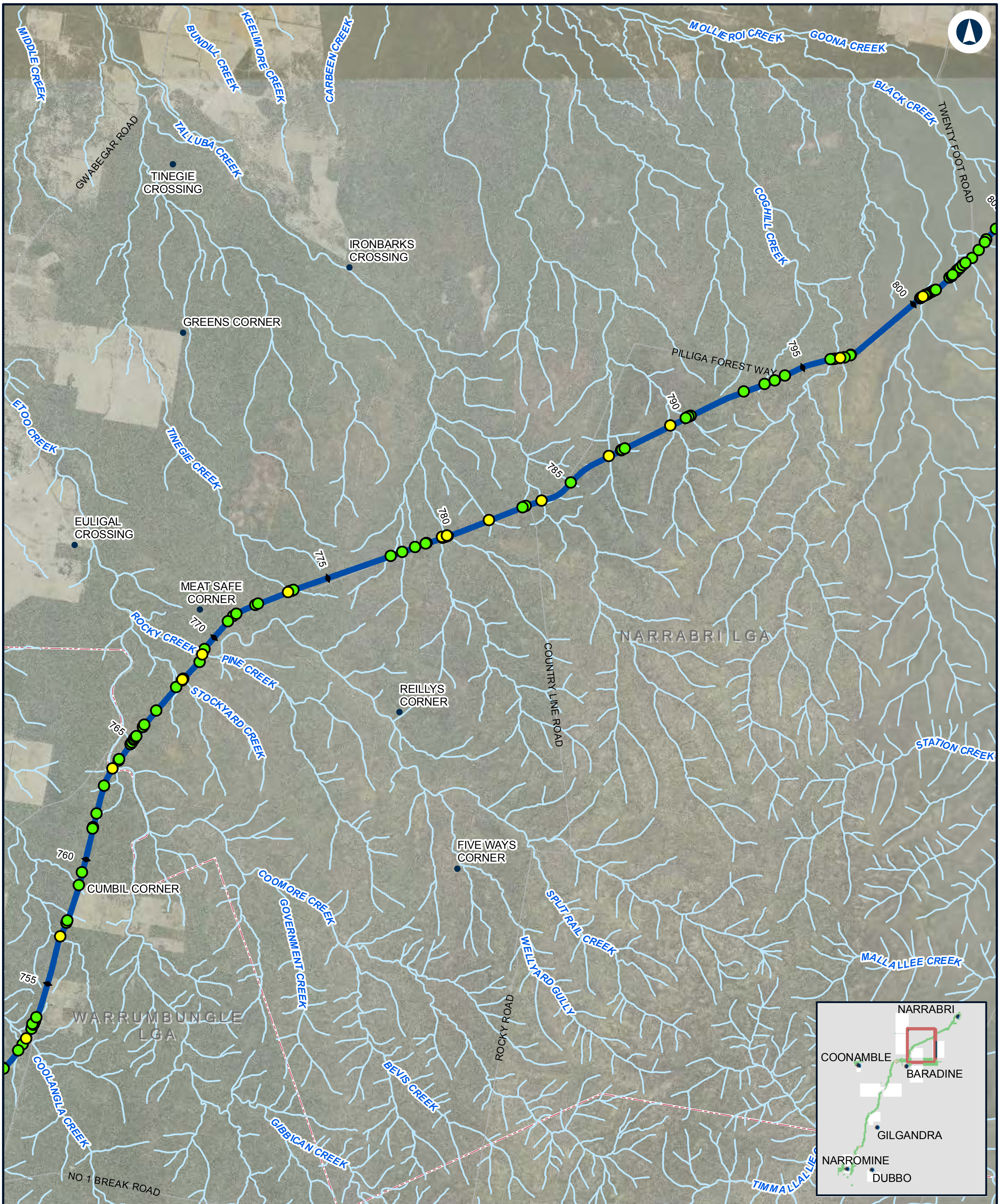

NARROMINE TO NARRABRI Proposed structure locations

Figure 3.7e

0 4 8 Km

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LEGEND

- Bridge
- Culvert
- Alignment
- Road

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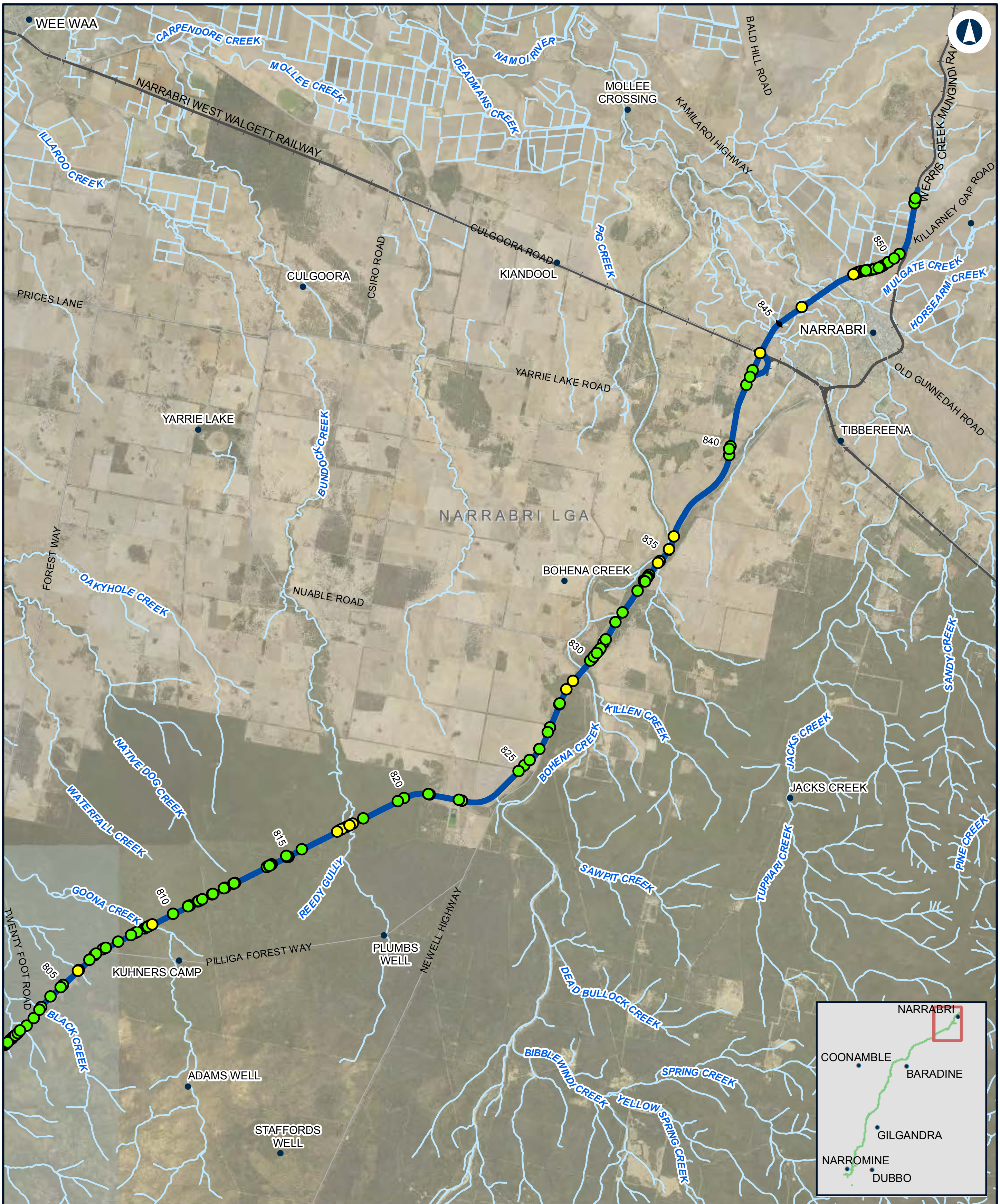

NARROMINE TO NARRABRI Proposed structure locations Figure 3.7f

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 10/09/2020 Paper: A4
Author: JacobsGHD Scale: 1:200,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- Bridge
- Culvert
- Alignment
- Watercourse
- Railway
- Road

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3.6 Flood impact assessment

3.6.1 Operational phase

The TUFLOW models used in of sizing bridges and culverts were updated as required to ensure that rail formation, culverts, bridges, roads and other works for the proposal were represented in the TUFLOW models. The updated TUFLOW models were run for the full range of design flood events up to and including the PMF event. TUFLOW modelling results were saved in geo- databases for assessing flooding impacts for the operation phase. Impacts of the proposal on flood levels, flow velocities, flood hazards and duration of inundation above 0.5 metre depth of flooding were assessed at residential and non-residential buildings, neighbouring infrastructure such as roads and rural areas.

3.6.2 Construction phase

All temporary construction works for the proposal were reviewed to identify a critical construction stage from a flooding perspective. The critical construction stage was represented in the models and the models were run for the 20% AEP, 5% AEP and 1% AEP events. Impacts of the proposal on flood levels, flow velocities, flood hazards and duration of inundation above 0.5 metre depth of flooding were assessed at residential and non-residential buildings, neighbouring infrastructure such as roads and rural areas.

3.6.3 Climate change

Impacts due to climate change were assessed for the 1% AEP event using guidelines from ARR 2019 and in accordance with the Inland Rail *Climate Change Risk Assessment Framework* (ARTC, 2019) and climate change risk assessment for the proposal. This scenario involved simulation of the 1% AEP event with a 22.8 per cent increase in rainfall depth based on recommendation of ARR 2019 to adopt the representative concentration pathways (RCP) 8.5 by the year 2090. RCP 8.5 refers to the upper range projection of greenhouse gas concentrations in the atmosphere as adopted by the IPCC in 2014 for the assessment of climate change impacts.

The same runoff routing parameter values, spatial and temporal distribution of rainfall, and rainfall losses adopted in the simulation of the 1% AEP event were also adopted for the climate change scenario.

3.6.4 Blockage

A blockage sensitivity assessment was undertaken in accordance with guidance in ARR 2019. This approach adopts a risk assessment framework that considers the catchment potential for debris loading and the interaction with a given structure. The types of debris considered are broadly categorised as floating debris of various sizes from small branches through to logs or trees, and non-floating debris which is the sediment load. A blockage factor was calculated for each structure based on the risk or potential for blockage to occur due to both floating and non-floating debris.

For bridges, the minimum span between bridge piers is 14 metres. This is a large opening and was considered unlikely to be blocked by floating debris. Deposition of sediments under bridges is unlikely to occur due to potential increases in flow velocities through structures in the rail embankment across floodplains. Therefore, no blockage factors were applied to bridges.

Estimated blockage factors for culverts range between zero and 100 per cent, depending on the culvert location and assessed risk rating. Culverts with blockage factors of 100 per cent are located within the Pilliga forest areas and at Mount Tenandra. The majority of the proposal is in a rural environment and limited measured data is available on historic flood behaviour, soil erosion and the movement of debris. To account for these uncertainties, blockage factors equivalent to twice the ARR 2019 calculated blockage were assessed in the hydraulics models and a minimum blockage factor of five per cent was adopted for all culverts.

Impacts of blockages on the flood immunity and afflux requirements for the proposal were assessed for the 1% AEP event under the existing climate and with the projected climate for the year 2090. The results of the blockage sensitivity assessment are presented in Section 7.1.14.

3.7 Consultation

Consultation with the community and stakeholders was undertaken for the proposal to collect information on historical flood behaviour, validate modelled flood behaviour, and to understand perceptions of the community and stakeholders on potential impacts of the proposal on flood behaviour. Further details on consultation activities carried out and considered in the flood assessment are provided in Section 4.

3.8 Independent review of flood models

The flood modelling for the proposal was independently peer reviewed by BMT in accordance with SEARs 9.2(b). The independent review of the flood models is provided in Appendix B. The independent review found that generally the hydrological and hydraulic modelling undertaken for the proposal is consistent with the relevant guidelines and is appropriate for the reference design phase of the proposal. Recommendations have been provided in relation to refinements of the hydrological and hydraulics models and these would be undertaken during detailed design.

3.9 Geomorphology

3.9.1 Existing conditions

A description of the existing conditions for the geomorphology of the watercourses traversed by the proposal has been compiled based on a desktop review of available spatial data and information (including field observations by surface water quality team). A key dataset is the State-wide River Styles Spatial Layer developed by NSW Office of Water (2012) and associated reports that document the River Styles Assessments completed for the Namoi, Castlereagh and Macquarie Catchment Areas (GHD, 2010; Lampert and Short, 2004).

The River Styles® framework (Brierley and Fryirs, 2003) is a river characterisation process that allows interpretation of river form and behaviour from which appropriate management approaches can be formulated. The first level of assessment is based on defining valley setting and channel continuity with further delineation being placed on the identification of key geomorphic units as displayed in Figure 3.8. These attributes provide the basis for interpretation of stream behaviour, condition and recovery potential.

The River Style of a stream that exists at any one point within a valley is dependent upon a large number of physical factors upstream, downstream and adjacent to the point of assessment. These factors determine the geomorphic character and behaviour of the reach and a river’s physical behaviour determines how it is to be managed.

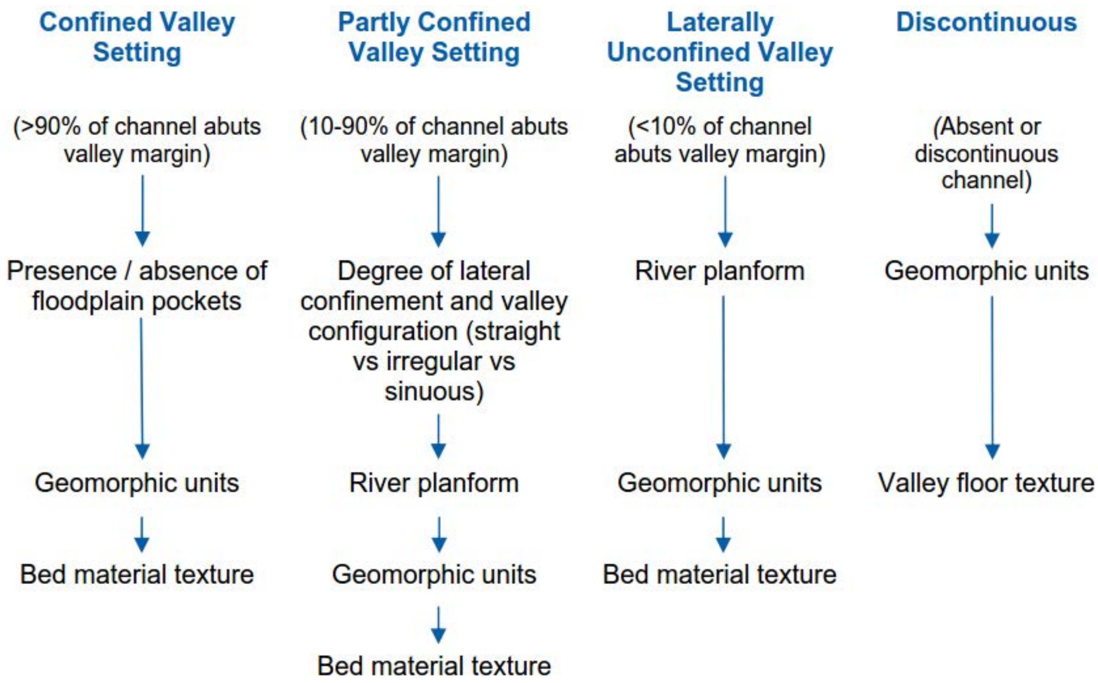


Figure 3.8 The River Styles procedural tree (GHD, 2010)

3.9.2 Hydraulic modelling

The outputs from hydraulic modelling were reviewed to inform an assessment of the impact of the proposal on the geomorphology of the watercourses.

A simple method based on maximum permissible velocity values was adopted to determine when a channel is stable/unstable. The approach as outlined here is based on that documented in Gippel *et. al.* (2008). The approach used only indicates whether a material subject to erosion falls into the category of stable or unstable (ie it does not predict degrees of instability). However, it can be assured that the further away is the velocity from the threshold of instability, the higher the risk of erosion. In practice, the calculated thresholds of stability are not sharply defined boundaries of stability. Variability of the composition of the bed and bank materials, variability in the resistance of the channel offered by vegetation, and downstream, vertical and across-river variations in velocity and shear stress mean that the thresholds are simply a guide to when the overall state of the channel shifts from being more prone to stability to being more prone to instability for the given flow conditions.

Sediment and soil properties naturally vary within a river reach. Thus, the maximum permissible velocity will vary along a river reach (ie some areas will be more stable than others). Upper and lower thresholds of maximum permissible velocity were defined on the basis of the range of soil types expected for the channel and floodplain areas. The velocities in the channels and floodplain surfaces were predicted by the hydraulic models.

The maximum permissible velocity (U_{max}) is the greatest mean channel velocity (U) that will not cause erosion of the channel body. A channel is stable when: $U < U_{max}$. Tables of maximum permissible velocity (Table 3.5) appear in many channel design, engineering and hydraulics publications (eg Chang, 1988), and they are all based on values for canals given by Fortier and Scobey (1926), and from the USSR (Anon, 1936), although some agencies have adjusted these standard values on the basis of local empirical knowledge (eg Stallings, 1999). Chow (1981) does not define what was meant by “water transporting fine suspended solids”, but it would appear from Ritzema (1994, p. 769) that this refers only to very high concentrations of suspended solids, in the order of greater than 20,000 mg/L, while the term “clear water” essentially means water with concentrations of suspended solids less than 1,000 milligrams per litre (mg/L). It is the latter case that applies to Australian rivers.

The values given in Table 3.5 assume a bare channel surface (ie no grass or other lining or vegetation) and a flow depth of one metre. Vegetation failure usually occurs at much higher levels of flow intensity than for soil (Fischenich, 2001). The values given in Table 3.5 and Table 3.6 are average values for channels, and assume a reasonable depth of flow. In addition, the values in Table 3.5 assumes average, uniform stands of each type of cover. In shallow flow situations, as would generally occur on floodplains, it is safe to assume that surfaces covered with sod forming grass would generally tolerate velocities of up to two metres per second.

Flows with long durations often have a more significant effect on erosion than short-lived flows of higher magnitude (Fischenich and Allen, 2000, p. 2-23). Fischenich (2001, p. 6) recommended application of a factor of safety to U_{max} "when flow duration exceeds a couple of hours". Graphs are provided in Fischenich (2001) for factoring according to event duration (Figure 3.9). The duration of flood events naturally varies, although in general the higher the magnitude, the longer the duration.

Table 3.5 Maximum permissible velocities for channels formed in a range of materials

Bed material (USD soil description)	Maximum permissible velocity (m/s)		
	Clear water [3]	Water transporting fine suspended solids [3]	Values used in Virginia (USA)[4]
Ordinary form loam [1]	0.8	1.1	0.9
Stiff clay, very colloidal [2]	1.1	1.5	1.0
Alluvial silts, colludial	1.1	1.5	*Not available*
Alluvial silts, non-colludial	0.6	1.1	*Not available*
Sandy loam, non-colludial	0.5	0.8	*Not available*
Fine gravel	0.8	1.5	*Not available*

Notes:
1. Plastic clay soil; mixture of clay, sand, and/or gravel, with minimum fines (silt and clay) content of 36% (Stallings, 1999).
2. Moderately to highly plastic clay; mixtures of clay, sand, and/or gravel, with minimum clay content of 36% (Stallings, 1999).
3. Fortier and Scobey (1926) – see Chow (1981, p. 165). The term "clear water" essential means water with concentrations of suspended solids less than 1,000 mg/L (Ritzema, 1994).
4. Stallings (1999).

Table 3.6 Maximum permissible velocities for channels with slopes of 0-5 per cent in easily eroded soils lined with grass

Cover	Permissible velocity (m/s)
Sod forming grass: Bermuda grass	1.8
Sod forming grass: Buffalo grass, Kentucky bluegrass, smooth brome, blue grama	1.5
Grass mixture	1.2
Bunch grass: Lespedeza sericea, weeping love grass, *ischaemum* (yellow blue stem), kudzu, alfalfa, crabgrass	0.8
Annuals	0.8

Source: Chow (1981, p. 185) using data from the U.S. Soil Conservation Service

Table 3.7 Maximum permissible velocities for channels lined with grass

Cover	Permissible velocity (m/s)
Class A turf	1.8 – 2.4
Class B turf	1.2 – 2.1
Class C turf	1.1
Long native grasses (U.S.A.)	1.2 – 1.8
Short native grasses (U.S.A.)	0.9 – 1.2

Source: Fischenich (2001) using data from various sources

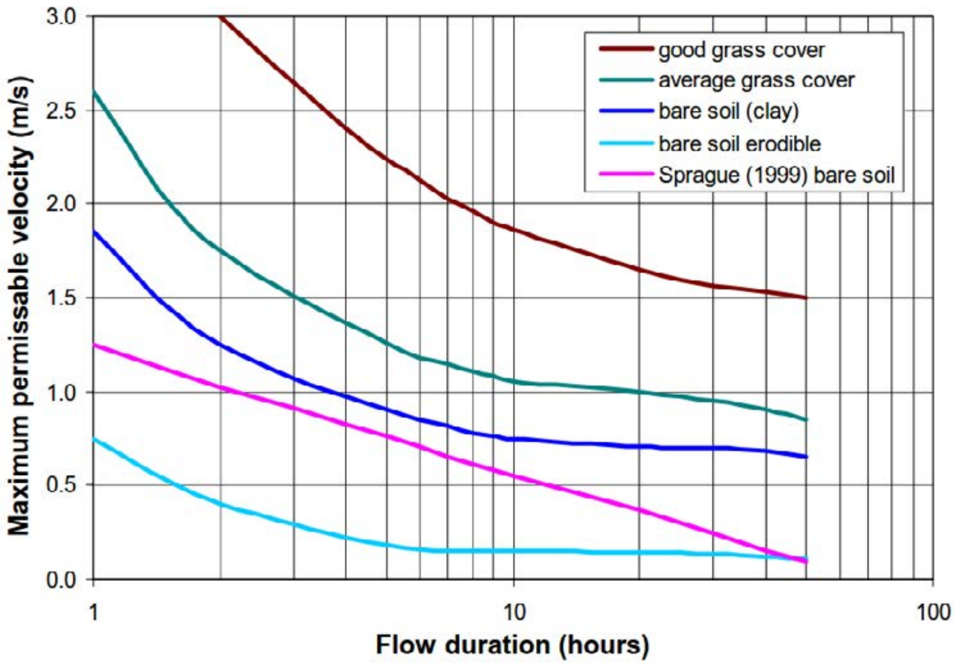


Figure 3.9 Erosion limits as a function of flow duration. Based on plots from Fischenich (2001, pp.6) and Sprague (1999)

For the sandy channels and floodplains of the watercourses along the proposal site, a maximum permissible velocity of 0.5 to 0.8 metres per second was adopted, which corresponds with the maximum permissible velocity of sandy loams and fine gravels under clear water conditions documented in Table 3.5. Vegetated surfaces would be expected to tolerate velocities up to two metres per second.

4. Consultation

Consultation with the community and stakeholders was undertaken for the proposal to collect information on historical flood behaviour and to understand perceptions of the community and stakeholders on potential impacts of the proposal on flood behaviour. Feedback from this consultation, as summarised below, has been considered in the flood modelling undertaken for the proposal.

4.1 Community consultation undertaken in 2016

A site inspection and community consultation were undertaken by Kellogg Brown & Root Pty Ltd (KBR) as part of phase 1 investigations for the proposal. The site inspection commenced in September 2016. Seven landholder meetings and inspection of selected waterway crossings were completed during the site inspection.

Key outcomes from consultation with landowners relevant to the proposal are summarised below.

4.1.1 Brooks Road, Curban

The owner of the property was interviewed with key notes as follows:

- The worst flooding occurred in 1955 and 1998.
- The depth of flooding at the entrance of the property was 1.6 metres in 1998.
- The runoff was reported as being fairly quick and the land is very susceptible to erosion.
- It was also reported that a scour hole greater than one metre deep was formed during a storm event after a new road was built in their paddock.

4.1.2 Yarrandale Road, Curban

A meeting was held with a group of landowners who identified flood breakout locations along Yarrandale Road and provided photos of flood inundation at “Karoona” property during the 2010 flood event.

4.1.3 Goorianawa Road, Black Hollow

The owner of the property was interviewed with key notes as follows:

- Localised flooding was observed in 2016 on 20 June, 5 July, 11 July, 22 July, 7 August, 2 September, 14 September and 19 September.
- It was reported that widespread flooding occurred after major storm events and flood waters passed through the property quickly.
- Flood flows were mainly sheet flows with high sediment loads.
- Quanda Creek passes through the property and occasionally breaks its banks and typically flooding occurs every two to four years.
- Flood waters came close to garage door of the property.

4.1.4 Island Road, Narrabri

The owner of the property identified that the property was not flooded in the 1955 flood. The owner also noted that the Narrabri Golf Club is located on a higher ground and the golf course is used for helicopter landing to provide flood relief.

4.2 Meetings with landowners in 2019 and early 2020

Between July 2019 and March 2020, ARTC carried out meetings with landowners along the proposal to discuss various aspects of the proposal, including historical flooding, flooding impacts on business operations and residential properties and access to farm water supply. In total, land owners of 117 properties were consulted during these meetings. Preliminary flood mapping for the 1% AEP event was also shown to the landowners and feedback was sought on the level of accuracy of the flood maps.

4.2.1 Flood impacts on business operations

Business operations of 79 properties were impacted during floods. Flood events of 2016 (54 properties), 1955 (34 properties) and 2010 (21 properties) were identified as the most common years of flooding by property owners. Business operations of eight and six properties were impacted due to flood events of 2019 and 1998 respectively.

The flood event of 2016 was identified as the worst flood event impacting on business operations by 33 respondents and 27 respondents identified the flood event of 1955 as the worst flood event impacting on business operations. Six respondents identified the flood event of 2019 as the worst event to impact on business operations. Flood events of 2010 and 1998 were identified as worst flood events impacting business operations by four respondents.

It was common for property owners to report two or more flooding events at a property, and as many as eight events were reported for any one property. The most commonly reported impacts to businesses from flooding include minor to major fence damage, erosion, ponding around crops (leading to crop damage) and vehicular bogging. Impacts were reported to last from two to four weeks in some cases, to as little as twelve hours. On average, respondents described boggy conditions lasting around one week.

Some landowners provided images of flooding events on their properties demonstrating the extent of the impacts experienced. A property owner located on the Newell Highway at Bohena Creek reported to have experienced flooding in 1955, 2004, 2010, and 2016. They reported two days of restricted access to the property during flooding events due to the driveway being inundated to depths of 0.5 metre (refer to Figure 4.1). A property owner located on Seven Mile Road, Tonderburine experienced restricted vehicular access to their property after a flood event due to soil erosion (refer to Figure 4.2).

Figure 4.1 Inundated driveway

Figure 4.2 Soil erosion

4.2.2 Flood impacts to residential property

Eleven residential properties were reported to be impacted by flooding and details on the impacted properties are provided in Table 4.1. Seven properties were reported to have impacted during the flood events of 1955, 2000, 2016, and in 2019. Of the seven properties, five properties were impacted by the flood event of 1955 and one of the properties impacted by the flood event of 1955 experienced damage to fencing during the flood event of 2019. A shed was flooded in 2000 and mud flow occurred in one property during the flood event of 2016. One house was raised after the 1955 flood. Landowners did not identify years in which the remaining properties were impacted. One shed was subject to above floor flooding for a duration of 36 to 48 hours. Access to properties were impacted as private roads, local roads or main roads were subject to inundation for up to two weeks.

Table 4.1 Impacts of flooding on residential properties

Property ID	Year impacted	Nature of damage	Flood mark available
2632396	2019 1955	Fence damaged. Approximately 1.5 m flood depth in the Cowal in 2016. Approximately 7 feet (over 2 m) flood depth in 1955 (impacted house and shed).	House and shed
4113621	NA	Shed inundated	Flood mark on the wall of shed
3773953	1955	House was inundated (up to 1 foot or 0.3 m). Since then house has been raised on brick piers.	NA
3773179	2000	Sheds were inundated up 5 inches (greater than 10 cm). It took 36-48 hours to dissipate.	Yes, please see maps
2638454	NA	As per flood maps: “Koorang” house + sheds were flooded.	As per flood maps
2638455	NA	As per flood maps: Koorang house + sheds have flooded.	As per flood maps
2655693	1955	Water was as high as 0.5 m in 1955 (advised by neighbour).	NA
2655534	1955	House was inundated with flood depth being as high as 1 m from the ground.	Flood marks present behind lining boards. Owner has had these flood marks surveyed.
3776289	1955	House was subject to approx. 0.5 m depth of flooding.	NA
3530213	2016	Water/mud ran over the back cement (100 mm). Water came through laundry.	NA
2955424	NA	NA	NA

4.2.3 Impacts of the proposal on-farm water supply

Landowners were queried whether any existing water flows to their properties need to be maintained for irrigation. Seventy landowners either did not provide a response or responded “no”. A total of 47 landowners identified the need to have existing water flows maintained on their properties. A number of landowners provided details on their private dams and other on-farm irrigation infrastructure. Acceptability of flood mapping.

Landowners were shown 1% AEP flood mapping for the existing development conditions during the meetings and landowners were asked to provide their views on the level of accuracy of the flood mapping. Eighty landowners confirmed reasonable accuracy of the flood mapping, seven landowners identified the need for partial updating of flood mapping and 11 landowners requested revision/updating of flood mapping. Nineteen landowners had no comments or declined to comment on the acceptability of flood mapping.

4.3 Community drop-in sessions

Eight community drop-in sessions were held in March 2020 in Narrabri, Baradine, Curban, Gilgandra and Narromine. These sessions provided the broader community an opportunity to engage and ask questions regarding the proposal. Many of the sessions were attended by directly and indirectly impacted land holders, along with local representatives from councils and a representative of NSW Parliament. At these sessions various discussions were held and enquiries were made regarding potential flooding impacts from the proposal.

Representatives from Narrabri Shire Council attended a drop-in session on 9 March 2020 and requested that further engagement occur with the Narrabri Floodplain Committee. Consultation with the Narrabri Floodplain Committee subsequently occurred in April 2020 (refer Section 4.5).

A representative of State Member, Roy Butler, attended the Narrabri Drop-in session. It was expressed that local input into the flood modelling was needed. This was achieved via the additional consultation occurring with the Narrabri Floodplain Committee in late April 2020.

Discussions were held with officers from Gilgandra Shire Council on 11 March 2020 regarding the proposal and potential impacts to council assets. These discussions were focussed on Gilgandra Shire Council's concerns regarding the potential scour risk to assets. ARTC advised that the impact of the proposal impact would be minimal due to the design objectives that had been adopted.

4.4 Consultation with Transport for NSW

A meeting was held on 28 November 2019 at Roads and Maritime Services (now Transport for NSW) Parkes office to discuss potential flooding impacts of the proposal on Newell Highway in the vicinity of Bohena Creek. The main objective of the meeting was to gather early input from Roads and Maritime Services on potential flooding impacts on Newell Highway due to the proposal.

Flood mapping for four flood events (1%, 2%, 5% and 20% AEP) without and with the proposal were provided to Roads and Maritime Services before the meeting. Roads and Maritime Services generally agreed that changes to the existing flood depth, flood hazard and duration of inundation on Newell Highway were generally minimal as a result of the proposal. They advised that the section of Newell Highway at Spring Creek was subject to frequent flooding. They also indicated that a heavy duty pavement upgrade of Newell Highway planned for 2024 could consider a flood immunity for the 20% AEP flood event.

4.5 Consultation with Narrabri Floodplain Risk Management Committee

A meeting was held with the Narrabri Floodplain Risk Management Committee on 28 April 2020 to discuss the approach to the flooding assessment undertaken for the proposal in Narrabri. The Narrabri Floodplain Risk Management Committee includes members of Narrabri Shire Council, SES, and OEH.

4.6 Stakeholder meetings in mid to late 2020

Between July 2020 and November 2020, ARTC held a number of meetings with landholders directly impacted by the final rail corridor. At these meetings landowners were provided updated property maps, clearly showing the location of the final rail corridor. The meetings also covered flood modelling results (flood levels with the proposal), operational noise, access, visual impacts, property acquisition and construction infrastructure.

ARTC also engaged with landowners whose property or properties where predicted to have potential above floor afflux impacts. During this engagement, ARTC explained the flood model and proposal structures nearby, the predicted impacts and possible mitigation measures.

Consultation also continued with Local and State Government entities, community and business groups, and other key stakeholders. All the feedback gathered, where applicable, was used to inform both the design and EIS process.

4.7 Draft EIS stakeholder briefings

Draft EIS stakeholder briefings were held during August 2020. This included five briefings with the N2N Community Consultative Committees, Government agencies, local government and the general public.

Online sessions included details about the proposal and EIS overview and a focus on EIS topics including biodiversity, Aboriginal heritage, flooding and hydrology, water resources, noise and vibration (construction and operation), land use and property, social and economic and traffic and access. Excluding the Community Consultative Committees briefing, 94 people attended the sessions. Questions asked by the community varied and included topics such as flooding, construction water use and legacy aspects.

4.8 Ongoing and future consultation

As described above ARTC has actively consulted with the community on flooding and hydrology. In accordance with the SEARs, ARTC has and will continue to consult with:

- DPIE Biodiversity Conservation Division (BCD) - Flood Management Division
- Narromine Shire Council
- Gilgandra Shire Council
- Warrumbungle Shire Council
- Coonamble Shire Council
- Narrabri Shire Council (including the Narrabri Floodplain Risk Management Committee)
- SES

A meeting was held with the Narrabri Floodplain Risk Management Committee on 28 April 2020 and a meeting was held with the Narromine Floodplain Risk Management Committee on 3 September 2020. Draft EIS Stakeholder Briefings held in August 2020 included attendees from Councils, SES and DPIE BCD Flood Management Division. ARTC will continue to meet with at a Local Government Area level with councils and the SES prior to EIS exhibition and during detailed design.

The approach to mitigating flooding and hydrology impacts includes continued consultation with councils, SES and to also consult with the relevant local emergency management committees.

5. Existing environment

5.1 Regional context

5.1.1 Regional catchments and watercourses

The proposal is located within the major regional water catchments of the Macquarie River basin, Castlereagh River basin, and Namoi River basin; all of which are located within the Murray-Darling Basin.

Macquarie River catchment

The Macquarie River is a perennial river and major tributary of the Barwon River. The river starts in the Great Dividing Range near Oberon and is formed by the junction of the Fish River and Campbells River upstream of Bathurst.

The Macquarie River flows northward through steep gorges before flowing into Burrendong Dam upstream of Wellington, which regulates downstream flows. The river then flows through Wellington, enters the Central West subregion upstream of Dubbo and passes through Dubbo and Narromine. Downstream of Narromine a complex system of anabranches and distributary creeks connects the Macquarie and Bogan rivers.

Downstream of the Macquarie Marshes the Macquarie River is joined by the Castlereagh River, then flows into the Barwon River upstream of Brewarrina. The Barwon River is a tributary of the Murray Darling Basin, meeting the Darling River near Bourke.

The proposal crosses the Macquarie River along the eastern outskirts of Narromine. The total upstream catchment area of the Macquarie River is 25,900 square kilometres and represents the largest upstream catchment area for a waterway crossing the proposal.

Castlereagh catchment

The Castlereagh River is a non-perennial (intermittent) river, which rises in the Warrumbungle Ranges and flows through Coonabarabran before entering hilly country. The river then flows through Binnaway, Mendooran, Gilgandra, Gulargambone and Coonamble and joins the Macquarie River downstream of the Macquarie Marshes. At Warrington, the river becomes less defined, becoming a series of pools and meandering, braided flow pathways, before becoming more defined around Youendah before meeting the Macquarie River west of Walgett.

The proposal crosses the Castlereagh River about five kilometres north-east of the Coonamble Railway, at chainage 651.7. The total upstream area of the Castlereagh River is 6,630 square kilometres.

Namoi River catchment

The Namoi River is a perennial river, which starts in the western slopes of the Great Dividing Range flowing westwards through Lake Keepit towards Boggabri, Narrabri and Wee Waa, before meeting the Barwon River at Walgett. The Barwon River is a tributary of the Murray Darling Basin, meeting the Darling River near Bourke.

The Namoi River basin is well drained by the Namoi River and its tributaries for most areas east of Pilliga. The surface drainage network extends through different landscape units ranging from uplands with steep terrain to flat low-lying alluvial plains (Lampert and Short, 2004).

The proposal crosses the Namoi River west of Narrabri. The total upstream catchment area of the Namoi River is 25,400 square kilometres.

5.1.2 Catchments and watercourses

In addition to the regional scale catchments discussed above, a number of local scale catchment watercourses cross the proposal. These range from small, unnamed tributaries with catchments of less than one km^2 to large watercourses with upstream catchment areas exceeding 2,000 km^2 (eg Bohena Creek).

Table 5.1 presents a list of the catchments, sub-catchments and named watercourses, including their respective flow type and hierarchy (derived through BoM Geofabric Surface Hydrology dataset), which are mapped as intersecting the proposal.

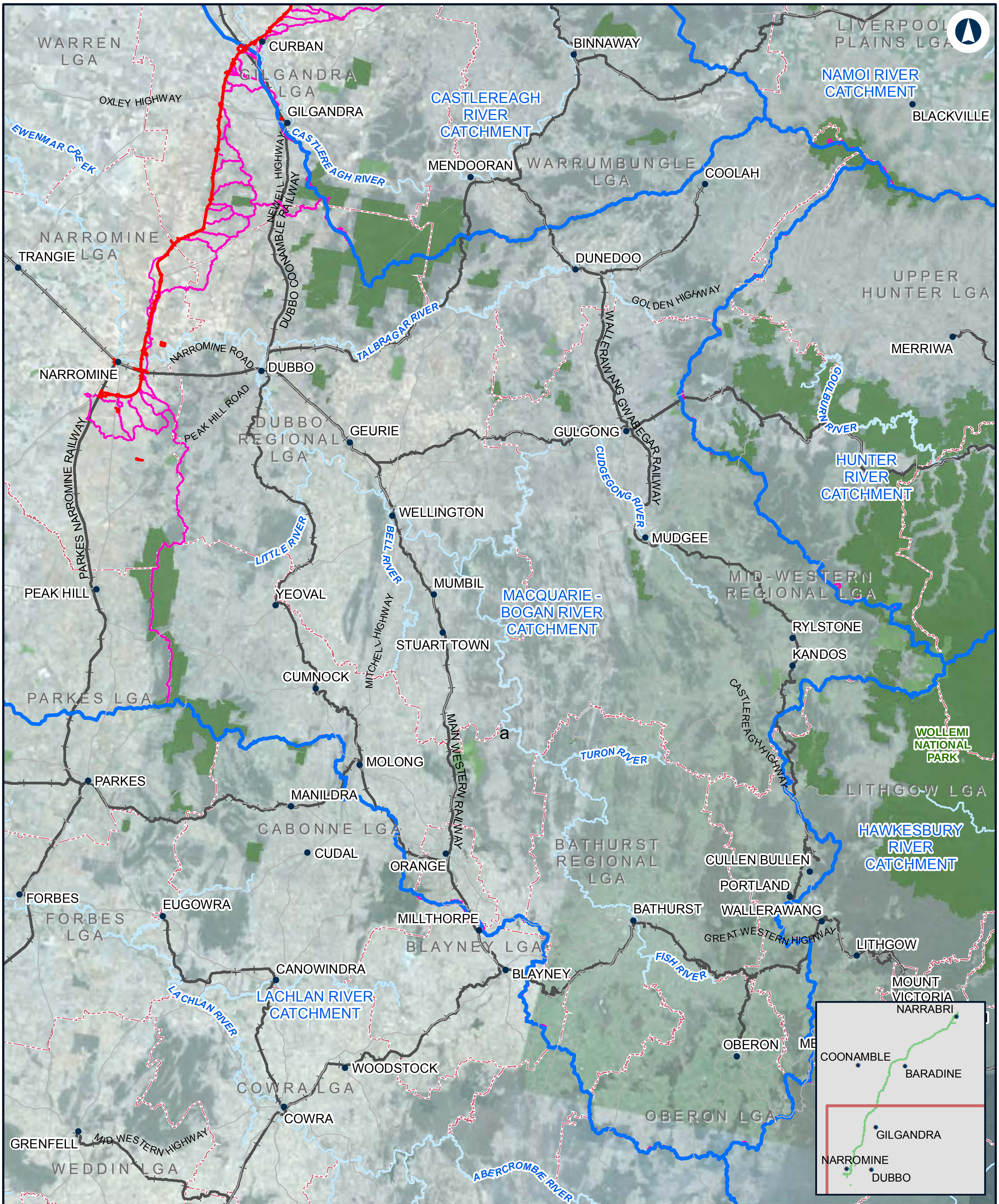
The catchments areas associated with sections of the alignment were delineated based on the SRTM DEM (section 3.3.3). Catchment areas presented in Table 5.1 are shown in Figure 5.1. Each of these catchments was further divided into sub-catchments for the purpose of modelling.

Table 5.1 shows that the majority of watercourses comprise minor watercourses with non-perennial (ephemeral / intermittent) flow conditions. Only two major perennial watercourses (Macquarie River and Namoi River) are intersected.

Table 5.1 Local catchments and watercourses intersecting the proposal

Basin	Catchments/ Watercourses	N2N Chainage (km)	Upstream catchment area (km^2)	Flow type/ hierarchy
Macquarie River basin	Yellow Creek	-	60	Non-Perennial - Minor
	Wallaby Creek	553.99	35	Non-perennial - Major
	Unnamed tributary of Backwater Cowal (South)	556.19	40	Non-Perennial - Minor
	Unnamed tributary of Backwater Cowal (North)	557.85	20	Non-Perennial - Minor
	Macquarie River	562.35	25,900	Perennial - Major
	Ewenmar Creek	595.24	130	Non-Perennial - Minor
	Goulburn Creek	599.20	25	Non-Perennial - Minor
	Emogandy Creek	602.66	40	Non-Perennial - Minor
	Native Dog Creek	607.15	15	Non-Perennial - Minor
	Pint Pot Gully	608.93	5	Non-Perennial - Minor
	Kickabil Creek	609.72	60	Non-perennial - Major
	Milpulling Creek	616.68	40	Non-perennial - Major
	Bundijoe Creek	623.23	19	Non-Perennial - Minor
	Marthaguy Creek	633.68	410	Non-Perennial - Major
Castlereagh River basin	Castlereagh River	651.73	6,630	Non-perennial - Major
	Judes Creek	659.20	20	Non-Perennial - Minor
	Gulargambone Creek	673.08	330	Non-Perennial - Minor
	Baronne Creek	682.60	430	Non-Perennial - Major
	Tenandra Creek	694.20	40	Non-Perennial - Minor
	Mungery Creek	700.02	25	Non-Perennial - Minor
	Caleriwi Creek	702.34	35	Non-Perennial - Major
	Quanda Quanda Creek	704.59	45	Non-Perennial - Minor

Basin	Catchments/ Watercourses	N2N Chainage (km)	Upstream catchment area (km^2)	Flow type/ hierarchy
	Black Gutter	708.47	< 5	Non-Perennial - Minor
	Salty Springs Creek	709.27	30	Non-Perennial - Minor
	Calga Creek	714.59	50	Non-Perennial - Minor
	Noonbar Creek	718.17	5	Non-Perennial - Minor
	Bucklanbah Creek	722.29	155	Non-Perennial - Minor
	Small Creek	728.11	5	Non-Perennial - Minor
	Teridgerie Creek	730.50	400	Non-Perennial - Major
	Ironbark Creek	737.89	35	Non-Perennial - Minor
Namoi River basin	Baradine Creek	747.77	980	Non-Perennial - Major
	Coolangla Creek	752.71	40	Non-Perennial - Minor
	Cumbil Forest Creek	758.97	10	Non-Perennial - Minor
	Etoo Creek	763.46	320	Non-Perennial - Major
	Stockyard Creek	767.94	15	Non-Perennial - Minor
	Rocky Creek	769.14	180	Non-Perennial - Minor
	Tinegie Creek	773.37	<5	Non-Perennial - Minor
	Talluba Creek	779.64	45	Non-Perennial - Minor
	Cubbo Creek	783.65	65	Non-Perennial - Minor
	Rocky Creek	789.38	20	Non-Perennial - Minor
	Coghill Creek	796.41	80	Non-Perennial - Major
	Mollieroi Creek	800.45	105	Non-Perennial - Major
	Black Creek	803.65	20	Non-Perennial - Minor
	Goona Creek	809.11	50	Non-Perennial - Minor
	Bundock Creek	817.65	80	Non-Perennial - Minor
	Bohena Creek	828.22	2,180	Non-Perennial - Major
	Namoi River	844.12	25,400	Perennial - Major
	Narrabri Creek	847.65	24,400	Perennial - Minor
	Breakout of Mulgate Creek	852.57	85	Non-Perennial - Minor



NARROMINE TO NARRABRI Waterways and catchments - Macquarie River Catchment Figure 5.1a

0 25 50 Km

Coordinate System: GDA 1994 MGA Zone 55

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Author: JacobsGHD Scale: 1:1,250,000
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LEGEND

- The proposal
- Waterway
- Major river catchment
- Catchment area

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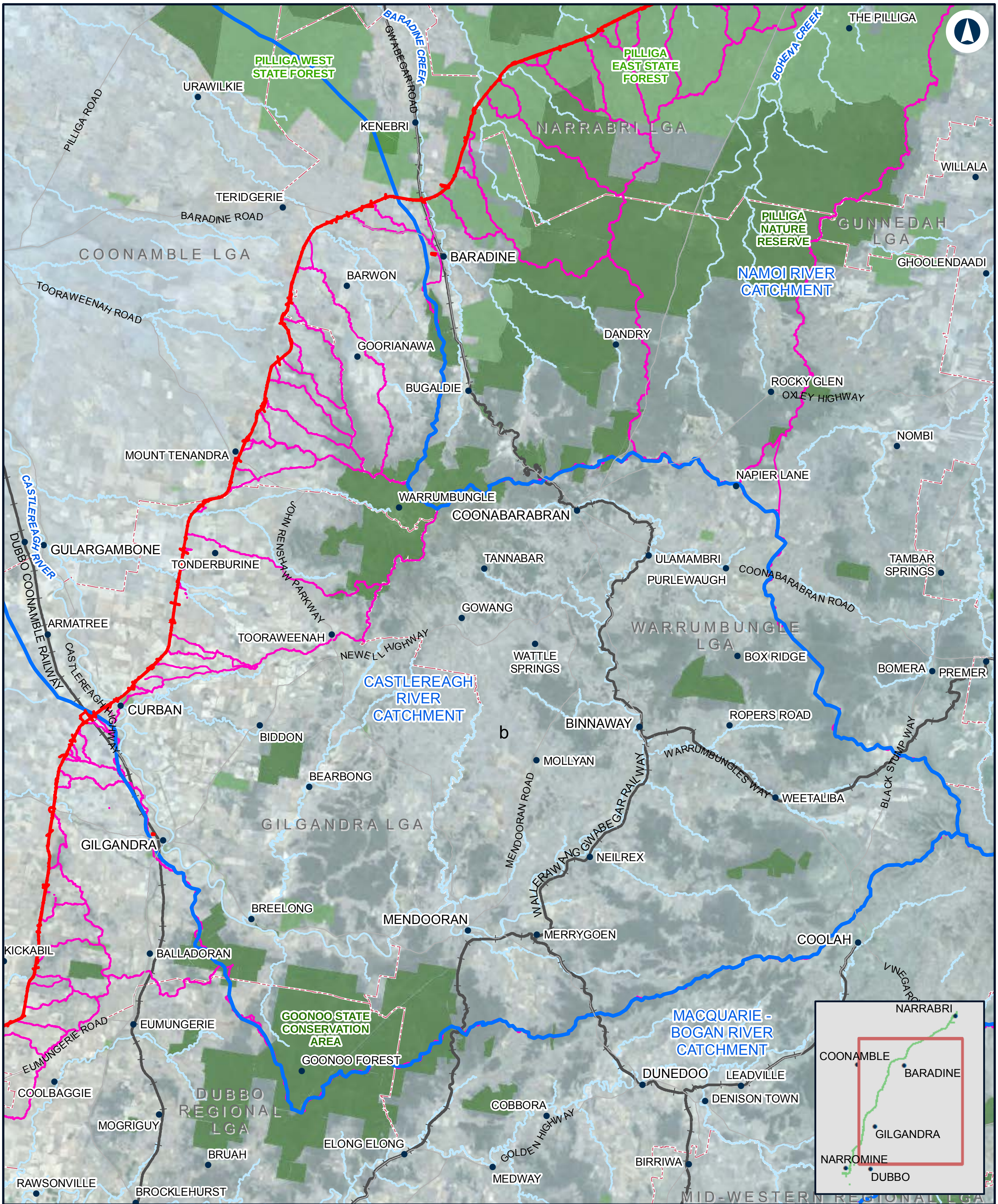

NARROMINE TO NARRABRI Waterways and catchments - Castlereagh River Catchment Figure 5.1b

0 10 20 Km

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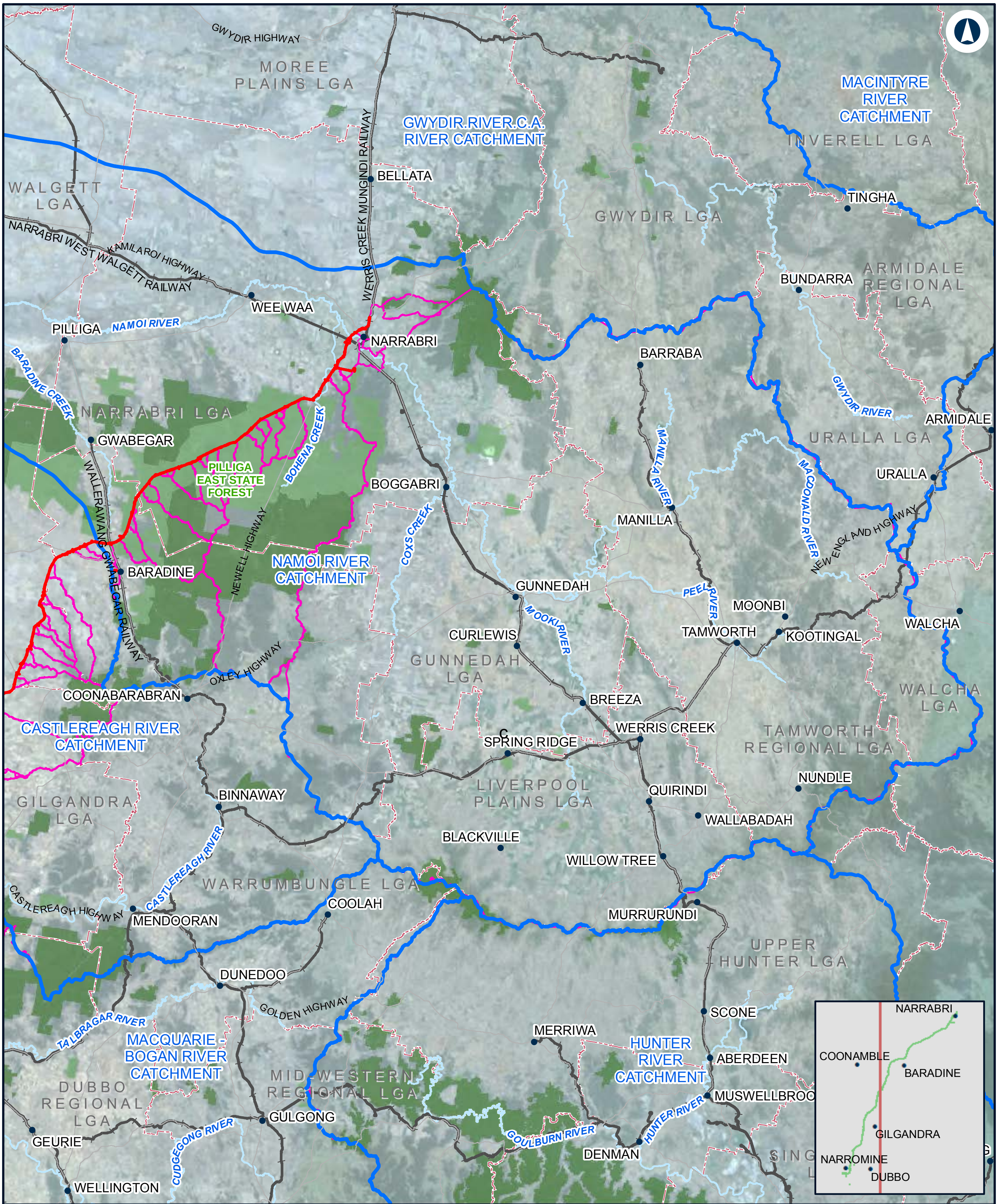

NARROMINE TO NARRABRI Waterways and catchments - Namoi River Catchment Figure 5.1c

0 30 60 Km

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LEGEND

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- Waterway
- Major river catchment
- Catchment area

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5.1.3 Rainfall

Figure 5.2 to Figure 5.4 present statistical measures of monthly rainfall at selected long-term BoM rainfall monitoring stations located along the proposal. Examination of mean annual rainfall indicates seasonal variations corresponding with a relatively 'wet' summer period (November – March) and relatively 'dry' winter period (April – October). Mean monthly rainfall varies between a high of about 80 millimetres during January to a low of about greater than 40 millimetres in August. Average annual rainfall varies between 554 and 678 millimetres.

Rainfall conditions during drier / drought years (10 percentile conditions) shows a greater variability along the proposal and less significant seasonal influence. Rainfall conditions during dry/drought years may vary between highs of about 15 millimetres during the summer period and lows of less than 5 millimetres during the winter period. Annual rainfall under 10 percentile conditions varies between 298 and 444 millimetres.

Rainfall conditions during wetter / flood years (90th percentile conditions) shows similar seasonality in trend to average rainfall conditions. Rainfall conditions during wet/flood years may vary between highs of about 150 millimetres during the summer period and lows of about 75 millimetres during the winter period. Annual rainfall under 90th percentile conditions varies between 764 and 945 millimetres.

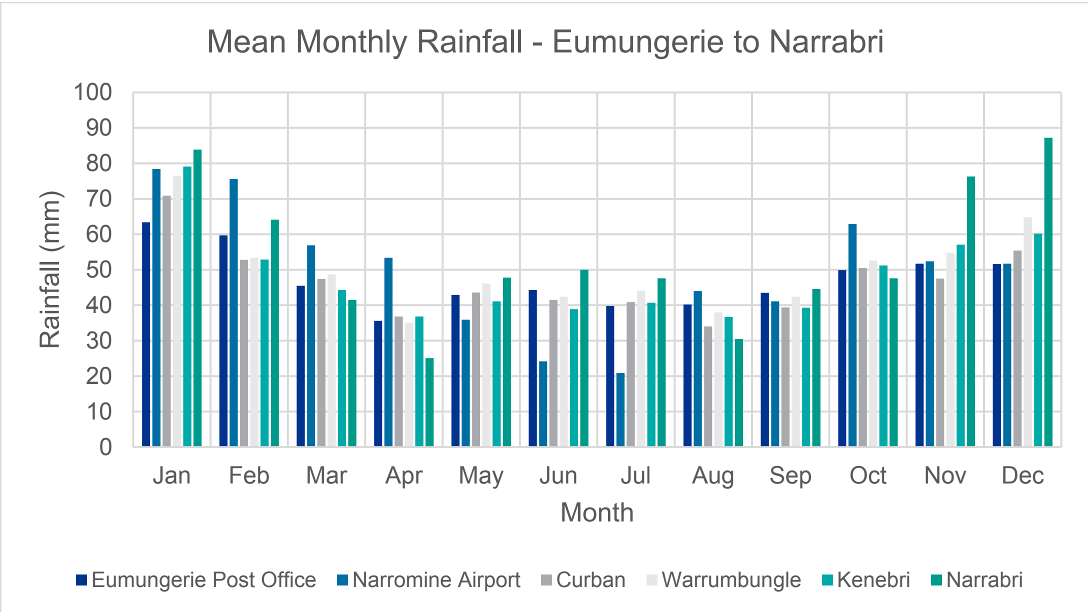

Figure 5.2 Mean monthly rainfall – Eumungerie to Narrabri

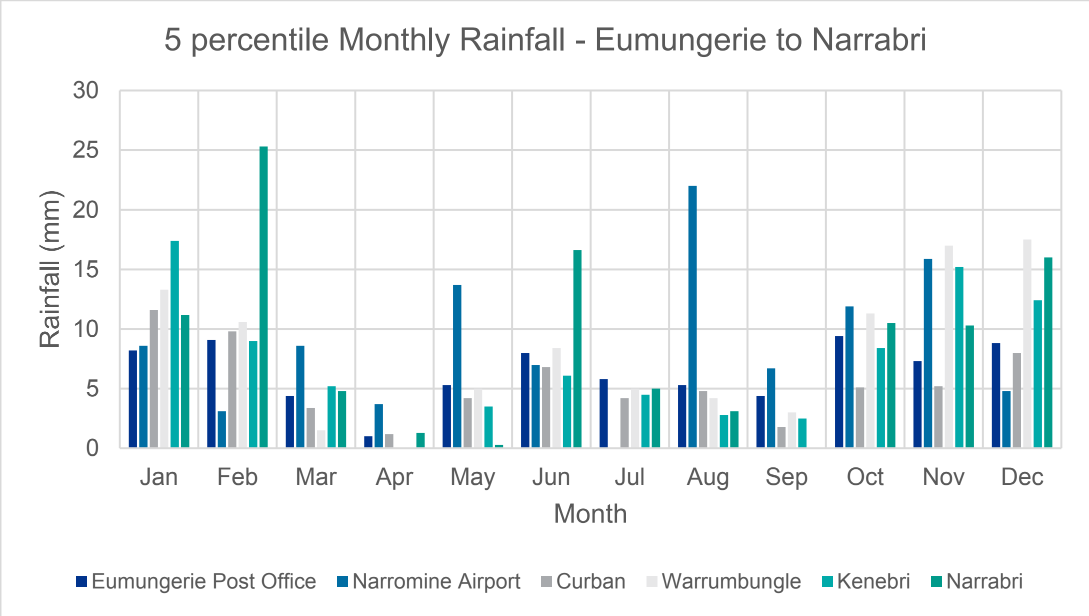

Figure 5.3 5 percentile monthly rainfall – Eumungerie to Narrabri

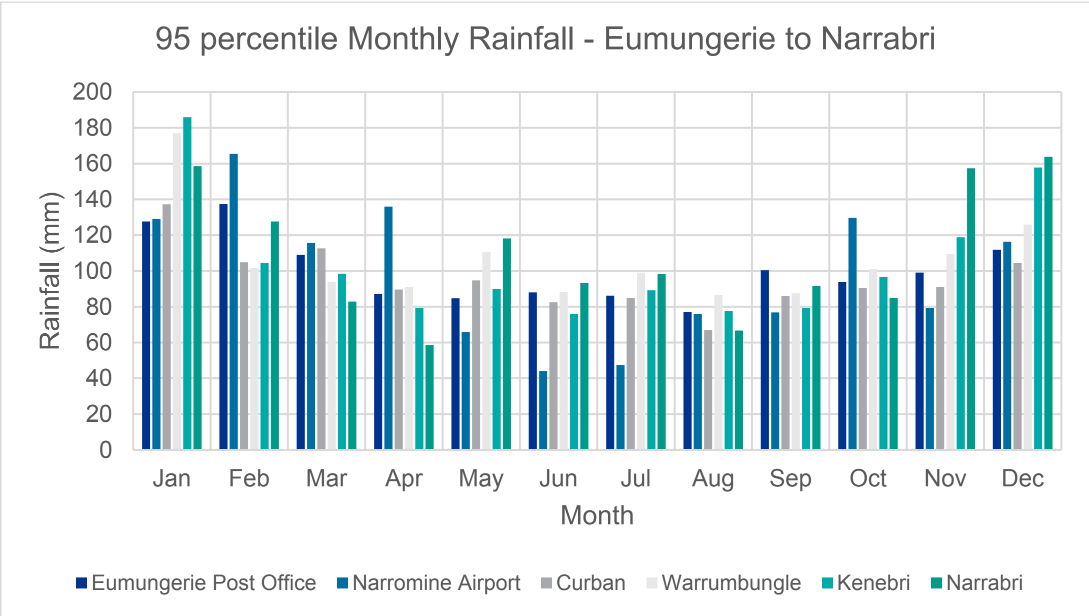

Figure 5.4 95 percentile monthly rainfall – Eumungerie to Narrabri

5.1.4 Evaporation

Figure 5.5 presents average monthly evaporation rates for the proposal alignment. Evaporation rates show marked seasonality between a summer maximum of approximately 280 millimetres per calendar month and a winter minimum of approximately 55 millimetres per calendar month. Average monthly evaporation rates typically exceed average monthly rainfall year-round, resulting in semi-arid conditions (aridity index of approximately 0.29) over an annual period.

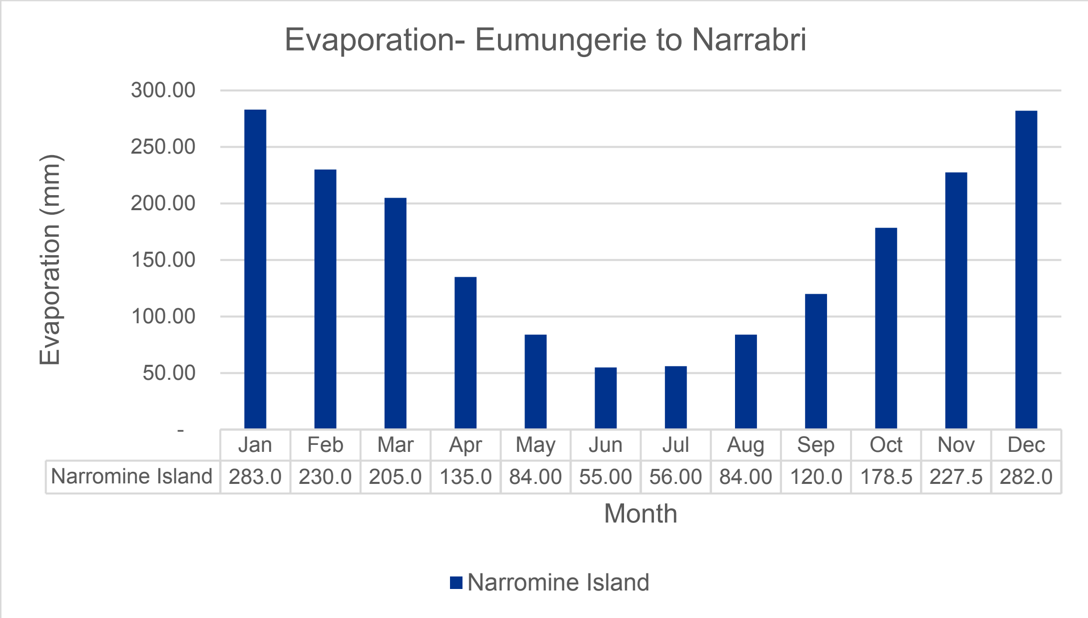

Figure 5.5 Monthly evaporation – Eumungerie to Narrabri

5.1.5 Land use

The land surrounding the study area primarily comprises agricultural uses, particularly cotton, wheat, and livestock. These industries have resulted in significant clearing of the landscape. 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, areas of 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 exist centred around Narromine, Gilgandra, Baradine and Narrabri.

Figure 5.6 shows the land uses along the proposal site along with forestry reserves, conservation reserves and national parks. As shown, the flatter portions of the catchments are generally used for agricultural uses.

NARROMINE TO NARRABRI Land Use

Figure 5.6

0 25 50 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

- The proposal
- Watercourse
- Railway
- Road

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5.1.6 Geology and soils

General

The proposal site is typically located within the Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary alluvium and colluvial deposits over Jurassic sedimentary rocks with Cainozoic mafic volcanic outcrops intermittently along the proposal site.

The geology includes a variety of Jurassic to recent sediments along with the volcanic ranges of the Warrumbungles and Nandewar Range. It includes both highly fertile basalt derived soils and very poor soils of the Pilliga sandstones. Soil erosion, salinity and soil structure decline are noted as the major soil issues of the area.

Additional detailed information is outlined within the EIS.

Soil groups and characteristics

Office of Environmental and Heritage (OEH) soil mapping data indicates that soil types along the proposal site can be best described in four broad areas which share a similar suite of soil types:

- Narromine to the Oxley Highway – the main soil types are dominated by ‘red brown earths, red earths and solodic soils’.
- Oxley Highway to Baradine – the main soil types are dominated by ‘grey, red and brown clays (vertosols), black earths (vertosols), red brown earths, red earths and non-calcic brown soils’.
- Baradine to Narrabri – the main soil types are dominated by ‘solodic soils and earthy sands’.
- Narrabri – the main soil types in the vicinity of Narrabri are dominated by ‘solodic soils’ south of Narrabri and ‘grey, red and brown clays (vertosols) and black earths (vertosols)’ close to Narrabri.

Descriptions and examples of these soil groups are provided in Table 5.2. The dominant Great Soil Groups are shown in Figure 5.7.

Table 5.2 Major soil groups

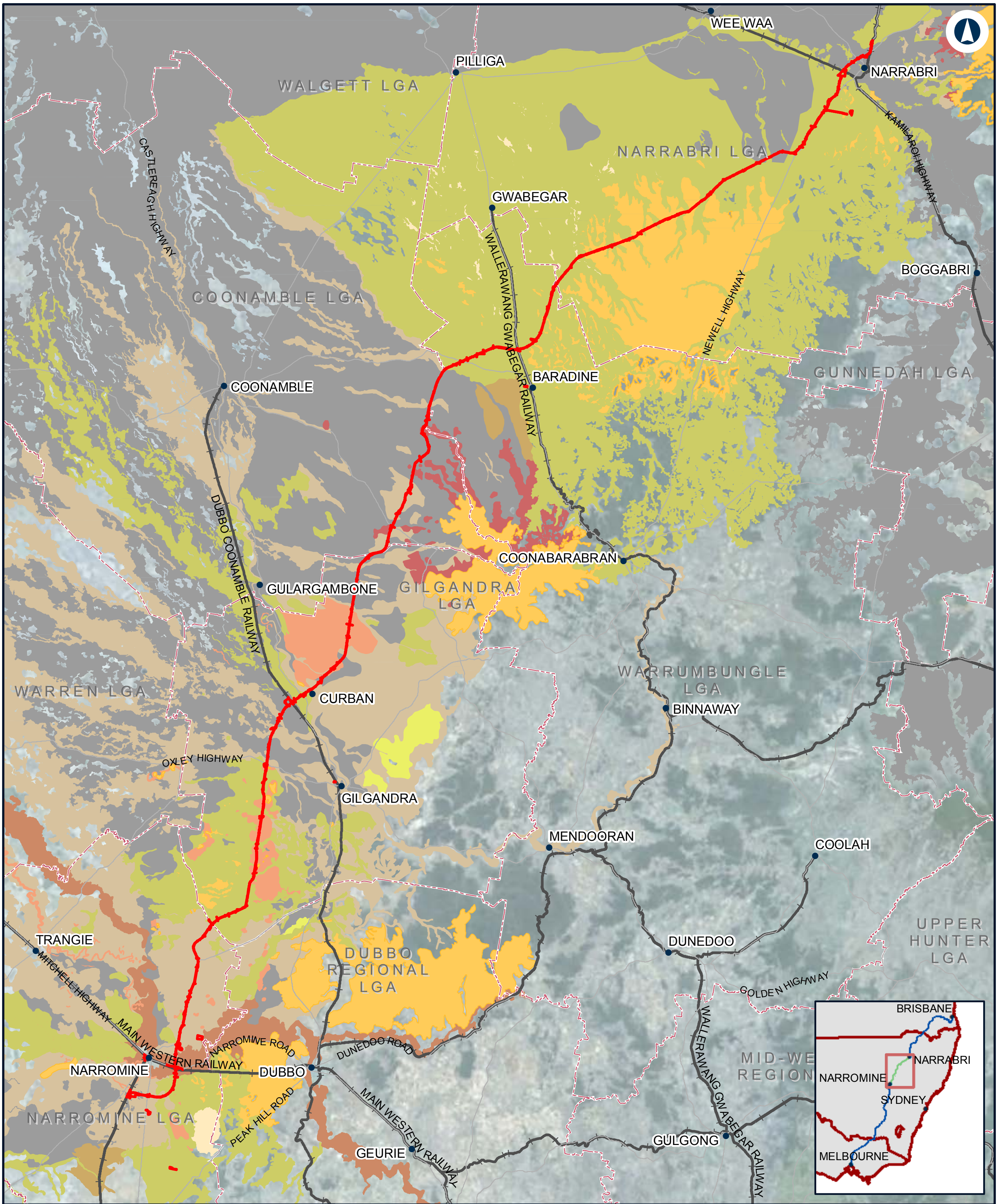
Soil group	Sub-group	Description
Cracking clays (Vertosols)	Black earths	Characterised by deep, high plasticity, clays that crack significantly when dry and swell when wet. Gilgais are commonly present. Commonly formed on weathered basalt rocks, or from alluvial clays sourced from the weathered basalt. Clay often “sodic” and prone to dispersive erosion.
	Grey brown clays	
	Grey red brown clays	
Duplex soils (also known as texture contrast soils)	Solodic soils	Characterised by texture contrast soils which comprise an upper pale (bleached) silt/ sand horizon (A2 horizon) abruptly overlying a clay-rich horizon. Commonly formed on weathered sedimentary rocks and the older Quaternary alluvium/colluvium. Clay-rich horizon typically “sodic” and prone to dispersive erosion.
	Podzolic soils	
	Non-calcic brown soils	

Soil group	Sub-group	Description
Non-cracking clays	Red earths Red brown earths Brown earths Earthy sands	Characterised by massive sandy textured, porous, earthy soil materials with generally gradual boundaries. Commonly formed on better drained weathered sedimentary rocks and better drained and/or younger Quaternary alluvium. Earthy sands are characterised by uniform profiles of coherent, clayey sands which are dominantly red in colour but in some cases yellow. These soils are usually deep and are characterised by uniform sand texture and a massive, single-grained structure.
Alluvial soils	Recent alluvium	Mostly associated with current stream and river courses. Comprise alluvial sands, silts and clays with little or no soil profile development. Exhibit significant variations in engineering character from soft/ loose to stiff/dense.

Acid sulfate soils

Acid Sulfate Soil (ASS) Risk Maps from the Australian Soil Resource Information System (ASRIS) database were reviewed to ascertain the potential ASS risk to the proposal. Given the location, distance from the coast, elevation (about 200 metres AHD) and that the review of ASRIS indicated there was typically ‘no known occurrence’ or a ‘low probability‘ of occurrence of ASS within the majority of the proposal site, the likelihood of ASS being present is considered low. However, it should be noted that although occurrence of ASS within the majority of the proposal is considered low and unlikely, ASRIS did indicate a ‘high probability’ of ASS around the Macquarie, Castlereagh and Namoi Rivers.

Additional detailed information is outlined in the EIS.



NARROMINE TO NARRABRI Soil landscape Figure 5.7

0 20 40 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 30/07/2020 Paper: A4
Author: JacobsGHD Scale: 1:40,000,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Railway
- Road
- Chromosols
- Dermosols
- Ferrosols
- Kandosols
- Kurosols
- Kurosols, Natric
- Rudosols
- Rudosols and Tenosols
- Sodosols
- Vertosols

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5.2 Flooding

5.2.1 Design flows

Peak discharges simulated by the hydrology models upstream of the proposal for all AEP events have been analysed to estimate peak discharge, storm duration and temporal pattern for each point of interest along the proposal. Storm durations ranging from 15 minutes to 168 hours were assessed for all flood events to ensure the critical duration was represented. Adopted peak discharge and critical storm duration for each flood event for each point of interest along the proposal are presented in Appendix C.

5.2.2 Descriptions of modelled flood behaviour

The following sections present general descriptions of flood behaviour under existing conditions within each model domain along the proposal site. Measures of flood behaviour provided include depth, extent, duration (exceeding 0.5 metres), and hazard rating (as a function of depth and velocity). Flood behaviour under existing conditions has been assessed for 20% AEP, 5% AEP, and 1% AEP events to provide representative account of flood behaviour in various flood events.

The existing 1% AEP flood extents along the length of the proposal are shown in Figure 5.8, and the following flood mapping is provided in Appendix D:

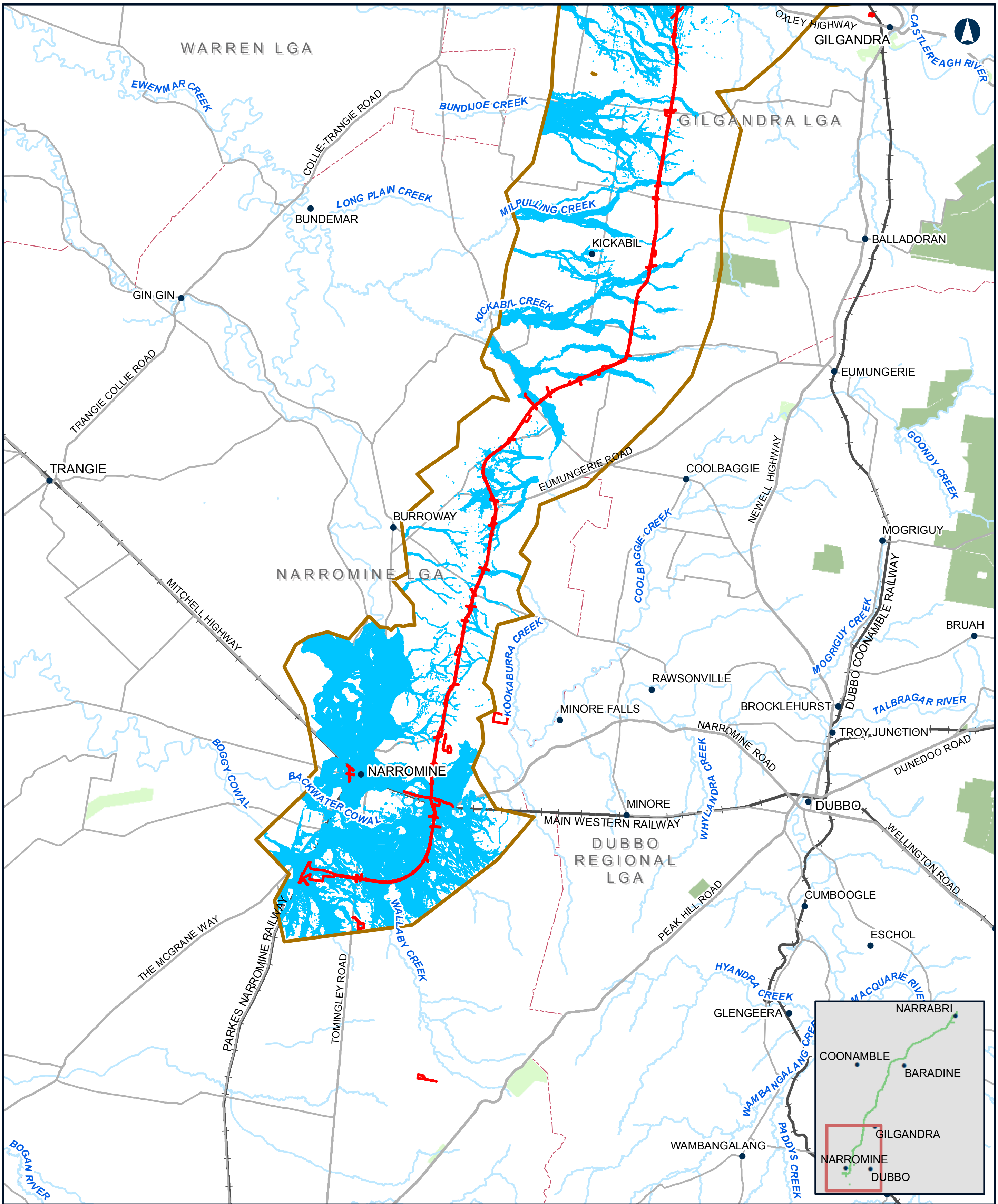
- flood depths – Figures 1.1a to 1.8n
- flood velocity – Figures 2.1a to 2.8n
- flood duration – Figures 3.1a – 3.8n
- flood hazard – Figures 4.1a – 4.8n.

More detailed flood mapping for the existing 1% AEP flood extents is provided in Appendix H for Narromine and Narrabri.

Inundation of buildings, roads, railways, and major land uses are discussed in Sections 5.2.3 to 5.2.6.

The extents of each flood model are listed in Table 3.4 and shown on Figure 3.4.

Flood hazard categories are based on those provided in Figure 2.1.



NARROMINE TO NARRABRI Existing 1% AEP flood extents Figure 5.8a

Coordinate System: GDA 1994 MGA Zone 55

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Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

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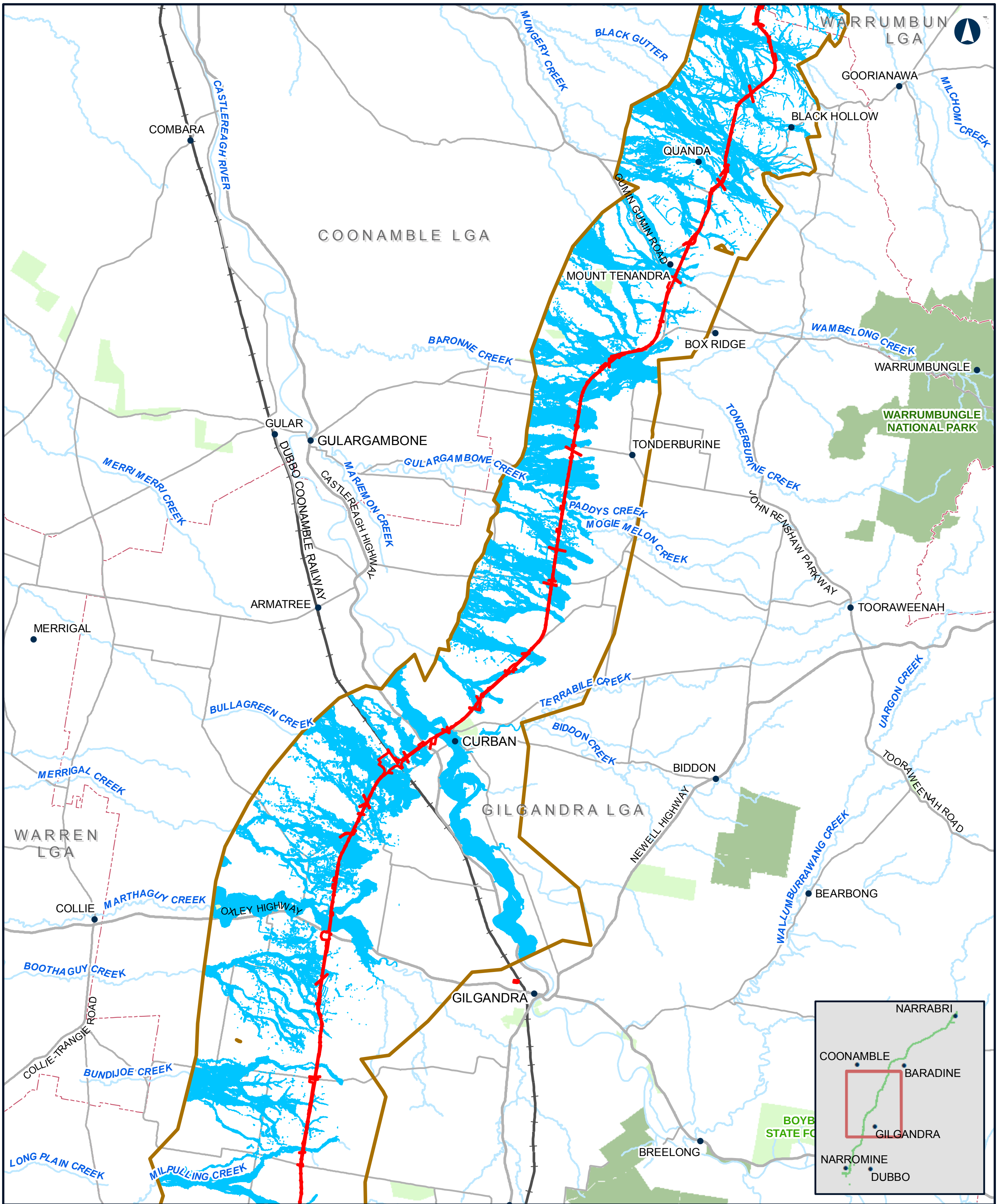

NARROMINE TO NARRABRI

Existing 1% AEP flood extents

Figure 5.8b

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LEGEND

- The proposal
- Study area
- Flood extent

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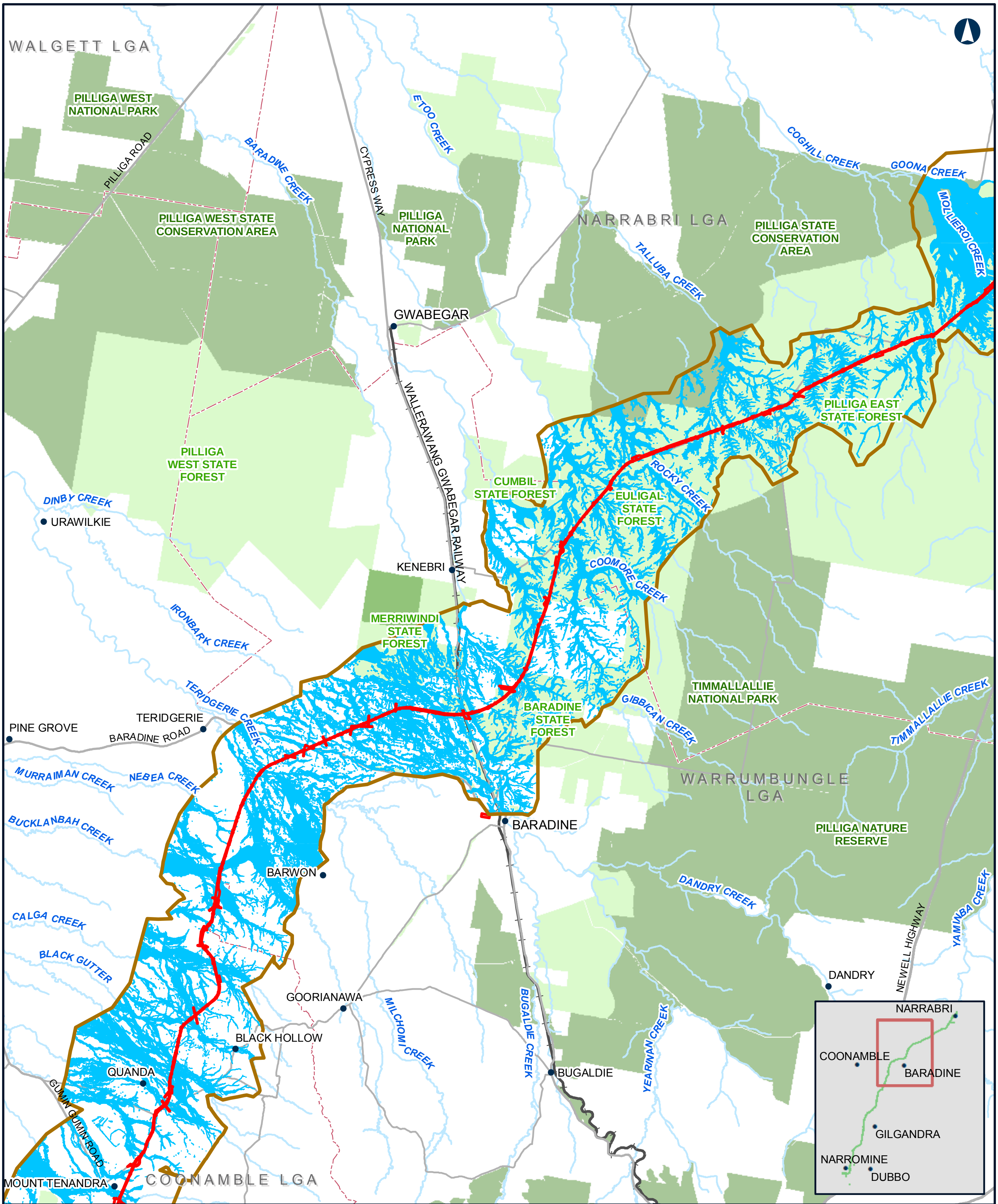

NARROMINE TO NARRABRI Existing 1% AEP flood extents Figure 5.8c

0 8 16 Km

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Data Sources: Basemap layers: NSWSS;

LEGEND
- The proposal
- Study area
- Flood extent

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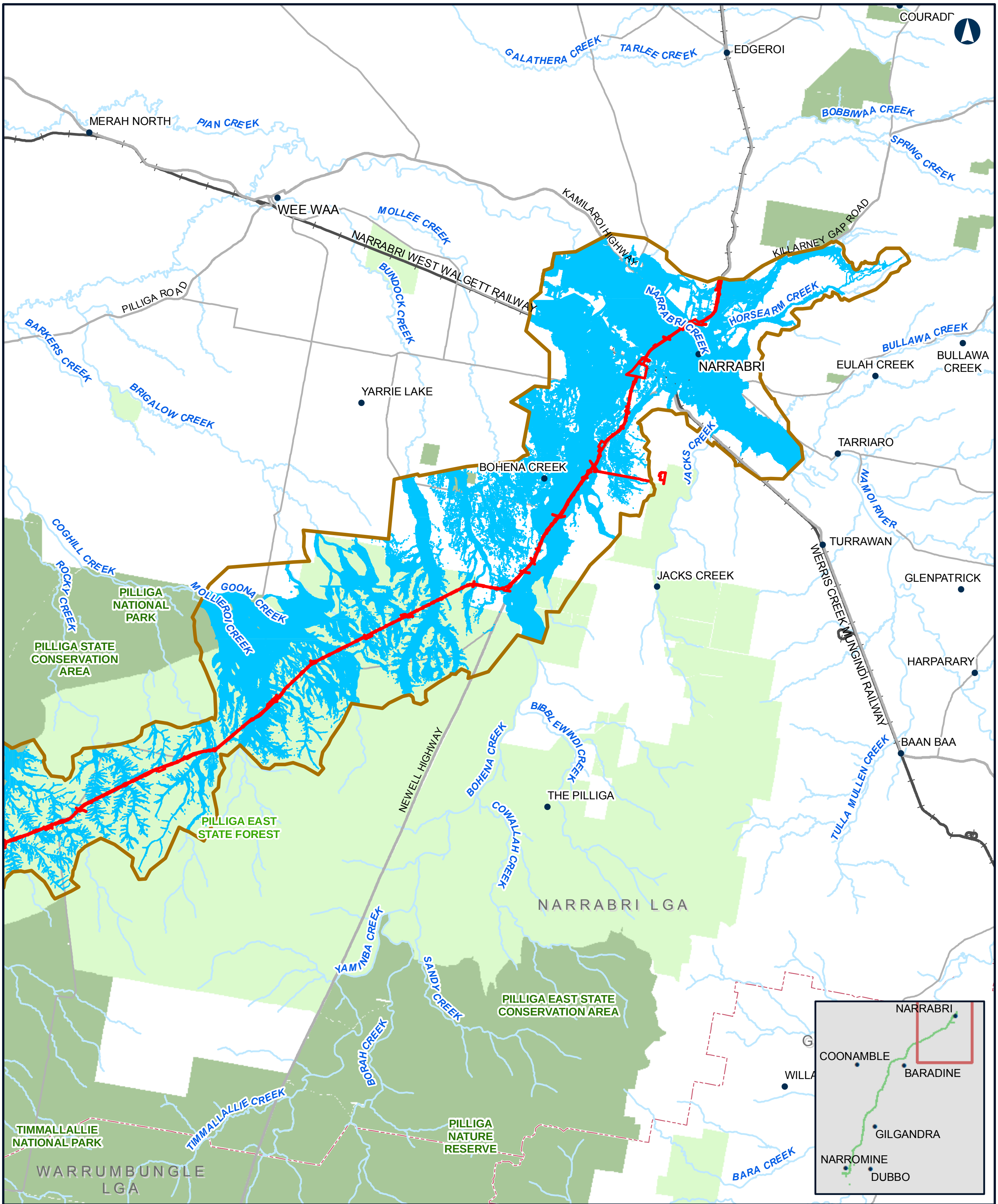

NARROMINE TO NARRABRI Existing 1% AEP flood extents Figure 5.8d

0 8 16 Km

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Date: 28/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent

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NFM: Chainages 547.00 – 569.40 (Macquarie River and Wallaby Creek)

The Narromine Flood Model (NFM) model domain includes the Macquarie River and Wallaby Creek and is located between chainages 547 and 569.4 of the proposed alignment, within the Narromine Shire LGA and includes the locality of Narromine.

The Macquarie River intersects the proposed alignment at chainage 563.1, flowing west before turning north. Wallaby Creek intersects the proposed alignment at chainage 554, flowing north before turning west.

Extent and depth

In small frequent flood events such as the 20% AEP, riverine flood extents are generally constrained to the main channel and floodways of the Macquarie River, with wider flooding into floodplains along Wallaby Creek. Overland flooding is present south of Narromine, between Gainsborough Road and the proposed alignment.

In the 5% AEP flood event and larger, riverine flood extents increase significantly for the Macquarie River into adjacent floodplains. There is further expansion of flooding into floodplains along Wallaby Creek downstream of the proposed alignment. Extents of overland flooding also increase between the proposed alignment and Gainsborough Road.

In the 1% AEP flood event there is significant riverine flooding into floodplains for the Macquarie River and Wallaby Creek, and overland flooding between the proposed alignment and Gainsborough Road. The majority of Narromine is flooded in the 1% AEP event including buildings, roads, and critical infrastructure by flooding from both Macquarie River and Wallaby Creek.

Flood depths typically vary between 3.5 and 7.5 metres along the floodway and inner floodplains of the Macquarie River in the 1% AEP event. Flood depths adjacent to the Macquarie River through Narromine are mostly between 0.5 and 1 metre with some smaller areas between 1 and 2 metres. Flood depths within the Wallaby Creek floodplains typically vary between 0.5 and 1 metre. Overland flood depths between Gainsborough Road and the proposed alignment are between 0.25 and 0.5 metres.

Hazard

In small, frequent flood events such as the 20% AEP riverine flood hazards are generally constrained to the main channels and floodways of the Macquarie River and Wallaby Creek. Overland flood hazards adjacent to Wallaby Creek and South of Gainsborough Road are generally low (H1 category).

In the 1% AEP event riverine flood hazards increase significantly in extent and magnitude for the Macquarie River and into Narromine. Flood hazard along the floodways and inner floodplains adjacent to the Macquarie River are high (H5-H6). Throughout Narromine, flood hazard is typically high (H3-H4) with localised zones of high hazard (H5-H6). Areas of overland flooding south of Gainsborough Road are generally low hazard (H1-H2).

Duration

Flood duration in the 1% AEP event for floodways and floodplains of Macquarie River typically vary between 40 and 80 hours. Overland flooding between Gainsborough Road and the proposed alignment occurs for less than 1 hour.

N2N14: Chainages 566.39 – 594.88 (minor watercourses)

The N2N14 model domain includes a number of minor unnamed watercourse and is located between chainages 566.39 and 594.88 of the proposed alignment, within the Narromine Shire LGA and includes the, localities of Burroway and Narromine.

The headwaters of a number of minor watercourses intersect the proposed alignment through the model domain as it passes across a north-south trending catchment divide.

Extent and depth

In all flood modelled scenarios up to and including the 1% AEP event, flood extents are generally constrained to main channels and channel floodways. There is some minor overland flooding in all modelled scenarios affecting upstream areas around Emogandy Road.

A number of rural properties with buildings are affected by flooding under all modelled scenarios between the 20% AEP event and 1% AEP event, including most notably a number of buildings located east of chainage 586.7 along an unnamed tributary to Ewenmar Creek.

Flood depths within channel floodplains typically vary between 0.1 metres and 0.2 metres within the southern portion of the study area in the 1% AEP event, increasing to between 0.3 metres and 0.7 metres in the northern portion of the study area within channel floodplains in the 1% AEP event.

Hazard

In all flood modelled scenarios up to and including the 1% AEP event riverine flood hazards are generally constrained to main channels and immediate floodplains. A number of rural properties with buildings are impacted by flooding between the 20% AEP event and 1% AEP event and are within areas of both low and high hazard (H1-H3). Buildings affected by high flood hazard are located along an un-named tributary to Ewenmar Creek, east of chainage 586.7.

Duration

Flood duration in the 1% AEP event for riverine and overland flooding is typically less than 0.5 hours. However, there are highly localised areas of ponding up to 30 hours.

N2N13: Chainages 593.34 – 624.82 (Ewenmar Creek to Bundijoe Creek)

The N2N13 model domain is located between chainages 593.34 and 624.82 of the proposed alignment and includes all waterways between Ewenmar Creek and Bundijoe Creek. The model domain is within the Gilgandra Shire LGA and includes the localities of Kickabil, Collie, Gilgandra and Balladoran.

Named watercourses intersecting the alignment through this study area include Ewenmar Creek (chainage 595.4), Goulburn Creek (chainage 599.2), Emogandy Creek (chainage 602.7), Native Dog Creek (chainage 607.2), Pint Pot Gully (chainage 608.93), Kickabil Creek (chainage 609.7), Milpulling Creek (chainage 616.7) and Bundijoe Creek (chainage 623.3). A number of unnamed creeks also intersect the proposed alignment through the model domain.

Extent and depth

Flood extents do not increase significant between 20% AEP and 1% AEP flood events. Flood extents are variable for waterways intersecting the alignment. In the 1% AEP event flooding typically affects channel floodplains up to 100 m from the main channel, except for Ewenmar Creek where flooding is observed at distances up to 300 metres from the main channel.

Flood depths in the 1% AEP event are typically between 0.7 metres to 1.2 metres in floodplains of Ewenmar Creek and Kickabil Creek, and typically between 0.1 metres to 0.6 metres for other waterways within the study area.

Hazard

In all flood modelled scenarios up to and including the 1% AEP event, riverine flood hazards are generally constrained to main channels and immediate floodplains. Flood hazard within channel floodways and inner floodplains are typically high (H3-H5) in the 1% AEP event. A number of properties with buildings are affected by high flood hazard within the study area.

Duration

Flood duration in the 1% AEP event for riverine and overland flooding is typically between 0.5 and 6 hours.

N2N11-12 – Chainages 623.91– 657.63 (Boothaguy Creek to Castlereagh River)

The N2N11-12 model domain is located between chainages 623.91 and 657.63 of the proposed alignment and includes all watercourses between an unnamed tributary to Boothaguy Creek and Castlereagh River, within the Gilgandra Shire LGA, and includes the localities of Collie, Curban and Gilgandra.

Marthaguy Creek and the Castlereagh River are the only named watercourses intersecting the proposed alignment at chainages 633.7 and 651.7, respectively. Marthaguy Creek has an upstream catchment area of about 410 square kilometres, and Castlereagh River has an upstream catchment area of about 6,630 square kilometres. An unnamed headwater tributary to Boothaguy Creek also intersects the alignment at chainage 627.3.

Extent and depth

In small frequent flood events, such as the 20% AEP, riverine flood extents are generally constrained to the main channel and floodway for the Castlereagh River and Marthaguy Creek, with some overbank flooding into floodplains along Marthaguy Creek. Overland flooding is present upstream of the proposed alignment between Marthaguy Creek and the Castlereagh River.

In the 5% AEP event riverine flood extents increase into floodplains and flood storage areas along the Castlereagh River, with flooding observed up to a distance of about 300 metres from the channel.

In the 1% AEP event riverine flood extents increase further into floodplains along the Castlereagh River, with overbank flooding observed up to a distance of about 800 metres from the channel. Flooding along Marthaguy Creek is observed up to about 600 metres from the channel. Overland flooding is present for the headwaters of Boothaguy Creek, Merrigal Creek, and Bullagreen Creek which are located west of the proposed alignment. Overland flooding contributing to Merrigal Creek and Bullagreen Creek also affects areas upstream of the proposed alignment between chainages 635.9 and 648.8.

Typical riverine flood depths for floodplains of Marthaguy Creek in the 1% AEP event are between 0.8 and 1.8 metres. Typical riverine flood depths for floodplains of the Castlereagh River are between 1.2 and 2.5 metres Overland flood depths associated with headwaters of Merrigal Creek and Bullagreen Creek are between 0.2 and 0.5 metres.

Hazard

In all flood modelled scenarios up to and including the 1% AEP event, riverine flood hazards associated with Marthaguy Creek and the Castlereagh River are generally constrained to main channels, floodways and immediate floodplains within 1 kilometre of the channel.

Flood hazards within floodways and inner floodplains of Marthaguy Creek typically high (H3-H5) in the 1% AEP event. Riverine flood hazards within the flooded extents of the Castlereagh River floodplains are typically high (H4-H5) in the 1% AEP event.

Flood hazard associated with areas of overland flooding are typically low (H1 to H2).

Duration

Flood duration in the 1% AEP event for riverine flooding associated with Marthaguy Creek is typically between 7 and 14 hours. Flood duration in the 1% AEP event for riverine flooding of floodplains associated with the Castlereagh River is typically between 40 and 50 hours.

Overland flood durations associated with headwaters of Boothaguy Creek, Merrigal Creek and Bullagreen Creek is typically less than 0.1 hours.

N2N10: Chainages 654.34 to 681.24 (Judes Creek to Gulargambone Creek)

The N2N10 model domain is located between chainages 654.34 and 681.24 of the proposed alignment and includes waterways between Judes Creek and Gulargambone Creek. The model domain is located within the Gilgandra Shire LGA and includes the localities of Gilgandra, Curban, Armatree and Tonderburine.

Judes Creek (chainage 659.20) and Gulargambone Creek (chainage 673.08) are the only named watercourses that intersect the proposed alignment through this model domain. Several smaller unnamed watercourses and tributaries to named creeks also intersect the proposed alignment across the model domain.

Extent and depth

In all flood modelled scenarios up to and including the 1% AEP event, riverine flood extents are typically constrained to main channels and floodways / immediate floodplains (within 200 metres of the channel) for both Judes Creek and Gulargambone Creek. Overland flooding in the 1% AEP is widespread across the study area and affects both upstream and downstream locations along the proposed alignment.

In the 1% AEP event typical flood depths in floodplains adjacent to Judes Creek are between 0.4 and 0.5 metres. Flood depths along floodplains of Gulargambone Creek in the 1% AEP event typically vary between 0.7 and 2.1 metres. Typical overland flood depths in the 1% AEP event vary between 0.15 and 0.3 metres.

Hazard

In the 1% AEP event riverine flood hazards within the flooded extents of both Judes Creek and Gulargambone Creek floodplains are typically high (H3). The hazards are typically low (H1-H2) within areas of overland flooding.

Duration

In the 1% AEP event flood durations along the floodplains of Judes Creek are between 0.1 and seven hours. Flood durations along the floodplains of Gulargambone Creek are between about four and 10 hours.

N2N9: Chainages 677.64 to 697.45 (Baronne Creek to Tenandra Creek)

The N2N9 model domain is located between chainages 677.7 to 697 of the proposed alignment and includes waterways between Baronne Creek and Tenandra Creek. The model domain is located within the Coonamble Shire LGA and Gilgandra Shire LGA, and includes the localities of including Gulargambone, Mount Tenandra and Tonderburine.

Baronne Creek (chainage 682.60) and Tenandra Creek (694.20) are the only named watercourses that intersect the proposed alignment through this model domain. Several smaller unnamed watercourses and tributaries to named creeks also intersect the proposed alignment across the model domain.

Extent and depth

In small frequent flood events, such as the 20% AEP, riverine flood extents for Baronne Creek are variable, with overbank flooding observed up to 700 metres from the channel. Riverine flooding associated with Tenandra Creek is generally confined to the channel and immediate overbank floodways (less than 20 metres). There is evidence of overland flooding across the model domain in the 20% AEP flood event, including overland flooding upstream of the proposed alignment (south of National Park Road) contributing to flows in Baronne Creek.

In the 5% AEP flood event, riverine and overland flood extents are marginally increased, with main effects being increased flood depths.

In the 1% AEP flood event riverine flood extents coalesce with overland flooding for Baronne Creek resulting in extensive flooding between Baronne Creek and National Park Road (up to two kilometres from the channel and outside the natural floodway). Riverine flooding for Tenandra Creek is generally limited to the channel and immediate floodplains.

In the 1% AEP riverine flood depths associated with Baronne Creek typically range between 0.5 and 1.5 metres. Areas of overland flooding that contribute to flows in Baronne Creek typically vary between 0.1 and 0.6 metres. Riverine flooding associated with Tenandra Creek is highly constrained and generally limited to between 0.1 and 0.3 metres depth in the immediate floodway and floodplains.

Hazard

In the 1% AEP event riverine flood hazards within the overbank flooded areas of Baronne Creek are typically high (H4-H5). Overland flood hazards adjacent to Baronne Creek are typically low to high (H1-H3).

Riverine flood hazards for Tenandra Creek are generally constrained to the immediate floodplains, however flood hazards outside of the main channel are typically low (H1). Overland flooding impacts across the model domain are variable, but typically low (H1).

Duration

In the 1% AEP flood event, flood durations along Baronne Creek vary significantly, however are typically between 10 and 20 hours in floodplains. Flood durations outside Baronne Creek including riverine flooding associated with Tenandra Creek and overland flooding areas are typically less than 0.1 hours.

N2N8: Chainages 696.95 to 717.56 (Mungery Creek to Calga Creek)

The N2N7 model domain is located between chainages 717.56 and 754.75 of the proposed alignment and includes waterways between Mungery Creek and Calga Creek. The model domain is located within the Coonamble Shire LGA, including Magometon, Quanda, Black Hollow, and Mount Tenandra localities.

Named watercourses intersecting the alignment include Mungery Creek (chainage 700.02), Caleriwi Creek (chainage 702.34), Quanda Quanda Creek (chainage 704.59), Black Gutter (chainage 708.47), Salty Springs Creek (chainage 709.27) and Calga Creek (chainage 714.59). Several smaller unnamed watercourses and tributaries to named creeks also intersect the proposed alignment across the model domain.

Extent and depth

In small frequent flood events such as the 20% AEP, riverine flood extents for named and unnamed watercourses are typically constrained to main channels, floodways and immediate floodplains (about 100 metres from the main channel). Areas of overland flooding are present, including overland flooding between Caleriwi Creek and Quanda Quanda Creek upstream of the proposed alignment.

In the 5% AEP flood event riverine and overland flood extents increase marginally both upstream and downstream of the alignment.

In the 1% AEP flood event riverine flood extents increase marginally for all named waterways overland flooding increases significantly downstream of the alignment. There is a significant increase in riverine flooding along the Calga Creek floodplains downstream of the alignment.

Riverine flood depths within channel floodplains in the 1% AEP flood event are variable for each waterway within the model domain. Typical flood depths within channel floodplains in the 1% AEP event are between 0.3 and 0.7 metres. Flood depths of approximately 0.6 to 0.7 metres are common within Calga Creek floodplain in the 1% AEP event.

Hazard

In the 1% AEP flood event, riverine flood hazards in floodplains are highly constrained to the channels and immediate overbank areas with flood hazards are typically high (H3 to H5). Calga Creek exhibits a consistent high riverine flood hazard (H5) and widest hazard area in the model domain for the 1% AEP event, however is typically constrained to an area of less than 100 metres from the channel. Areas of overland flooding and smaller unnamed watercourses are typically low hazard (H1) in the 1% AEP event.

Duration

In the 1% AEP flood event, riverine flooding of the wider floodplains away from the creek channels is short-lived and does not typically persist. Riverine flooding in the creek channels and immediate floodplains (about 20 metres from the channel) may be flooded for durations up to 28 hours.

N2N7: Chainages 717.56– 754.75 (Noonbar Creek to Coolangla Creek)

The N2N7 model domain is located between chainages 717.56 and 754.75 of the proposed alignment and includes waterways between Noonbar Creek and Coolangla Creek. The model domain is largely located within the Warrumbungle Shire LGA (Baradine and Kenebri localities), Coonamble Shire LGA (Teridgerie locality), and Narrabri Shire LGA (Pilliga locality). The town of Baradine is located about 7 kilometres east (upstream) of the proposed alignment.

Named watercourses that intersect the proposed alignment within the model domain include Noonbar Creek (chainage 718.17), Bucklanbah Creek (chainage 722.3), Small Creek (chainage 728.1), Teridgerie Creek (chainage 730.5), Ironbark Creek (chainage 737.9), Baradine Creek (chainage 747.8), and Coolangla Creek (chainage 752.71). A number of unnamed minor watercourses comprising tributaries to larger waterways also intersect the proposed alignment within the model domain.

Extent and depth

In small frequent flood events such as the 20% AEP, riverine flood extents are typically constrained to the channel, floodways and immediate floodplains for all named watercourses and associated tributaries. There is some minor overland flooding and flows through unmapped drainage channels outside of mapped waterways.

In the 5% AEP flood event, riverine flood extents are increased but generally remain confined to the immediate channel and floodplains, with the exception of Bucklanbah Creek, which causes flooding up to 700 metres from the main channel. There is increased overland flooding, including extensive overland flooding south of Teridgerie Creek and upstream of the proposed alignment.

In the 1% AEP flood event, riverine flood extents are increased further but typically remain constrained to channels, floodways and immediate floodplains, with the exceptions of Bucklanbah Creek, which shows further overbank flooding up to 700 metres from the channel, and Baradine Creek, which floods up to 350 metres from the channel. Overland flooding increases in both magnitude and extent, with extensive overland flooding upstream of the proposed alignment, between Bucklanbah Creek and Teridgerie Creek.

In the 1% AEP riverine flood depths within immediate floodplains typically vary between 0.5 and 1.8 metres for Bucklanbah Creek, and 1.5 to 4.5 metres for Baradine Creek. Overland flood depths typically vary between 0.4 and 0.8 metres.

Hazard

In small, frequent flood events such as the 20% AEP, flood hazards within the floodplains of Bucklanbah Creek, Teridgerie Creek, and Baradine Creek are typically high (H3-H5). Noonbar Creek, Small Creek, Ironbark Creek, and Coolangla Creek are typically low to high hazard (H1-H3) within floodplains. Overland flooding produces areas of low hazard (H1) across the study area.

In the 1% AEP event flood hazards within floodplains of Bucklanbah Creek, Teridgerie Creek, and Baradine Creek are typically high (H4-H5). Flood hazards within floodplains of Noonbar Creek, Small Creek, Ironbark Creek, and Coolangla Creek are typically low to high (H1-H3).

Overland flooding away from riverine flood extents is generally low hazard (H1, H2), with localised areas of high hazard (H3) along roads (eg Cumbil Road). Flood hazard associated with overland flooding between Teridgerie Creek and upstream tributaries is low to high (H2-H4) with localised variations.

Duration

Flood duration in the 1% AEP event within the floodplains of Teridgerie Creek typically varies between 10 and 20 hours, with some limited back swamp areas ponding up to 50 hours. Flood duration in the 1% AEP event within the floodplains of Baradine Creek and associated tributaries typically varies between 3 and 6 hours.

N2N6: Chainages 754.75– 775.67 (Cumbil Forest Creek to Tinegie Creek)

The N2N6 model domain is located between chainages 754.75 and 775.67 of the proposed alignment and includes waterways between Cumbil Forest Creek and Tinegie Creek. The model domain is split between the Warrumbungle Shire LGA and Narrabri Shire LGA, including Kenebri, Baradine, and Pilliga localities.

Named watercourses that intersect the proposed alignment within the model domain include Cumbil Forest Creek (chainage 758.97), Etoo Creek (chainage 763.46), Stockyard Creek (chainage 767.94), and Tinegie Creek (chainage 773.37). A number of unnamed minor watercourses comprising tributaries to larger waterways also intersect the proposed alignment within the model domain.

Extent and depth

In small frequent flood events, such as the 20% AEP riverine flood extents are typically constrained to immediate floodplains (within 100 metres) of the named waterways, except for Etoo Creek where flood extents may extend up to 200 metres from the channel. No significant overland flooding is observed.

In the 5% AEP flood event, both riverine and overland flood extents increase marginally. The greatest increases in flood extent occur along Etoo Creek (typically less than a maximum of 40 metres). Increase in flood depths are typically less than or equal to about 0.5 metres.

In the 1% AEP flood event, riverine and overland flood extents increase marginally. The greatest increases in flood extent occur along Etoo Creek (typically less than a maximum of 80 metres). Increase in flood depths are typically less than or equal to about 0.5 metres.

Typical flood depths are variable for watercourses within the study area. In the 1% AEP flood event flood depths are greatest within floodplains of Etoo Creek (1.0 metres to 2.6 metres) and Rocky Creek (1.0 metres to 2.0 metres). Flood depths within floodplains of Stockyard Creek are typically between 0.4 metres and 1.0 metres in the 1% AEP event, whilst flood depths along floodplains of other minor waterways are typically between 0.1 metres and 0.5 metres.

Hazard

In small frequent flood events, such as the 20% AEP, flood hazards within the floodplains of Etoo Creek and Rocky Creek are typically high (H3-H5). Smaller watercourses including Cumbil Forest Creek, Stockyard Creek, and Tinegie Creek are typically low to high (H1-H3).

In the 1% AEP flood event, flood hazards within the floodplains of Etoo Creek and Rocky Creek increase with significantly greater areas of high hazard (H5-H6). Smaller watercourses including Cumbil Forest Creek, Stockyard Creek, and Tinegie Creek show greater variability, with ranges between low and high hazard (H1-H4).

Duration

Flood duration in the 1% AEP event within the floodplains of Etoo Creek and Rocky Creek are typically between 10 and 20 hours. Flood duration along smaller watercourses including Cumbil Forest Creek, Stockyard Creek, and Tinegie Creek are typically between 1 and 10 hours.

N2N5: Chainages 775.67– 785.82 (Talluba Creek)

The N2N5 model domain is located between chainages 775.67 and 785.82 of the proposed alignment. The model domain is located within the Narrabri Shire LGA, and includes the locality of Pilliga.

Talluba Creek (chainage 779.64) is the only named watercourse that intersects the proposed alignment through the model domain. A number of unnamed minor watercourses comprising tributaries to Talluba Creek also intersect the proposed alignment within the model domain.

Extent and depth

In small frequent flood events, such as the 20% AEP, riverine flood extents are typically constrained to floodways (within 40 metres) of all main channels.

In the 5% AEP flood event, riverine flood extents increase marginally but are typically constrained to floodways within 60 metres of main channels.

In the 1% AEP flood event, riverine flood extents increase but are typically constrained to floodways within 70 metres of main channels.

Flood depths in the 1% AEP event are typically between 0.5 metres and 2.0 metres for Talluba Creek floodplains, and between 1.0 metres and 4.0 metres for an unnamed waterway at chainage 783.72. Flood depths along floodways of other unnamed waterways are typically less than 0.5 metres in the 1% AEP event.

There is no significant overland flooding or flooding into wider floodplains / storage areas within the model domain in or below the 1% AEP event.

Hazard

In small, frequent flood events such as the 20% AEP, flood hazards within the floodway of Talluba Creek are typically moderate to very high (H3-H5). Flood hazard within the unnamed waterway at chainage 783.72 is typically high to very high (H4-H5). Flood hazard within floodplains of other unnamed waterways is typically low to moderate (H1-H3). Where present, overland flood hazard is low (H1).

In the 1% AEP event, flood hazards within the floodway of Talluba Creek are typically high (H4-H5). Flood hazard within the unnamed waterway at chainage 783.72 is typically high (H5-H6). Flood hazard within floodways of other unnamed waterways is typically low to high (H2-H4). Where present, overland flood hazard is low (H1).

Duration

Flood durations in the 1% AEP within the floodplains of Talluba Creek and the unnamed waterway at chainage 783.72 are typically between 5 hours and 20 hours. Flood durations along smaller watercourses comprising tributaries to Talluba Creek are typically between one hour and 10 hours.

N2N4: Chainages 785.82– 797.54 (Rocky Creek to Coghill Creek)

The N2N4 model domain is located between chainages 785.82 and 797.54 of the proposed alignment. The model domain is located within the Narrabri Shire Council LGA and includes the locality of Pilliga.

Several named and unnamed watercourses intersect the proposed alignment through the model domain. Named watercourses that intersect the alignment include Rocky Creek (chainage 789.38) and Coghill Creek (chainage 796.41).

Extent and depth

In small, frequent flood events such as the 20% AEP, riverine flood extents are observed to be variable, but generally constrained to the channel and immediate floodways, with a distance of less than 50 metres in most cases. Flooding for Coghill Creek is more extensive than other waterways within the model domain, with flooding observed up to 250 metres from the channel into floodplains.

In the 5% AEP flood event, riverine flood extents increase marginally and are generally reflective of flood extents in the 20% AEP event, except for local areas along Rocky Creek and Coghill Creek upstream of the proposed alignment where additional areas of overbank flooding occurs.

In the 1% AEP flood event, increases in riverine flood extents are typically limited with increase in runoff resulting in infilling of floodplains between main channels. Flood extents for Rocky Creek are generally between 50 and 120 metres. Flood extents for Coghill Creek are generally between 150 and 350 metres.

Flood depths within channel floodways in the 1% AEP event are typically between 0.2 and 1.2 metres for Rocky Creek, and between 0.5 and 1.5 metres for Coghill Creek. Flood depths in unnamed waterways typically vary between 0.5 and 1.5 metres.

Flood depths in the 1% AEP event are variable. Typical flood depths for Rocky Creek are between 0.2 and 1.2 metres.

Hazard

In small, frequent flood events such as the 20% AEP, riverine flood hazards along Rocky Creek and unnamed waterways are typically very low to moderate (H1-H3), and flood hazards along Coghill Creek are typically moderate to very high (H3-H5).

In the 1% AEP event, flood hazards along Rocky Creek, Coghill Creek and an unnamed creek at chainage 786.88 are typically high (H3-H5). Flood hazards along other unnamed waterways are typically low to high (H1-H3).

Duration

Flood durations in the 1% AEP event within the floodways and floodplains of Coghill Creek are typically between 5 and 25 hours. Flood durations for Rocky Creek and other unnamed waterways are typically between 1 and 5 hours.

N2N23: Chainages 797.54 – 818.86 (Mollieroi Creek to Bundock Creek)

The N2N23 model domain is located between chainages 797.54 and 818.86 of the proposed alignment. The model domain is located within Narrabri Shire LGA, and includes the Pilliga, Wee Waa, Yarrie Lake, and Bohena Creek localities.

Several named and unnamed watercourses intersect the alignment through the model domain. Named watercourses include Mollieroi Creek (chainage 800.45), Black Creek (chainage 803.32), Goona Creek (chainage 809.11), and Bundock Creek (chainage 817.65).

Extent and depth

In small, frequent flood events such as the 20% AEP, riverine flood extents are observed to be variable, but typically constrained to within 150 metres of the channel and along the channel floodway. Flood extents along Bundock Creek are observed to be significantly wider than other waterways within the model domain with flooding into channel floodplains up to a distance of about 600 metres from the channel.

In the 5% AEP event, riverine flood extents increase further into floodplains which run parallel to channel floodways. Increase in flood extents are typically minimal except for Mollieroi Creek, which shows overbank flooding into floodplains bypassing the floodway downstream of the alignment. Bundock Creek also shows expansion of flooding into floodplains parallel to the floodway upstream of the proposed alignment.

In the 1% AEP event, increase in riverine flood extents are typically minimal, except for Bundock Creek, which shows further expansion of floodplains parallel to the main floodway upstream of the proposed alignment. Flood extents for Bundock Creek are typically between 250 and 500 metres upstream of the proposed alignment. Flood extents for remaining waterways are typically between 50 and 250 metres, with flooding principally along channel floodways.

Flood depths along floodways in the 1% AEP are typically between 0.8 and 1.2 metres for Bundock Creek and Goona Creek, between 0.8 and 1.5 metres for Mollieroi Creek, and typically less than 0.5 metres for smaller channels.

Hazard

In small frequent flood events, such as the 20% AEP, riverine flood hazards are typically low to high (H1-H3), except for flood hazards along Mollieroi Creek, which show generally high flood hazard (H3-H5).

In the 1% AEP flood event, riverine flood hazards are generally unchanged, however hazard extents are increased into wider areas of channel floodways and floodplains. Overland flood hazards are typically low (H1-H2).

Duration

Flood durations in the 1% AEP event for Mollieroi Creek, Goona Creek, and Bundock Creek are typically between 7 and 15 hours. Flood durations along smaller channels including Black Creek are typically less than 5 hours.

N2N1: Chainages 818.86 – 843.89 (Bohena Creek)

The N2N1 model domain is located between chainages 818.86 and 843.89 of the proposed alignment. The model domain is located within Narrabri Shire LGA, and includes the localities of Pilliga, Bohena Creek, Jacks Creek and Narrabri.

Bohena Creek intersects the proposed alignment at chainage 828.2, adjacent to Cains Crossing Road, and about 17 kilometres south of Narrabri. Bohena Creek has an upstream catchment area of about 2,180 square kilometres and flows north-west across the proposed alignment before turning north, meandering gently towards the Namoi River.

Extent and depth

In small frequent flood events such as the 20% AEP, riverine flood extents are typically constrained to the Bohena Creek channel floodway / immediate floodplains both upstream and downstream of the Newell Highway and proposed alignment. Areas of overland flooding are also present downstream of the alignment between Nuable Road and Yarrie Lake Road.

In the 5% AEP flood event and larger, riverine flood extents and depths increase significantly along Bohena Creek, increasing flooded areas up to 1.2 kilometres from the channel. Minor tributaries to Bohena Creek also show overbank flooding. In the 5% AEP event the Newell Highway is flooded over a 7.5 kilometre stretch between Glenwood Lane and Tomlinson Lane and outside of the channel floodway. Westport Road, Cains Crossing Road, Nuable Road, and Sawpit Road are also affected by the 5% AEP event.

1% AEP flood extents are generally consistent with extents under the 5% AEP flood event, however increased flood depths are present across the floodplains of the main channel and associated tributaries. Riverine flood depths in the 1% AEP event vary between about 2.0 metres and 3.5 metres in the floodplains either side of Bohena Creek, with depths of up to about eight metres within the main channel / floodway.

Hazard

In small, frequent flood events such as the 20% AEP flood hazard within the floodplains of Bohena Creek and associated tributaries are typically high (H3-H5).

Flood hazard in the 1% AEP event is increased significantly in both magnitude and extent across the floodplains of Bohena Creek and associated tributaries. Flood hazards along Bohena Creek and adjacent floodplains are typically high (H5-H6).

Duration

Flood duration in the 1% AEP event within the floodplains of Bohena Creek typically varies between 10 and 20 hours, with some limited back swamp areas ponding up to 50 hours.

Narrabri: Chainages 833.70 – 853.00 (Namoi River and Narrabri Creek)

The Narrabri model domain is located between chainages 833.70 and 853.00 of the proposed alignment. The model domain is located within Narrabri Shire LGA and includes the Narrabri locality.

The Namoi River intersects the proposed alignment at chainage 844.1 immediately west of Narrabri and north of Bohena Lane. The Namoi River flows west/north-west through Narrabri and across the proposed alignment.

Narrabri Creek is located north of the Namoi River, flowing across the northernmost area of Narrabri and intersecting the proposed alignment at chainage 847.7. A number of small unnamed tributaries to Narrabri Creek are present between chainages 845.7 and 847.2, with headwaters originating west of (downstream) of Narrabri.

Extent and depth

In small frequent flood events such as the 20% AEP, flood extents are typically constrained to the main channels and floodways of the Namoi River and Narrabri Creek. Some overbank flooding into wider floodplains are observed along Narrabri Creek, and its tributaries (Horsearm Creek and Mulgate Creek).

In the 5% AEP flood event and larger, flood depths increase significantly into floodplains throughout the model domain and across Narrabri. A significant number of residential, commercial, and industrial properties, arterial and access roads, Narrabri Railway Station, and critical infrastructure (including Narrabri Hospital, SES, and fire station), are affected by floodwaters between about 0.2 and 0.8 metres deep.

In the 1% AEP event major flooding occurs within the model domain and across Narrabri. Flooding from the Namoi River typically affects areas of the town to the east of the Namoi River, while Narrabri Creek floods areas between the Namoi River and Horsearm Creek. Mulgate Creek affects commercial properties immediately east of the proposed alignment.

Flood depths in the 1% AEP event vary across Narrabri. Flood depths in areas affecting residential and commercial properties located between Narrabri Creek and Horsearm Creek typically vary between 0.8 and 1.3 metres. Typical flood depths in areas between Narrabri Creek and Namoi River (through the town) are between 0.9 and 1.6 metres with areas as deep as about 2.8 metres (where a chute connects Narrabri Creek with the Namoi). South of the Namoi River, flood depths affecting residential properties between Mooloobar Road and Gumbidguwa Road are typically between 1.2 and 1.8 metres.

Hazard

In small frequent flood events such as the 20% AEP, flood hazard within the floodplains of Narrabri Creek, Horsearm Creek, Mulgate Creek and the Namoi River are low (H1). Where hazards are present, they are primarily associated with overland flow.

Flood hazard in the 1% AEP event varies across Narrabri. Flood hazard affecting residential and commercial properties located between Narrabri Creek and Horsearm Creek is high (typically varying between H3 and H4, with areas of H5 and H6 within the immediate floodways).

Areas between Narrabri Creek and Namoi River are also high (typically ranging between H3 and H4) in the 1% AEP event, however a chute connecting Narrabri Creek with the Namoi River results in an area of H5 hazard, affecting a number of residential properties and roads. South of the Namoi River, residential properties between Mooloobar Road and Gumbidguwa Road typically experience high hazard of H3 and H4, with some H5 category areas along Ugoa Street and Clarke Street.

Critical infrastructure is also affected in the 1% AEP event including the Narrabri Hospital, SES, fire station and primary school.

Duration

Flood duration in the 1% AEP event varies across Narrabri. Flood durations in areas affecting residential and commercial properties located between Narrabri Creek and Horsearm Creek typically vary between 20 and 30 hours. Areas between Narrabri Creek and Namoi River are typically flooded between about 30 to 45 hours, affecting residential properties. South of the Namoi River, residential properties between Mooloobar Road and Gumbidguwa Road are flooded 35 to 45 hours.

5.2.3 Inundation of buildings

Geo-databases containing flood modelling data have been interrogated to identify peak flood levels, peak flood depths, flood hazard categories and duration of inundation of lands where the buildings are situated.

For the purposes of this assessment:

- Buildings include residences, educational facilities, health facilities, community facilities, commercial/industrial premises and other structures (such as garages).
- Sensitive buildings include all of the above buildings but do not include other structures.

Surveyed floor levels of buildings, where available, have been used to define depth of flooding above floor levels of buildings. In the case of buildings without surveyed floor levels, ground levels at the centroid of buildings have been extracted from the best available DEM to define floor levels of buildings on the assumption that floor levels are located 0.3 metres above ground level. This was checked against surveyed floor level data provided by Narrabri Shire Council and found to provide a good estimation of floor levels. It is to be noted that no buildings are located within N2N4 and N2N5 model domains.

Above floor flooding

A summary of all types of buildings subject to above floor flooding under existing conditions for the selected flood events are provided in Table 5.3. It is to be noted that no buildings located within N2N23 model domain are subject to above floor flooding in the PMF event.

There are 117 buildings along the proposal which are subject to above floor flooding in the 20% AEP event and the majority of the impacted buildings are located within N2N1 model domain representing Bohena Creek and its floodplain. There are 18 buildings in Narrabri which are subject to above floor flooding in the 20% AEP event.

In the case of the 5% AEP event, in total, 1,510 buildings (Table 5.3) are subject to above floor flooding of which 1,224 buildings are located within the model domain for Narrabri. In total, 3,312 buildings are subject to above floor flooding in the 2% AEP event.

Table 5.3 shows that in the 1% AEP event, 6,110 buildings are subject to above floor flooding and the majority (3,508) of the buildings are located within Narrabri model domain followed by buildings (2,250) located within Narromine (NFM) model domain. The majority of buildings subject to above floor flooding during flood events rarer than the 1% AEP event are located within Narrabri model domain.

Table 5.3 Number of buildings subject to above floor flooding (number of impacted buildings with surveyed floor levels shown in brackets) – existing conditions

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	13	57	103	2,250	3,241	2,978	3,600	4,572
N2N14	0	4	6	9	12	12	15	32
N2N13	3	5	9	14	23	23	33	142
N2N11-12	6	10	32	44	65	60	83	372
N2N10	1	1	4	6	10	10	17	166
N2N9	0	0	5	5	8	8	9	76
N2N8	2	2	0	2	8	6	10	62
N2N7	1	6	10	14	39	34	60	395
N2N6	1	2	2	2	2	2	2	17
N2N5	0	0	0	0	0	0	0	0
N2N4	0	0	0	0	0	0	0	0
N2N23	0	0	0	0	0	0	0	0
N2N1	72 (0)	199 (1)	242 (1)	256 (1)	304 (2)	292 (2)	317 (2)	466 (2)
Narrabri	18 (0)	1,224 (402)	2,899 (1,012)	3,508 (1,331)	4,792 (2,201)	4,341 (1,866)	5,020 (2,324)	6,137 (2,797)
Total	**117 (0)**	**1,510 (406)**	**3,312 (1,011)**	**6,110 (1,325)**	**8,504 (2,197)**	**7,766 (1,869)**	**9,166 (2,325)**	**12,437 (2,797)**

In the 1% AEP event with the projected climate for the year 2090, a total of 8,504 buildings are subject to above floor flooding. Total number of impacted buildings in the 0.5% and 0.2% AEP event are 7,766 and 9,166 respectively.

In total, 12,437 buildings are subject to above floor flooding in the PMF event and about 50 per cent of the impacted buildings are located within Narrabri model domain and about one-third of the impacted buildings are located within Narromine (NFM) model domain.

Further analysis of above floor flooding for the 1% AEP flood event by building type is provided in Table 5.4, which shows that a total of 2,573 sensitive buildings are currently subject to above floor flooding. The majority of these, 2,514, are located in Narromine and Narrabri. Of the 6,109 buildings subject to above floor flooding, 1,328 (22 per cent) have surveyed floor levels.

Table 5.4 Number of buildings (by type) subject to above floor flooding in the 1% AEP flood event – existing conditions

Building type	1% AEP
Residential	2,113
Community facility	60
Educational facility	13
Health facility	2
Commercial/Industrial	385
Other	3,536
Total	**6,109**

Flood hazards

Flood hazards on lands where the impacted buildings are situated have been assessed. The number of buildings and their surrounds subject to high flood hazard category (H3, H4, H5 and H6) within each TUFLOW model domain are shown in Table 5.5. Table 5.5 shows that the total percentages of buildings subject to high flood hazard generally increase with increased magnitude of flooding. In the case of the PMF event, about 98 per cent of the buildings impacted by flooding are subject to high flood hazard. Approximately 44 per cent of the impacted buildings are subject to high flood hazard in the 20% AEP event.

Table 5.5 Number of impacted buildings located on lands subject to high flood hazard – existing conditions

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	0	14	37	1,595	2,802	2,455	3,395	4,557
N2N14	0	0	0	3	6	7	9	30
N2N13	0	3	4	4	7	7	22	120
N2N11-12	0	6	17	29	47	43	67	328
N2N10	0	0	1	1	1	1	2	129
N2N9	0	0	1	4	5	5	6	69
N2N8	0	0	0	0	0	0	1	38
N2N7	1	1	2	6	27	27	41	372
N2N6	0	2	1	2	2	2	2	17
N2N5	0	0	0	0	0	0	0	0

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
N2N4	0	0	0	0	0	0	0	0
N2N23	0	0	0	0	0	0	0	0
N2N1	41	178	212	224	274	265	293	458
Narrabri	10	706	2,361	3,495	4,550	4,046	4,776	6,090
Total	**52**	**910**	**2,636**	**5,363**	**7,721**	**6,858**	**8,614**	**12,208**
% of total buildings [1]	**44%**	**60%**	**80%**	**88%**	**90%**	**88%**	**93%**	**98%**

Note 1: subject to above floor flooding

Duration of inundation

The average duration of flooding above 0.5 metres depth of flooding near buildings subject to above floor flooding is presented in Table 5.6 for each TUFLOW model domain and each flood event. Buildings located within Narrabri TUFLOW model domain are subject to the longest average duration of inundation between 20 to 57 hours for all but the PMF flood event, while buildings located within NFM TUFLOW model domain are subject to the longest duration of inundation in the PMF event. The average duration of inundation is typically less than three hours for TUFLOW model domains of N2N8, N2N9, N2N10, N2N13 and N2N14. The duration of inundation varies between three and 12 hours at impacted buildings located within TUFLOW model domains for N2N6, N2N7 and N2N11-12. The average duration of inundation varies between five and 18 hours within the N2N1 TUFLOW model domain.

Table 5.6 Average duration (hours) of inundation at buildings and surrounds above 0.5 metres depth of flooding – existing conditions

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	0	4	8	23	40	37	48	82
N2N14	0	2	0	0	1	1	1	3
N2N13	5	6	3	3	3	2	2	4
N2N11-12	8	11	7	10	10	6	8	12
N2N10	0	4	1	1	1	1	0	2
N2N9	0	0	1	3	4	3	4	3
N2N8	0	0	0	0	0	0	2	2
N2N7	3	6	6	4	4	4	4	4
N2N6	0	5	5	8	10	10	11	4
N2N5	0	0	0	0	0	0	0	0
N2N4	0	0	0	0	0	0	0	0
N2N23	0	0	0	0	0	0	0	0
N2N1	5	9	11	14	14	13	18	10
Narrabri	20	21	30	31	40	38	42	57

5.2.4 Inundation of roads

All named roads have been analysed to identify flooded sections of each road located within each TUFLOW model domain. Flood hazards, and duration of flooding above 0.5 metres flood depth were also analysed.

Flooding of highways

Five highways are located within fourteen TUFLOW domains in the close proximity of the proposal as follows:

- Mitchell Highway (NFM TUFLOW model)
- Castlereagh Highway (N2N11-12 TUFLOW model)
- Oxley Highway (N2N11-12 TUFLOW model)
- Newell Highway (N2N1 and Narrabri TUFLOW models)
- Kamilaroi Highway (Narrabri TUFLOW model)

The lengths of each highway subject to flood inundation for the selected flood events are shown in Table 5.7. In total, about 2.6 kilometres of the Newell Highway is subject to flooding in the 20% AEP event in the proximity of Bohena Creek. About one kilometre of the Oxley Highway, and about 0.5 kilometres of the Mitchell Highway are also subject to flooding in the 20% AEP event. All highways are impacted in the 5% AEP event.

Table 5.7 Length (kilometres) of highways subject to flooding – existing conditions

Highway	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Mitchell Highway	0.5	0.5	0.6	8.4	9.2	8.9	10.6	13.7
Castlereagh Highway	0	0.7	2.6	2.8	3.9	4	6	23.7
Oxley Highway	1	1.4	1.9	2.2	2.9	2.8	3.3	11.1
Newell Highway (N2N1)	2.6	9	10.7	11.1	11.7	11.6	11.8	16.5
Kamilaroi Highway	0	1.1	2.1	2.8	4.6	3.6	5.9	13.5
Newell Highway (Narrabri)	0	0.1	1.5	1.7	2.5	2.3	3.0	8.7

Table 5.8 shows per cent length (within the model domain) of each inundated highway subject to high flood hazard (H3, H4, H5 and H6 identified in Figure 2.1). Sections of the Newell Highway (Bohena Creek) and Kamilaroi Highway are impassable in the 20% AEP event due to high flood hazard and sections of the Castlereagh Highway, Oxley Highway and Newell Highway (Narrabri) are also impassable in the 5% AEP event. Several sections of all highways, except the Mitchell Highway, are impassable in the 2% AEP event.

Table 5.8 Per cent length of inundated highways subject to high flood hazard – existing conditions

Highway	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Mitchell Highway	0	0	0	93	91	92	93	100
Castlereagh Highway	-	100	53	100	73	93	96	96
Oxley Highway	0	92	80	88	96	82	91	92
Newell Highway (N2N1)	85	99	100	99	100	100	100	99
Kamilaroi Highway	100	90	75	66	71	78	84	100
Newell Highway (Narrabri)	-	0	71	69	70	69	63	100

The maximum duration of flooding above 0.5 metres flood depth for each highway is shown in Table 5.9. Durations of inundation for all highways and flood events generally vary between 33 and 94 hours. Only the Newell Highway (Narrabri) is subject to shorter duration of flooding, which is subject to 8 hours of inundation above 0.5 metres depth of flooding in the 5% AEP event.

Table 5.9 Maximum duration (hours) of inundation of highways above 0.5 metres depth of flooding – existing conditions

Highway	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Mitchell Highway	0	0	0	48	66	61	73	94
Castlereagh Highway	-	33	55	58	60	33	43	43
Oxley Highway	34	35	34	39	41	35	36	53
Newell Highway (N2N1)	45	47	43	50	51	51	51	58
Kamilaroi Highway	58	69	73	58	59	59	59	61
Newell Highway (Narrabri)	0	8	66	43	47	46	49	58

Flooding of other named roads

A summary of flood immunity, flood hazard and duration of inundation for other named roads (ie excluding highways) located within the TUFLOW model domains is presented in Table 5.10. In the 20% AEP event, about 163 kilometre sections of named roads are subject to flooding, 76 per cent length of the flooded roads are subject to high flood hazard and the average duration of flooding above 0.5 metres depth of flooding is 28 hours. In the case of flood events rarer than the 20% AEP event, more than 90 per cent length of the flooded roads are subject to high flood hazard and the average duration of flooding is up to 52 hours.

Table 5.10 Summary of flooding on named roads – existing conditions

Event	Total length of roads flooded (km)	% of flooded road subject to high flood hazard	Average duration of inundation (hour)	Maximum duration of inundation (hour)
20% AEP	163	76	28	111
5% AEP	290	90	32	96
2% AEP	366	92	39	94
1% AEP	461	94	37	95
1% AEP + CC	551	96	42	97
0.5% AEP	529	96	41	96
0.2% AEP	598	98	44	96
PMF	953	99	52	99

5.2.5 Inundation of existing rail lines

Existing rail lines have been analysed to identify flooded sections of each rail line within each TUFLOW model domain. Duration of inundation above 0.5 metres flood depth has also been analysed.

Except for the Main Western Line (Dubbo to Narromine and Narromine to Cobar Lines) and the Narrabri to Walgett Line (Narrabri) all the remaining rail lines located within the TUFLOW model domains are subject to flooding in the 20% AEP event as shown in Table 5.11. The Main Western Line is overtopped in the 5% AEP event and the Narrabri to Walgett Line (Narrabri) is overtopped in the 2% AEP event.

Table 5.11 Length (kilometres) of existing rail line flooded – existing conditions

Rail line	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Main Western Line	0	0.1	0.1	2.1	6.8	6	9.2	14.3
Parkes to Narromine Line	1.7	2.5	3.1	5.1	6.6	6.1	7.4	11.7
Dubbo to Coonamble Line	0.5	0.6	0.6	0.7	0.7	0.8	3	22.5
Binnaway to Gwabegar Line (non-operational)	0.2	0.6	1	1.3	4.6	3.6	5.3	16.1

Rail line	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Narrabri to Walgett Line (N2N1)	2.3	5.5	6.1	6.6	6.8	6.7	7.4	8.8
Narrabri to Walgett Line (Narrabri)	0	0	0.2	0.4	2.3	0.9	2.9	4.3
Mungindi Line	0.1	0.9	3.4	4.1	5.9	4.9	6.3	13.1

Maximum durations of inundation for each line within the TUFLOW model domains are shown in Table 5.12. The maximum duration of inundation for the Dubbo to Coonamble Line is generally shorter than 4 hours for all but the PMF event. The duration of inundation for the other lines varies between 21 and 99 hours.

Table 5.12 Maximum duration (hours) of flooding of railway above 0.5 metres depth of flooding – existing conditions

Rail line	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Main Western Line	0	0	0	55	81	77	84	97
Parkes to Narromine Line	8	20	32	54	69	66	86	99
Dubbo to Coonamble Line	0	1	0	1	1	1	4	30
Binnaway to Gwabegar Line (non-operational)	23	44	26	26	27	27	28	29
Narrabri to Walgett Line (N2N1)	22	42	44	44	47	47	49	25
Narrabri to Walgett Line (Narrabri)	80	71	70	54	51	51	53	58
Mungindi Line	21	71	87	65	65	65	65	68

5.2.6 Inundation of major land uses

A summary of major land uses for all areas included in the TUFLOW models domains is presented in Table 5.13. Cropping is the dominant land use (48 per cent) and represents almost half of the total area represented in the TUFLOW models, followed by grazing and pasture (29 per cent) and forests (20 per cent).

Table 5.13 Significant land uses

Land use	Total area (ha)	%
Forests	74,386	20
Grazing, pasture	107,804	29
Cropping	180,115	48.4
Horticulture	278	0.1
Residential and farm infrastructure	3,870	1
Transport, communication	2,004	0.5
Water, marsh, wetland	2,290	0.6
Services, utilities, water treatment	593	0.2
Others	753	0.2
Total	**372,095**	**100**

Forested lands

Forested areas subject to different depths of flooding are shown in Table 5.14. About 10,915 hectares of forested lands are subject to flooding in the 20% AEP flood event. In the case of the PMF event, 53,609 hectares of forested lands are impacted by flooding.

Table 5.14 Forested lands subject to different flood depths – existing conditions

Event	Inundated areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	6,922	1,938	1,120	668	267	**10,915**
5% AEP	10,136	2,749	2,215	1,040	579	**16,718**
2% AEP	12,470	3,087	2,804	1,338	748	**20,448**
1% AEP	13,443	3,408	3,198	1,595	943	**22,585**
1% AEP + CC	15,635	4,172	3,617	2,168	1,280	**26,872**
0.5% AEP	15,143	3,941	3,483	1,989	1,183	**25,739**
0.2% AEP	16,351	4,296	4,061	2,437	1,496	**28,641**
PMF	21,126	7,043	7,238	9,092	9,110	**53,609**

Forested lands subject to different duration of flood inundation above 0.5 metres depth are shown in Table 5.15. Generally, the majority of the forested areas are subject to less than 24 hours of inundation above 0.5 metres flood depth.

Table 5.15 Forested lands subject to different duration of flood inundation above 0.5 metres depth – existing conditions

Event	Inundated Forested land (ha)				
	0 - 3 hrs	3 - 6 hrs	6 - 12 hrs	12 - 24 hrs	> 24 hrs
20% AEP	344	457	635	547	60
5% AEP	706	1,020	1,234	810	130
2% AEP	1,007	1,260	1,705	1,122	47
1% AEP	904	1,404	2,126	1,200	102
1% AEP + CC	1,092	1,464	2,865	1,475	176
0.5% AEP	1,022	1,309	2,679	1,439	213
0.2% AEP	1,407	1,572	2,854	1,801	373
PMF	7,685	8,870	6,845	1,685	368

Grazing area

Grazing areas subject to different depths of flooding are shown in Table 5.16. About 19,757 hectares of grazing areas are subject to flooding in the 20% AEP flood event and almost half of the flooded areas are subject to up to 0.25 metres depth of flooding. In the case of the PMF event, 70,443 hectares of grazing areas are impacted by flooding and the majority of the flooded areas are subject to greater than one metre flood depth.

Table 5.16 Grazing areas subject to different flood depths – existing conditions

Event	Inundated areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	9,348	4,045	2,928	1,845	1,591	**19,757**
5% AEP	10,553	5,243	5,163	4,849	3,844	**29,653**
2% AEP	11,356	5,263	5,683	5,945	5,403	**33,650**
1% AEP	12,043	5,491	5,800	6,530	6,456	**36,319**
1% AEP + CC	13,081	6,376	6,407	6,973	9,316	**42,152**
0.5% AEP	12,979	6,297	6,174	7,142	8,294	**40,886**
0.2% AEP	13,219	6,654	7,022	7,199	10,584	**44,679**
PMF	10,596	7,365	11,748	15,014	25,721	**70,443**

Grazing areas subject to different duration of flood inundation above 0.5 metres depth are shown in Table 5.17. The majority of the grazing areas are subject to less than 24 hours of inundation above 0.5 metres flood depth.

Table 5.17 Duration of flood inundation of grazing areas above 0.5 metres depth – existing conditions

Event	Inundated areas (ha)				
	0 - 3 hrs	3 - 6 hrs	6 - 12 hrs	12 - 24 hrs	> 24 hrs
20% AEP	690	922	1,401	1,035	2,459
5% AEP	967	1,452	3,735	2,573	5,998
2% AEP	5,956	1,518	3,621	3,868	7,249
1% AEP	1,164	1,576	3,440	4,200	8,765
1% AEP + CC	1,665	1,864	3,661	4,773	11,117
0.5% AEP	1,578	1,813	3,689	4,918	9,994
0.2% AEP	2,012	2,411	3,945	3,869	12,997
PMF	8,374	10,697	10,485	6,964	16,561

Cropping lands

Cropping lands subject to different depths of flooding are shown in Table 5.18. About 19,222 hectares of cropping lands are subject to flooding in the 20% AEP flood event with most of this subject to up to 0.25 metres depth of flooding. In the case of the PMF event, 113,298 hectares of cropping lands are impacted by flooding and the majority of the flooded areas are subject to less than one metre flood depth.

Table 5.18 Cropping lands subject to different flood depths – existing conditions

Event	Inundated areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	14,233	3,075	1,347	490	76	**19,222**
5% AEP	18,976	5,556	3,190	1,586	890	**30,199**
2% AEP	21,142	6,785	4,092	2,327	1,251	**35,597**
1% AEP	23,368	8,263	5,115	3,722	1,864	**42,332**
1% AEP + CC	25,533	10,363	6,934	5,309	2,957	**51,096**
0.5% AEP	25,272	10,253	6,484	4,949	2,713	**49,670**
0.2% AEP	26,714	11,757	8,292	5,923	4,067	**56,753**
PMF	22,033	19,620	28,394	23,401	19,850	**113,298**

Cropping lands subject to different duration of flood inundation above 0.5 metres depth are shown in Table 5.19. The majority of the cropping lands are subject to less than 24 hours of inundation above 0.5 metres flood depth.

Table 5.19 Duration of flood inundation for cropping lands above 0.5 metres depth – existing conditions

Event	Inundated areas (ha)				
	0 - 3 hrs	3 - 6 hrs	6 - 12 hrs	12 - 24 hrs	> 24 hrs
20% AEP	339	300	337	204	641
5% AEP	1,107	939	1,266	865	1,948
2% AEP	13,761	999	1,568	1,118	3,295
1% AEP	1,182	1,068	1,709	1,581	5,600
1% AEP + CC	1,813	1,341	1,865	1,708	8,973
0.5% AEP	1,865	1,277	1,951	2,374	7,178
0.2% AEP	2,521	1,801	2,287	2,055	10,247
PMF	20,817	14,901	9,642	7,673	20,472

Horticultural lands

There are only 278 hectares of horticultural lands within the TUFLOW model domains. About ten per cent (refer to Table 5.20) of the horticultural lands are subject to flooding in the 2% AEP event and 258 hectares of horticultural lands are subject to flooding in the PMF event.

Table 5.20 Horticultural lands subject to different flood depths – existing conditions

Event	Inundated areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	1	2	3	-	-	**6**
5% AEP	5	8	10	5	1	**28**
2% AEP	3	5	12	8	1	**29**
1% AEP	7	17	73	104	4	**204**
1% AEP + CC	4	12	35	161	5	**218**
0.5% AEP	8	9	46	149	5	**217**
0.2% AEP	3	7	22	164	22	**219**
PMF	2	2	6	29	219	**258**

Horticultural lands subject to different duration of flood inundation above 0.5 metres depth are shown in Table 5.21. The majority of horticultural lands are subject to longer than 24 hours of flood inundation above 0.5 metres flood depth in flood events larger than the 2% AEP event.

Table 5.21 Duration of flood inundation for horticultural lands above 0.5 metres depth – existing conditions

Event	Inundated areas (ha)				
	0 - 3 hrs	3 - 6 hrs	6 - 12 hrs	12 - 24 hrs	> 24 hrs
20% AEP	1	2	1	-	-
5% AEP	0	0	5	0	1
2% AEP	1	4	5	2	10
1% AEP	0	2	9	16	152
1% AEP + CC	0	0	8	3	190
0.5% AEP	0	1	9	3	187
0.2% AEP	0	0	9	2	197
PMF	0	0	8	5	241

5.3 Geomorphology

5.3.1 River Style categories

A River Styles Assessment has been undertaken for 40 of the waterways traversed by the proposal covering most of the named waterways that are mapped as a Major Hydroline (NSW Office of Water, 2012). Although it is noted that there are two exceptions (Stockyard Creek and Black Creek which are both named waterways and mapped as Major Hydroline). The River Style Mapping does not provide an assessment of smaller watercourses, mapped as Minor Hydrolines. The assessment identified 10 different River Styles in four broad categories as discussed below.

The primary attributes that define each River Style identified within the proposal site and listing of watercourses with each River Style is summarised in Table 5.22 with further information presented in Appendix E.

Confined Valley Setting

In this Confined Valley Setting, bedrock or hardened sedimentary deposits control the planform of the stream channel. The stream generally lacks a floodplain or there are occasional floodplain pockets. The streams in this category are generally located in high-energy settings - middle to upper catchment positions, the relatively steeper gradients and confinement can generate moderate to high stream powers. Watercourses in this category have a Confined Valley, Sand River Style (Coolangla Creek, Cumbil Forest Creek, Rocky Creek, Talluba Creek, Coghill Creek and Mollieroi Creek).

Partly Confined Valley Setting

The two broad categories of River Styles mapped under the Partly Confined Valley Setting can be defined as either Bedrock Controlled or Planform Controlled:

- Rivers in a Bedrock Controlled Setting typically consist of a single bedrock controlled channel where the valley shape itself controls the sinuosity and floodplain extents of the river. The Bedrock Controlled River Styles are based on the dominant bed load, which can vary from gravel, through to sand and fine-grained. The Macquarie River has a Bedrock Controlled, Sand River Style.

- Planform Controlled rivers are generally found in more regular and wider valley settings, where the valley has less influence on channel position. As a result, the channels of Planform Controlled rivers have greater potential to adjust laterally and vertically. Planform controlled rivers in the proposal site are Low Sinuosity Sand (Ewenmar Creek, Native Dog Creek, Kickabil Creek, Bundijoe Creek, Castlereagh River, Gulargambone Creek, Quanda Quanda Creek, Salty Springs Creek, Teridgerie Creek and Baradine Creek) and Fine Grained (Calga Creek).

Laterally Unconfined Valley Setting

Laterally Unconfined Valley Settings give rise to a number of different channel planforms and these are characterised with respect to number of channels, sinuosity and lateral stability. In the instream zone, erosional or depositional forms and bank-attached and mid-channel features are differentiated. Bed material texture is used for a finer level of differentiation, highlighting differences between gravel, sand and fine-grained variants. River Styles are Low Sinuosity Gravel (Namoi River and Narrabri Creek), Sand (Emogandy Creek, Marthaguy Creek, Caleriwi Creek, Etoo Creek and Goona Creek) and Fine-Grained (Baronne Creek and Bucklanbah Creek) and Channelised Fill (Wallaby Creek, Goulburn Creek, Pint Pot Gully and Milpulling Creek).

Discontinuous

The watercourses in this group are located in lower energy settings. The Discontinuous Channel categories include Valley Fill Sand (Tenandra Creek, Mungery Creek, Black Gutter and Small Creek), Fine-Grained (Judes Creek) and Lowland Chain of Ponds (Tinegie Creek, Bundock Creek and Bohena Creek).

Table 5.22 Summary of River Styles for watercourses in the proposal site

River Style	Planform			Channel geometry	Bed materials	Bank/floodplain materials	Watercourses
	Number of channels	Lateral stability	Sinuosity				
Confined Valley Setting							
Confined valley, sand	1	Stable, potential for localised expansion	Low	Symmetrical	Sand with some fines	Bedrock	Coolangla Creek, Cumbil Forest Creek, Rocky Creek, Talluba Creek, Coghill Creek, Mollieroi Creek
Partly Confined Valley Setting							
Bedrock controlled, sand	1	Stable, potential for localised channel expansion	Generally low, dictated by valley	Compound or irregular	Bedrock with some sand bedload	Bedrock or alluvial bank fines/sands	Macquarie River
Planform controlled, low sinuosity sand	1	Laterally stable, adjusts through channel expansion	Low	Symmetrical	Sands	Bedrock/terrace or alluvial banks sands and fines	Ewenmar Creek, Native Dog Creek, Kickabil Creek, Bundijoe Creek, Gulargambone Creek, Quanda Quanda Creek, Salty Springs Creek, Teridgerie Creek, Baradine Creek, Castlereagh River
Planform controlled, low sinuosity fine grained	1	Moderately laterally stable, adjusts through lateral migration and avulsion	Low	Trench-like symmetrical	Cohesive fines	Bedrock or alluvial banks cohesive fines	Calga Creek
Laterally Unconfined Valley Setting							
Low sinuosity, gravel	1	Laterally active, adjusts through channel expansion and/or avulsion	Low to moderate	Compound to asymmetrical	Gravel armoured	Cohesive fines	Namoi River, Narrabri Creek

River Style	Planform			Channel geometry	Bed materials	Bank/floodplain materials	Watercourses
	Number of channels	Lateral stability	Sinuosity				
Low sinuosity, sand	1	Relatively laterally active, adjusts through channel expansion and/or avulsion	Low	Symmetrical to compound, low width/depth ratio	Sands with scattered gravels	Fine sands and organic matter	Emogandy Creek, Marthaguy Creek, Caleriwi Creek, Etoo Creek, Goona Creek
Low sinuosity, fine-grained	1	Relatively laterally stable	Low-moderate	Symmetrical to compound	Cohesive fines, may have scattered gravels	Cohesive fines	Baronne Creek, Bucklanbah Creek
Channelised fill	1	Laterally stable	Low	Symmetrical or compound	Fines or sands	Fines and sands	Wallaby Creek, Goulburn Creek, Pint Pot Gully, Milpulling Creek
Discontinuous							
Valley fill, sand	no channel	Prone to incision	Low	Symmetrical	Organic rich mud and/or sands	n/a	Tenandra Creek, Mungery Creek, Black Gutter, Small Creek
Valley fill, fine grained	no channel	Prone to incision	Low	Symmetrical	Organic rich mud and silt	n/a	Judes Creek
Lowland chain of ponds	Usually 1 but up to 3	Laterally stable, prone to incision	Low	Symmetrical	Organic rich sand and fines	Organic rich sand and fines	Tinegie Creek, Bundock Creek, Bohena Creek

Note: In the River Styles Spatial Layer Coolangla Creek, Cumbil Forest Creek, Rocky Creek, Talluba Creek, Coghill Creek and Mollieroi Creek were labelled as having a *Bank confined, sand* River Style description. This River Style did not exist in the Namoi River Style Report (Lampert and Short, 2004) and it appears that it has been mislabelled. This was changed to *Confined valley, sand.* Tinegie Creek was also lacking a River Style description, this has been reviewed and classified as *Lowland chain of ponds.*

5.3.2 Geomorphic condition and fragility

Outhet and Cook (2004) describe a rapid method of condition assessment that frames geomorphic condition in the context of natural and human induced variability and divide stream condition into three broad categories: good (e.g natural and intact); moderate (e.g noticeably impacted by human disturbances); and poor (e.g degraded). The characteristics relating to each of the categories of geomorphic condition are outlined in Table 5.23.

Table 5.23 Criteria for assessment of geomorphic condition

Good Condition - must contain all of the following characteristics:
• River character and behaviour is similar to the pre-development state presenting a high potential for ecological diversity. • Minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance. • Relatively intact and effective vegetation coverage dominated by native species, giving resistance.
Moderate Condition - contains one or more of the following characteristics:
• Localised degradation of river character and behaviour, typically marked by modified patterns of geomorphic units. • Patchy effective vegetation coverage allowing some localised accelerated erosion.
Poor condition - contains one or more of the following characteristics:
• Abnormal or accelerated geomorphic instability (reaches are prone to accelerated and / or inappropriate patterns or rates of planform change and / or bank and bed erosion). • Excessively high volumes of sediment inputs which blanket the bed, reducing flow diversity. • Absent or geomorphologically ineffective coverage by vegetation (allowing most locations to have accelerated rates of erosion).

Stream fragility, or adjustment potential, refers to the sensitivity or susceptibility of a stream to changes or alterations in its geomorphic category when exposed to disturbances such as degradation. Streams with higher fragility have a lower threshold to threatening processes and will show more geomorphic and physical change than streams that are less fragile or susceptible. Understanding geomorphic categories and their potential fragility with respect to River Style is important for management of rivers as a means of assessing river vulnerability. The three levels of stream fragility outlined by Outhet et al (2004) are derived from rivers potential to geomorphically adjust and include:

- Low Fragility – not easily destroyed, this river has little potential to be disturbed or change its geomorphic category however, some slight changes in bedform may occur.
- Moderate Fragility – the potential for adjustment is limited to only localised changes where there is a direct exposure to threatening processes. The geomorphic character can alter significantly however there is only a slight potential for changes in overall geomorphic category as resilience thresholds are high.
- High Fragility – this river is highly susceptible and sensitive and has a significant potential for adjustment. Greater lengths of river are also altered when disturbances are introduced. The geomorphic character can alter significantly as can the geomorphic category as resilience thresholds are low and easily breached.

Table 5.24 shows the condition and fragility of the watercourses within the proposal site determined as part of the River Style Assessment. Watercourses that were classed as having good geomorphic condition include the Macquarie River, Ewenmar Creek and Tinegie Creek. The majority of watercourses (27) were assessed as having moderate geomorphic condition. A number of watercourses (10) were assessed as having poor geomorphic condition, in particular those that had Channelised Fill River Styles. These reaches are typically degraded where sediment regimes have been altered through intense land use and vegetation removal and significant erosion of the bed and banks is evident (GHD, 2010; Lampert and Short, 2004).

The fragility of the River Styles was assessed as moderate to high for all watercourses. In the Partly Confined and Laterally Unconfined settings, watercourses with sand and gravel tend to be more prone to adjustment than their fine-grained counterparts. The Discontinuous River Styles all have a high fragility, meaning they are sensitive to disturbance and have significant adjustment potential. It is common for discontinuous styles to transform to other styles such as Channelised Fill and Low Sinuosity, Sand. These alterations have the potential to release large amounts of sediment resulting in sedimentation impacts downstream (GHD, 2010; Lampert and Short, 2004).

Table 5.24 Condition and fragility of watercourses in the proposal site

Chainage (km)	Watercourse	River Style Assessments Valley Setting	River Style	Condition	Fragility
Macquarie Catchment					
6.9	Wallaby Creek	Laterally Unconfined	Channelised fill	Poor	Moderate
16	Macquarie River	Partly Confined	Bedrock controlled, sand	Good	Moderate
48.4	Ewenmar Creek	Partly Confined	Planform controlled, low sinuosity, sand	Good	High
52	Goulburn Creek	Laterally Unconfined	Channelised fill	Poor	Moderate
55.9	Emogandy Creek	Laterally Unconfined	Low sinuosity, sand	Moderate	High
60.2	Native Dog Creek	Partly Confined	Planform controlled, low sinuosity, sand	Poor	High
62	Pint Pot Gully	Laterally Unconfined	Channelised fill	Poor	Moderate
62.8	Kickabil Creek	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
69.7	Milpulling Creek	Laterally Unconfined	Channelised fill	Poor	Moderate
76.2	Bundijoe Creek	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
87.5	Marthaguy Creek	Laterally Unconfined	Low sinuosity, sand	Moderate	High
Castlereagh Catchment					
105.2	Castlereagh River	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
112.1	Judes Creek	Discontinuous	Valley fill, fine grained	Moderate	High
125.9	Gulargambone Creek	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
135.5	Baronne Creek	Laterally Unconfined	Low sinuosity, fine grained	Moderate	Moderate
147.1	Tenandra Creek	Discontinuous	Valley fill, sand	Moderate	High
153.5	Mungery Creek	Discontinuous	Valley fill, sand	Moderate	High
155.2	Caleriwi Creek	Laterally Unconfined	Low sinuosity, sand	Poor	High
157.8	Quanda Quanda Creek	Partly Confined	Planform controlled, low sinuosity, sand	Poor	High
161.65	Black Gutter	Discontinuous	Valley fill, sand	Moderate	High
162.4	Salty Springs Creek	Partly Confined	Planform controlled, low sinuosity, sand	Poor	High
167.7	Calga Creek	Partly Confined	Planform controlled, low sinuosity, fine grained	Moderate	Moderate
175.4	Bucklanbah Creek	Laterally Unconfined	Low sinuosity, fine grained	Moderate	Moderate

Chainage (km)	Watercourse	River Style Assessments			
		Valley Setting	River Style	Condition	Fragility
181.3	Small Creek	Discontinuous	Valley fill, sand	Moderate	High
183.65	Teridgerie Creek	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
Namoi Catchment					
200.95	Baradine Creek	Partly Confined	Planform controlled, low sinuosity, sand	Moderate	High
205.9	Coolangla Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
209.95	Cumbil Forest Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
216.8	Etoo Creek	Laterally Unconfined	Low sinuosity, sand	Moderate	High
222.35	Rocky Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
226.7	Tinegie Creek	Discontinuous	Lowland chain of ponds	Good	High
232.8	Talluba Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
242.55	Rocky Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
249.8	Coghill Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
253.65	Mollieroi Creek	Confined Valley	Confined valley, sand	Moderate	Moderate
262.3	Goona Creek	Laterally Unconfined	Low sinuosity, sand	Moderate	High
270.9	Bundock Creek	Discontinuous	Lowland chain of ponds	Moderate	High
282.6	Bohena Creek	Discontinuous	Lowland chain of ponds	Moderate	High
297.6	Namoi River	Laterally Unconfined	Low sinuosity, gravel	Poor	Moderate
300.75	Narrabri Creek	Laterally Unconfined	Low sinuosity, gravel	Poor	Moderate

Note: In the River Styles Spatial Layer Coolangla Creek, Cumbil Forest Creek, Rocky Creek, Talluba Creek, Coghill Creek and Mollieroi Creek were labelled as having a *Bank confined, sand* River Style description. This River Style did not exist in the Namoi River Style Report (Lampert and Short, 2004) and it appears that it has been mislabelled. This was changed to *Confined valley, sand.* Tinegie Creek was also lacking a River Style Description, this has been reviewed and classified as *Lowland chain of ponds.*

5.3.3 Existing flow velocities

Maximum flow velocities from the flood modelling results were reviewed against the geomorphological conditions of the waterways for a range of flood events to assess the sensitivity of the waterways under existing conditions. Modelled maximum velocity for a range of design events (5, 2 and 1% AEP) were compared with maximum permissible velocity values for sandy loams (0.5 metres per second), fine gravels (0.8 metres per second) and vegetated surfaces (2 metres per second). The existing flow velocities have been plotted for the four broad categories of River Styles and these are shown in Figure 5.9, Figure 5.10, Figure 5.11 and Figure 5.12.

The results of this assessment show the range of velocities across the different streams generally exceed the thresholds for erosion of substrates. It is expected that 1%, 2% and 5% AEP events would play an important role in maintaining the morphology and form of the channel and floodplain environments. Those waterways which have previously been assessed in the Regional River Style Assessments as having a high fragility would be highly susceptible and sensitive to a significant potential for adjustment under existing conditions.

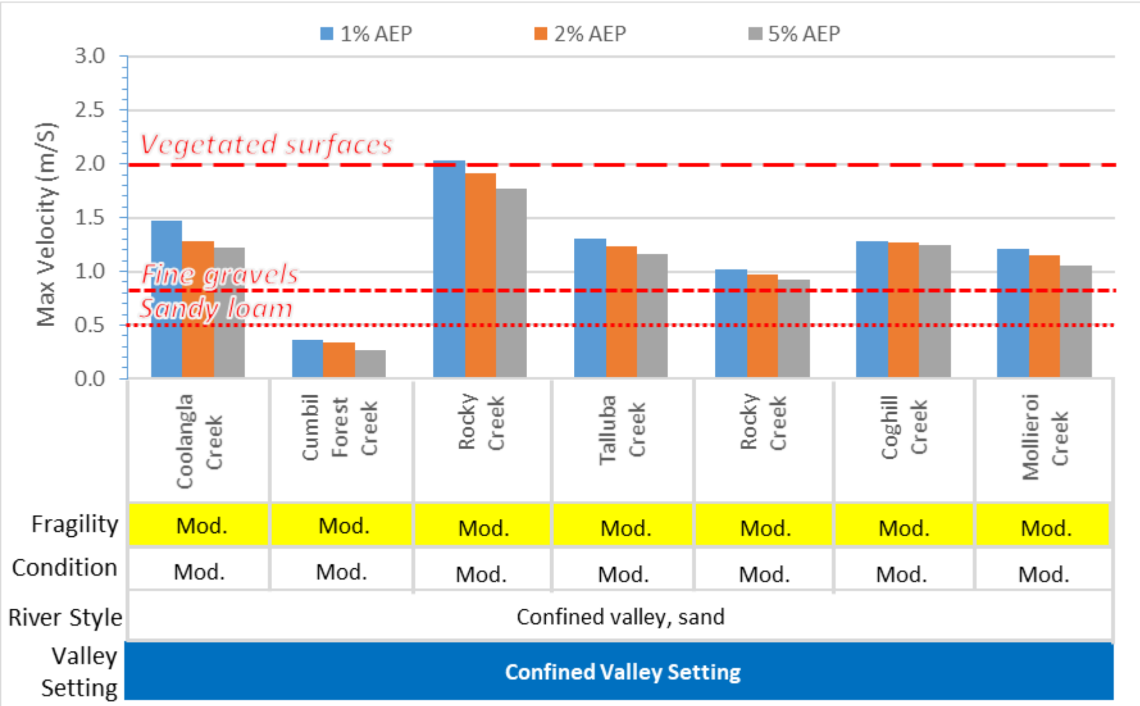


Figure 5.9 Existing maximum velocity for Confined Valley River Styles

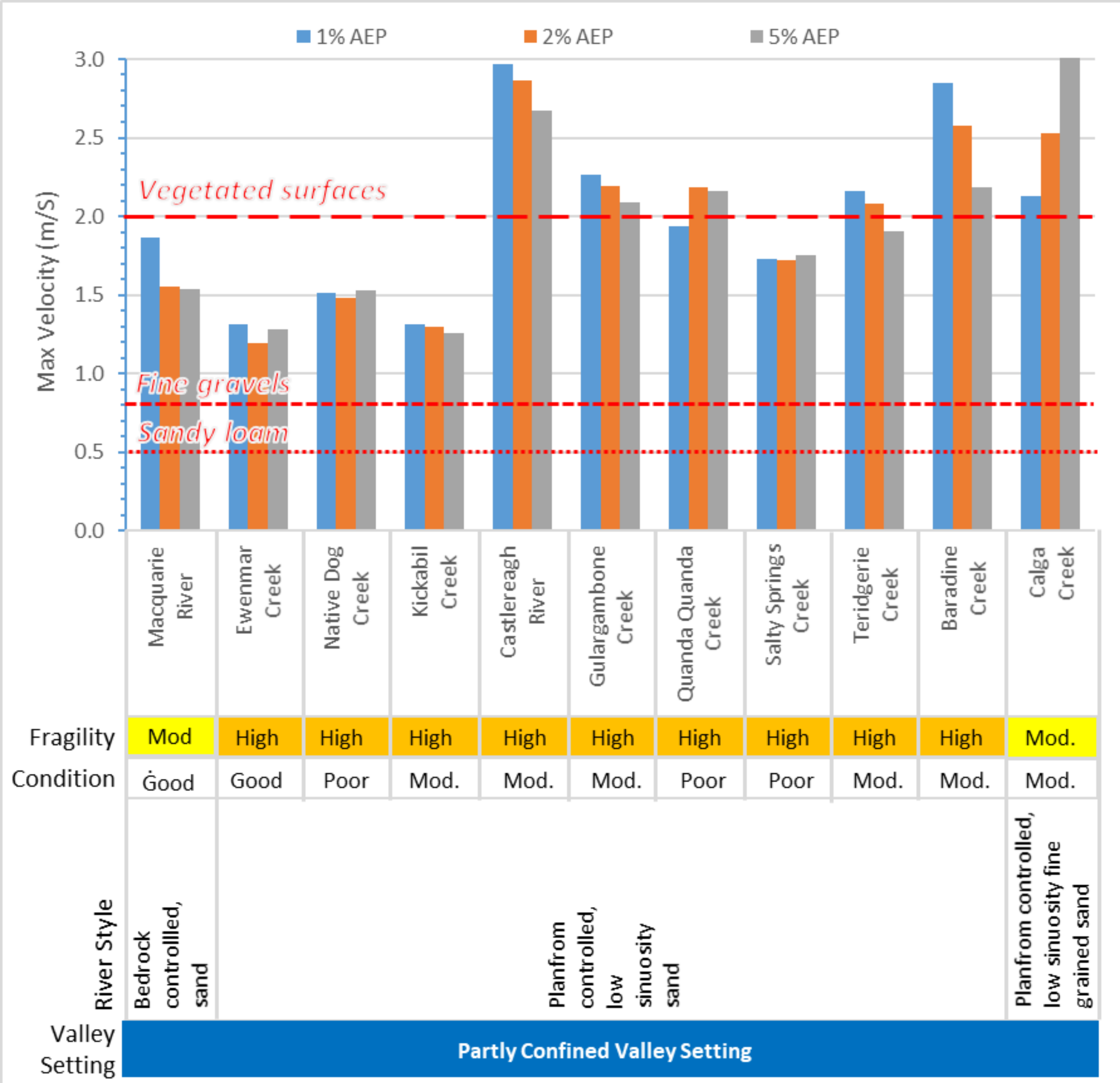


Figure 5.10 Existing maximum velocity for Partly Confined Valley River Styles

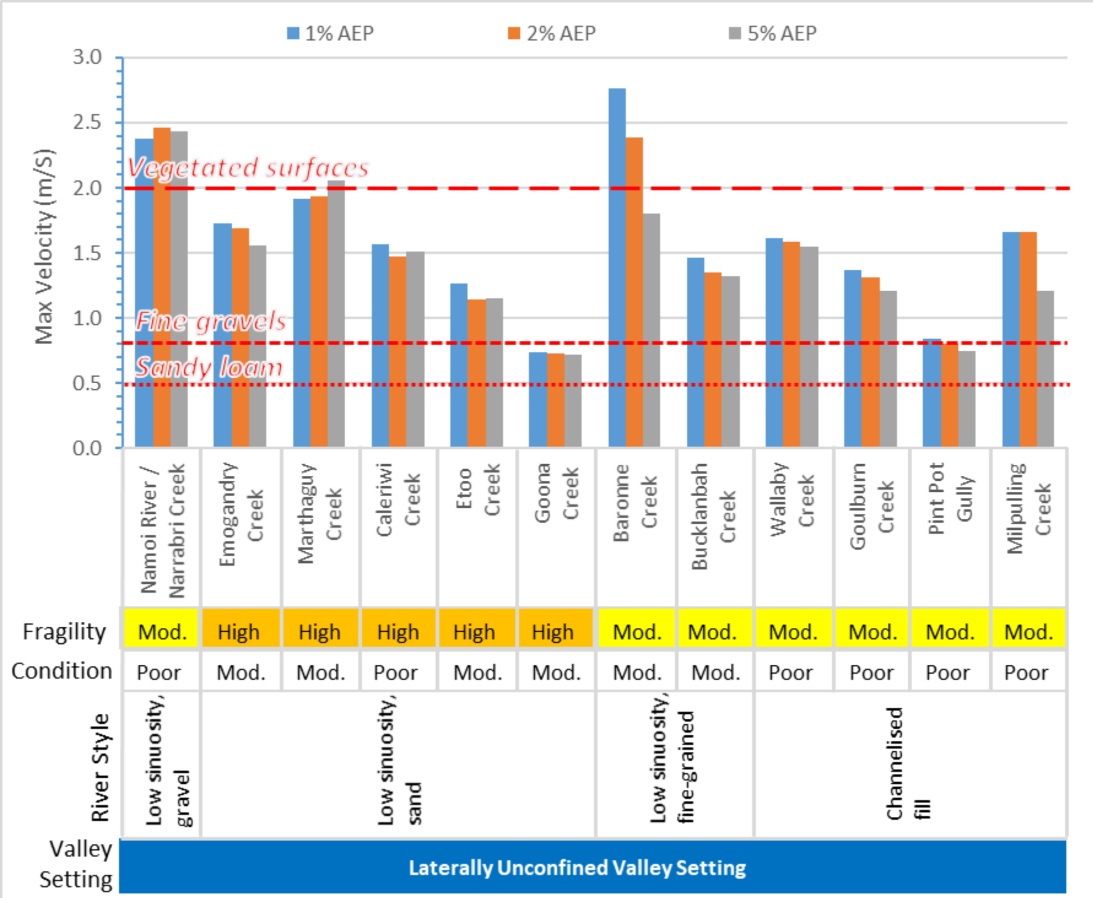


Figure 5.11 Existing maximum velocity for Laterally Unconfined Valley River Styles

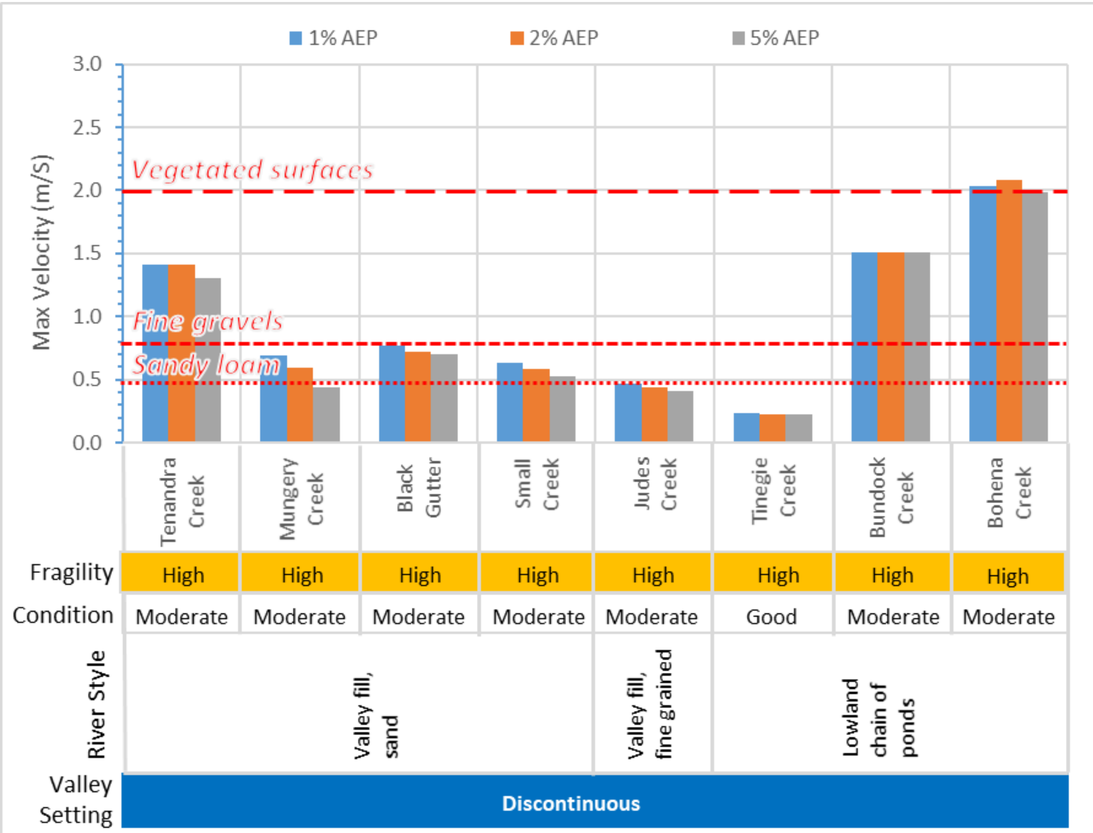


Figure 5.12 Existing maximum velocity for Discontinuous River Styles

6. Construction impact assessment

6.1 Flooding

6.1.1 Potential flood impacts

Construction activities have the potential to worsen flooding conditions for a given flood event when compared to both existing and operational conditions. It is anticipated that overall construction would take about 48 months, subject to weather conditions. Construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures outside the operational footprint, which would be removed following the completion of construction activities.

Without the implementation of appropriate management measures, inundation of the construction footprint by floodwater has the potential to:

- Cause damage to the works and delays in construction programming.
- Pose a safety risk to construction workers.
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters.
- Obstruct the passage of floodwater and overland flow through the provision of temporary measures such as construction compounds and stockpiles, which in turn could exacerbate existing flooding conditions.

The location and layout of construction work sites and compounds would be prepared with consideration of overland flow paths, avoiding flood liable land where practicable to avoid detrimental impacts. Prior to construction, a flood and emergency response plan would be prepared and implemented as part of the construction environmental management plan (CEMP). The plan would include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It would also include measures to manage flood risks during construction and address flood recovery during construction.

The following sections describe the construction activities that have the greatest potential to affect the existing flood conditions and an assessment of their potential impacts.

Earthworks

The earthworks associated with the construction of the railway embankment would cause flow constriction and a minor loss of flood storage. The flow constriction caused by the railway embankment would have a greater effect on flood behaviour compared to the minor loss of floodplain storage. The inundation of the earthworks by floodwater also has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving waterways. It would therefore be necessary to plan, implement and maintain measures to manage the diversion of floodwater either through or around the construction areas.

Construction compounds

Construction compounds located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would therefore be necessary to locate site facilities outside high hazard areas with safe evacuation routes.

Based on the EIS design there are 67 construction compounds proposed along the length of the proposal. Of those, 27 would be affected by 1% AEP flooding, and 25 would be affected by 5% AEP flooding. For ancillary sites with flood immunity less than 5% AEP, a flood and emergency response plan would be prepared. This plan should consider likelihood of flooding, evacuation routes, warning times, and potential impacts from the compound flooding.

Stockpiles

Stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to large quantities of material being washed into the receiving waterways.

Bridge construction

In-stream works required to construct new bridges over the major rivers are exposed to the impact of flooding as higher flow velocities generally occur in the river channels compared to overbank or floodplain areas. Temporary structures required to construct the bridges such as crane pads, barges, scaffolding etc. have the potential to be washed away in a flood event causing damage downstream by colliding into other structures.

These in-stream works can also have an impact on flood levels influencing flood behaviour and potentially result in flood impacts that are greater than operational phase, depending on the stage of construction.

Temporary sediment basins and waterway crossings

Temporary sediment basins would be required during construction to capture runoff from disturbed construction areas and prevent sedimentation and pollution of downstream receiving waters. The temporary sediment basins would typically be located near receiving watercourses and consist of an earth embankment to provide the necessary storage capacity. The sediment basin embankments located on the floodplain have the potential to obstruct floodwater and alter flooding patterns.

Temporary creek crossings would also be required during construction to allow construction vehicles to drive between the banks of creeks. Temporary crossings may include low lying causeways, consisting of a low-level trafficable weir with culverts conveying low flows. The temporary crossings would remain dry during normal creek flow conditions when the water is low but could become covered by water in times of floods.

Borrow pits

Four borrow pits would be established on private land for the supply of fill material for construction of the proposal. The borrow pit locations are not known to be subject to flooding in events up to the 1% AEP flood event. During construction, water at the borrow pits would be managed as follows:

- Up slope diversion drains would convey clean water around the site.
- Sedimentation basins would collect all dirty water (including any groundwater seepage) from disturbed areas within the site.

Water contained within sediment basins would be discharged to the nearest watercourse prior to or immediately following forecast rainfall events that are likely to produce basin inflows. Appropriate scour protection would be provided at the outlets. The basins would include overflow bypass structures to enable stormwater discharge during heavy storm events where the design capacity of the sediment basins may be exceeded. Alternatively, water may be re-used (as a supplementary source to the primary water supply) during construction for activities such as dust suppression. All erosion and sediment measures would be implemented at the sites in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom, 2004) and *Managing Urban Stormwater: Soils and Construction Volume 2C Unsealed Roads* (Department of Environment and Climate Change NSW, 2008a).

Following extraction of all required material from the borrow pits, all facilities would be removed and the pits would be stabilised and rehabilitated. Rehabilitation of the borrow pits would be undertaken in accordance with the borrow pit rehabilitation strategy and the approach outlined in the EIS. It is proposed to use excess material (that does not meet design specifications or cannot be feasibly used within the rail formation) from the main construction works to assist with the reshaping of the borrow pits. The borrow pits would be returned to their original condition as far as is reasonably practicable or otherwise as agreed with the landholder. In addition to this, the final landform shall be safe, stable, non-polluting, sustainable, and free-draining to as close as practicable, the pre-existing conditions.

The *ARTC Inland Rail Narromine to Narrabri Borrow Pit Rehabilitation Strategy* (JacobsGHD, 2020b) establishes objectives, performance indicators and indicative completion criteria, and outlines a monitoring program to ensure the completion criteria are met. These would be further refined during detailed design to ensure the sites are rehabilitated to an appropriate standard and to ensure that all flow paths are stable and appropriate scour protection is provided where required.

6.1.2 Modelled flood impacts

The configuration and staging of construction works have been reviewed to assess potential flooding impacts during construction of the proposal. For the purpose of quantifying the potential construction phase flood impacts, a critical (or worst case) stage of construction has been identified on the basis of the following considerations:

- All construction compounds and storage areas are protected from flooding up to and including the 5% AEP event.
- At least, two crane pads are located on the ground for each bridge and all crane pads are located one metre above the existing ground.
- All sediment basins are in operation and each basin is 2.5 metres high above the existing ground.
- Construction of the rail formation is complete.
- Construction of all culverts are finished, and culverts do not require pre-loading.
- Superstructures of all bridges are yet to be complete.

The flood models were updated to represent the construction works based on the above assumptions. All models were run for the 20%, 5% and 1% AEP events.

Flooding extents for the 1% AEP event during construction are shown in Figure 6.1. Mapping of flood impacts during the construction stage are provided in Appendix E and the following sections provide a summary of afflux in the 1% AEP event. For the purpose of this assessment an afflux value equal to or greater than 10 millimetres was adopted as a trigger value for reporting.

While the findings of this initial assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be carried out during detailed design, as layouts and construction staging strategies are further developed.

It should also be noted that all construction infrastructure is temporary and the assessment should be read in context of the likelihood of a flood of a given AEP occurring during the construction period. In addition, given the short duration of construction relative to the operational life of the proposal, these impacts should be considered in context of the predicted operational impacts detailed in section 7. The chance of occurrence of a given AEP flood event during the construction period (four years) is significantly lower than the operational phase life of the proposal. The chance of occurrence of a 1% AEP flood event for the construction phase and the operational phase are approximately 4.9 per cent and 63.4 per cent respectively. However, the chance of occurrence of a 20% AEP flood event for the construction phase and the operational phase are approximately 67.2 per cent and 100 per cent respectively.

NFM: Chainages 547.00 – 569.40 (Macquarie River and Wallaby Creek)

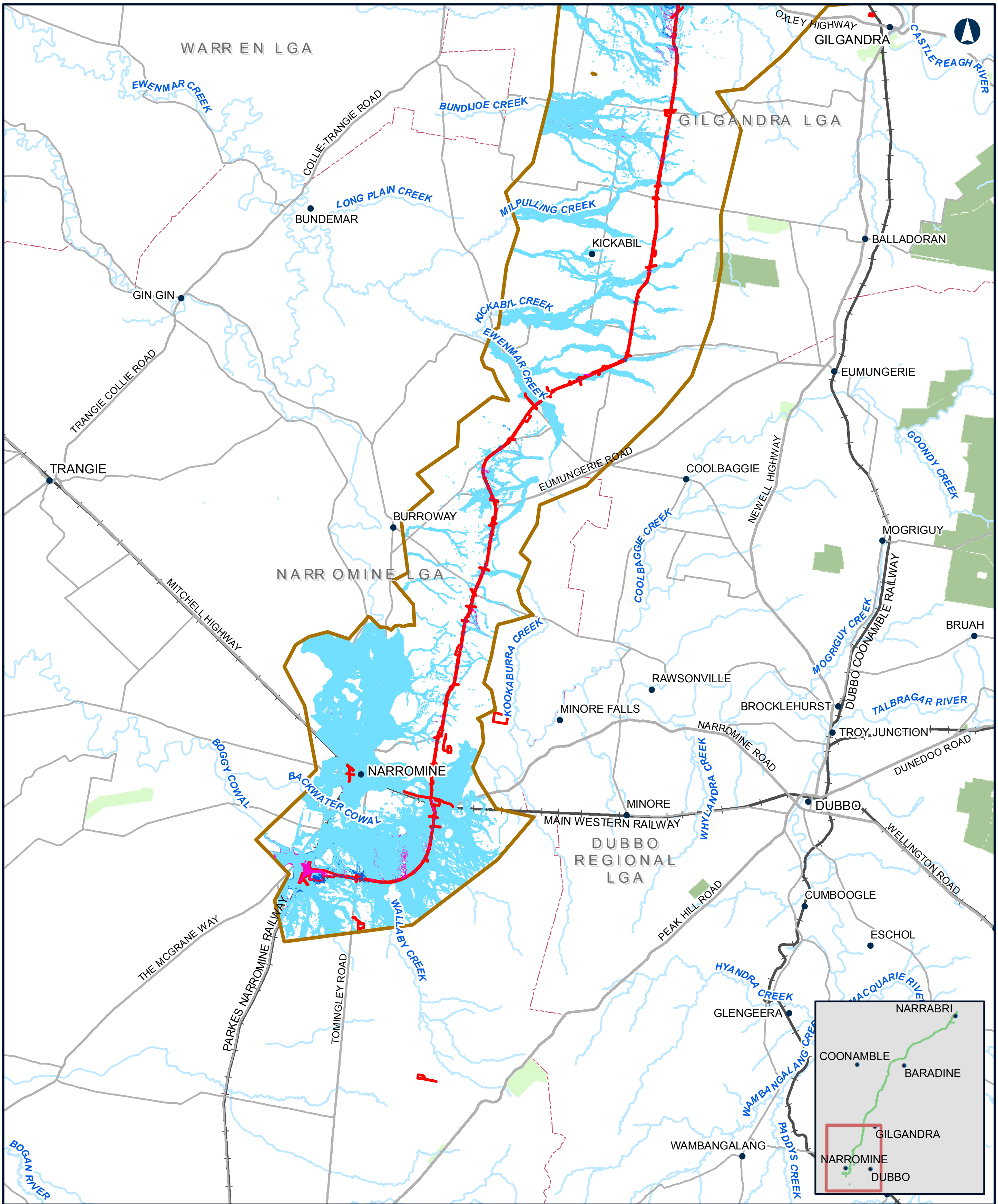
Changes to flood levels are variable within the model domain in the 1% AEP event. Both increases and decreases in flood levels are shown either side of the alignment. Several areas of flood level change between 10 millimetres and greater than 1.0 metres are shown, including:

- A large area of land between chainages 547 and 551.2 (east of McGrane Way), south of the alignment with afflux values of between 10 millimetres and greater than 1.0 metres affecting a number of buildings, including several residential buildings with afflux of between 0.2 metres and 1.0 metres.
- Areas immediately adjacent to the alignment (upstream and downstream) with afflux values of between approximately 10 millimetres and 1.0 metres at locations closest to the alignment.
- A localised area downstream of the alignment between chainages 556.5 and 558.1 within the floodplain of an unnamed tributary to Wallaby Creek with afflux values of between approximately 10 millimetres and 0.1 metres affecting several buildings.
- A large area adjacent to the Macquarie River generally upstream (east) of the alignment between chainages 561.0 and 565.3, with afflux values of between 10 millimetres and 0.05 metres are shown. Several buildings including residential properties are affected to the north of the Mitchell Highway.

N2N14: Chainages 566.39 – 594.88 (minor watercourses)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by significant changes to flood conditions.

Where present, increased flood levels of between 10 millimetres and 0.2 metres are typically constrained to areas immediately adjacent to the proposal corridor (between 50 metres and 150 metres) upstream, downstream, and either side of drainage structures; except for at several creeks where afflux of between 10 millimetres and 0.2 metres are present up to 1.0 kilometres downstream.



NARROMINE TO NARRABRI Change in 1% AEP flood extent – Construction Figure 6.1a

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 4/11/2020 Paper: A4
Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was wet now dry
- Was dry now wet

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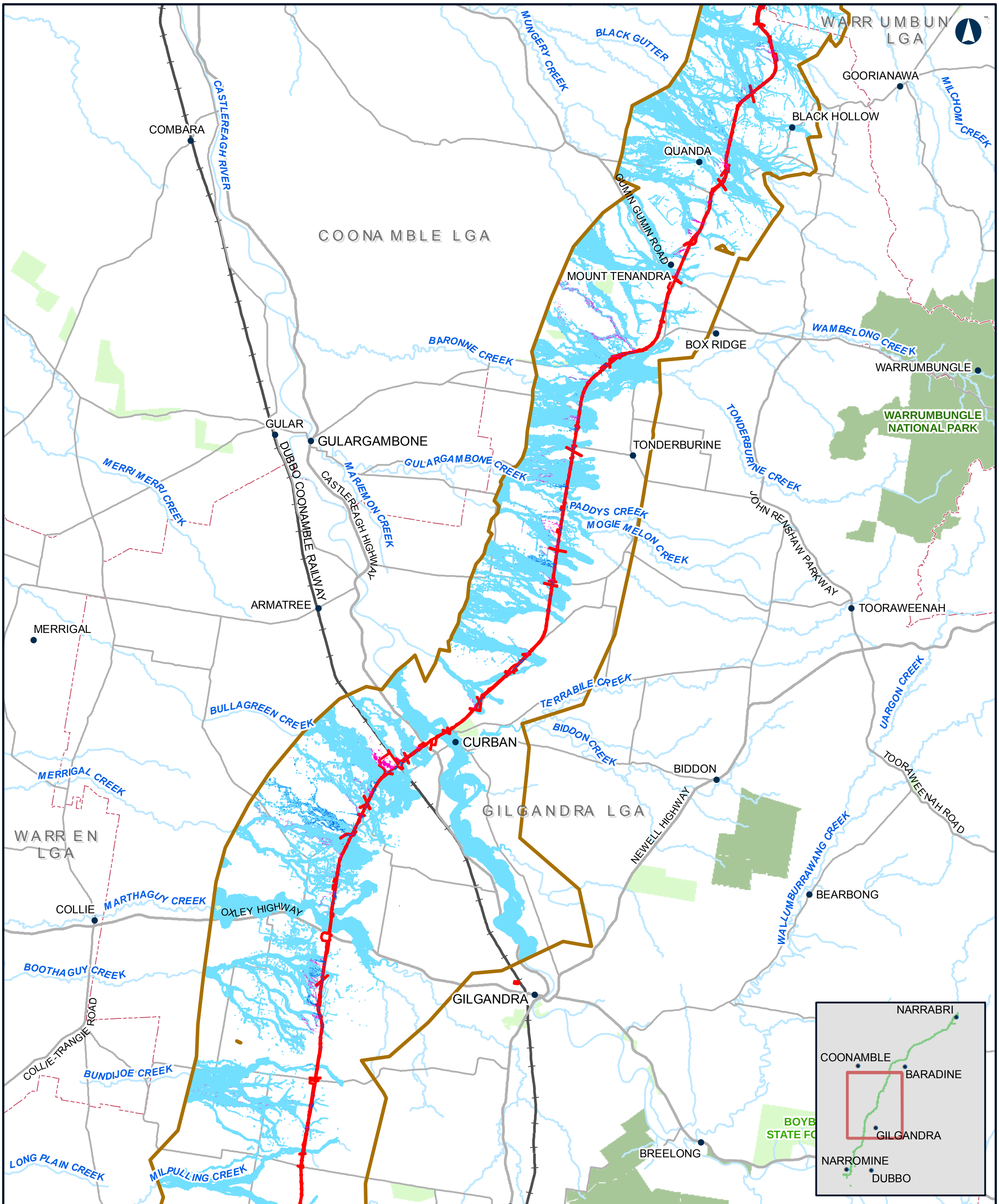

NARROMINE TO NARRABRI Change in 1% AEP flood extent – Construction Figure 6.1b

0 8 16 Km

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Date: 4/11/2020 Paper: A4
Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was wet now dry
- Was dry now wet

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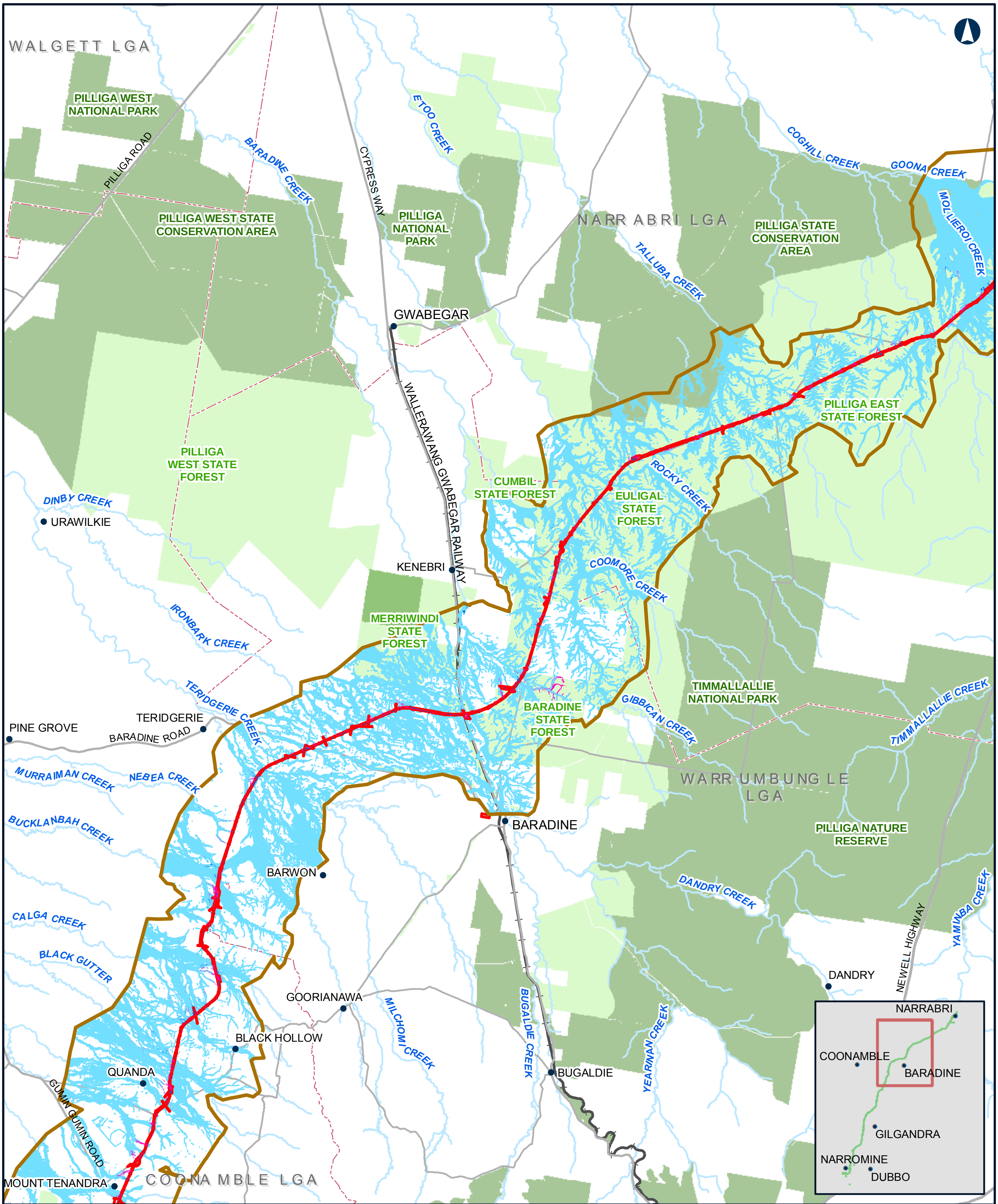

NARROMINE TO NARRABRI

Change in 1% AEP flood extent – Construction

Figure 6.1c

Coordinate System: GDA 1994 MGA Zone 55

Date: 4/11/2020
Paper: A4
Author: JacobsGHD
Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

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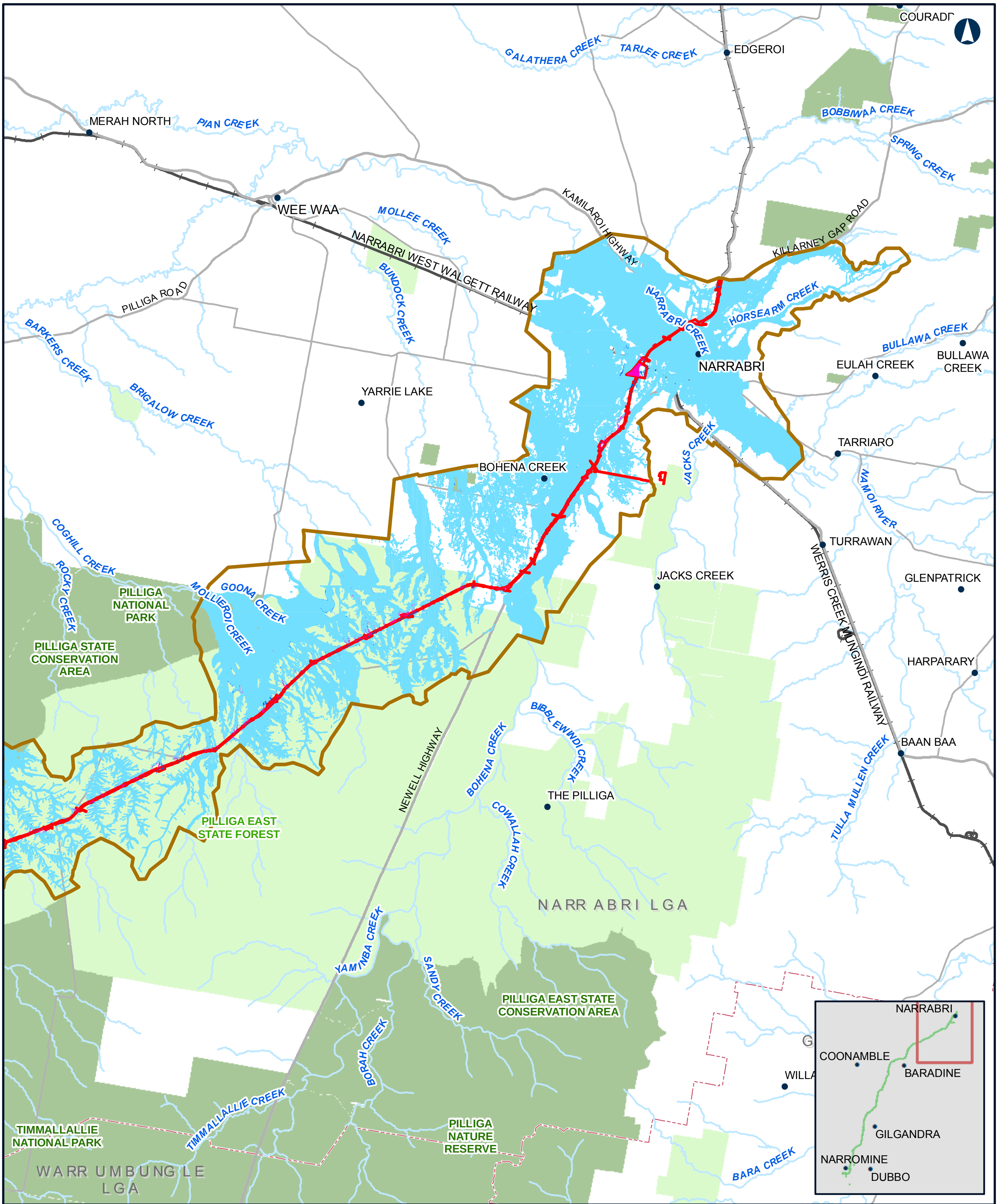

NARROMINE TO NARRABRI

Change in 1% AEP flood extent – Construction

Figure 6.1d

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 4/11/2020 Paper: A4
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Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was wet now dry
- Was dry now wet

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N2N13: Chainages 593.34 – 624.82 (Ewenmar Creek to Bundijoe Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 0.2 metres and 1.0 metres are commonly observed at and either side of creek crossings through the model domain, up to distances of approximately 100 metres to 150 metres upgradient of the proposal corridor. Afflux values of between 10 millimetres and 0.2 metres may be observed to a greater distance (up to 0.8 kilometres) upgradient of the proposal corridor, and up to distances of approximately 300 metres downstream of the proposal corridor.

N2N11-12 – Chainages 623.91– 657.63 (Boothaguy Creek to Castlereagh River)

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment. A number of buildings including residential properties are affected by increased flood levels between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 100 metres to 300 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain, except for the Castlereagh River where afflux of between 10 millimetres and 0.2 metres is shown up to a distance of approximately 2.7 kilometres, affecting a number of buildings including residential properties. Localised areas of afflux between 0.2 metres and 1 metre are observed at several locations upstream of the alignment, up to an approximate distance of 100 metres.

Afflux values of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances. An area between chainages 641.3 and 642.5 is affected by a downstream increase in flood levels of between 10 millimetres and 0.2 metres, affecting a number of residential buildings.

N2N10: Chainages 654.34 to 681.24 (Judes Creek to Gulargambone Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level greater than 10 millimetres) or flood extents are observed. Several buildings appear to be affected by significant increases in flood levels greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 100 metres to 300 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain, except for Gulargambone Creek where afflux between 10 millimetres and 0.2 metres is observed up to 1.2 kilometres upstream.

Localised areas of afflux between 0.2 metres and one metre are observed at several locations upstream of the alignment, to variable distances, but typically less than 100 metres, except for Gulargambone Creek where it is observed up to 300 metres upgradient.

Afflux values of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances. An area between chainages 668.1 and 668.8 is affected by a downstream increase in flood levels of between 10 millimetres and 0.2 metres, affecting one residential property.

N2N9: Chainages 677.64 to 697.45 (Baronne Creek to Tenandra Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, one building appears to be affected by significant increase in flood levels (greater than 10 millimetres) west of chainage 705.9.

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 50 metres to 150 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain, except for Baronne Creek where afflux of between 10 millimetres and 0.2 metres is observed up to a distance of approximately 300 metres.

Localised areas of afflux between 0.2 metres and 1 metre are observed at several locations upstream of the alignment, to variable distances, but typically less than 50 metres, except for Baronne Creek where afflux of between 0.2 metres and one metre is observed up to a distance of approximately 150 metres.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances, but typically less than 800 metres along drainage lines.

N2N8: Chainages 696.95 to 717.56 (Mungery Creek to Calga Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 50 metres to 150 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain, except for Calga Creek where afflux of between 10 millimetres and 0.2 metres is observed up to a distance of approximately 275 metres.

A localised area of afflux between 0.2 metres and one metre is observed between chainages 714.5 and 714.8 at the crossing of Calga Creek, affecting upstream areas to a distance of approximately 150 metres.

Afflux values of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances, including up to approximately three kilometres downstream of the alignment between chainages 705.7 and 705.9 (south of Green Hill) as overland flow.

N2N7: Chainages 717.56– 754.75 (Noonbar Creek to Coolangla Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 50 metres to 400 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain, except for Teridgerie Creek and Baradine Creek where afflux of between 10 millimetres and 0.2 metres is observed up to a distance of approximately 2.1 kilometres upstream.

Localised areas of afflux between 0.2 metres and one metre are observed at a few limited locations upstream of the alignment, to variable distances, but typically less than 50 metres.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances, but typically less than 800 metres along drainage lines or overland flow paths.

N2N6: Chainages 754.75– 775.67 (Cumbil Forest Creek to Tinegie Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 800 metres to 900 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain.

A localised area of afflux between 0.2 metres and one metre is observed either side of the alignment at the crossing at chainage 756.8 up to a distance of 150 metres from the proposal corridor.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances, but typically less than 150 metres along drainage lines or overland flow paths, except for chainage 777.6 where downstream increase in flood levels between 10 millimetres and 0.2 metres are observed up to approximately 450 metres.

N2N5: Chainages 775.67– 785.82 (Talluba Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 50 metres to 150 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain.

Localised areas of afflux between 0.2 metres and one metre are observed at a few limited locations (i.e. chainage 779.9 and 781.6) either side of the alignment, to variable distances, but typically less than 150 metres.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances, but typically less than 350 metres along drainage lines or overland flow paths.

N2N4: Chainages 785.82– 797.54 (Rocky Creek to Coghill Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, except for floodplain areas along Coghill Creek. No buildings appear to be affected by increased flood levels greater than greater than 10 millimetres.

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 350 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain.

A localised area of afflux between 0.2 metres and one metre is observed between chainages 796.6 and 796.7 at the crossing of Coghill Creek, affecting upstream areas to a distance of approximately 50 metres.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment to variable distances. Downstream increases in flood levels are most widespread and far reaching along Coghill Creek, where increased flood levels of between 10 millimetres and 0.2 metres are observed to a distance of approximately 1.75 kilometres.

N2N23: Chainages 797.54 – 818.86 (Mollieroi Creek to Bundock Creek)

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings appear to be affected by significant increases in flood levels (greater than 10 millimetres).

Afflux values of between 10 millimetres and 0.2 metres are typically shown up to distances of 100 metres to 200 metres upgradient of the proposal corridor, at and either side of drainage crossings through the model domain; except for Goona Creek and Bundock Creek where afflux of between 10 millimetres and 0.2 metres are shown up to approximately 600 metres and 900 metres respectively.

Localised areas of afflux between 0.2 metres and one metre are observed at a several locations upstream of the alignment, including Goona Creek and Coghill Creek, to variable distances, but generally less than 100 metres.

N2N1: Chainages 818.86 – 843.89 (Bohena Creek)

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, with a large area of increased flood levels greater than 10 millimetres change shown adjacent to the alignment and the Newell Highway along Bohena Creek on both upstream and downstream sides.

Afflux values of between 10 millimetres and 0.2 metres are observed between chainages 828.2 and 836.7 up to distances of between approximately 500 metres and approximately 1.8 kilometres on the upstream side of the alignment, along Bohena Creek, affecting several buildings including residential buildings east of the Newell Highway.

Increased flood levels of between 10 millimetres and 0.2 metres are observed downstream of the alignment between chainages 828.2 and 836.7 along Bohena Creek, up to a distance of between approximately 2.0 kilometres and 3.0 kilometres, affecting a number of buildings, including several residential buildings between Bohena Creek and Merlville.

Increased flood levels are also present downstream west of the alignment between chainages 841.3 and 843.89 adjacent to Yarrie Lake Road and Culgoora Road. Increases in flood levels include areas of between 10 millimetres to 0.2 metres, 0.2 metres to one metre and a smaller area of greater than one metre between chainages 842.2 and 842.6. A number of buildings including residential buildings are affected by increases in flood levels between 10 millimetres and one metre through this area.

Narrabri: Chainages 833.70 – 853.00 (Namoi River and Narrabri Creek)

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment however increases are generally prevalent. Widespread increase in flood levels of between 10 millimetres and 0.05 metres are shown between chainages 844.4 and 848.9 affecting Narrabri along areas adjacent to both the Namoi River and Narrabri Creek.

Afflux values of between 10 millimetres and 0.05 metres between chainages 844.4 and 848.9 are observed up to a distance of approximately 800 metres upstream of the alignment and up to 400 metres downstream of the alignment. A large number of buildings including residential buildings are affected by afflux values of between 10 millimetres and 0.2 metres both upstream and downstream of the alignment.

6.1.3 Impacts to buildings

The number of buildings with above floor flooding within each TUFLOW model domain which are impacted by more than 10 millimetres increase in depth during the construction phase in the 20%, 5% and 1% AEP events are shown in Table 6.1. In total, seven, 57 and 133 buildings that are subject to above floor flooding are impacted during the construction phase in the 20%, 5% and 1% AEP flood events respectively. The majority of the impacted buildings in the 20% AEP flood event are located at Narromine, while the majority of the impacted buildings in the 5% and 1% AEP flood events are located at or near Narrabri.

In the 20% AEP event, one impacted building is located within N2N10 TUFLOW model domain and six impacted buildings are located within NFM TUFLOW model domain.

Table 6.1 shows that 35 of the buildings impacted in the 5% AEP event are located within N2N1 TUFLOW model domain, 14 impacted buildings are located within Narrabri TUFLOW model domain and six impacted buildings are located within NFM TUFLOW model domain.

In the case of the 1% AEP event, 53, 47 and 26 impacted buildings are located within TUFLOW model domains for N2N1, Narrabri and NFM respectively.

Table 6.1 Number of buildings subject to above floor flooding and impacted more than 10 millimetres afflux - construction phase (number of impacted buildings with surveyed floor levels shown in brackets)

TUFLOW model	20% AEP	5% AEP	1% AEP
NFM	6	6	26
N2N14	0	0	0
N2N13	0	0	0
N2N11-12	0	1	6
N2N10	1	1	0
N2N9	0	0	0
N2N8	0	0	0
N2N7	0	0	1
N2N6	0	0	0
N2N1	0	35	53
Narrabri	0	14 (8)	47 (18)
Total	**7**	**57 (8)**	**133 (18)**

Flood hazards to impacted buildings remain unchanged in the 20% AEP event. However, flood hazards at 12 buildings and surrounds are increased from low to high hazard in the 5% AEP event. In the case of the 1% AEP event, flood hazard to eight buildings and surrounds are increased from low to high. All buildings and surrounds, where flood hazard is increased from low to high, are located within NFM, N2N1 and Narrabri TUFLOW model domains.

The duration of flood inundation at nine, 66 and 134 buildings are increased more than 10 per cent in the 20%, 5% and 1% AEP event respectively and the majority of the impacted buildings are located within Narrabri TUFLOW model domain.

6.1.4 Impacts to roads

Highways

No additional lengths of highways are overtopped in the 20%, 5% and 1% AEP events during the construction phase. However, flood hazards on 43% and 2% of existing overtopped sections of Oxley Highway and Newell Highway respectively are increased from low hazard to high hazard in the 20% AEP event. The duration of inundation is increased on overtopped sections of Oxley Highway in the 5% AEP event only, and Kamilaroi Highway in the 20% AEP event only.

Other named roads

A summary of flood impacts on named roads for the construction phase for the 20%, 5% and 1% AEP event is presented in Table 6.2. This shows minor increases of 1% in the total length of overtopping of named roads for the 20% and 1% AEP flood events. High flood hazard on five per cent of the road subject to flooding is increased in the 20% AEP event only. However, both the change in the average and the maximum duration of inundation remain less than 10 per cent for most flood events.

Table 6.2 Summary of flood impacts on named roads – construction phase

Event	Change in total length (%)	Change in total length subject to high hazard (%)	Change in average duration of inundation (%)	Change in maximum duration of inundation (%)
20% AEP	1	5	>10%	<10%
5% AEP	-2	0	<10%	>10%
1% AEP	1	0	<10%	<10%

6.1.5 Impacts to existing rail lines

Impacts of the proposal on overtopping of the existing railways during the construction phase have been assessed for the 20%, 5% and 1% AEP events. Table 6.3 shows that overtopping lengths of the Main Western Line, Parkes to Narromine Line, Binnaway to Gwabegar Line (non-operational), and Narrabri to Walgett Line (N2N1) generally remain unchanged or reduced during the construction phase for all flood events assessed.

Overtopping lengths of the Dubbo to Coonamble Line are increased 10 per cent and 22 per cent in the 20% and 5% AEP flood events respectively. While overtopping lengths of the Mungindi Line are increased 75 per cent and 7 per cent in the 20% and 5% AEP flood events respectively. However, the overtopping length of both lines is not impacted in the 1% AEP event.

Table 6.3 shows that the overtopping length of the Narrabri to Walgett Line (Narrabri) is increased 21% in the 20% AEP event. However, overtopping lengths for the railway remain unchanged in the two larger flood events. The overtopping length of the Dubbo to Coonamble Line is increased in all events modelled.

Table 6.3 Change (per cent) in overtopping length of rail lines - construction phase

Rail line	20% AEP	5% AEP	1% AEP
Main Western Line	0%	-63%	1%
Parkes Narromine Line	-29%	-55%	-25%
Dubbo to Coonamble Line	10%	22%	29%
Binnaway to Gwabegar Line (non-operational)	1%	-7%	-2%
Narrabri to Walgett Line (N2N1)	0%	-2%	0%
Narrabri to Walgett Line (Narrabri)	21%	0%	-3%
Mungindi Line	75%	7%	0%

The change in duration of inundation is less than 10 per cent for all flood events for all existing rail lines except for the Parkes to Narromine Line and Dubbo to Coonamble Line. In the case of the Dubbo to Coonamble Line, the change in duration of inundation is more than 10 per cent for all flood events. However, the change in duration of inundation is more than 10 per cent for the Parkes to Narromine Line in the 1% AEP event only.

6.1.6 Impacts to major land uses

Impacts of the proposal during the construction phase on flooding of major land uses including forested lands, grazing areas, cropping lands and horticultural areas are generally minor on depth and duration of flood inundation.

6.2 Geomorphology

6.2.1 Instream structures

The construction of instream structures, such as culverts and bridge footings, requires direct disturbance to the bed and banks of the waterway and its floodplain. This can result in the disturbance to bed and bank sediments resulting in generation of sediment and instream turbidity.

6.2.2 General construction

General construction activities associated with the proposal have the potential to cause geomorphological impacts on the waterways as a result of:

- General construction activities in the riparian zone during construction phase, including:
  - Disturbance of soil, loss of vegetation, increased erosion, runoff from laydown areas and construction access tracks, changes to stormwater quality or quantity entering the waterway from surrounding areas of construction impacts.
  - Clearing of riparian vegetation which will reduce the hydraulic roughness and resistance of these surfaces to scour.
  - Construction of access tracks with orientation parallel to the direction of in-channel or out of channel floodplain flows, these will tend to function as preferred flow paths, potentially triggering further incision and the migration of flow paths away from their existing alignment.

- Changes to water quality, including:
  - Polluted runoff, spills from construction and hardstand areas, or disturbance of contaminated soil.
  - Increased sediment input into the waterway leading to increased turbidity in the water column.
  - Interstitial habitat in bed substrates can be affected by infilling with fine sediment.

6.3 Summary of potential construction impacts and risks

The following sections provide a summary of potential construction impacts and risks associated with the proposal. Detailed mitigation measures to address these are provided in Section 9.

6.3.1 Flooding and hydrology

Without the implementation of appropriate management measures, the inundation of the construction footprint by floodwater has the potential to:

- Cause damage to the works and delays in construction programming. ·
- Pose a safety risk to construction workers.
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters.
- Obstruct the passage of floodwater and overland flow through the provision of temporary measures such as construction compounds and stockpiles, which in turn could exacerbate existing flooding conditions.

6.3.2 Geomorphology

The construction of the proposal has the potential to impact on the geomorphological condition and stability of the waterways. The key activities which could result in channel and floodplain instabilities are:

- Instream structures – direct disturbance to bed and banks of the waterway and its floodplain, hydraulic changes associated with flow through instream structures increase risk of erosion and sedimentation.
- Vegetation removal – vegetation removal will reduce hydraulic roughness and resistance of surfaces to scour, thereby increasing the risk of erosion and sedimentation.
- Construction of access roads – where orientated parallel to direction of in-channel or out of channel floodplain flows, these will tend to function as preferred flow paths, potentially triggering further incision and migration of flow paths away from their existing alignment.
- Construction of waterway crossings – the construction of waterway crossings comprises of culverts and bridges, both of which can require instream works. Piling is required at the larger bridge structures crossing the Macquarie River and Naomi River/Narrabri Creek which can result in moderate impact to substrates due to disturbance. Additionally, installation of culverts would require some bed levelling and instream disturbance of substrates.
- Construction of railway line, access and haulage roads – clearing of vegetation and soil compaction during construction of these features and from movement of heavy machinery changes the roughness and resistance of surfaces, potentially triggering erosion and migration of flow paths.

7. Operational impact assessment

7.1 Flooding

7.1.1 Potential flood impacts

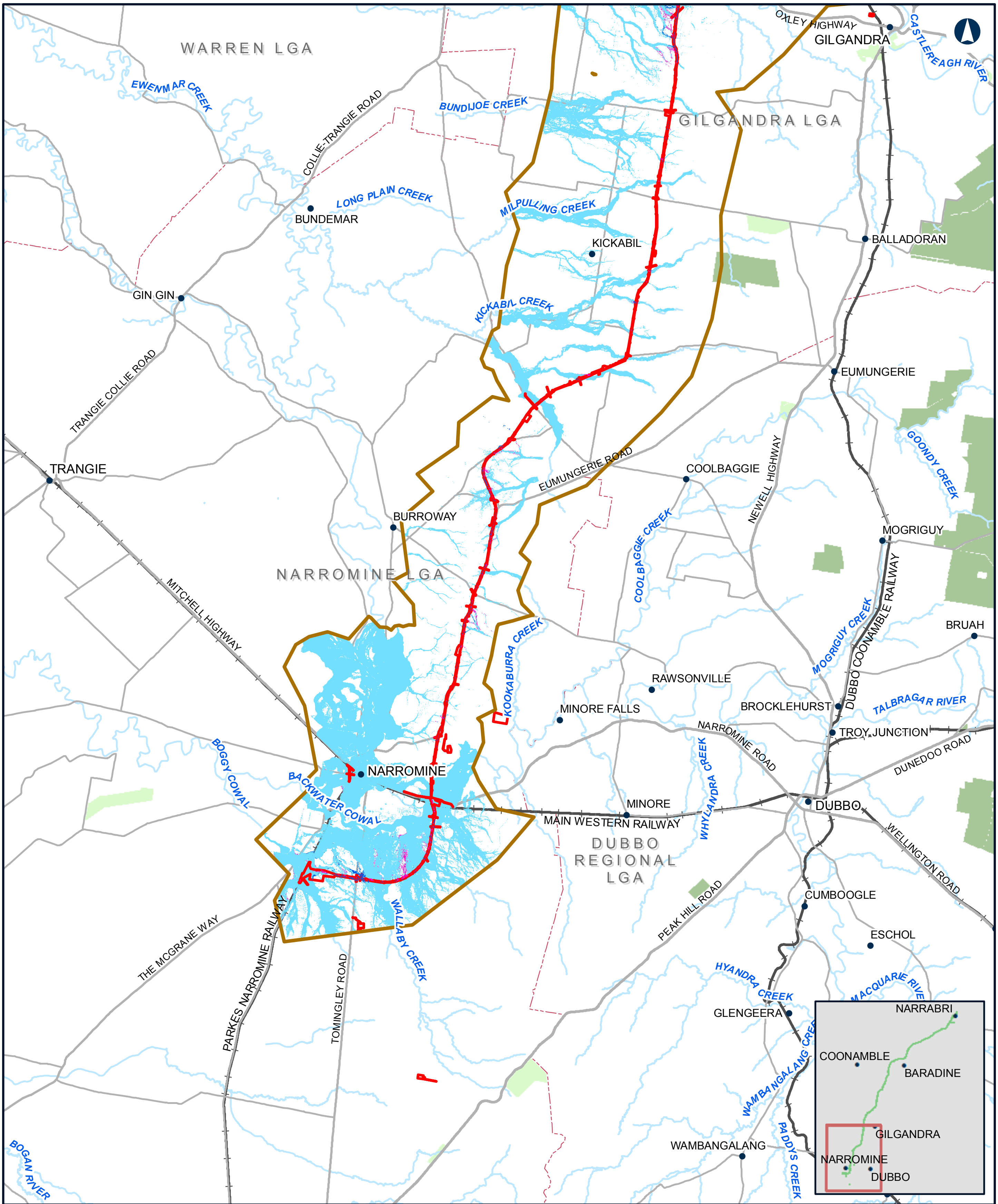
Operation of the proposal has the potential to worsen existing flooding conditions as the new railway embankment would cause flow constriction through the new culverts and bridges and a minor loss of flood storage. The flow constriction caused by the railway embankment and culverts and bridges would have a greater effect on flood behaviour compared to the minor loss of floodplain storage. The constriction of flood flows would typically cause an increase in flood level upstream of the railway. The operational impact on flood behaviour would be less than the construction phase impact due to the removal of temporary works and facilities required only to construct the proposal.

7.1.2 Modelled flood impacts

Predicted flooding extents for the 1% AEP event during operation are shown in Figure 7.1. Mapping of flood impacts during the operational stage are provided in Appendix G and the following sections provide a summary of afflux, change in hazard, and change in duration in the 1% AEP event. More detailed flood mapping for the 1% AEP event during operation is provided in Appendix H for Narromine and Narrabri.

For the purpose of this assessment, the following trigger values were adopted for reporting:

- An afflux value equal to or greater than 10 millimetres
- A change in flood hazard from low (H1 to H2) to high (H3 to H6)
- A change in duration greater than 10 per cent



NARROMINE TO NARRABRI Change in 1% AEP flood extent - Operational Figure 7.1a

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 5/11/2020 Paper: A4
Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was dry now wet
- Was wet now dry

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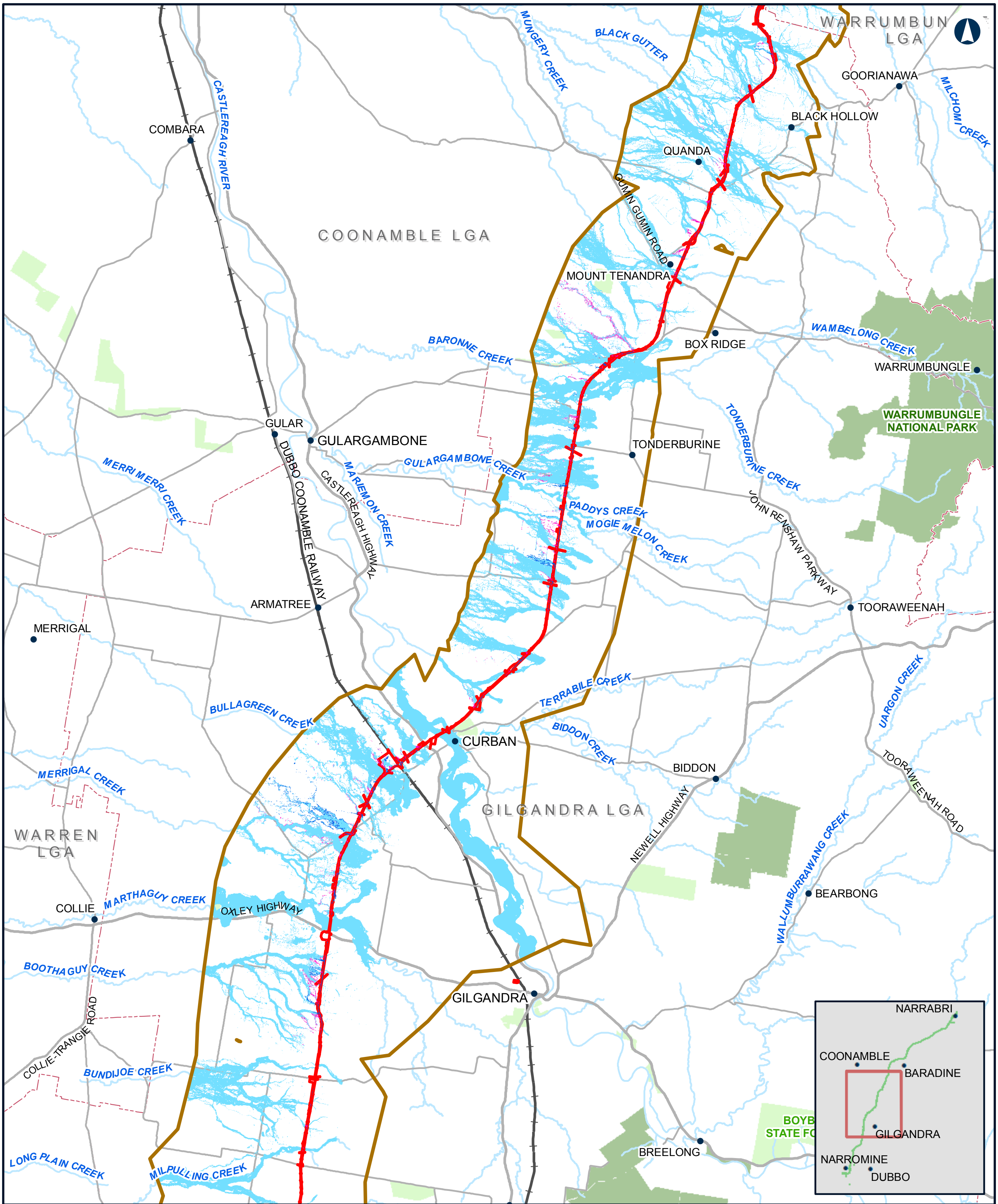

NARROMINE TO NARRABRI

Change in 1% AEP flood extent - Operational

Figure 7.1b

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 5/11/2020 Paper: A4
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Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was dry now wet
- Was wet now dry

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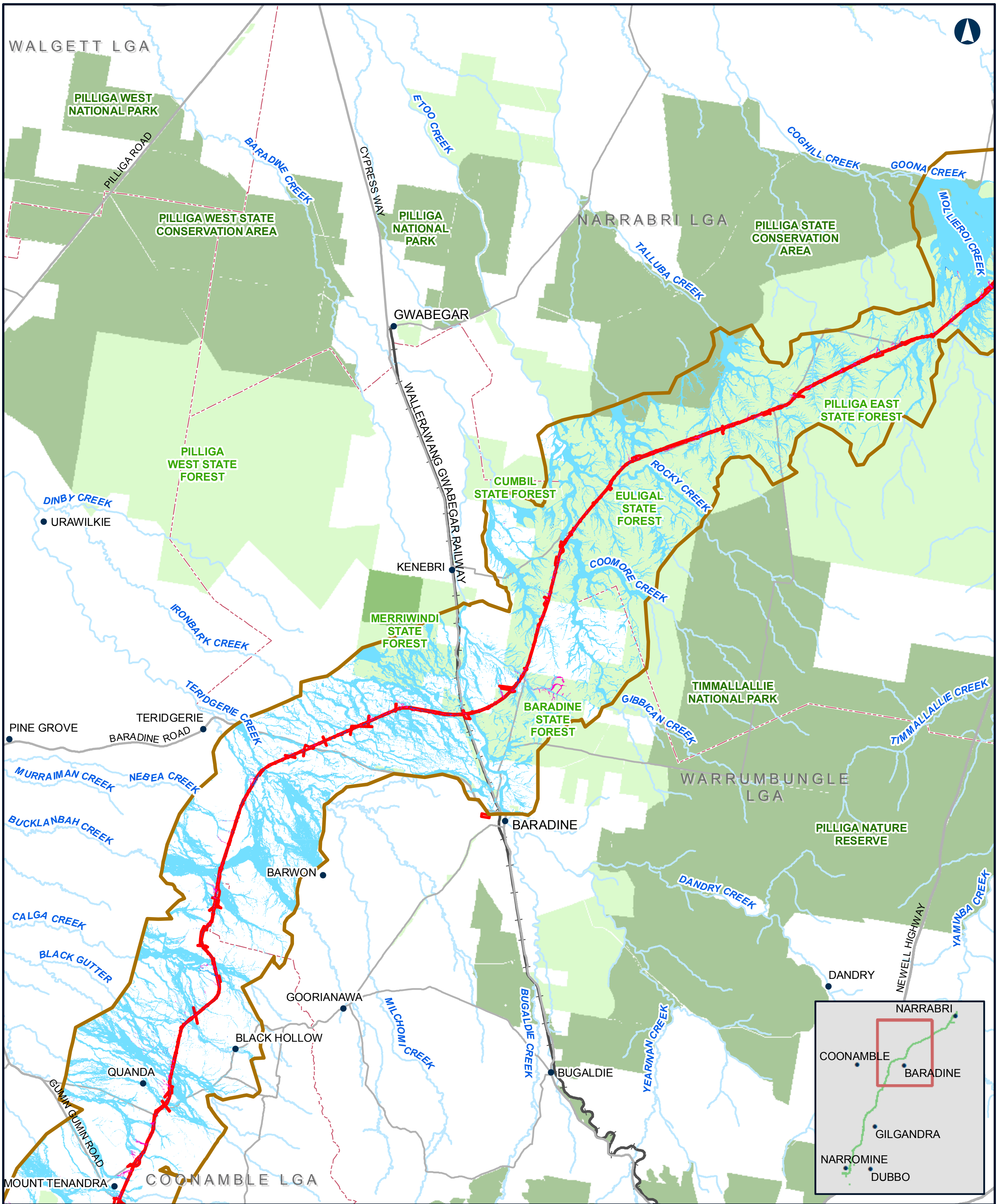

NARROMINE TO NARRABRI Change in 1% AEP flood extent - Operational Figure 7.1c

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 5/11/2020 Paper: A4
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Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was dry now wet
- Was wet now dry

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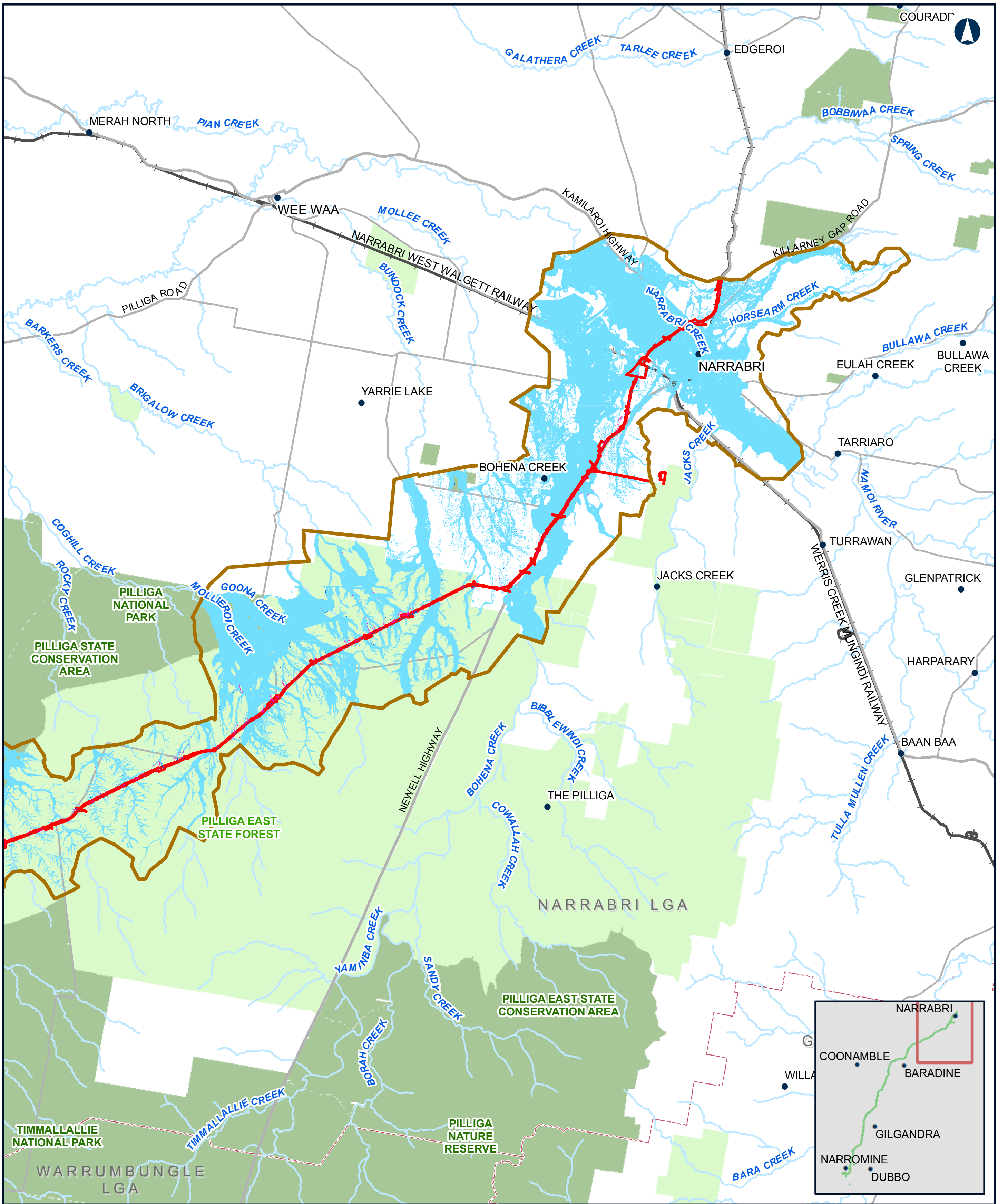

NARROMINE TO NARRABRI Change in 1% AEP flood extent - Operational Figure 7.1d

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 5/11/2020 Paper: A4
Author: JacobsGHD Scale: 1:400,000
Data Sources: Basemap layers: NSWSS;

LEGEND

- The proposal
- Study area
- Flood extent
- Was dry now wet
- Was wet now dry

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NFM: Chainages 547.00 – 569.40 (Macquarie River and Wallaby Creek)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment. Several areas of flood level change between 10 millimetres and 0.2 metres are shown, including:

- A localised area between chainages 547.1 and 550.5 (east of McGrane Way) with afflux values of between 10 millimetres and 0.05 metres affecting one residential building.
- Areas immediately adjacent to the alignment (upstream and downstream) with afflux values of between approximately 0.1 metres and 0.5 metres that does not impact any existing infrastructure or properties.
- A localised area downstream of the alignment between chainages 556.5 and 558.1 within the floodplain of an unnamed tributary to Wallaby Creek with afflux values typically between 10 millimetres and 0.1 metres that affects rural land.
- An area adjacent to the Macquarie River generally upstream (east) of the alignment between chainages 561.0 and 562.3, with afflux values of between 10 millimetres and 0.05 metres are shown. This causes a minor increase in peak flood depths on a one kilometre length of Mitchell Highway, one kilometre length of Webbs Siding Road.

There appear to be no widespread increases in extents of flooding except for highly localised areas generally located adjacent to the alignment.

Change in hazard

There are no significant widespread changes in flood hazard throughout the study area except for highly localised areas that are typically constrained to areas immediately adjacent to the operational footprint.

Areas of increased flood hazard are typically reflective of localised changes from dry conditions to low flood hazard, representing the marginal increases in flood extents, along with some areas of increase from low to high hazard.

Change in duration

Changes in flood duration vary within the NFM model domain, affecting floodplains for both Wallaby Creek and Macquarie River. Where there are increases in peak flood levels, increases in flood durations are typically between 10 per cent and 20 per cent.

N2N14: Chainages 566.39 – 594.88 (minor watercourses)

Afflux

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by significant changes to flood levels.

Where present, increased flood levels are typically constrained to areas immediately adjacent to the operational footprint and upstream / downstream of drainage structures. Afflux values typically range between 0.01 and 0.2 metres at locations adjacent to the rail corridor.

Change in hazard

Adverse changes in flood hazard are typically constrained to areas immediately adjacent to the operational footprint through the model domain.

Adverse changes in flood hazard are reflective of localised increases from dry conditions to low hazard category.

Overall there are no significant adverse changes in flood hazard upstream or downstream of the operation footprint within the model domain.

Change in duration

There are no significant increases in flood duration within the model domain.

N2N13: Chainages 593.34 – 624.82 (Ewenmar Creek to Bundijoe Creek)

Afflux

There are no widespread significant increases in flood levels (ie greater than 10 millimetres) upstream or downstream of the operational footprint within the model domain, except for:

- Areas immediately adjacent to the alignment upstream and downstream of drainage structures with afflux values typically less than 0.2 metres.
- An area upstream of the alignment along Ewenmar Creek up to a distance of 800 metres with afflux values of less than 0.2 metres.

No buildings are affected by significant changes to flood levels.

Change in hazard

There are no significant widespread changes in flood hazard throughout the study area except for highly localised areas that are typically constrained to areas immediately adjacent to the operational footprint.

Areas of increased flood hazard are typically reflective of localised changes from dry conditions to low flow hazard, representing the marginal increases in flood extents, along with limited areas of increase from low to high hazard.

Change in duration

There are no significant increases in flood duration within the model domain, except for limited highly localised areas along the fringes of channel floodplains immediately adjacent to the alignment drainage structures.

N2N11-12 – Chainages 623.91– 657.63 (Boothaguy Creek to Castlereagh River)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment. Approximately 8 buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of less than 400 metres from the operational footprint.

Increases in flood levels are also shown downstream of drainage structures, with increases immediately downstream of the proposal typically between 0.05 metres and 0.2 metres. Afflux of between 0.02 metres and 0.03 metres occurs west of the proposal between chainages 641.3 and 641.8, affecting several residential buildings south of Forans Road.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category. However, some limited areas of change from low to high or dry to hazard are also present (eg around Curban Park at chainage 641.6).

Change in duration

Changes in flood durations are generally constrained to immediate floodplains and floodplain fringes for both Marthaguy Creek and the Castlereagh River in the 1% AEP event.

Increases in flood duration are typically limited to relative increases of up to 20 per cent along the Castlereagh River floodplain adjacent and either side of the operational footprint. Highly localised fringes of between 50-100 per cent are also observed.

N2N10: Chainages 654.34 to 681.24 (Judes Creek to Gulargambone Creek)

Afflux

Changes to flood levels are variable but limited within the model domain. Both increases and decreases in flood levels are shown, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 150 metres and 300 metres from the operational footprint, except for Gulargambone Creek where increases of between 10 millimetres and 0.2 metres are shown up to a distance of 700 metres.

Increased flood levels are observed downstream of the alignment along drainage lines and overland flow paths downstream of drainage structures. Increases of between 10 millimetres and 0.1 metres are shown up to a distance of approximately 2.2 kilometres downstream of the alignment, however are limited in lateral extent (ie typically less than 300 metres width).

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category. However, some localised areas of change from low to high hazard are also present upstream of the operational footprint (e.g around chainage 664.9).

Change in duration

There are no widespread changes in flood duration within the model domain. Increases in flood duration are typically constrained to narrow regions along floodplain fringes.

N2N9: Chainages 677.64 to 697.45 (Baronne Creek to Tenandra Creek)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed. One building is affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 150 metres and 300 metres from the operational footprint.

A localised increase of between 0.2 metres and 0.5 metres is observed between chainages 682.1 and 682.7 at the Baronne Creek crossing, and extends about 120 metres east of the operational boundary. The localised afflux affects existing rural lands only and does not impact any existing buildings or infrastructure.

Increased flood levels are observed downstream of the alignment along drainage lines and overland flow paths downstream of drainage structures. Increases are typically between 10 millimetres and 0.03 metres and are shown up to a distance of approximately 4.3 kilometres downstream of the alignment, however are limited in lateral extent (ie typically less than 200 metres width).

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint and some newly flooded areas at greater distances.

Adverse changes are reflective of localised increases from both low to high hazard, and dry conditions to low hazard category. Isolated areas of high hazard from increased flood extents are present adjacent to Tenandra Creek immediately next to the operational footprint.

Change in duration

Changes in flood duration affect floodplain areas along both Baronne Creek and Tenandra Creek.

Areas of increased flood duration are generally sinuous and inter-connected in a braided fashion along Baronne Creek, up to a distance of 1.2 kilometres. Increased flood duration along Tenandra Creek is generally constrained to within 200 metres of the channel at locations downstream of the proposed alignment. Percentage increases in flood duration are typically around five per cent, with narrow fringes of between 20 per cent and 50 per cent.

N2N8: Chainages 696.95 to 717.56 (Mungery Creek to Calga Creek)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 50 metres and 100 metres from the operational footprint.

Increased flood levels are observed downstream of the alignment along drainage lines and overland flow paths downstream of drainage structures. Increases of between 10 millimetres and 0.05 metres are shown up to a distance of approximately 3.2 kilometres downstream of the alignment at some locations, however these areas are limited in lateral extent (ie typically less than 300 metres width).

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from both low to high hazard, and dry conditions to low hazard category. Isolated areas of high hazard from increased flood extents are present adjacent to the alignment along Goorianawa Road.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N7: Chainages 717.56– 754.75 (Noonbar Creek to Coolangla Creek)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 50 metres and 100 metres from the operational footprint, except for locations upstream of Teridgerie Creek and Baradine Creek where afflux of between 10 millimetres and 0.2 metres are shown up to distances of approximately 2.0 kilometres.

Increased flood levels are observed downstream of the alignment along drainage lines and overland flow paths downstream of drainage structures. Increases of between 10 millimetres and 0.05 metres are shown up to a distance of approximately 0.8 kilometres downstream of the alignment at some locations, however these areas are limited in lateral extent (ie typically less than 150 metres width).

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from both low to high hazard, and dry conditions to low hazard category.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N6: Chainages 754.75– 775.67 (Cumbil Forest Creek to Tinegie Creek)

Afflux

Changes to flood levels are variable but generally minimal within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 50 metres and 100 metres from the operational footprint, except for locations upstream of Etoo Creek and Rocky Creek where afflux of between 10 millimetres and 0.2 metres are shown up to distances of approximately 0.8 kilometres.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard or previously dry conditions as a result of increased flood extent.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N5: Chainages 775.67– 785.82 (Talluba Creek)

Afflux

Changes to flood levels are variable but generally minimal within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values between 10 millimetres and 0.2 metres are typically observed in areas adjacent to Pilliga Forest Way and at drainage structures located along the alignment within the model domain, up to a distance of 100 metres upgradient of the operational footprint. At several waterway crossings afflux values of between 10 millimetres and 0.2 metres extend up to a distance of 400 metres upstream.

Limited highly localised areas of high afflux (0.2 metres to 1.0 metres) are present immediately adjacent to the operational footprint within the model domain.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard or previously dry conditions as a result of increased flood extent.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N4: Chainages 785.82– 797.54 (Rocky Creek to Coghill Creek)

Afflux

Changes to flood levels are variable but generally minimal within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are commonly observed upstream of the alignment at drainage structures across creek lines, typically up to 150 metres upgradient of the operational footprint, except for an unnamed creek at chainage 790.3 where values of between 10 millimetres and 0.2 metres are observed up to 800 metres.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard or previously dry conditions as a result of increased flood extent and flooding, particularly in areas immediately adjacent to and upstream of the operational footprint.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N23: Chainages 797.54– 818.86 (Rocky Creek to Coghill Creek)

Afflux

Changes to flood levels are variable but generally minimal within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, however no widespread significant increases in level (greater than 10 millimetres) or flood extents are observed, and no buildings are affected by flood level changes between 10 millimetres and 0.2 metres.

Afflux values of between 10 millimetres and 0.2 metres are frequently observed upstream of the alignment both at and between drainage structures; and are typically constrained to distances of between 50 metres and 150 metres from the operational footprint, except for locations upstream of Bundock Creek where afflux of between 10 millimetres and 0.2 metres are shown up to approximately 0.85 kilometres.

Increased flood levels are observed downstream of the alignment along drainage lines and overland flow paths downstream of drainage structures. Increases of between 10 millimetres and 0.05 metres are shown up to a distance of approximately 0.9 kilometres downstream of the alignment at some locations (e.g at chainage 802.2 and 808.3), however these areas are limited in lateral extent (i.e. typically less than 200 metres wide).

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard particularly in areas immediately adjacent to and upstream of the operational footprint.

Change in duration

There are no widespread changes in flood duration within the model domain.

N2N1: Chainages 818.86 – 843.89 (Bohena Creek)

Afflux

Changes to flood levels are variable within the model domain. Both increases and decreases in flood levels are shown either side of the alignment, with a large area of increased flood levels greater than 10 millimetres change shown adjacent to the alignment and the Newell Highway along Bohena Creek on both upstream and downstream sides, affecting a number of buildings.

Afflux values of between 10 millimetres and 0.2 metres are observed between chainages 828.2 and 836.7 up to a distance of approximately 1 kilometre on the upstream side of the alignment along Bohena Creek and the associated floodplain, affecting one residential building between Westport Road and the Newell Highway.

Increased flood levels of between 10 millimetres and 0.1 metres are observed downstream of the alignment between chainages 828.2 and 836.7 along Bohena Creek, up to a distance of between two kilometres and three kilometres, affecting a number of buildings, including several residential buildings between Bohena Creek and Merlville.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard particularly in areas immediately adjacent to and upstream of the operational footprint.

Change in duration

There are no widespread / significant changes in flood duration within the model domain.

Narrabri: Chainages 833.70 – 853.00 (Namoi River)

Afflux

Changes to flood levels are variable but within the model domain. Both increases and decreases in flood levels are shown either side of the alignment. Increases in levels greater than 10 millimetres or flood extents are generally limited in extent, except for areas upstream of the alignment between chainages 847.4 to 848.4.

Afflux values of between 10 millimetres and 0.2 metres between chainages 847.4 and 848.4 are observed up to a distance of approximately 600 metres upstream of the alignment and either side of Narrabri Creek. A number of buildings including residential properties are affected.

Change in hazard

There are no widespread changes in flood hazard throughout the model domain area except for localised areas that are typically constrained to locations immediately adjacent to the operational footprint along diversion drains and some newly flooded areas at greater distances.

Adverse changes are typically reflective of localised increases from dry conditions to low hazard category, with limited areas of change to high hazard from previously low hazard particularly in areas immediately adjacent to and upstream of the operational footprint.

Change in duration

There are no widespread / significant changes in flood duration within the model domain, except for some minor increases around Wee Waa Road.

7.1.3 Impacts to buildings

For the purposes of this assessment:

- Buildings include residences, educational facilities, health facilities, community facilities, commercial / industrial premises and other structures (such as garages).
- Sensitive buildings include all of the above buildings but do not include other structures.

Flood inundation

Summary of building impacts for a range of flood events

The number of buildings impacted by more than a 10 millimetre increase in flood levels for the selected flood events are shown in Table 7.1. There is one building impacted more than 10 millimetres in the 20% AEP event, which is located in Narromine. There are 47 buildings which are impacted more than 10 millimetres in the 5% AEP event and 29 of these buildings are located in within the N2N1 model domain.

Table 7.1 shows that a total of 71 buildings are impacted more than 10 millimetres due to the proposal in the 1% AEP event. The majority of these are located near or within Narrabri and Narromine.

The number of buildings impacted more than 10 millimetres in the 1% AEP event with climate change, 0.5% AEP, 0.2% AEP and PMF event are 693, 95, 3,070 and 7,035 respectively.

The potentially affected buildings include residences, educational facilities, health facilities, community facilities, commercial / industrial premises and other structures (such as garages). Most of these have not been subject to detailed survey to confirm the floor level of the buildings relative to the ground level. In the case of buildings without surveyed floor levels, ground levels at the centroid of buildings have been extracted from the best available DEM to define floor levels of buildings on the assumption that floor levels are located 0.3 metres above ground level. This was checked against surveyed floor level data provided by Narrabri Shire Council and found to provide a good estimation of floor levels. There are also likely to be localised modifications in existing ground levels and flow paths that could affect floodwater behaviour.

A summary of all buildings subject to greater than 10 millimetre afflux under operational conditions for the 1% AEP event is provided in Figure 7.2.

Sensitive buildings Residential, educational, health, community and industrial/commercial						Other buildings Other structures such as garages and sheds				
Narromine	Other Areas	Bohena Creek	Narrabri	Total		Narromine	Other Areas	Bohena Creek	Narrabri	Total
ABOVE FLOOR										
3	2	3	14	22	Flood above floor with 10mm afflux	11	4	26	8	49
BELOW FLOOR										
2	0	0	4	6	Flood below floor with 10mm afflux	10	3	1	2	16
TOTAL										
5	2	3	18	28	Total with 10mm afflux	21	7	27	10	65

Figure 7.2 Summary of buildings subject to greater than 10 mm afflux – operation (1% AEP event)

Table 7.1 Number of buildings subject to above floor flooding and impacted more than 10 millimetres afflux – operational phase (number of impacted buildings with surveyed floor levels shown within brackets)

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	1	10	16	14	605	34	2,520	406
N2N14	0	0	0	0	0	0	0	3
N2N13	0	0	0	0	0	0	0	25
N2N11-12	0	0	6	6	7	7	11	170
N2N10	0	0	0	0	0	0	0	66
N2N9	0	0	0	0	0	0	0	25
N2N8	0	0	2	0	0	0	0	7
N2N7	0	0	0	0	0	0	0	52
N2N6	0	0	0	0	0	0	0	1
N2N1	0	29	29	29	28	20	294 (2)	400 (2)
Narrabri	0	8 (8)	20 (12)	22 (13)	53 (27)	34 (19)	245 (123)	5,880 (2,756)
Total	**1**	**47 (8)**	**73 (12)**	**71 (13)**	**693 (27)**	**95 (19)**	**3,070 (125)**	**7,035 (2,758)**

Summary of above floor flooding impacts for the one per cent AEP event

Further analysis of above floor flooding for the 1% AEP flood event by building type is provided in Table 7.2, which predicts that for:

- All buildings – 6,100 would be subject to above floor flooding, of which 1,329 (22 per cent) have surveyed floor levels. This is nine less than existing conditions.
- Sensitive buildings – 2,567 would be subject to above floor flooding, of which 1,316 (51 per cent) have surveyed floor levels. This is six less than existing conditions and is comprised of nine that would no longer be subject to above floor flooding and three that are not currently subject to above floor flooding would experience above floor flooding.

The majority of impacted buildings are located near or within Narromine and Narrabri.

Table 7.2 Number of buildings (by type) subject to above floor flooding in the 1% AEP flood event – operational phase

Building type	1% AEP	
	Number	Change
Residential	2,108	-5
Community facility	60	0
Educational facility	13	0
Health facility	2	0
Commercial/Industrial	384	-1
Total (sensitive buildings)	**2,567**	**-6**
Other	3,533	-3
Total (all buildings)	**6,100**	**-9**

Of the 2,567 sensitive buildings (Table 7.2) subject to above floor flooding, the majority are predicted to experience a negligible change (i.e. less than 10 millimetre increase or decrease) to existing conditions.

As shown in Table 7.1, 71 buildings are predicted to be subject to above floor flooding and experience an afflux of greater than 10 millimetres. Of these 71 buildings, 22 are sensitive buildings that are predicted to experience an increase of between 10 and 100 millimetres, of which all but one experience above floor flooding under existing conditions.

Additional assessment and modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined above) and determine if the proposal could be modified so that flooding characteristics are not worsened or minimised as far as practicable, up to and including the 1% AEP event.

Flood hazard

Impacts of the proposal on flood hazard to buildings and surrounds are presented in Table 7.3. Table 7.3 shows flood hazard to buildings and surrounds changed from low hazard (H1 and H2) to high hazard (H3, H4, H5 and H6) due to the proposal for the selected flood events. In the 5% AEP event flood hazard to three buildings are increased from low to high hazard. In the 1% AEP event, flood hazard to one building, located in Narromine, is increased from low hazard to high hazard. In the case of the 0.2% AEP event and the PMF event, flood hazards to 21 and 24 buildings respectively are increased from low hazard to high hazard with the proposal.

Table 7.3 Number of buildings subject to above floor flooding and changed flood hazard categories from low to high – operational phase

TUFLOW model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	0	0	3	1	19	4	15	0
N2N14	0	0	0	0	0	0	0	1
N2N13	0	0	0	0	0	0	0	2
N2N11-12	0	0	0	0	0	0	0	5
N2N10	0	0	0	0	0	0	0	8
N2N9	0	0	0	0	0	0	0	0
N2N8	0	0	0	0	0	0	0	0
N2N7	0	0	0	0	0	0	0	2
N2N6	0	0	0	0	0	0	0	0
N2N1	0	1	0	0	1	0	4	5
Narrabri	0	2	1	0	1	1	2	1
Total	**0**	**3**	**4**	**1**	**21**	**5**	**21**	**24**

Flood duration

The number of buildings impacted by more than 10 per cent increase in duration of flood inundation above 0.5 metres flood depth for the selected flood events are presented in Table 7.4. In total, duration of inundation at 142 buildings is increased more than 10 per cent above 0.5 metres flood depth in the 1% AEP event and 114 of the impacted buildings are located within Narrabri model domain.

Table 7.4 Number of buildings subject to above floor flooding and more than 10 per cent increase in duration of inundation above 0.5 metres flood depth – operational phase

TUFLOW Model	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
NFM	0	0	1	8	62	10	41	29
N2N14	0	0	1	1	0	0	0	2
N2N13	0	0	2	0	0	0	0	4
N2N11-12	0	3	6	11	0	0	2	70
N2N10	0	0	0	0	0	0	0	24
N2N9	0	0	1	1	0	0	0	5
N2N8	0	0	0	0	0	0	0	5
N2N7	0	0	0	0	0	0	0	48
N2N6	0	0	0	0	0	0	0	0
N2N1	1	1	3	7	3	1	8	60
Narrabri	2	56	4	114	49	50	52	9
Total	**3**	**60**	**18**	**142**	**114**	**61**	**108**	**256**

The potentially impacted buildings include residences, industrial structures, commercial businesses, public buildings and garages/sheds. Most of these have not been subject to detailed survey to confirm the floor level of the buildings relative to the ground level. There is also likely to be localised modifications in existing ground levels and flow paths that would affect floodwater behaviour.

Additional assessment would be undertaken during detailed design to confirm the floor levels of sensitive buildings. This would also include further consideration of the relative change in flooding levels compared to the existing situation and whether or not the proposal would result in a material change in the impact of flooding to the building.

Further modelling would also be undertaken during detailed design to determine if the proposal could be modified so that flooding characteristics with regards to property and buildings are not worsened or minimised as far as practicable. Where localised impacts are unavoidable further consultation with the affected property owners would be undertaken to identify measures that could be implemented to minimise the impacts as far as practicable.

7.1.4 Impacts to roads

Highways

Changes in length of highways overtopped due to the proposal are presented in Table 7.5. Impacts of the proposal on overtopping of the highways are generally negligible for all but the PMF event for Newell Highway (N2N1 TUFLOW model). An additional 11 per cent length of Newell Highway is overtopped in the PMF event.

Table 7.5 Changes (per cent) in length of highways overtopped due to the proposal – operational phase

Name of highways	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Mitchell Highway	0%	0%	0%	0%	0%	0%	0%	1%
Castlereagh Highway	-	0%	0%	0%	0%	0%	0%	0%
Oxley Highway	0%	0%	0%	0%	0%	0%	0%	1%
Newell Highway (N2N1)	-1%	-2%	0%	0%	0%	0%	1%	11%
Kamilaroi Highway	0%	0%	1%	0%	0%	0%	0%	0%
Newell Highway (Narrabri)	-	0%	0%	0%	0%	0%	0%	8%

Other named roads

A summary of impacts of the proposal on flooding of other named roads (excluding highways) within all TUFLOW model domains for the proposal is presented in Table 7.6. Changes in overtopping of additional roads due to the proposal are considered minor for all flood events.

Table 7.6 Summary of flood impacts on named roads – operational phase

Event	Change in total length (%)	Change in total length of roads subject to high hazard (%)	Change in average duration of inundation (%)	Change in maximum duration of inundation (%)
20% AEP	0	5	<10%	<10%
5% AEP	0	0	<10%	<10%
2% AEP	0	1	<10%	<10%
1% AEP	0	0	<10%	<10%
1% AEP + CC	1	1	<10%	<10%
0.5% AEP	1	1	<10%	<10%
0.2% AEP	-1	1	<10%	<10%
PMF	-1	1	<10%	<10%

7.1.5 Impacts to existing rail lines

Overtopping

Changes in flood behaviour due to the proposal on existing rail lines have been assessed. Table 7.7 shows changes in overtopping of rail lines for selected flood events due to the proposal. Overtopping of the Main Western Line (Dubbo to Narromine Line and Narromine to Cobar Line), Parkes to Narromine Line, Binnaway to Gwabegar Line (non-operational) and Narrabri to Walgett Line (N2N1 TUFLOW model) generally remains unchanged with the proposal.

Table 7.7 Changes (per cent) in overtopping length of rail lines – operational phase

Rail line	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Main Western Line	0%	0%	0%	1%	1%	0%	1%	0%
Parkes to Narromine Line	7%	6%	-4%	-7%	-3%	-4%	-5%	0%
Dubbo to Coonamble Line	-2%	6%	7%	17%	14%	13%	3%	1%
Binnaway to Gwabegar Line (non-operational)	1%	-7%	-4%	-2%	0%	0%	0%	-4%
Narrabri to Walgett Line (N2N1)	0%	5%	0%	0%	0%	0%	0%	1%
Narrabri to Walgett Line (Narrabri)	21%	0%	7%	-3%	0%	0%	0%	-3%
Mungindi Line	75%	6%	-20%	-1%	-1%	-1%	0%	0%

Overtopping of the Dubbo to Coonamble Line is increased by up to a maximum of 17 per cent in the 1% AEP event. Overtopping of the Narrabri to Walgett Line (Narrabri TUFLOW model) is increased by 21 per cent and seven per cent respectively in the 20% and 2% AEP events. Overtopping remains generally unchanged in other flood events. Overtopping of the Mungindi Line is increased by 75 per cent and six per cent in the 20% AEP and 5% AEP events respectively, however, is reduced or unchanged in the 2% AEP event and larger.

While these lines are already subject to extensive flooding during these events, further refinement would be undertaken during detailed design to minimise these increases where practicable in order to in order to limit impacts to train operations.

Duration of inundation

The impact of the proposal on the maximum duration of inundation of rail lines above 0.5 metres flood depth have been assessed for selected flood events and outcomes of the assessment are shown in Table 7.8. Table 7.8 shows that increases in the duration of inundation of the Binnaway to Gwabegar Line (non-operational), Narrabri to Walgett Line (N2N1 and Narrabri TUFLOW models), and Mungindi Line are less than 10 per cent with the proposal. However, the duration of inundation is more than 10 per cent higher for the Main Western Lin (0.5% AEP event only), Parkes to Narromine Line (5% and 2% AEP events), and Dubbo to Coonamble Line (all but 0.2% AEP and PMF event).

Table 7.8 Changes (per cent) in maximum duration of inundation of rail lines above 0.5 metres flood depth with the proposal

Rail line	20% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.5% AEP	0.2% AEP	PMF
Main Western Line	-	-	-	<10%	<10%	>10%	<10%	<10%
Parkes to Narromine Line	<10%	>10%	>10%	<10%	<10%	<10%	<10%	<10%
Dubbo to Coonamble Line	>10%	>10%	>10%	>10%	>10%	>10%	<10%	<10%
Binnaway to Gwabegar Line (non-operational)	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%
Narrabri to Walgett Line (N2N1)	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%
Narrabri to Walgett Line (Narrabri)	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%
Mungindi Line	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%

7.1.6 Impacts to major land uses

Forested Lands

Forested lands impacted at different flood depths due to the proposal are shown in Table 7.9, which shows marginal reduction in flooding of forested lands due to the proposal for all flood events.

Table 7.9 Forested lands subject to different flood depths – operational phase

Event	Change in flooded areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	-51	-13	-4	-3	-1	**-70**
5% AEP	-67	-10	-18	-3	-2	**-100**
2% AEP	-109	-8	-15	-3	-2	**-138**
1% AEP	-130	-11	-14	-3	-2	**-161**
1% AEP + CC	-164	-28	-14	-13	-3	**-223**
0.5% AEP	-165	-24	-10	-12	-2	**-213**
0.2% AEP	-203	0	-58	-15	-2	**-278**
PMF	-146	-140	10	-128	-2	**-406**

Grazing areas

Grazing areas impacted at different flood depths due to the proposal are shown in Table 7.10 which shows minor changes in flooding of grazing areas due to the proposal for all flood events.

Table 7.10 Grazing areas subject to different flood depths – operational phase

Event	Change in flooded areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	-51	12	-3	-4	-5	**-51**
5% AEP	-89	-53	-126	-127	-212	**-608**
2% AEP	-79	-4	-2	-20	-14	**-120**
1% AEP	-89	2	-4	-22	-17	**-131**
1% AEP + CC	-94	-48	-51	-13	-16	**-222**
0.5% AEP	-86	-24	-7	-23	-18	**-157**
0.2% AEP	-177	-11	-142	-60	17	**-373**
PMF	-243	-217	-932	187	-1,008	**-2,213**

Cropping lands

Cropping areas impacted at different flood depths due to the proposal are shown in Table 7.11, which shows minor reduction in flooding of cropping lands due to the proposal for all flood events.

Table 7.11 Cropping lands subject to different flood depths – operational phase

Event	Change in flooded areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	-111	23	-25	-4	-1	**-118**
5% AEP	-643	-440	-702	-403	-394	**-2,583**
2% AEP	-236	-9	-12	5	-1	**-253**
1% AEP	-254	-41	-26	5	0	**-317**
1% AEP + CC	-253	-85	-34	32	8	**-331**
0.5% AEP	-227	-68	-44	24	5	**-310**
0.2% AEP	-295	-139	-58	7	46	**-439**
PMF	-784	-1,739	-2,619	-1,087	-2,269	**-8,498**

Horticultural lands

Horticultural lands impacted at different flood depths due to the proposal are shown in Table 7.12, which shows minor changes in flooding of horticultural lands due to the proposal.

Table 7.12 Horticultural lands subject to different flood depths – operational phase

Event	Change in flooded areas (ha)					Total
	0 m - 0.25 m	0.25 m - 0.5 m	0.5 m - 1 m	1 m - 2 m	> 2 m	
20% AEP	0	0	0	0	0	**0**
5% AEP	-3	-3	-5	-4	-1	**-16**
2% AEP	0	0	0	0	0	**0**
1% AEP	0	0	0	0	0	**0**
1% AEP + CC	0	0	-1	1	0	**0**
0.5% AEP	0	0	0	0	0	**0**
0.2% AEP	0	0	-1	0	1	**0**
PMF	-1	-2	-6	-16	-27	**-53**

7.1.7 Velocity and scour impacts

Scour protection would be provided at culvert outlets with consideration to the quantitative design objectives provided in Section 3.2.2 and the predicted flow velocities in Section 7.2. A typical layout and section of scour protection that would be provided at culvert outlets is shown in Figure 7.3 and Figure 7.4.

For bridges in water courses, scour protection would be provided at piers and abutments as required. Typical sections of scour protection provided at a bridge abutment and pier is shown in Figure 7.5 and Figure 7.6.

The new rail corridor would have a minimum width of 40 metres, with some variation to accommodate particular infrastructure and to cater for local topography. The typical minimum width between the toe of formation and rail corridor boundary is six metres, however it is greater in some areas. Within the extent of a culvert, there is no earth formation. Culverts are approximately seven metres wide (perpendicular to the track) and as a result there is a minimum width of approximately 14 metres between the face of the culvert and the rail corridor boundary, however this is also greater in some areas (greater than 20 metres in places). Based on the reference design this is sufficient space to accommodate the proposed scour protection and this will be further refined during detailed design.

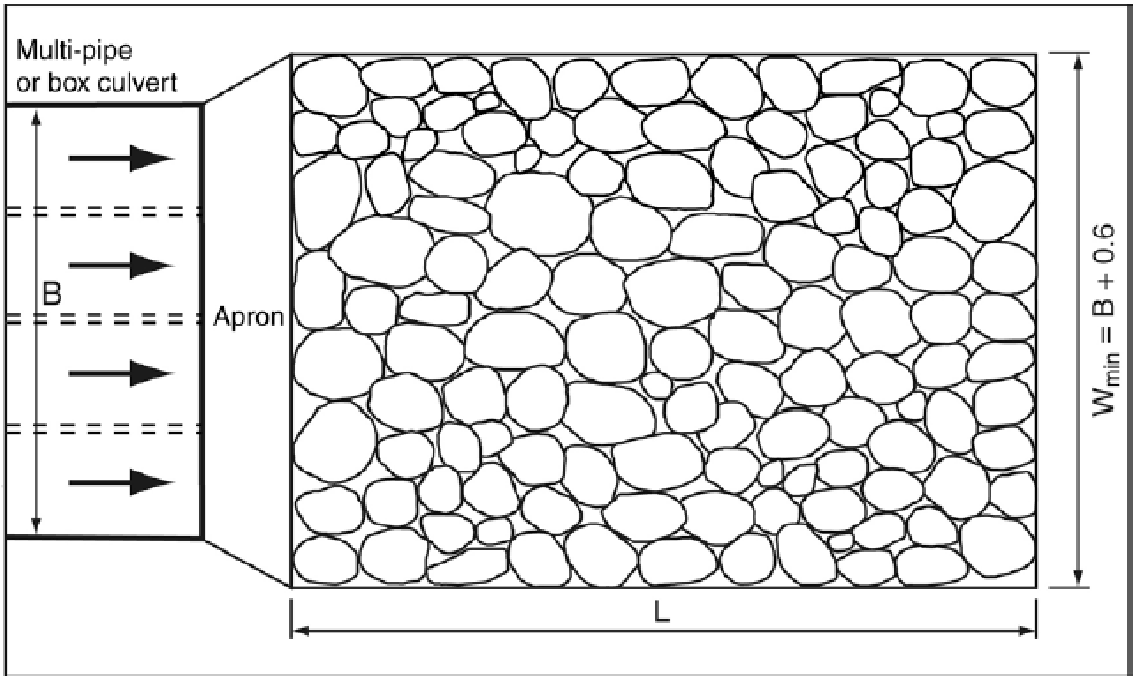

Figure 7.3 Typical plan layout of culvert scour protection (Catchments & Creeks Pty Ltd)

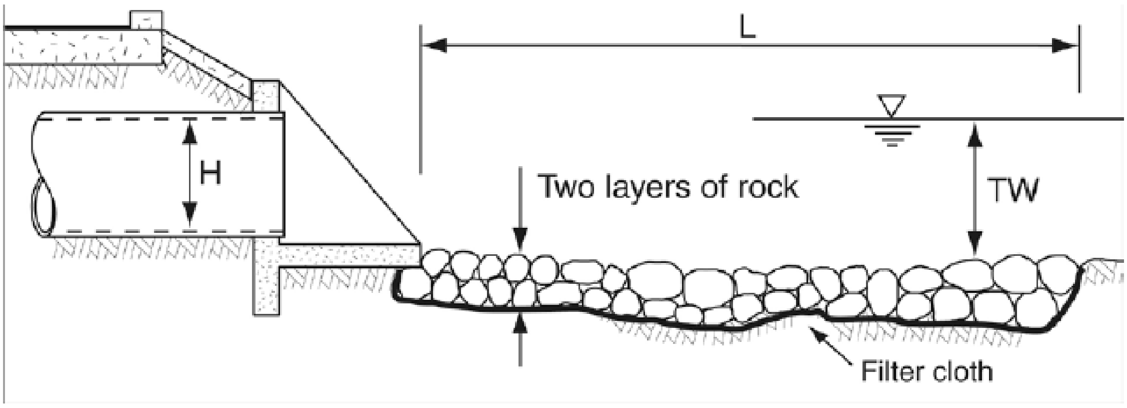

Figure 7.4 Typical section of culvert scour protection (Catchments & Creeks Pty Ltd)

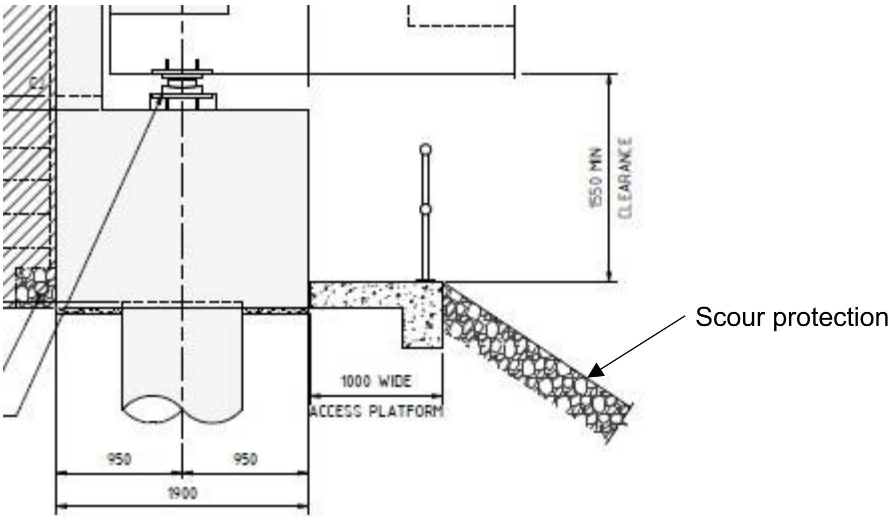

Figure 7.5 Typical scour protection at bridge abutments

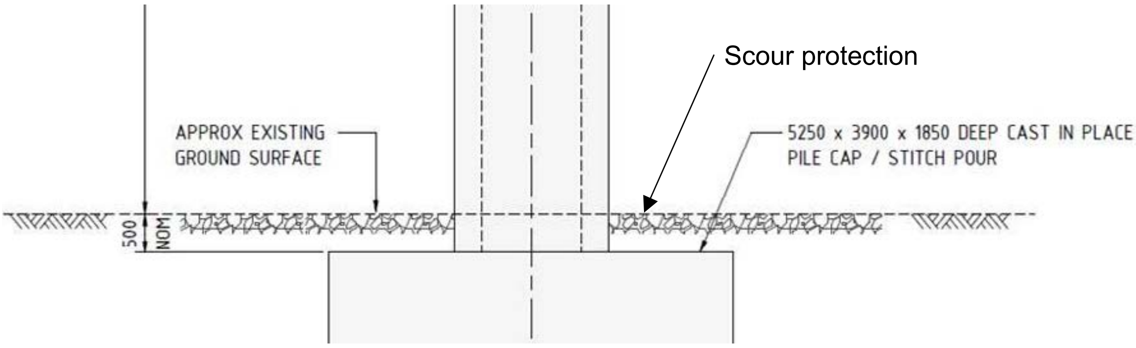

Figure 7.6 Typical scour protection at bridge piers

7.1.8 Consistency with floodplain management plans

A number of state government and council floodplain management plans were identified and reviewed as part of this assessment (refer to Section 2.2). The Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020 (refer to Section 2.2.6) covers a part of the urban area of Narrabri and is within the study area for this assessment. The *Narromine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2009) developed by Narromine Shire Council covers the urban area of Narromine and is within the study area of this assessment. Consistency of the proposal with both plans are discussed below.

Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020

The Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020 is applicable to construction and demolition of existing or proposed flood works which include an access road, a supply channel, a stock refuge, an infrastructure protection work, an ecological enhancement work, an Aboriginal cultural value enhancement work and a heritage site enhancement work within the Lower Namoi Valley Floodplain. The proposed Narrabri bridge which crosses the Lower Namoi Management Zone AD and Lower Namoi Management Zone B of the Plan is not a flood work. However, temporary infrastructure required to construct the bridge such as access tracks, crane pads, barges, scaffolding etc. have the potential to impact on flood behaviour.

Piers for the bridge have been streamlined to minimise adverse impacts to flooding. In addition, scour protection measures would be provided for piers (refer to Figure 7.6) to ensure minimal impact on soil erodibility. Temporary construction infrastructure has been designed to minimise interference with flood behaviour in order to minimise impacts to surrounding land as far as practicable. Further investigations will be undertaken during detailed design to ensure that the proposed bridge and associated temporary infrastructure is consistent with the requirements for both Lower Namoi Management Zone AD and Lower Namoi Management Zone B.

While the provisions of *the Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020* do not apply to State significant infrastructure projects, such as the proposal, the relevant matters have been considered in this assessment (refer to Section 6).

Narromine Floodplain Risk Management Study

The *Narromine Floodplain Risk Management Study and Plan* recommends implementing development controls such as a flood planning level for new development set at the 1% AEP flood level with a 0.5 metre freeboard. As the proposal will have only a minor impact on the peak 1% AEP flood levels within Narromine, the proposal will have no significant impact on the extent of the flood planning area and therefore the area of land to which the flood planning controls would apply.

The *Narromine Floodplain Risk Management Study and Plan* also recommends carrying out feasibility studies for flood mitigation works including upgrade of the existing Narromine river bank levee and upgrading the hydraulic capacity of culverts under the Parkes to Narromine Line. The extent of Council's proposed levee bank works is located to the west of the proposed bridge over Macquarie River where there would be minimal changes in peak flood levels. Therefore, the proposal would not limit or preclude the potential future levee bank works. The culverts under the Parkes to Narromine Line identified for potential upgrade could not be located from the information available. However, the existing section of the Parkes to Narromine Line between the proposal and Narromine was subject to assessment as part of the *Parkes to Narromine Project Environmental Impact Statement* in 2017 (GHD), which included flood modelling, and the suggested upgrades from the 2009 report are now likely redundant. Irrespective, the proposal would not preclude any further upgrades to any existing culverts under existing rail lines near Narromine.

During detailed design there would be ongoing consultation with councils and DPIE to further review consistency of the proposal with any future floodplain risk management studies and/or plans developed for the catchments crossed by the proposal.

7.1.9 Compatibility with flood hazard and hydraulic functions

The compatibility of the proposal with the flood hazard of the land and the hydraulic functions of flow conveyance, floodways and flood storage has been considered throughout the design process (refer Section 3.5). Firstly, an understanding of existing flood behaviour was developed including consideration of high hazard areas where significant flow conveyance occurs. This was then followed by an iterative approach to identify the minimum elevation of the rail formation, and the required location and size of hydraulic structures.

The flood models representing the operational phase of the proposal were initially run for the selected design flood events to satisfy the flood immunity requirement for the proposal. Several iterations were then undertaken to locate and size hydraulic structures required to minimise the hydraulic impacts associated with the proposal. The hydraulic structures were sized to maintain flow conveyance and to limit afflux on the upstream side of the railway in events up to the 1% AEP.

The design of each bridge and culvert structure would be further developed and refined during detailed design considering the flood hazard, and loads imposed on the structures during a flood.

7.1.10 Emergency management arrangement impacts

Local flood plans (refer to Section 2.2.8) outline the existing emergency management arrangements for flooding including preparedness measures before a flood, response operations during a flood, and recovery measures after a flood. The plans outline responsibilities and arrangements between SES, local and State government agencies, and community members. The proposal has the potential to impact flood response operations during a flood due to changes in flood behaviour. Any flood preparedness and recovery measures that are carried out before and after a flood has occurred would not be impacted by the proposal.

Key response measures during a flood include property protection and evacuation and traffic management. The local flood plans identify that existing property protection options are very limited in Narromine and Narrabri due to the large number of properties that can be affected by existing flooding (SES, 2014 and 2015). As identified in Section 5.2.3, there are about 2,250 buildings in Narromine and 3,508 buildings in Narrabri that would be flooded above floor level in the existing 1% AEP event. The proposal would cause a minor increase in depth of flooding to a small proportion (about one per cent) of buildings already affected by 1% AEP flooding, but would not cause any significant increase in the number of buildings affected by flooding. Therefore, no significant impacts to the existing property protection measures identified in the relevant local flood plans are expected due to the proposal.

The existing roads and highways would be used to evacuate the community, however there are no dedicated flood evacuation routes identified within the study area. The proposal would result in negligible to minor impacts to the length and duration of flooding to roads and highways (refer Section 7.1.4), therefore the proposal would not result in any significant impact to existing flood evacuation, road traffic control, and road closure arrangements.

For large scale evacuation from Narrabri, existing options include via air, rail, and road (SES, 2015). The proposal would potentially provide an alternate evacuation option given the flood immunity provided by the new rail line.

Consultation carried out with the local councils regarding potential flood impacts of the proposal and emergency management arrangements for flooding is summarised in section 4. Further consultation during detailed design would be carried out with the relevant local council and local emergency management committees, DPIE, the SES and potentially impacted landholders.

Impacts of the proposal to flooding of emergency facilities are minor. The proposal results in less than 10 millimetres afflux at Narromine Hospital for all flood events up to and including the PMF event. In the case of Narrabri Hospital, the afflux in the 1% AEP event is nil and a maximum afflux of 100 millimetres in the PMF event. Both Narromine and Narrabri hospitals will be consulted during detailed design to identify any modifications required to update the current flood evacuation plans for both hospitals due to the proposal.

7.1.11 Social and economic impacts

Community impacts

Social impacts of flooding on the community relate to the intangible impacts such as the stress, anxiety, and ill-health that can be associated with the effects of flood inundation. These are often caused by the disruptions that flooding has to daily life, such as property damage, clean-up work, reduced access to supplies, restricted vehicular access, potential isolation, loss of electricity and telephones, odour associated with flood water, leeches/snakes, debris and rubbish, sewage spills, the risk of infection, ponding and slow drainage (time of inundation) after the flood event.

The proposal would not cause any significant broad scale social impacts as a result of changes to flood behaviour. Locally, the proposal would impact on the general connectivity between some agricultural land parcels and movement of cattle and farm machinery between paddocks during a flood event. Most owners of farming properties may have evacuation procedures specific to their individual circumstances, which may include arrangements between neighbouring owners or family members which are not formalised or documented. ARTC is continuing to consult with property owners directly impacted by the proposal about potential property impacts and opportunities to minimise impacts on the use and functioning of rural properties. Further discussion on potential impacts to agricultural activities is provided below.

Economic impacts of flooding are those tangible financial impacts as a result of damage or loss caused by floodwaters to buildings, infrastructure, and agricultural activity, as well as costs associated with loss of wages, loss of production, and clean-up costs.

The proposal would cause some minor impacts associated with increased depth and duration of flooding to a number of buildings in Narromine and Narrabri that are already affected by flooding. These impacts would be minimised as far as practicable through further design refinement during detailed design and ongoing consultation with local emergency management committees.

The impact of the proposal on flooding to roads and rail infrastructure is generally negligible with only minor changes to the length and duration of flooding affecting existing roads and railways (refer Sections 7.1.4 and 7.1.5). As a result, the economic impacts of the proposal in relation to existing road and rail infrastructure damage would also be negligible.

Impacts to agricultural activities

The socio-economic impacts of flooding on agricultural land and agricultural production can be both positive and negative across the study area with the net effect depending on the agricultural enterprise under consideration. The general characteristics of flooding that could impact on agricultural land use are timing (season), volumes, duration (number of days) and frequency of flood events. Production impacts will change depending on the type of land use (e.g grazing versus cropping) and also from one property to another depending on the type of enterprise and the proportion of the total property affected. The modelling under the 20% AEP flood event shows that the majority of the cropping and grazing areas are currently subject to less than 24 hours of inundation above 0.5 metres flood depth. Given the proposal would not cause any broad scale changes to flood behavior, these potential impacts are expected to be negligible.

While the impacts from flooding could differ across the study area, above average rainfall and widespread flooding can replenish underground and surface irrigation water sources and can have a beneficial impact in future years arising from soil and water changes. While a flood will not only generate financial benefits in increased stocking rates, more assured cropping patterns and deliver greater profits, there are also significant social and environment benefits derived. These socio-economic benefits such as security of family life, economic and environmental sustainability while interdependent of each other can be apparent for some years after a flood event.

Across floodplain communities, the economic benefits associated from flooding events on agricultural land are widely recognised and the benefits gained from these flooding events may be apparent for some years after the event. A flood event usually results in guaranteed cropping in the first year, with further opportunities to establish a crop in the subsequent years. In addition, small follow up rainfall events across the study area will also be of greater benefit because of residual sub-soil moisture.

Similarly, for grazing enterprises, following a flood event, there is also the opportunity to increase stock numbers due to increases in crop and pasture production and generally cattle numbers increase more than sheep as cattle can readily adapt to wet conditions and can be more readily made available on an agistment arrangement. The benefits from increased grazing will be accrued in the first year following a flood event and then declines in subsequent years as the quality and quantity of feed available declines.

Flood events can also deliver improved ecological outcomes and can trigger dormant seed species to sprout and increase plant density while many native plants and animals are generally adapted to the natural cycles of floods and droughts that are widespread across rural and regional Australia.

The effects of flooding and the subsequent impacts on agricultural land will depend on a number of factors including velocity and flow, soil types, depth and duration of the event, amount of soil and debris deposited, the pasture species/crop type and the season or growth phase of the plants. Some of the damages caused by floods that could impact on the productivity and profitability of agricultural enterprises within the study area include:

- Potential for stock losses due mainly to issues with management.
- Potential to ruin existing forage crops and pastures which may not regrow for some months.
- Environmental damage, growth of woody weeds and loss of some species.
- Interrupted access and interruption to management including minor damage to fencing and roadways.

Floods can impact on grazing enterprises through reduced carrying capacity on land as a result of loss of pastures and could also bring a range of animal health problems. In some areas there could be waterlogging that can reduce crop and pasture growth, promote weed incursion and potentially damage or kill pastures. While some pastures can be tolerant to waterlogging the impact of inundation and duration on pastures species includes:

- Short term duration (less than seven days) can (a) damage sensitive species and (b) can deliver subsequent benefits by wetting the soil profile to depth that enables active growth after recession.
- Medium term duration (from seven to 14 days) can severely affect sensitive species.
- Extended duration (more than 14 days) will kill introduced productive pasture species and will set back moderately tolerant species.

The modelling shows that the average duration of flooding will be generally less than 24 hours in duration and therefore should avoid the medium and extended duration impacts on pasture species outlined above. The duration of flooding on agricultural land will be largely unaffected by the proposal with modelled changes typically less than 10 per cent and some localised changes of 20 per cent to 50 per cent. In addition, there would be no significant change in the extent of flooding on grazing and cropping lands with the flood modelling results showing an overall minor reduction in the areas subject to flooding (refer Section 7.1.6). Therefore, the impact the proposal would have on flooding to cropping and grazing lands would also be minor.

Damage to pasture and crop yields are modest at low flow durations and then increase before reaching a threshold level that causes pasture and crop death. Pastures that have become severely damaged or killed might require resowing/ renovating to restore their productive capacity to pre-flooding levels. This will require direct costs of pasture re-establishment (seed, fertiliser, herbicides, machinery, labour etc.) and also the cost of providing feed for livestock for a period while the newly sown pasture becomes established and is able to be grazed again by livestock. Given the generally short term duration of flooding across the study area, it is not expected that pastures will be required to be resown or renovated following a 1% AEP flood event.

Floods can also cause environmental damage and promote weed invasions on crop and pasture land. Flood affected pastures are less vigorous and therefore less able to out-compete weeds. In addition, the flood event provides an opportunity to carry novel weed seeds onto agricultural land where they were not previously established, resulting in additional time and costs to manage. Sediment and soil properties naturally vary within a river reach, so therefore floods can also remove significant amounts of topsoil over large areas from one property and deposit it on a downstream property. Given the proposal would not cause any broad scale changes to flood behavior, these potential impacts are expected to be negligible.

As outlined in the *ARTC Inland Rail Narrabri to Narromine Agriculture and Land Use Assessment* (JacobsGHD, 2020a), farming operations across the study area centralise their operations around a central 'hub' and have been located in these areas as they are 'high and dry' which allows for all weather access. While this key agricultural infrastructure is generally located outside of flood prone land, peak flood events can still cause damage to internal roads, fencing (including the collection of debris along fence lines) and cause equipment to bog or livestock to become isolated. Given the proposal would not cause any broad scale changes to inundation of agricultural land, these potential impacts are expected to be minor to negligible.

Flood events can also result in both interrupted access and interruption to management. Interrupted access occurs on land that is not directly flooded but which cannot be accessed by agricultural landholders during a flood event. Interrupted access is a function of the topography of the land and internal road network and the impacts can be many and varied. Interrupted access could lead to lost grazing opportunities and/or interruptions to crop and livestock husbandry that could reduce production and profitability. Given the proposal would not cause any broad scale changes to inundation of agricultural land, these potential impacts are expected to be minor to negligible.

Interruption to management is where landholders are required to divert time and energy away from their normal property management when confronted with flooding and may result in the landholder incurring additional costs to ensure the efficient operation of agricultural land. In addition, diversion of land manager time to flood management could reduce oversight of agricultural enterprises which in turn could cause production losses. Given the proposal would not cause any broad scale changes to inundation of agricultural land, these potential impacts are expected to be minor to negligible.

Overall, given the proposal would not cause any broad scale changes to flood behavior, the impact of flooding impacts on agricultural land uses as a result of the proposal are generally negligible.

7.1.12 Climate change impacts

The 1% AEP event has been selected for assessment of potential impacts due to climate change. This scenario involves simulation of the 1% AEP event with a 22.8 per cent increase in rainfall depth based on recommendation of ARR 2019 to adopt the RCP 8.5 by the year 2090 as defined in Section 3.6.3.

The same runoff routing parameter values, spatial and temporal distribution of rainfall, and rainfall losses adopted in the simulation of the 1% AEP event have also been adopted for the climate change scenario. The estimated peak discharges for the 1% AEP event with the projected climate change for the year 2090 are generally higher than peak discharges for the 0.5% AEP event and smaller than peak discharges for the 0.2% AEP event under the existing climate.

The 1% AEP flood levels upstream of the proposed hydraulic structures would increase by up to a maximum of 1.78 metres as a result of climate change impacts. The median increase would be 0.07 metres. The proposal has been designed to be above the 1% AEP, and in a number of locations is not overtopped by the 1% AEP with climate change flood level. Where required in accordance with ARTC climate change requirements, bridges also include a freeboard where the flood level increase caused by climate change is 0.4 metres or more. Therefore, the proposal would be resilient to climate change impacts on flooding.

7.1.13 Risk of rail formation overtopping and failure

The proposal is not overtopped in the 1% AEP event both under the existing climate and with climate change. The proposal is overtopped in very rare to extreme flood events including the 0.2% AEP flood event and larger. The total length of the proposal overtopped in these extreme events is shown in Table 7.13.

Table 7.13 Length of proposal overtopped in extreme flood events

Design event	Length of proposal overtopped (km)
0.2% AEP	0.2
0.05% AEP	3
0.01% AEP	24
PMF	26

The maximum depth of overtopping of the proposal is about 3.5 metres at chainage 560.3. The difference between headwater level and tailwater level at chainage 560.3 in the PMF event is about 0.1 metres which implies that the proposal is not functioning as a water retaining structure and a potential failure of the rail formation would have insignificant consequences downstream. Therefore, there would be no additional risk to people or property as a result of the proposal overtopping.

The maximum difference in headwater and tailwater level in the PMF event is 2.7 metre at chainage 572 and the proposal is not overtopped in the PMF event at this location. However, there are several locations along the proposal where differences in headwater and tailwater levels are reasonably high and the proposal is subject to a shallow depth of overtopping over the rail. Under these circumstances, it is expected that the railway ballast would be washed away and depths of overtopping of the rail formation would be reduced resulting in reduced differences in headwater levels and tailwater levels along the formation.

It is to be noted that safety railings for culverts and bridges have been assumed 100 per cent blocked and railway ballast has been assumed as a solid obstruction to flood flow. Hence it is very likely that differences between headwater levels and tailwater levels would be lower than those estimated by the TUFLOW models and the proposal is not expected to act as a water retaining structure during extreme flood events.

7.1.14 Blockage assessment

All TUFLOW hydraulics models representing the operational phase of the proposal were updated to represent the adopted culvert blockage factors. All TUFLOW models were run for the 1% AEP event both under the existing climate and with climate change using the same inflow hydrographs adopted for the operational phase of the proposal. Flood modelling results have been assessed to identify impacts on the design criteria and flood management objectives for the proposal due to debris blockages.

Flood immunity

Approximately 1.4 kilometres of the proposal is overtopped in the 1% AEP event due to the adopted blockage factors. The overtopped sections of the proposal are located between chainage 762.9 to 802.9 kilometres and the majority of overtopped sections are located within the Pilliga Forest. The maximum depth of overtopping is estimated at 0.7 metres between chainage 779.0 to 779.5 kilometres.

In the case of the 1% AEP event with climate change, an approximately 2.1 kilometres of the proposal are overtopped with a maximum depth of overtopping of approximately 0.8 metres. The overtopped sections of the proposal are located between chainage 762.9 to 808.9 kilometres.

Impacts on buildings

The number of buildings impacted by more than a 10 millimetres increase in flood depths within each TUFLOW model domain for the 1% AEP event both under the existing climate and with climate change are shown in Table 7.14. Table 7.14 shows that in total, 76 buildings and 767 buildings are subject to more than 10 millimetres of flood impact in the 1% AEP event and the 1% AEP event with climate change respectively.

A comparison between Table 7.14 and Table 7.1 shows that an additional five buildings are subject to more than a 10 millimetre increase in flood levels in the 1% AEP event, two of which are located within NFM model, two within the N2N1 model and one within the Narrabri model. A further comparison of the two tables also shows that an additional 74 buildings are subject to more than a 10 millimetre increase in flood levels in the 1% AEP event with climate change due to blockages. The majority of the 74 buildings are located within the NFM, N2N1 and Narrabri model domains.

Table 7.14 Number of buildings impacted more than 10 millimetres afflux with debris blockages (number of impacted buildings with surveyed floor levels shown within brackets)

TUFLOW Model	1% AEP	1% AEP + CC
NFM	16	622
N2N14	0	0
N2N13	0	0
N2N11-12	6	7
N2N10	0	0
N2N9	0	0
N2N8	0	0
N2N7	0	0
N2N6	0	0
N2N1	31	54
Narrabri	23 (13)	84 (40)
Total	**76 (13)**	**767 (40)**

Impacts to roads

Culvert blockage has a negligible impact on the length of inundated highways located within all TUFLOW models. The increased length of inundated highways is 1 per cent or less in the 1% AEP event both under the existing climate and with climate change for all roads.

Impacts on existing railways

Debris blockage has negligible impacts on the length of railways subject to flooding in the 1% AEP event, except for a 20 per cent reduction in the length of the Parkes to Narromine Line subject to flooding. However, in the case of the 1% AEP event with climate change, the length of the Dubbo to Coonamble Line subject to flooding is increased by 15 per cent.

Impacts on major land uses

Changes in forested, grazing, cropping and horticultural areas subject to different flood depths with culvert blockage were also assessed. The results showed only minor changes in flooded areas subject to different flood depths in comparison with existing conditions.

7.2 Geomorphology

7.2.1 Instream structures

The permanent presence of instream structures can cause hydraulic changes that has the potential to impact on the geomorphological condition and stability of the waterways. An increase in water flowing through culverts and bridges has the potential to result in erosion and impacts to downstream stream stability.

Hydraulic modelling was undertaken to assess the potential operational impacts the works may have on geomorphological conditions of the waterways for a range of flood events. Modelled maximum velocities at culverts and bridges for a range of design events (50, 20, 10, 5, 2 and 1% AEP) were compared with maximum permissible velocity values (for geomorphological analysis as defined in Section 3.9.2) for sandy loams (0.5 metres per second), fine gravels (0.8 metres per second) and vegetated surfaces (2 metres per second).

Hydraulic modelling results of maximum velocities at culverts and bridges have been plotted for the four broad categories of River Styles and these are discussed below.

Without mitigation these impacts could result in increased erosion and scour. Suitable designed scour protection and energy dissipation measures will minimise the potential for scouring and erosion.

Confined Valley Setting

As discussed in Section 5.3, there are seven waterways in this category which have a Confined Valley, Sand River Style (Lampert and Short, 2004). These River Styles are generally located in high-energy settings – middle to upper catchment positions, the relatively steeper gradients and confinement can generate moderate to high stream powers. Lampert and Short (2004) assessed all seven waterways as having a moderate condition and fragility, with localised degradation of river character and behaviour or patchy vegetation coverage allowing some accelerated erosion.

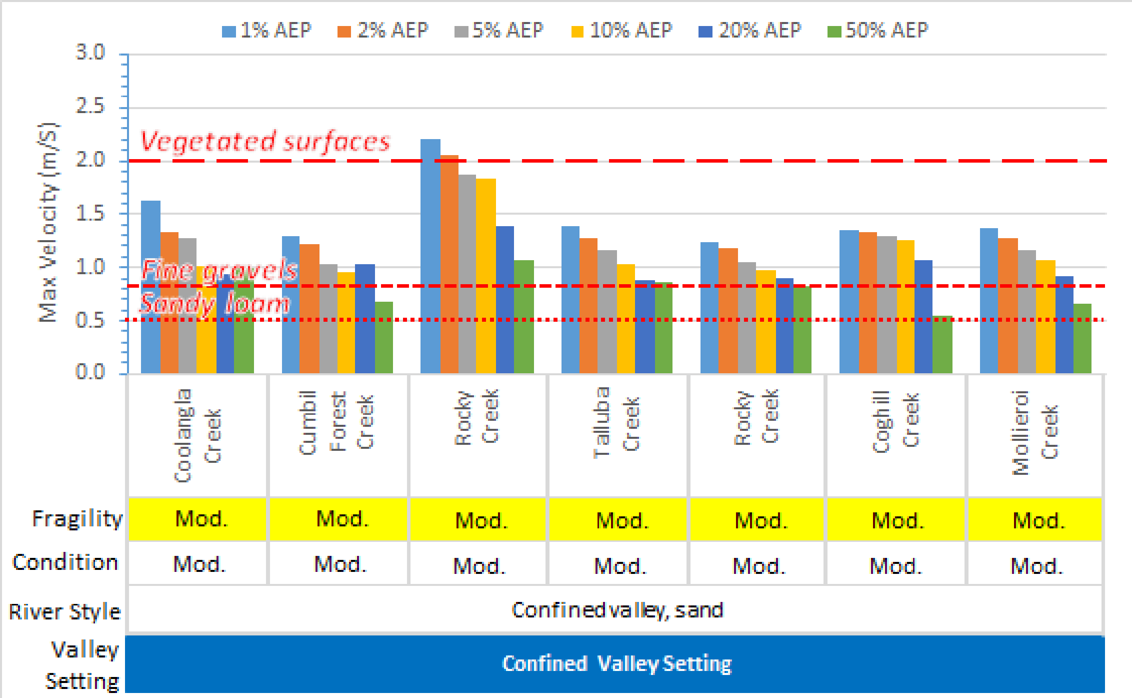

Figure 7.7 Maximum velocity for Confined Valley River Styles

Velocity values are such that erosion of bare sediments would be expected to occur for the range of flow conditions modelled for all waterways. As shown in Figure 7.7 maximum velocity values exceed the permissible velocity for sandy loam sediments (0.5 metres per second) from the 50% AEP up to the 1% AEP for all waterways. The permissible velocity for fine gravels (0.8 metres per second) is exceeded from the 50% AEP up to the 1% AEP for four of the seven waterways (Coolangla Creek, Rocky Creek, Talluba Creek and Rocky Creek) and from the 20% AEP up to the 1% AEP for the three remaining waterways (Cumbil Forest Creek, Coghill Creek and Mollieroi Creek).

Velocity values exceed the maximum permissible velocity for vegetated surfaces at one of the two Rocky Creek waterways from the 2% AEP up to the 1% AEP.

Partly Confined Valley Setting

As discussed in section 5.3, there are eleven waterways that have Partly Confined Valley Settings. Streams in this group fall in two broad categories of River Styles, Bedrock Controlled and Planform Controlled (sand and fine grained). The Bedrock Controlled River Styles, which includes the Macquarie River, haves bed loads which can vary from gravel, through to sand and fine-grained.

The Macquarie River has a Bedrock Controlled, Sand River Style. GHD (2010) assessed this watercourse as having a good condition with moderate fragility, its character and behaviour similar to pre-development state. However, localised changes would be expected in response to direct exposure to threatening processes (i.e. disturbance to the channel environment, changes in channel hydraulics).

As shown in Figure 7.8 maximum velocities exceed the permissible velocity values for sandy loam (0.5 metres per second) and fine gravels (0.8 metres per second) from the 50% AEP to the 1% AEP for the Macquarie River. Velocity values exceed 1.5 metres per second from the 10% AEP to the 1% AEP, but do not exceed the permissible velocity value for vegetated surfaces (two metres per second).

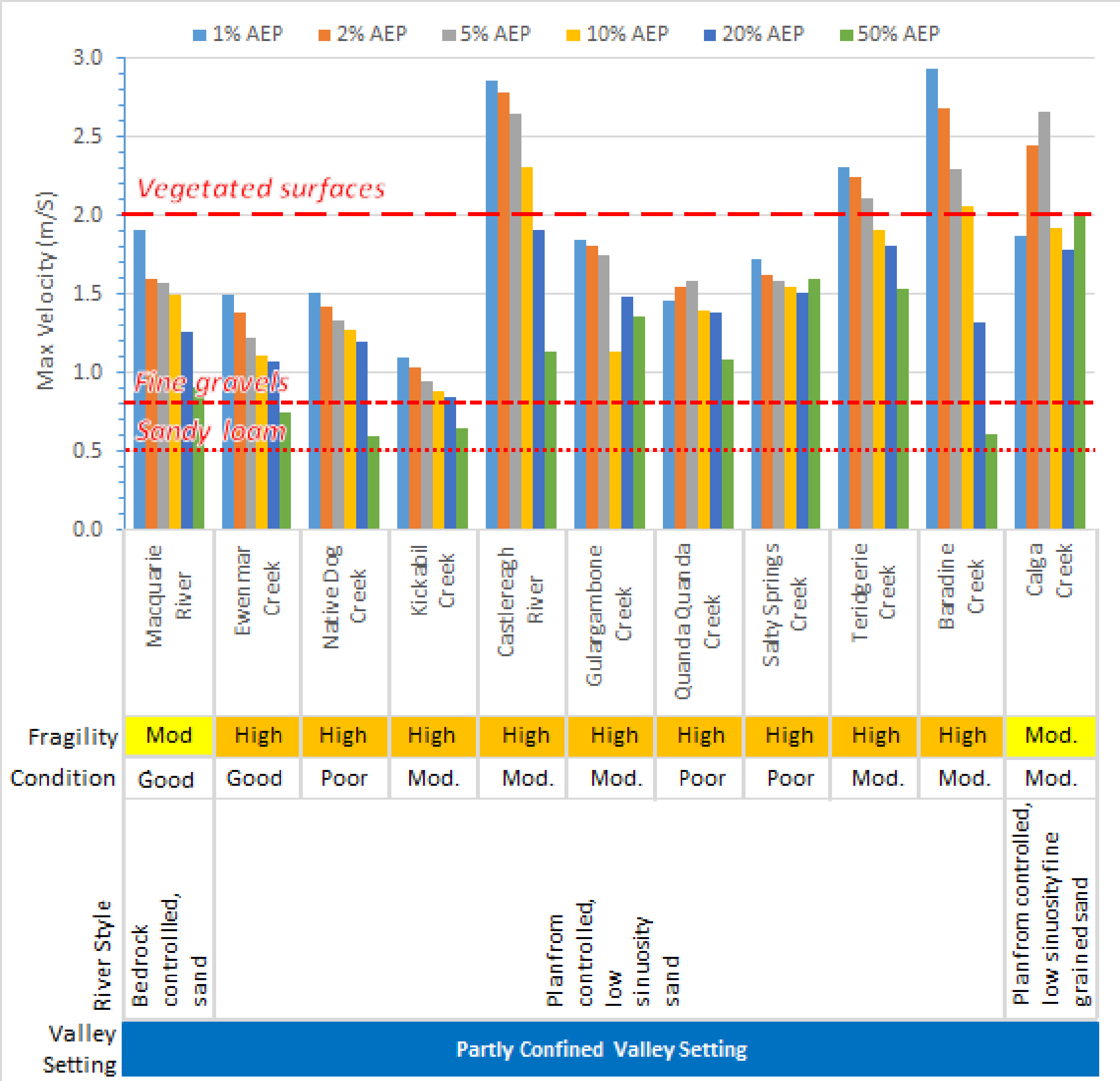

Figure 7.8 Maximum velocity for Partly Confined Valley River Styles

The remaining waterways in the Partly Confined Valley Setting category have Planform Controlled River Styles with sand and fine grained variants. In contrast to Bedrock Controlled streams, Planform Controlled waterways have a greater potential to adjust their morphology in response to flows. The condition of these waterways was variable ranging from poor to moderate and good (GHD, 2019; Lampert and Short, 2004). Nine of the ten Planform Controlled waterways were assessed as having a high fragility, these are highly susceptible and sensitive and have a significant potential for adjustment (GHD, 2019; Lampert and Short, 2004). Greater lengths of the waterway are also altered when disturbances are introduced (ie physical disturbance associated with vegetation clearing, changes in channel hydraulics).

Maximum velocity values exceed the permissible velocity for Sandy loam (0.5 metres per second) from the 50% AEP up to the 1% AEP for all of the Planform Controlled waterways. The threshold for erosion of fine gravels (0.8 metres per second) is exceeded by maximum velocities from the 50% AEP up to the 1% AEP for six waterways (Castlereagh River, Gulargambone River, Quanda Quanda Creek, Salty Springs Creek, Teridgerie Creek and Calga Creek). It is also exceeded from the 20% AEP up to the 1% AEP for four waterways (Ewenmar Creek, Native Dog Creek, Kickabil Creek and Baradine Creek).

Maximum velocities do not approach the threshold for erosion of vegetated surfaces (2 metres per second) for three waterways (Gulargambone River, Quanda Quanda Creek and Salty Springs Creek). This maximum velocity threshold is exceeded by flows from the 10% AEP to 1% AEP for two waterways (Castlereagh River and Baradine Creek) and 5% AEP up to 1% AEP for two waterways (Teridgerie Creek and Calga Creek).

Laterally Unconfined Valley Setting

As discussed in section 5.3, there are twelve waterways that have Laterally Unconfined Valley Settings. Waterways in this group are characterised by a number of different channel planforms that vary with respect to number of channels, sinuosity and lateral stability. In the instream zone, erosional and depositional forms and bank-attached and mid-channel features are differentiated. Bed materials can also vary with gravel, sand and fine-grained variants. River Styles are Low Sinuosity Gravel, Sand and Fine-Grained and Channelised Fill.

Lampert and Short (2004) assessed the Namoi River and Narrabri Creek streams as having a Low Sinuosity Gravel River Style, with poor (e.g degraded) condition and moderate fragility. Velocity values are such that erosion of bare sediments would be expected to occur for the range of flow conditions modelled. As shown in Figure 7.9 maximum velocity values exceed the permissible velocity threshold for sandy loam sediments (0.5 metres per second) and fine gravels (0.8 metres per second) from the 50% AEP up to the 1% AEP. Maximum velocity values exceed the threshold for erosion of vegetated surfaces for flows from the 10% AEP up to the 1% AEP.

Waterways with a Low Sinuosity Sand River Style were assessed as having either a moderate or poor condition. All of these waterways were assessed as having a high fragility. These waterways are highly susceptible and sensitive and have a significant potential for adjustment (GHD 2010; Lampert and Short, 2004). Greater lengths of the waterway are also altered when disturbances are introduced (ie physical disturbance associated with vegetation clearing, changes in channel hydraulics). The velocity values are such that erosion of bare sediments would be expected to occur for the range of flow conditions modelled. Maximum velocity values exceed the threshold for erosion of sandy loam sediments (0.5 metres per second) and fine gravels (0.8 metres per second) from the 50% AEP up to the 1% AEP. Velocity values do not exceed the threshold for erosion of vegetated surfaces (2 metres per second).

GHD (2010) assessed Baronne Creek and Bucklanbah Creek as having a Low Sinuosity Fine-Grained River Style with moderate condition and fragility. This was due to localised degradation of river character and behaviour or patchy vegetation coverage allowing some accelerated erosion. Maximum velocity values exceed the threshold for erosion of sandy loam sediments (0.5 metres per second) and fine gravels (0.8 metres per second) from the 50% AEP up to the 1% AEP for both waterways. Velocity values exceed the threshold for erosion of vegetated surfaces (2 metres per second) from the 50% AEP up to the 1% AEP for Baronne Creek. Velocity values do not exceed this threshold for Bucklanbah Creek.

GHD (2010) assessed the Channelised Fill River Style waterways as having poor (ie degraded) condition with moderate fragility. Maximum velocity values exceed the threshold for erosion of sandy loam (0.5 metres per second) from the 50% AEP up to the 1% AEP for three waterways (Wallaby Creek, Goulburn Creek and Milpulling Creek) and 20% AEP up to the 1% AEP for Pint Pot Gully. Velocity values exceed the threshold for erosion of fine gravels (0.8 metres per second) from the 50% AEP up to the 1% AEP for three waterways (Wallaby Creek, Goulburn Creek and Milpulling Creek) and 2% AEP up to 1% AEP for Pint Pot Gully. The threshold for erosion of vegetation surfaces is only exceeded for Wallaby Creek for 50% AEP flows.

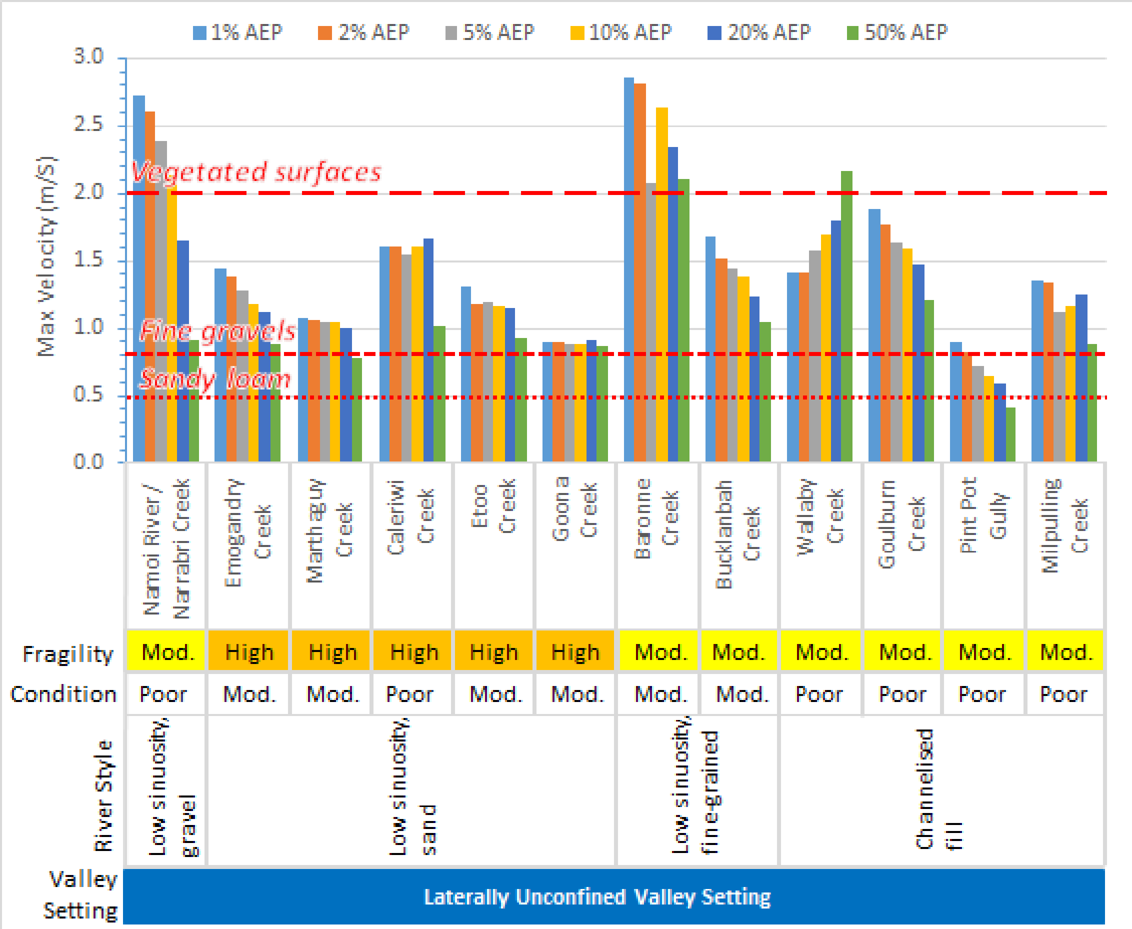

Figure 7.9 Maximum velocity for Laterally Unconfined Valley River Styles

Discontinuous

As discussed in Section 5.3, there are eight waterways that have Discontinuous Valley Settings. Waterways in this group are located in lower energy settings. They include Valley Fill Sand (Tenandra Creek, Mungery Creek, Black Gutter and Small Creek), Fine-Grained (Judes Creek) and Lowland Chain of Ponds River Styles (Tinegie Creek, Bundock Creek and Bohena Creek). These waterways were assessed as having a high fragility, meaning they are sensitive to disturbance and have significant adjustment potential. It is common for discontinuous styles to transform to other styles such as Channelised Fill and Low Sinuosity, Sand (GHD, 2010; Lampert and Short, 2004).

GHD (2010) assessed waterways with a Valley Fill Sand River Style as having a moderate condition with a high fragility. These waterways are highly susceptible and sensitive and have a significant potential for adjustment. Greater lengths of the stream are also altered when disturbances are introduced (i.e. physical disturbance associated with vegetation clearing, changes in channel hydraulics). As shown in Figure 7.10 maximum velocity values exceed the threshold for erosion of sandy loam (0.5 metres per second) from 50% AEP up to the 1% AEP for three waterways (Mungery Creek, Black Gutter and Small Creek) and 20% AEP to 1% AEP for Tenandra Creek. Velocity values exceed the threshold for erosion of fine gravels (0.8 metres per second) from 50% AEP up to the 1% AEP for Mungery Creek and 20% AEP up to the 1% AEP for Black Gutter and Small Creek. Velocity values remain below the threshold to erode vegetated surfaces (2.0 metres per second).

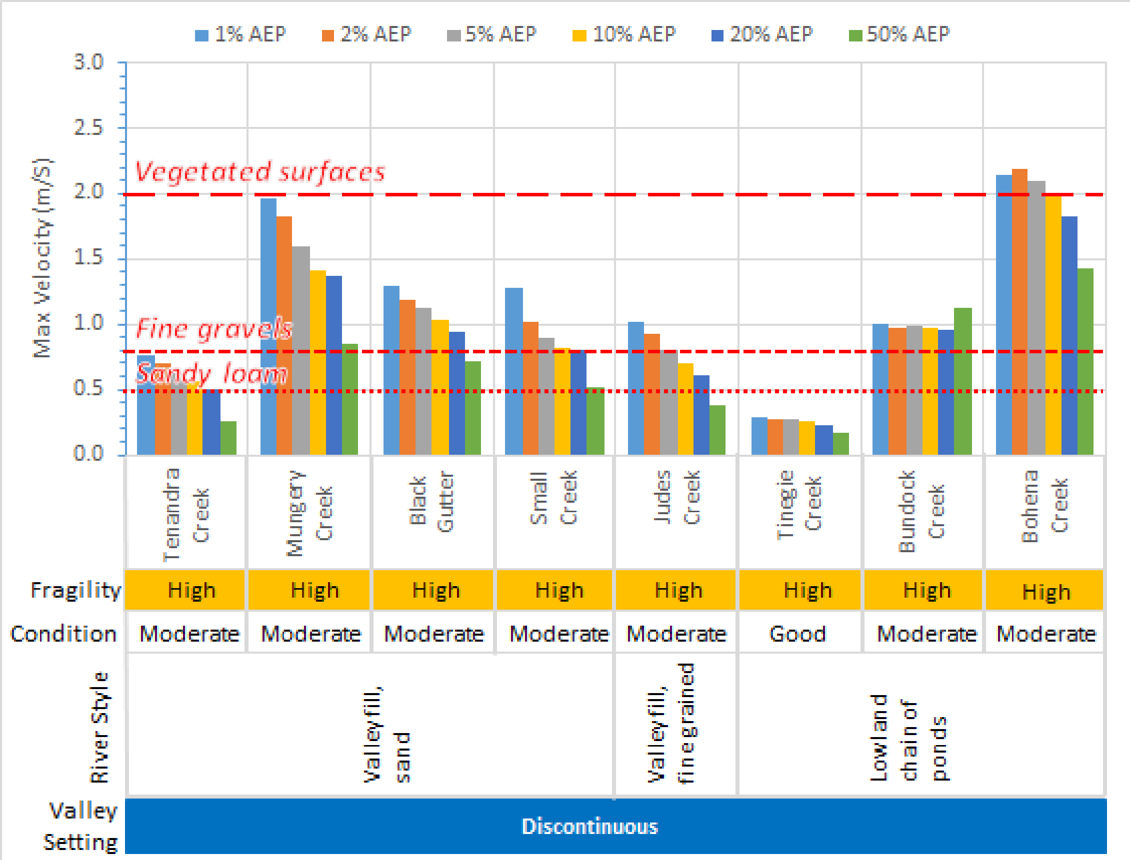

Figure 7.10 Maximum velocity for Discontinuous River Styles

Judes Creek has a Valley Fill Fine Grained River Style and similarly to waterways with a Valley Fill Sand River Style was assessed by GHD (2010) as having a moderate condition with a high fragility. Maximum velocity values exceed the threshold for erosion of sandy loam (0.5 metres per second) from 20% AEP up to the 1% AEP. Velocity values exceed the threshold for erosion of fine gravels (0.8 metres per second) from 5% AEP up to the 1% AEP. Velocity values remain below the threshold to erode vegetated surfaces (2 metres per second).

Three of the eight waterways were assessed by Lampert and Short (2004) as having a Lowland Chain of Ponds River Style in moderate or good condition with high fragility. The modelled velocity ranges for flow events were quite different across the three waterways. Maximum velocity values from the 50% AEP up to the 1% AEP were below 0.3 metres per second at Tinegie Creek, and as such do not exceed the threshold values for erosion. Velocity values at Bundock Creek exceed the threshold for erosion of sandy loam (0.5 metres per second) and fine gravels (0.8 metres per second) from 50% AEP up to the 1% AEP, but did not exceed the threshold to erode vegetated surfaces (2.0 metres per second). Velocity values at Bohena Creek exceed the threshold for erosion of sandy loam (0.5 metres per second) and fine gravels (0.8 metres per second) from 50% AEP up to the 1% AEP. The threshold for erosion of vegetated surfaces (2.0 metres per second) is exceeded for Bohena Creek from the 10% AEP to the 1% AEP.

7.2.2 Changes in existing velocities

Hydraulic modelling results were also used to assess the changes in flow velocities and the potential impact this would have on geomorphological conditions of the waterways. Results of flow velocity for existing and operational conditions have been plotted for the four broad categories of River Styles and these are discussed below. The operational condition flow velocities represent the velocity in the culverts and bridges to ensure the assessment considers the effect of the new structures.

Confined Valley Setting

Changes in existing peak velocities at waterways with a Confined Valley River Style are shown in Figure 7.11. Peak velocities for design conditions are generally the same or marginally lower than existing conditions. No overall change in geomorphological stability is expected for these watercourses except for Cumbil Forrest Creek where peak velocities change from 0.3-0.4 metres per second to 0.7-1.3 metres per second. There is a potential for increased scouring and erosion at Cumbil Forrest Creek, however with suitably designed scour protection and energy dissipation measures the potential for scouring and erosion will be minimised.

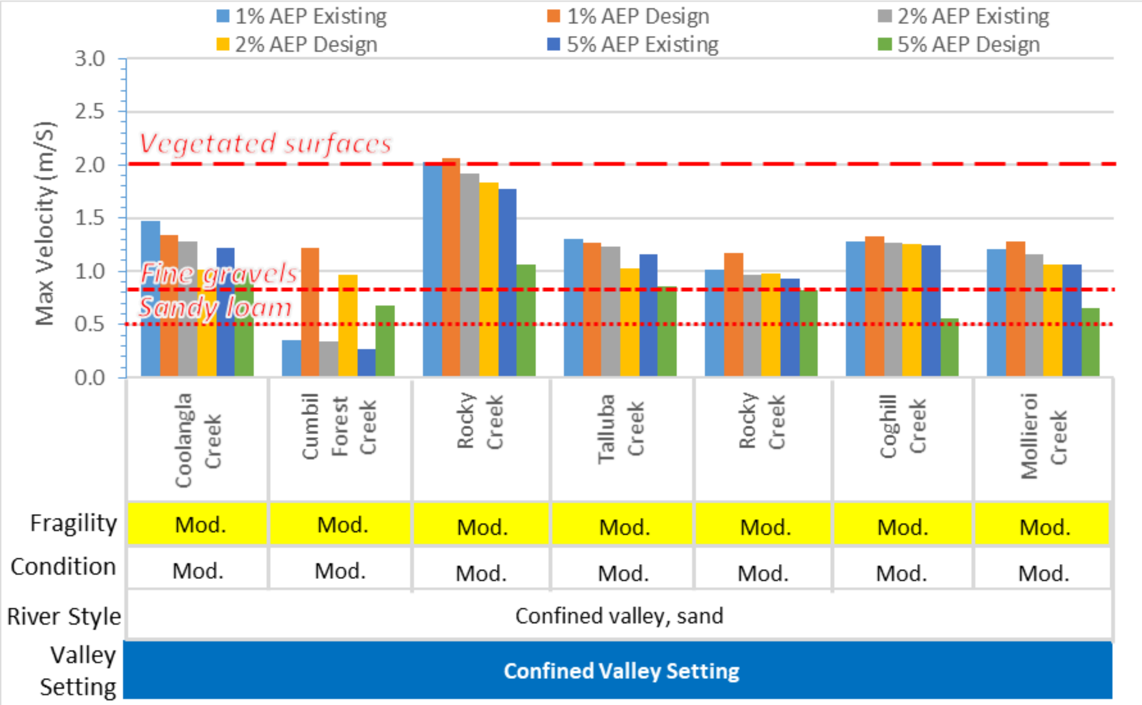

Figure 7.11 Change in maximum velocity for Confined Valley River Styles

Partly Confined Valley Setting

Changes in existing peak velocities at waterways with a Partly Confined Valley River Style are shown in Figure 7.12. Peak velocities for design conditions are all lower than velocities for existing conditions. The order of magnitude of change is unlikely to result in a change to the stability of the watercourse or mobility of sediments through the crossing area.

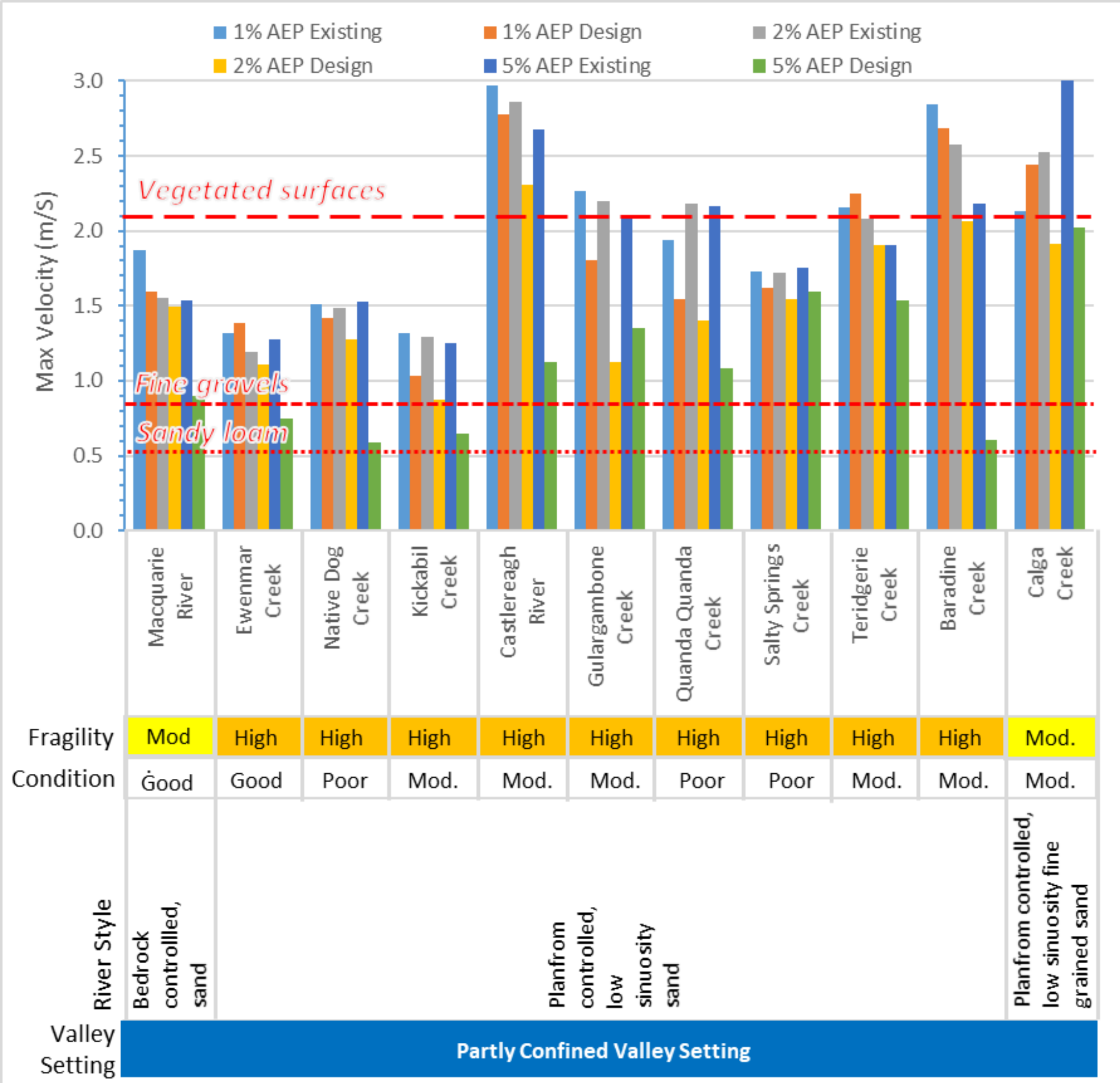

Figure 7.12 Change in maximum velocity for Partly Confined Valley River Styles

Laterally Unconfined Valley Setting

Changes in existing peak velocities at waterways with a Laterally Unconfined Valley River Style are shown in Figure 7.13. There is some variability in velocity changes with slight increases at some waterways and reductions at others. The order of magnitude of change is unlikely to result in a change to the stability of the watercourse or mobility of sediments through the crossing area. The exception to this is Marthaguy Creek, where there is around 50 per cent reduction in velocity values for the 1%, 2% and 5% AEP flood events in the operational phase. Velocity values still exceed thresholds for erosion of sandy loam and fine gravel sediments, however this consistent reduction in velocities could lead to conditions more favourable for aggradation of sediments and debris in the crossing area.

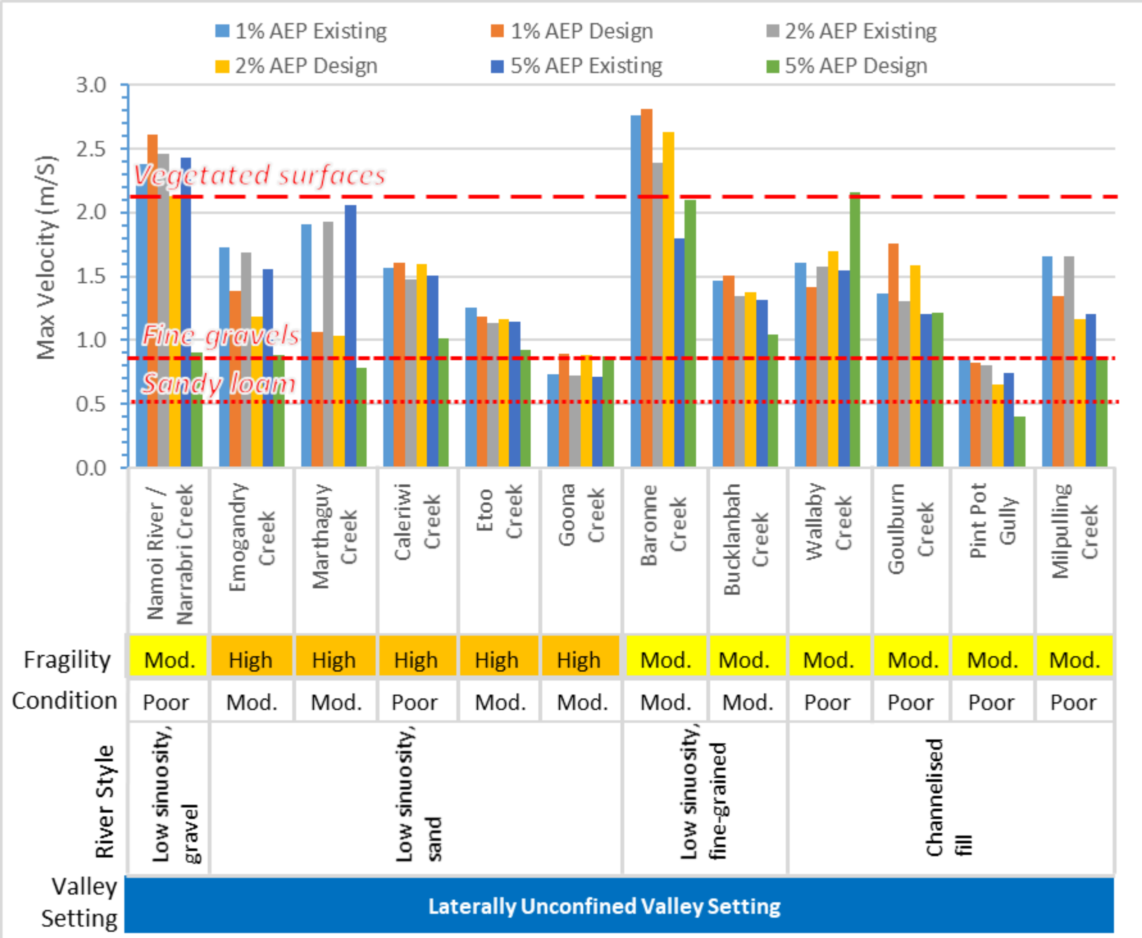

Figure 7.13 Change in maximum velocity for Laterally Unconfined Valley River Styles

Discontinuous

Changes in existing peak velocities at waterways with a Discontinuous River Style are shown in Figure 7.14. There results show there is some variability in velocity changes with slight increases at some waterways and reductions at others. Discontinuous river styles are highly sensitive to flow changes so the magnitude of flow velocity changes may be more significant and likely to impact on their stability. For example, peak velocities for Mungery Creek during the operational phase (0.9-1.8 m/s) are significantly higher than existing conditions (0.4-0.7 m/s). These flow changes could significantly alter the behaviour of the system, leading to incision and channelisation of any valley fills. Suitably designed scour protection and energy dissipation measures will ensure the potential for scouring and erosion will be minimised.

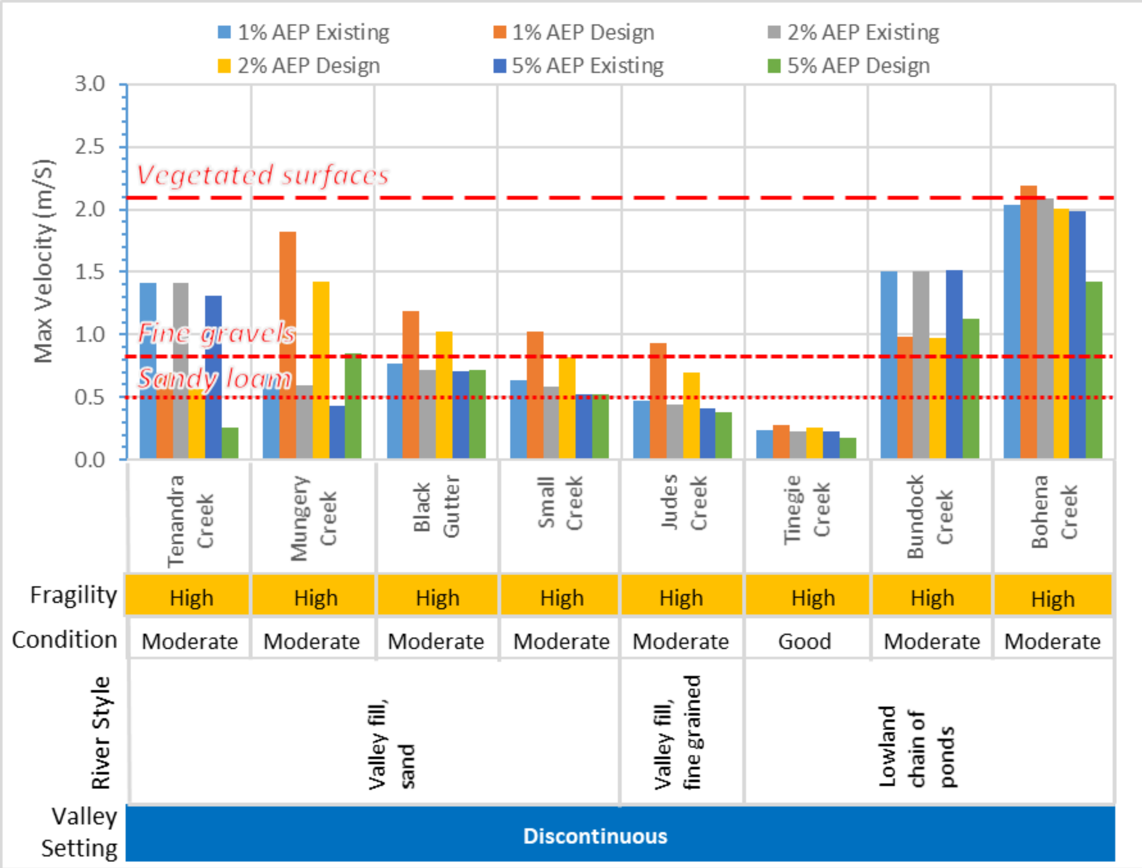

Figure 7.14 Change in maximum velocity for Discontinuous River Styles

Overland flow paths

Within overland flow paths that are away from defined watercourses, existing flood behaviour is generally characterised by widespread shallow flows with low velocities. The flood modelling results and impact assessments of afflux and velocity indicate the existing overland flood behaviour is not expected to significantly change following construction of the proposal. Therefore, the propensity of soils to scour and risk of erosion within overland flow paths is not expected to increase as a result of the proposal.

7.2.3 General operation

General operations associated with the use of constructed rail and road infrastructure have the potential to cause geomorphological impacts on the waterways as a result of:

- Works to maintain integrity and hydraulic performance of instream structures, including:
  - Culvert/bridge works to remove build-up of sediments, vegetation and wood to maintain hydraulic capacity.
  - Maintenance work to repair damages experienced as a result of flood events (ie loss of rock from channel bed and banks).
- Use of and maintenance of access road, including:
  - Erosion and sedimentation arising from increased runoff from roads and transport downstream.

7.3 Summary of potential operational impacts and risks

The following sections summarise the key potential operational impacts and risks associated with the proposal. Detailed mitigation measures that minimise potential operational impacts are provided in Section 9.

7.3.1 Flooding and hydrology

The operational phase of the proposal will result in some minor changes to existing flood behaviour that has the potential to impact flooding to existing buildings, roads, railways, and agricultural cropping and grazing areas.

Afflux upstream of the proposal is typically between 0.05 and 0.2 metres, while localised increases in flood levels immediately downstream of drainage structures typically range between about 0.05 and 0.1 metres. Adverse changes in flood hazard are typically constrained to areas immediately adjacent to the operational footprint, and changes in duration of flooding are typically negligible.

The impact of the proposal on flooding to existing buildings is most apparent at Narromine and Narrabri. There are 51 buildings located near or in Narrabri and 14 buildings at Narromine that are subject to above floor flooding and impacted more than 10 millimetres due to the proposal in the 1% AEP event. This represents about one per cent of buildings within the study area already affected by 1% AEP flooding.

For the purposes of this assessment:

- Buildings include residences, educational facilities, health facilities, community facilities, commercial/industrial premises and other structures (such as garages).
- Sensitive buildings include all of the above buildings but do not include other structures.

Further analysis of above floor flooding for the 1% AEP flood event by building type predicts that for:

- All buildings – 6,100 would be subject to above floor flooding, of which 1,329 (22 per cent) have surveyed floor levels. This is nine less than existing conditions.
- Sensitive buildings – 2,567 would be subject to above floor flooding, of which 1,316 (51 per cent) have surveyed floor levels. This is six less than existing conditions and is comprised of nine that would no longer be subject to above floor flooding and three that are not currently subject to above floor flooding would experience above floor flooding.

The majority of impacted buildings are located near or within Narromine and Narrabri.

Of the 2,567 sensitive buildings subject to above floor flooding, the majority are predicted to experience a negligible change (ie less than 10 millimetre increase or decrease) to existing conditions.

A total of 71 buildings are predicted to be subject to above floor flooding and experience an afflux of greater than 10 millimetres. Of these 71 buildings, 22 are sensitive buildings that are predicted to experience an increase of between 10 and 100 millimetres, of which all but one experience above floor flooding under existing conditions.

Additional assessment and modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined above) and determine if the proposal could be modified so that flooding characteristics are not worsened or minimised as far as practicable, up to and including the 1% AEP event.

Conservative bridge loss coefficient adopted in the flooding assessment for all models except Narromine and Narrabri will be updated based on the detailed information on bridge span, piers and scour protection at the detailed design stage. In addition, bank of culverts longer than two to three TUFLOW model grids will be represented as two- dimensional structures in the TUFLOW model. If necessary, a longer bridge span and/or smaller bridge piers aligned with the direction of flood flow may be adopted where practical in detailed design to minimise impacts to buildings due to the proposal.

The impact of the proposal on flooding to highways, roads, railways, and agricultural land uses are generally negligible. There are some minor increases in the length of rail line overtopped by floodwaters for the Parkes to Narromine Line, Dubbo to Coonamble Line, Narrabri to Walgett Line, and Mungindi Line.

7.3.2 Geomorphology

The permanent presence of instream structures can cause hydraulic changes that have the potential to affect the geomorphological condition and stability of watercourses. An increase in water flowing through culverts and bridges has the potential to result in erosion and impacts on downstream stream stability. As discussed in Section 7.2.2 there would be a general overall reduction in peak velocities, with marginal increases for a limited number of watercourses.

The watercourses crossed by the proposal represent a range of conditions, with the majority already experiencing high levels of degradation and erosion due to existing land uses and flow velocities. Therefore, the modelled changes as a result of the proposal are unlikely to result in any significant changes to existing conditions. However, predicted flow velocities in a number of cases would exceed (as they currently do for the existing situation) the desirable velocities for sandy loams (0.5 metres per second), fine gravels (0.8 metres per second) and vegetated surfaces (two metres per second). As such, scour protection would be provided at bridges and culvert outlets as required. All scour protection would fit within the rail corridor. Typical layouts for scour protection are provided in Section 7.1.7.

Within overland flow paths that are away from defined watercourses, existing flood behaviour is generally characterised by widespread shallow flows with low velocities. The flood modelling results and impact assessments of afflux and velocity indicate the existing overland flood behaviour is not expected to significantly change following construction of the proposal. Therefore, the propensity of soils to scour and risk of erosion within overland flow paths is not expected to increase as a result of the proposal.

During operation, the activities which pose the highest risk and could result in channel and floodplain instabilities are:

- Scour at railway culvert and bridge crossings – faster flows at railway crossing, at piles or edges of rail embankments could lead to potential scouring of waterways.
- Maintenance/repair of instream structures – removal of sediment, vegetation and wood from instream structures has the potential to change hydraulics upstream and downstream which may impact on condition and stability of the waterway.
- Use of and maintenance of access roads – erosion and sedimentation arising from increased runoff from roads and transport downstream.

8. Cumulative impact assessment

8.1 Overview

For an EIS, cumulative impacts can be defined as the successive, incremental, and combined effect of multiple impacts, which may in themselves be minor, but could become significant when considered together. The methodology and projects considered for the cumulative impact assessment are provided in detail in the EIS (Part D chapter D1). The study area for the cumulative flooding and hydrology assessment is defined by the surface water catchments traversed by the proposal. Seven major projects were identified as having a cumulative impact and sufficient information to undertake a cumulative impact assessment. These include:

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

8.2 Flooding and geomorphology

The relevant projects and assessment of cumulative flooding and geomorphology impacts is provided in Table 8.1 and shown in Figure 8.1. The assessment of cumulative impacts is based on the most current and publicly available information. In many instances this is a high-level qualitative assessment.

Table 8.1 Cumulative flooding and geomorphology impacts

Project and status	Cumulative impacts
Western Slopes Pipeline Not yet approved	Construction of the pipeline and the proposal have the potential to overlap. Cumulative construction impacts on flooding and geomorphology are expected to be short term and may include localised changes to flooding regimes due to obstacles to overland flow; and localised geomorphology impacts due to disturbance of waterway bed and banks. Cumulative operational impacts to flooding and geomorphology would be negligible as the pipeline will be located below the ground and will not affect flood behaviour.
Inland Rail - Narrabri to North Star Not yet approved.	The interface between is located at a catchment divide of relatively small tributaries where there is limited interaction or overlap of flood behaviour. As such, cumulative flooding and geomorphology impacts during construction and operation would be minor.
Inland Rail - Parkes to Narromine Approved. Under construction.	The connection between the proposal and Parkes to Narromine Line is located at a minor creek called Yellow Creek where existing 1% AEP peak flood depths behind the Parkes to Narromine line are typically less than one metre deep. The potential cumulative operational flood and geomorphology impacts are considered minor.

Project and status	Cumulative impacts
Narrabri Gas Project Not yet approved.	The proposal is located on the northern boundary of the gas processing and water treatment facilities and will pass through the gas field within Pilliga East State Forest. Planning approval for the Narrabri Gas Project is expected in mid-2020, with drilling to commence mid-2020. Construction of the proposal and the Narrabri Gas Project have the potential to overlap. A hydrology and geomorphology assessment carried out for the Narrabri Gas Project found there would be negligible flooding and geomorphology impacts associated with the construction and operation of the project. Cumulative geomorphic impacts, such as erosion or deposition, would be localised and negligible with the implementation of suitable construction and mitigation measures such as erosion and sediment controls. The key potential impact on hydrology and geomorphology from the Narrabri Gas Project would be associated with the managed release of treated water to Bohena Creek. The assessment found there would be no impacts to flood levels or water volumes when releases are made under appropriate flow conditions. The study also found that due to the relatively small and dispersed footprint of the project there would be low residual risk from flooding. Hence the Narrabri Gas Project would have no impact on flood discharges and levels at the proposal site, and there would be no cumulative flooding or geomorphology impacts associated with the proposal and Narrabri Gas Project.
Silverleaf Solar Farm Not yet approved.	There is the potential for construction of the proposal and the Silverleaf Solar Farm to overlap. The extent of soil disturbance during construction of the solar farm is expected to be minor and potential impacts would be minimised with local stormwater and erosion and sediment controls. The magnitude of cumulative construction impacts associated with flooding and geomorphology would be localised and minor. The solar farm would result in removal of existing site dams and small additional hardstand areas for site infrastructure. The dam removal and relatively small extent of the proposed impermeable areas of the solar farm (less than 1% of the total site area) would not cause any appreciable changes in flood behaviour. Therefore, operational cumulative impacts for flooding and geomorphology are expected to be minor.
Narromine Solar Farm Approved.	It is considered unlikely that construction of the solar farm and the proposal would overlap. Therefore, no cumulative construction impacts to flooding and geomorphology would occur. Operation of the solar farm would result in a marginal increase in imperviousness of the site. Any flooding and geomorphology impacts would be minor and manageable considering the topographic relief of the site. Cumulative operational impacts would therefore be minor.
Gilgandra Solar Farm Approved.	Due to the large distance between the project sites, cumulative construction and operational impacts to flooding and geomorphology would be negligible.

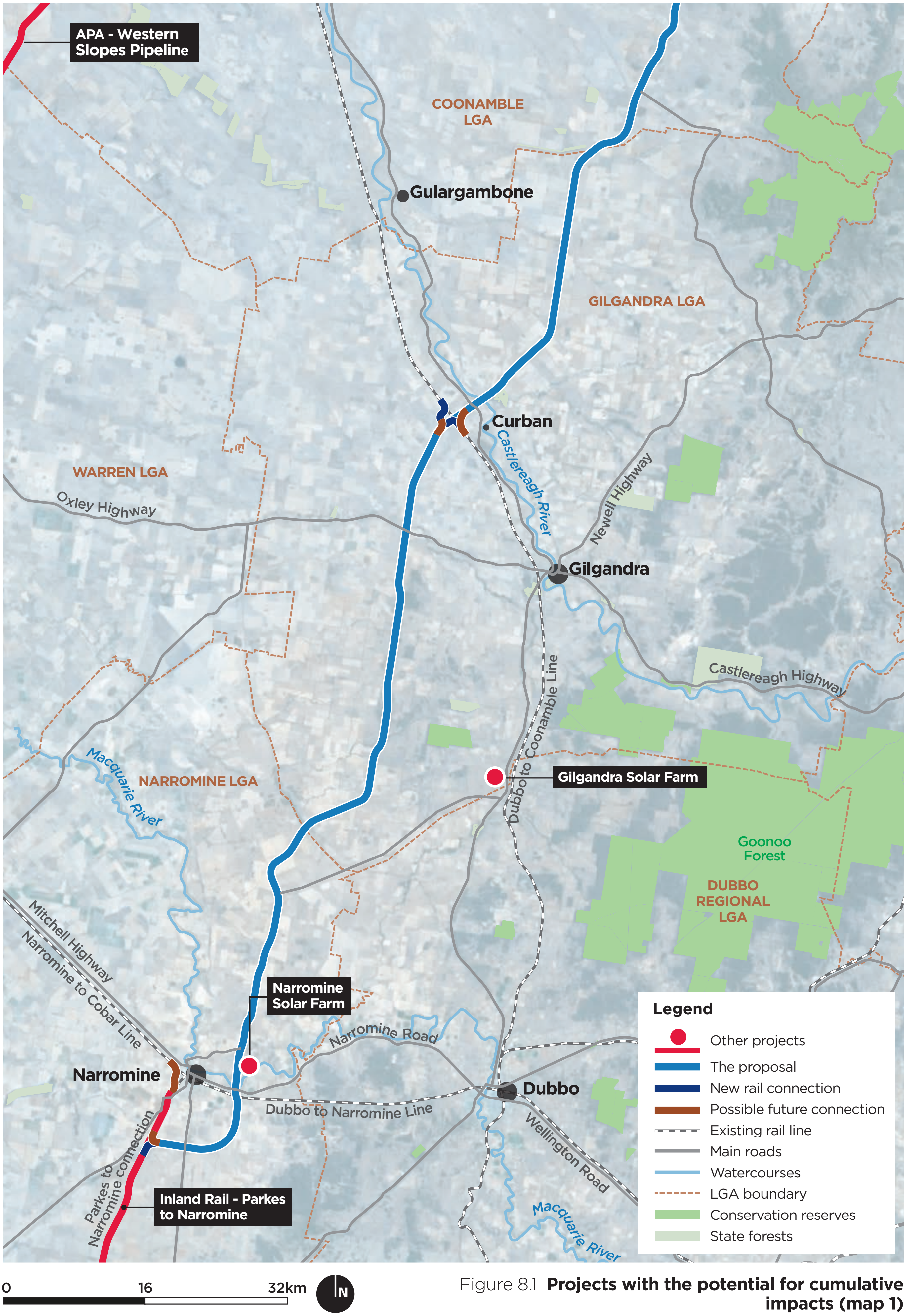

Figure 8.1 **Projects with the potential for cumulative impacts (map 1)**

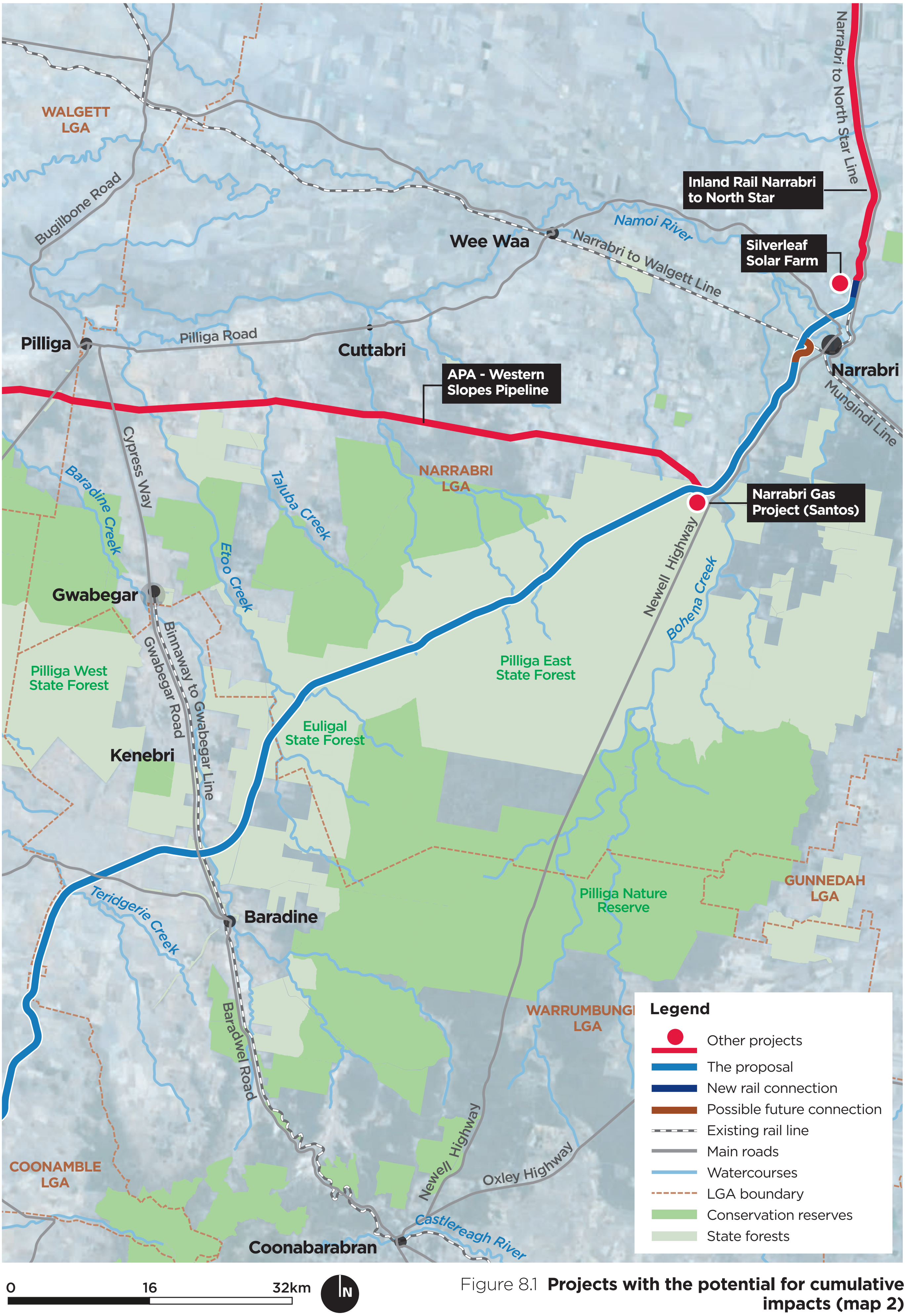

Figure 8.1 **Projects with the potential for cumulative impacts (map 2)**

9. Recommended mitigation measures

9.1 Mitigation measures

Measures to avoid, minimise or manage impacts to flooding and hydrology, and geomorphology are detailed in Table 9.1.

Table 9.1 Mitigation measures

Stage	Issue/impact	Mitigation measures
Detailed design / pre-construction	*Flooding impacts*	The design would continue to be refined where practicable to not worsen existing flooding characteristics at sensitive buildings, up to and including the 1% AEP event. Detailed flood modelling would consider potential changes to: • Building and property inundation (including floor level surveys and consideration of existing inundation levels) • Existing rail line, at rail connections • Road flood levels and extent of flooding along roads • Overland flow paths and storage effects of construction and operational infrastructure Flood modelling would have regard to the guidelines listed in section 2. Flood modelling, and any mitigation identified as an outcome of modelling, would consider floodplain risk management plans, and would be undertaken in consultation with the relevant local council and local emergency management committees, the Department of Planning, Industry and Environment, the NSW State Emergency Service and potentially impacted landholders.
	Downstream watercourse stability	Further modelling would be undertaken during detailed design to confirm the locations downstream of culverts that require erosion protection, and to confirm the extent and type of protection required.
Construction	*Flooding impacts*	Construction planning and the layout of construction work sites and compounds would be undertaken with consideration of overland flow paths and flood risk, avoiding flood liable land and flood events where practicable.
		A flood and emergency response plan would be prepared and implemented as part of the CEMP. The plan would include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It would also include measures to manage flood risks during construction and address flood recovery during construction.

Stage	Issue/impact	Mitigation measures
	Downstream watercourse stability	A geomorphology monitoring program would be implemented in accordance with the soil and water management plan. The monitoring would observe any changes in the geomorphological stability of the waterways that may be attributable to the proposal and to inform appropriate management responses. The monitoring program would be developed in consultation with the Department of Planning, Industry and Environment and with reference to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Governments, 2018).
	Flooding impacts (temporary accommodation facilities)	The Narromine South and Narrabri West temporary workforce accommodation facilities would incorporate appropriate flood protection measures, such as elevating buildings on stilts and storing hazardous materials above the flood levels that inundate these sites.

9.2 Proposed monitoring program

A geomorphology monitoring program would be implemented in accordance with the soil and water management plan as part of the construction environmental management plan for the proposal. The monitoring would observe any changes in the geomorphological stability of the waterways that may be attributable to the proposal and to inform appropriate management responses. The program would be developed in consultation with DPIE and relevant councils and with reference to *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Governments, 2018).

The monitoring frequency during construction would be confirmed during detailed design however would include at least monthly construction monitoring at all monitoring sites, including event-based monitoring where practicable, following wet weather events. The physical condition of bed and banks of the waterway upstream and downstream of railway culverts and bridges should be regularly monitored, particularly after flooding once the channels have returned to low or cease-to-flow conditions so to permit inspection of the condition of the waterway and instream structures. The outcomes of this monitoring would also inform asset maintenance works (ie removal of sediments, blockages, repair of bed and bank stabilisation works).

10. Conclusion

The proposal traverses the catchments of the Namoi River, the Castlereagh River and the Macquarie-Bogan River. While these catchments rise near the Great Dividing Range, the study area itself is characterised by moderately flat catchments and floodplains. Major land uses within these catchments include grazing, dryland cropping and conservation, with the majority of the construction activities for the proposal occurring within greenfield land.

The construction phase of the proposal has the potential to change existing flood behaviour. Construction compounds and activities such as earthworks, stockpiling and instream works have the potential to obstruct the passage of floodwater and overland flow, which in turn could exacerbate existing flooding conditions.

Prior to construction, flood and emergency response plan would be prepared and implemented as part of the CEMP. The plan would include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It would also include measures to manage flood risks during construction and address flood recovery during construction.

The operational phase of the proposal would result in some minor changes to existing flood behaviour that has the potential to impact flooding to existing buildings, roads, railways, and agricultural cropping and grazing areas.

The impact of the proposal on flooding to existing buildings is most apparent at Narromine and Narrabri. There are 51 buildings located near or in Narrabri and 14 buildings at Narromine that are subject to above floor flooding and impacted more than 10 millimetres due to the proposal in the 1% AEP event. This represents about one per cent of buildings within the study area already affected by 1% AEP flooding.

For the purposes of this assessment:

- Buildings include residences, educational facilities, health facilities, community facilities, commercial/industrial premises and other structures (such as garages).
- Sensitive buildings include all of the above buildings but do not include other structures.

Further analysis of above floor flooding for the 1% AEP flood event by building type predicts that for:

- All buildings – 6,100 would be subject to above floor flooding, of which 1,329 (22 per cent) have surveyed floor levels. This is nine less than existing conditions.
- Sensitive buildings – 2,567 would be subject to above floor flooding, of which 1,316 (51 per cent) have surveyed floor levels. This is six less than existing conditions and is comprised of nine that would no longer be subject to above floor flooding and three that are not currently subject to above floor flooding would experience above floor flooding.

The majority of impacted buildings are located near or within Narromine and Narrabri.

Of the 2,567 sensitive buildings subject to above floor flooding, the majority are predicted to experience a negligible change (i.e. less than 10 millimetre increase or decrease) to existing conditions.

A total of 71 buildings are predicted to be subject to above floor flooding and experience an afflux of greater than 10 millimetres. Of these 71 buildings, 22 are sensitive buildings that are predicted to experience an increase of between 10 and 100 millimetres, of which all but one experience above floor flooding under existing conditions.

Additional assessment and modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined above) and determine if the proposal could be modified so that flooding characteristics are not worsened or minimised as far as practicable, up to and including the 1% AEP event.

The waterways within the study area are generally in poor to moderate geomorphic condition with moderate to high fragility. The construction and the operation of the proposal has the potential to impact on the waterways within the study area. Potential impacts to geomorphology could result from:

- Erosion of soils and sedimentation of waterways
- Changes to flow rates, volumes and flow paths within waterways and drainage lines
- Permanent watercourse crossings and construction of bridges altering flow and water quality
- Runoff from the rail and road infrastructure

To minimise the impacts to surface water quality a range of measures would be refined and/or implemented during detailed design and the construction and operational phases of the proposal.

Overall with the implementation of the proposed mitigation measures, the proposal is expected to have minimal impacts on geomorphology values during both the construction and operation phases.

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Appendices