PART B
Impact assessment
proposal infrastructure

INLAND RAIL

CHAPTER B3
Flooding

Narromine to Narrabri
Environmental Impact Statement

ARTC

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

IR_1929

Contents

Figures

Tables

B3. Flooding

This chapter provides a summary of the impacts of the Narromine to Narrabri project (the proposal) on flooding. A full copy of the assessment results is provided in Technical Report 3—Flooding and hydrology assessment.

B3.1 Approach

A summary of the approach to the assessment is provided in this section, including the legislation, guidelines and/or policies driving the approach and the methodology used to undertake the assessment. A more detailed description of the approach and methodology is provided in Technical Report 3.

B3.1.1 Legislative and policy context to the assessment

Relevant legislation, policies and guidelines

The assessment was undertaken in accordance with the SEARs and with reference to the requirements of relevant legislation, policies and/or assessment guidelines, including:

- The EP&A Act, *Water Management Act 2000* (NSW), *Water Act 1912* (NSW) and the *Dams Safety Act 2015* (NSW)
- New guideline and changes to section 117 direction and EP&A Regulation on flood prone land, Planning Circular PS 07-003 (Department of Planning, 2007) and *Floodplain Development Manual: The Management of Flood Liable Land* (DIPNR, 2005)
- *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Ball et al., 2019)
- The flood-related planning controls contained in local planning instruments relevant to the study area—the *Narromine Local Environmental Plan 2011*, *Gilgandra Local Environmental Plan 2011*, *Warrumbungle Local Environmental Plan 2013, Coonamble Local Environmental Plan 2011* and *Narrabri Local Environmental Plan 2012*
- Relevant local flood studies and plans—*Narromine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2009); *Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020* (NSW Government, 2020); *Narrabri Flood Study—Namoi River, Mulgate Creek and Long Gully* (WRM, 2016); *Narrabri Floodplain Risk Management Study and Plan, Volume I: Supplementary Flood Study—Namoi River, Mulgate Creek and Long Gully* (WRM, 2019); *Gilgandra Shire Local Flood Plan* (SES, 2008); *Warrumbungle Shire Flood Emergency Sub Plan* (SES, 2013); *Narromine Shire Flood Emergency Sub Plan* (SES, 2014); and *Narrabri Shire Flood Emergency Sub Plan* (SES, 2015)
- *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)
- *Engineering Practices Manual, Civil Engineering, Track Drainage—Design and Construction* (ARTC, 2013).

Secretary's Environmental Assessment Requirements

The SEARs relevant to flooding, together with a reference to where they are addressed in the EIS, are provided in Appendix A.

B3.1.2 Methodology

Study area

The study area for the assessment was defined based on the watercourses and associated floodplains crossed by the proposal site. It comprises the proposal site together with an area of the floodplain (upstream and downstream) to include any potential changes due to the proposal.

Key tasks

Key tasks undertaken for the flooding and geomorphology assessments of the proposal are outlined below. Further information on the methodology is provided in Technical Report 3.

Flooding

The assessment involved:

- Identifying rainfall runoff and peak flows for each catchment through a review of existing flood studies and models, existing climatic conditions, existing stream gauge data and hydrological modelling and analysis
- Undertaking hydraulic modelling using a range of different flood models (see below)
- Using the results of modelling to assess the potential impacts of constructing and operating the proposal on buildings, infrastructure and land uses
- Recommending mitigation and management measures for identified impacts.

Modelling

Hydrological modelling and analysis was undertaken to identify runoff and flow for a range of rainfall events in the catchment areas through which the proposal site passes. Rainfall runoff and peak flows for each catchment were identified through a combination of existing flood studies and models, existing climatic conditions and existing stream gauge data. Where existing models were available these were incorporated into the models that were developed for the proposal.

Hydraulic modelling was then undertaken to define flood levels, flood depths, flood hazard and velocities in the channels and floodplains that are traversed by the proposal site. Flood hazard is defined in categories from low (generally safe for people, vehicles and properties) to extreme (unsafe for vehicles and people and all building types considered vulnerable to failure). Refer to Technical Report 3 for further details on the classifications.

Due to the length of the proposal site, 14 hydraulic models were developed. Each hydraulic model covers a portion of the proposal site and an area of the floodplain upstream and downstream in order to include any potential upstream breakouts and changes in flood behaviour due to the proposal.

Modelling of a range of flood events was undertaken for the existing conditions and operational phase (i.e. with the proposal in place). This included the 20, five, two, one, 0.5 and 0.2 per cent annual exceedance probability (AEP) and the probable maximum flood (PMF) flood events. Impacts due to climate change were also assessed using guidelines from *Australian Rainfall and Runoff; A Guide to Flood Estimation* (Ball, et al., 2019). This scenario involved simulation of the 1 per cent (%) AEP flood event with a 22.8 per cent increase in rainfall depth. Modelling of the selected construction scenario (i.e. with the proposal partially constructed) was undertaken for the 20, five and one per cent (%) AEP flood events.

The models were calibrated against observed stream data and recorded flood levels and validated against relevant information, including consultation with councils, other independent estimates and methods detailed in *Australian Rainfall and Runoff; A Guide to Flood Estimation* (Ball, et al., 2019). Additional model validation was also undertaken based on feedback from landholders regarding historic flood behaviour. During landholder meetings (see Table A4.1) landholders were shown mapping of the 1% AEP event under existing conditions. Feedback from this consultation indicated that the majority of people agreed that the mapping was accurate. Where feedback was received that the mapping needed refinement, this was considered, as relevant, in the ongoing development of the flood models.

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

Further information on the modelling undertaken is provided in Technical Report 3. The models were also independently peer reviewed as described in Technical Report 3.

Geomorphology

The assessment involved:

- Identifying the existing geomorphology conditions of the watercourses traversed by the proposal site based on targeted site inspections and a desktop review of available spatial data and information, including the state-wide River Styles Spatial Layer and associated reports that document the River Styles Assessments
- Comparing the predicted flow velocities from hydraulic modelling with the existing conditions
- Assessing the potential impacts of constructing and operating the proposal on watercourse geomorphology
- Recommending mitigation and management measures for identified impacts.

B3.1.3 Risks identified

The environmental risk assessment for the proposal (see Appendix E) included an assessment of the potential risks associated with flooding. The assessed level for the majority of potential risks was medium to high. Risks with an assessed level of medium or above included:

- Impact of flooding on unprotected areas during construction resulting in wash-outs or erosion
- Sedimentation and changes to geomorphology in watercourses during construction
- Presence of, or change to, structures associated with construction and operation could impact upstream and downstream flood behaviour
- Potential changes to road overtopping frequencies and levels impacting emergency service management during operation
- Changes to flood characteristics as a result of impacts on the hydraulics of the catchment during operation.

The flooding and hydrology assessment considered the potential risks identified by the environmental risk assessment, in addition to potential risks and impacts identified by the scoping report (see section A9.1), the SEARs and relevant guidelines and policies (as appropriate).

B3.1.4 How potential impacts have been avoided/minimised

The proposal has been designed to avoid and minimise potential flooding impacts and modifications to surface flows as far as possible. The strategies that have been, and would continue to be, implemented include:

- Designing the proposal to keep the track and ballast above the one per cent (%) AEP flood event level and limit afflux to residences and key infrastructure to 10 millimetres (mm), where practicable
- Designing flow discharge points (culverts and longitudinal drainage) to include erosion controls, such as rock protection, to slow flow velocities and minimise the risk of erosion as surface water enters and exits the structure
- Designing bridges and culverts to have a minimal impact on existing surface flow paths across the proposal site.

B3.2 Existing environment

B3.2.1 Catchments and watercourses

The proposal is located within the major regional water catchments of the Macquarie River, Castlereagh River and Namoi River, all of which are located within the Murray-Darling Basin. The total upstream catchment area of the three rivers is:

- Macquarie River—about 25,900 square kilometres (km^2)
- Castlereagh River—6,630 km^2
- Namoi River—25,400 km^2.

Further information on the catchments, and watercourses crossed by the proposal site, is provided in chapter B2. The catchments and watercourses are shown in Figure B2.1.

With the exception of the Macquarie River, Namoi River and Narrabri Creek, which are perennial (permanent) watercourses, surface water within the proposal site is characterised by non-perennial (ephemeral or intermittent) watercourses. This is a result of the size of the contributing catchment area, rainfall pattern and lack of base flow resulting from groundwater expression.

A geomorphic condition assessment undertaken for 40 of the watercourses crossed by the proposal site identified that, in accordance with the River Styles Assessment methodology, only the Macquarie River, Ewenmar Creek and Tinegie Creek are in good condition. The majority (27) were assessed as having moderate condition. The remainder (10) were assessed as having poor condition. The moderate and poor condition watercourses are typically degraded where sediment regimes have been altered as a result of existing land uses and vegetation removal. Significant erosion of the bed and banks is evident. In addition, the fragility of all watercourses was assessed as moderate to high. An assessment of other minor non-perennial watercourses was not undertaken as there was insufficient information to extrapolate the assessment.

A list and description (including an assessment of geomorphic condition) of the watercourses crossed by the proposal site is provided in Technical Report 3.

B3.2.2 Flooding

Flooding characteristics

General

In general, the study area is characterised by relatively flat land, with flooding tending to quickly break out of the main channels and inner floodplains of watercourses, resulting in broad-scale inundation of floodplains. A summary of the key results of the flood modelling undertaken for the assessment is provided below. Further information and full modelling results are provided in Technical Report 3.

The frequency of flood events is generally referred to in terms of their annual exceedance probability (AEP). For example, for a five per cent AEP flood, there is a five per cent probability (or a one in 20 chance) that there would be floods of a greater magnitude each year. For a one per cent AEP flood, there is a one per cent probability (or a one in 100 chance) that there would be floods of greater magnitude each year.

Areas of existing flooding inundation for a range of flood events are summarised in Table B3.1. Existing flooding extents for the one per cent AEP event are shown in Figure B3.1.

TABLE B3.1 TOTAL AREAS OF FLOODING—EXISTING

Flood event	Area of existing inundation (hectares)
20% AEP	52,521
5% AEP	77,271
1% AEP	106,564
1% AEP with climate change	126,042
PMF	245,482

Extents and depths

Around Narromine, flooding is typically constrained to the Macquarie River (and associated tributaries) and adjacent floodplains during smaller more frequent events, such as the 20% AEP event. During larger floods, such as the 1% AEP event, there is significant riverine flooding in the Macquarie River and Wallaby Creek, of up to 7.5 metres (m) deep.

In small, frequent flood events, such as the 20% AEP, flooding is generally constrained to the main channel and floodway for the Castlereagh River and Marthaguy Creek. In the 1% AEP event flooding extends up to 800 m from the Castlereagh River, with depths up to 2.5 m, and up to 600 m from Marthaguy Creek, with depths up to 1.8 m. Overland flood depths associated with headwaters of Merrigal Creek and Bullagreen Creek are between 0.2 and 0.5 m.

Around Narrabri, flooding is typically constrained to the Namoi River and Narrabri Creek with some overtopping during smaller, more frequent, events, such as the 20% AEP. In larger flood events, flooding extents occur across large areas of Narrabri and surrounds. In the 1% AEP event, flood depths can be up to 1.8 m. This can affect residential and commercial properties and community infrastructure, including schools and hospitals.

For the majority of other catchments located along the proposal site, flooding in the 1% AEP event is typically characterised by widespread, but relatively shallow, overland flows. In smaller, more frequent events, flooding is usually limited to the main channels and immediate surrounds.

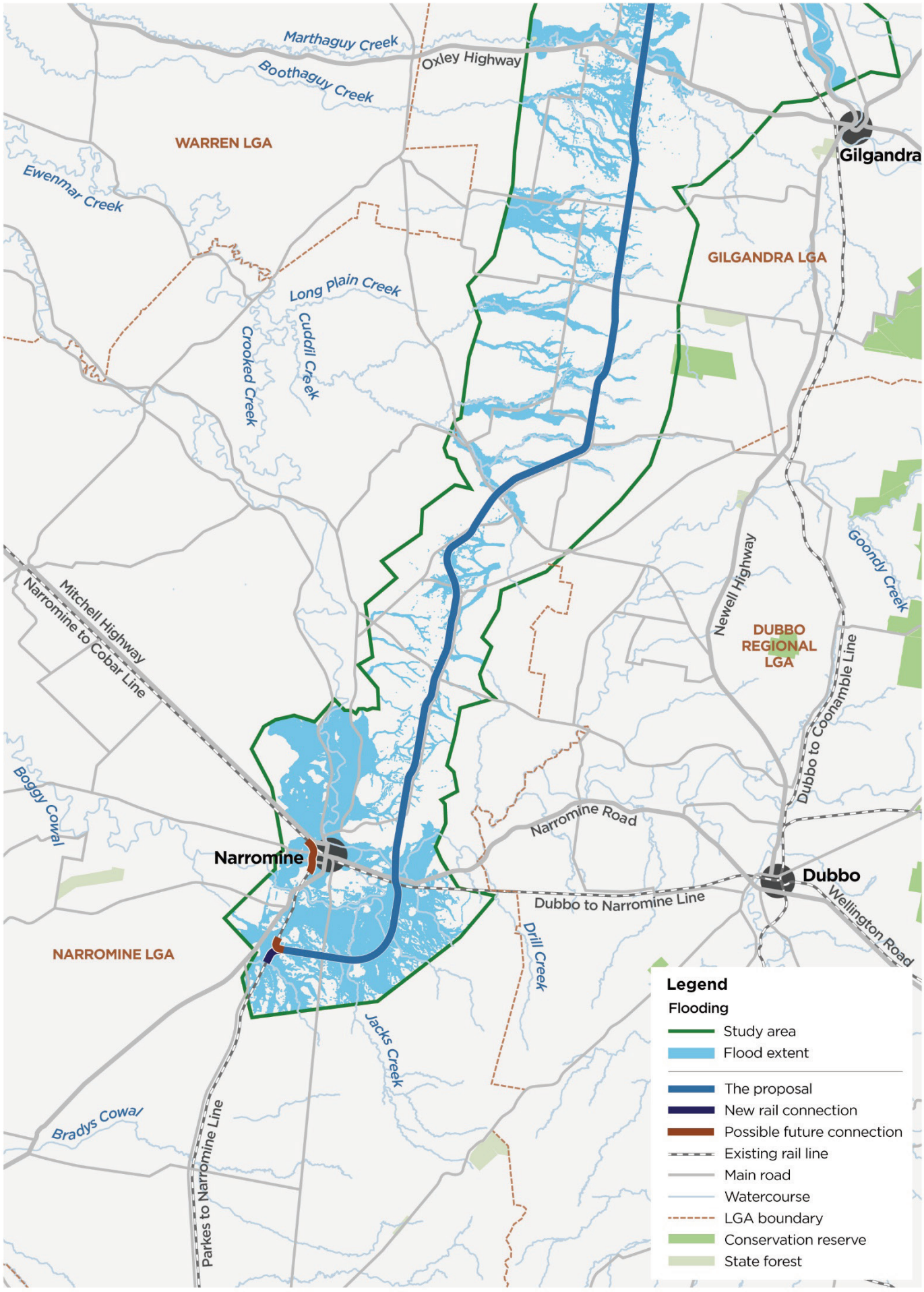

Figure B3.1 **Existing flooding extents - one per cent AEP event (map 1)**

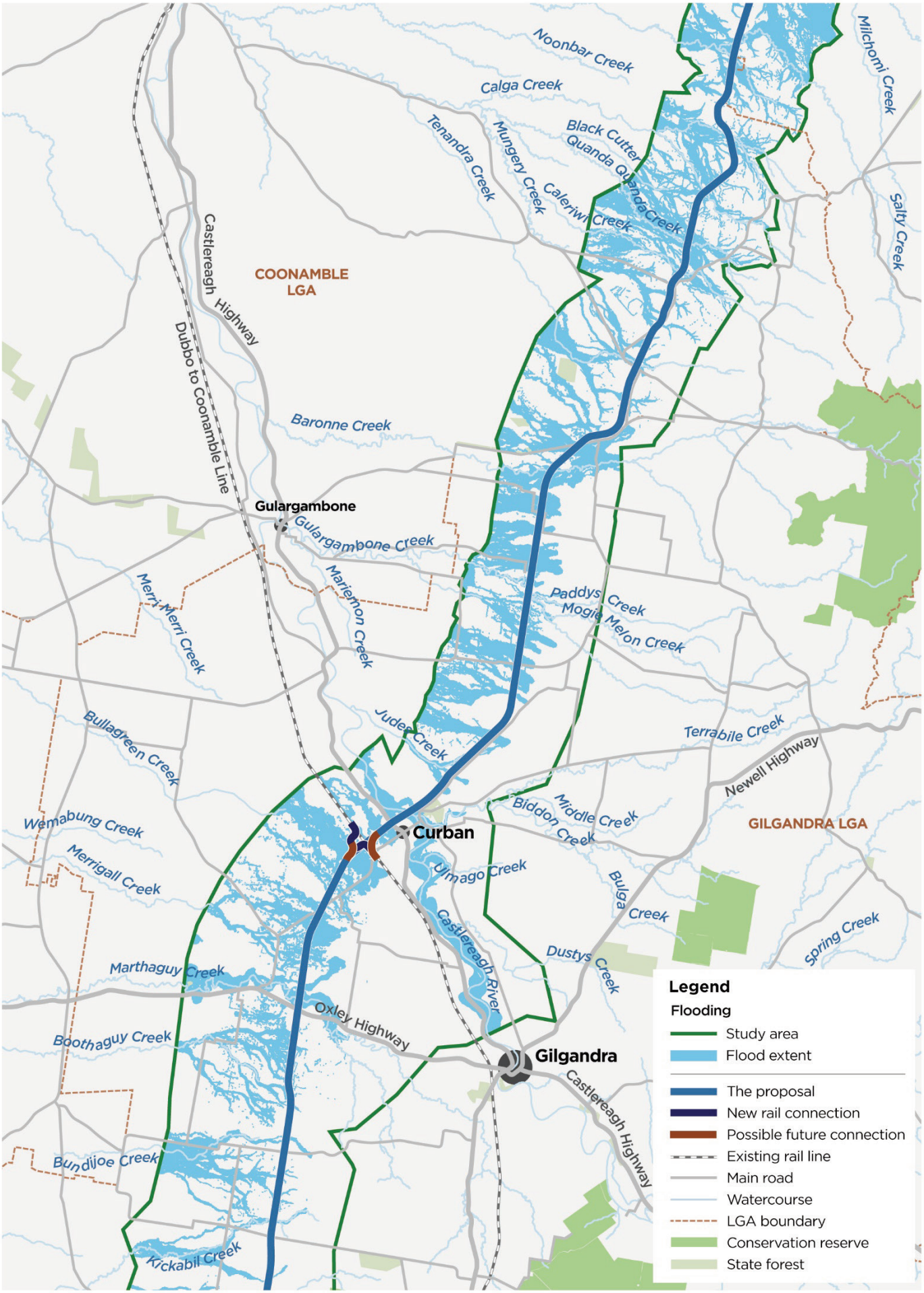

Figure B3.1 **Existing flooding extents - one per cent AEP event (map 2)**

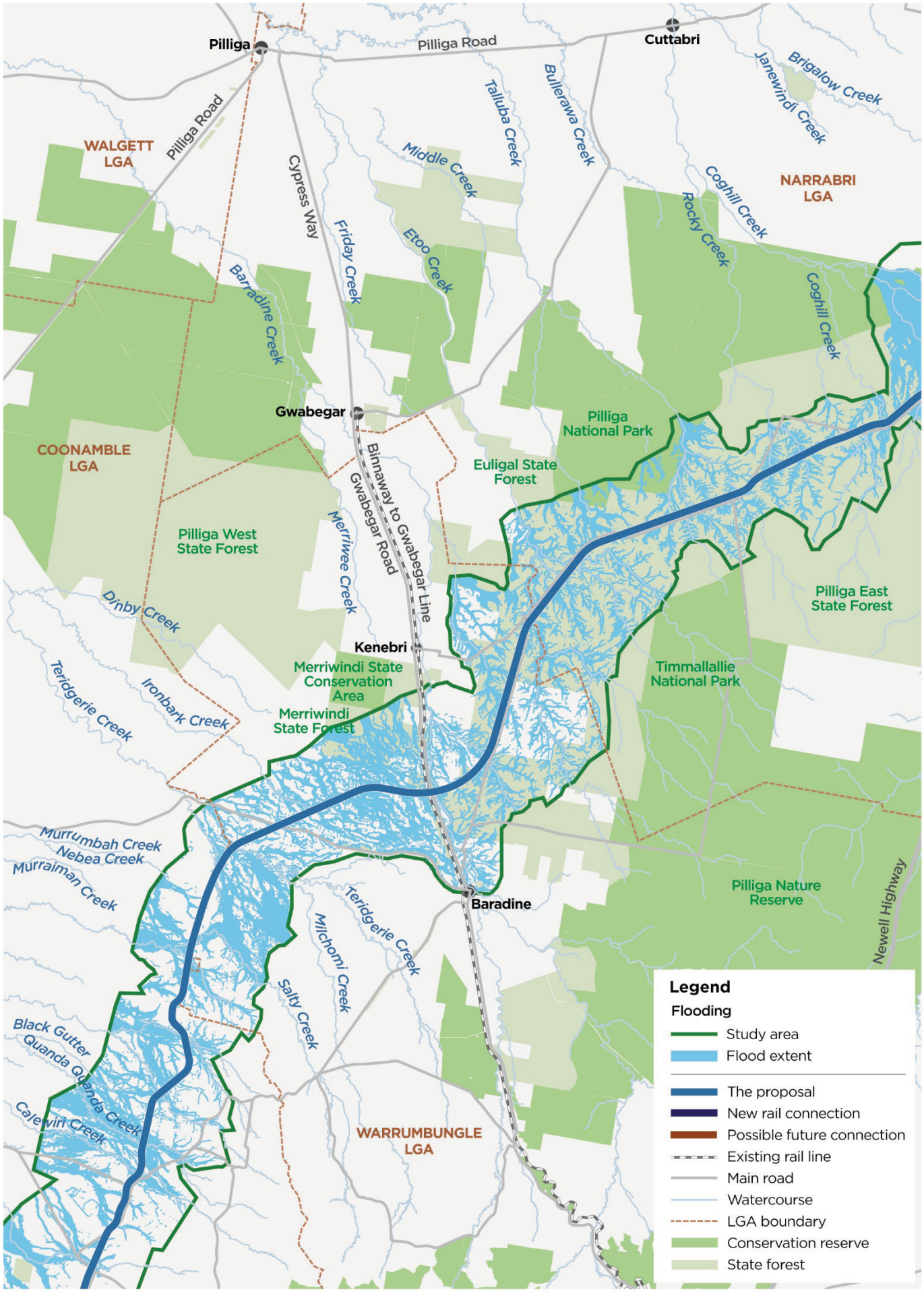

Figure B3.1 **Existing flooding extents - one per cent AEP event (map 3)**

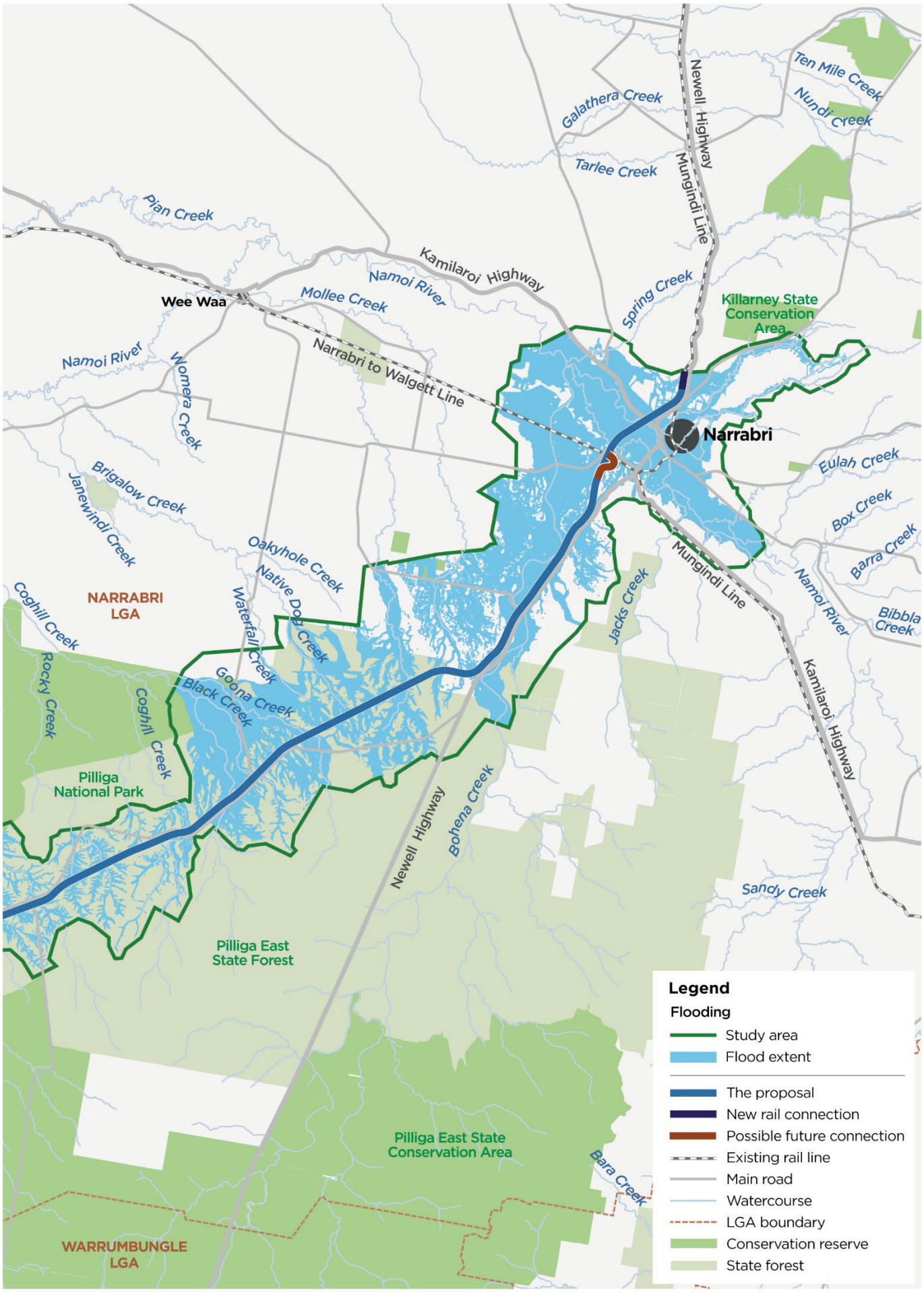

Figure B3.1 **Existing flooding extents - one per cent AEP event (map 4)**

Flood hazard

Flood hazards around the Macquarie River and Wallaby Creek channels and inner floodplains vary from low, during the 20% AEP event, to very high to extreme in the 1% AEP event. Throughout Narromine, flood hazard is typically moderate to high, with localised zones of very high and extreme in the 1% AEP event.

In the 1% AEP event, flood hazards around the Castlereagh River are typically high to very high. Around Marthaguy Creek, hazards are typically moderate to very high. Flood hazard associated with areas of overland flooding is typically low.

In small frequent flood events, such as the 20% AEP, flood hazard within the overland flow from Namoi River and Narrabri Creek (and associated tributaries) are low. In the 1% AEP event flood hazards increase substantially and vary widely, but typically vary between moderate to high and, in some cases, high to extreme.

For the majority of other catchments located along the proposal site, flood hazard in the 1% AEP event is typically characterised by moderate to very high in the main channels/inner floodplains and low to moderate in areas of overland flooding. Floodplains around some watercourses, such as Bucklanbah Creek, Teridgerie Creek, Baradine Creek and Bohena Creek, have areas of high to extreme flood hazard in the 1% AEP event.

Flow velocities

Peak flow velocities under existing conditions for a range of flood events, based on hydraulic modelling, are summarised in Table B3.2 for all watercourses (based on the River Styles® framework). Peak flows for the 20% AEP and 1% AEP events, respectively, are:

- Macquarie River—1.3 to 1.9 metres per second (m/s)
- Castlereagh River—1.9 to 3 m/s
- Namoi River—1.7 to 2.4 m/s
- Other watercourses—up to 2.3 m/s in the 20% AEP and up to 3.4 m/s in the 1% AEP.

As noted in section B3.2.1, the majority of watercourses are in poor to moderate condition and have a moderate to high fragility. This indicates that the majority are already experiencing high levels of degradation and erosion due to existing land uses and flow velocities.

TABLE B3.2 SUMMARY OF PEAK FLOW VELOCITIES (METRES PER SECOND)—EXISTING

River style	20% AEP	5% AEP	1% AEP	PMF
Confined valley	0.9 to 1.4	0.3 to 1.8	0.4 to 2	2.2 to 5.1
Partly confined valley	0.8 to 1.9	1.3 to 3.3	1.3 to 3	2.8 to 5.7
Laterally unconfined valley	0.6 to 2.3	0.7 to 3	0.7 to 3.4	1.8 to 3.9
Discontinuous	0.2 to 1.8	0.2 to 1.5	0.2 to 2	0.9 to 5.3

Inundation time

Flood durations in the 1% AEP event typically vary between 40 and 80 hours for the Macquarie River, 40 and 50 hours for the Castlereagh River and 20 and 45 hours around Narrabri. For the majority of other catchments located along the proposal site, flood duration in the 1% AEP event is typically characterised by inundation of floodplains for up to 20 hours, with areas of limited ponding around some watercourses for up to 50 hours.

Rail lines

Table B3.3 provides a summary of the potential overtopping of existing rail lines for a range of flood events, as follows:

- Length (kilometres) located on land subject to flooding that could result in overtopping of the rail line
- Maximum duration (hours) where flood levels are more than 0.5 m above ground level and could result in overtopping of the rail line.

Except for the Main Western Line (Dubbo to Narromine Line and Narromine to Cobar Line), all existing operational rail lines are potentially subject to relatively minor extents and duration of flooding in the 20% AEP event. In 1% AEP event, all existing operational rail lines are potentially flooded for extended periods (44 to 65 hours), with the exception of the Dubbo to Coonamble Line, which is inundated for one hour.

TABLE B3.3 SUMMARY OF POTENTIAL OVERTOPPING OF EXISTING RAIL LINES—EXISTING

Rail line	Overtopping	20% AEP	5% AEP	1% AEP	PMF
Main Western Line	Length (km)	0	0.1	2.1	14.3
	Duration >0.5 m (hours)	0	0	55	97
Parkes to Narromine Line	Length (km)	1.7	2.5	5.1	11.7
	Duration >0.5 m (hours)	8	20	54	99
Dubbo to Coonamble Line	Length (km)	0.5	0.6	0.7	22.5
	Duration >0.5 m (hours)	<0.1	1	1	30
Binnaway to Gwabegar Line (non-operational)	Length (km)	0.2	0.6	1.3	16.1
	Duration >0.5 m (hours)	23	44	26	29
Narrabri to Walgett Line (west of the proposal site)	Length (km)	2.3	5.5	6.6	8.8
	Duration >0.5 m (hours)	22	42	44	25
Narrabri to Walgett Line (east of the proposal site)	Length (km)	<0.1	<0.1	0.4	4.3
	Duration >0.5 m (hours)	80	71	54	58
Mungindi Line	Length (km)	0.1	0.9	4.1	13.1
	Duration >0.5 m (hours)	21	71	65	68

Roads

Table B3.4 provides a summary of the potential overtopping of existing highways and other roads for a range of flood events, as follows:

- Length (km) located on land subject to flooding that could result in overtopping of the road
- Maximum duration (hours) where flood levels are more than 0.5 m above ground level and could result in overtopping of the road
- Length (percentage) located on land subject to a high flood hazard.

The Oxley Highway, Newell Highway (Bohena Creek) and Kamilaroi Highway (minor extent only) are inundated for extended periods of time in the 20% AEP event, with the Newell Highway and Kamilaroi Highway being subject to a high flood hazard. The Castlereagh Highway is inundated in the 5% AEP event for up to 33 hours. In the 1% AEP event, all highways and extensive lengths of other named roads are inundated and subject to high flood hazards.

TABLE B3.4 SUMMARY OF OVERTOPPING OF EXISTING ROADS—EXISTING

Rail line	Overtopping	20% AEP	5% AEP	1% AEP	PMF
Mitchell Highway	Length inundated (km)	0.5	0.5	8.4	13.7
	Duration >0.5 m (hours)	0	0	48	94
	Length high hazard (%)	0	0	93	100
Castlereagh Highway	Length (km)	0	0.7	2.8	23.7
	Duration (hours)	0	33	58	43
	Length high hazard (%)	0	100	100	96
Oxley Highway	Length (km)	1	1.4	2.2	11.1
	Duration (hours)	34	35	39	53
	Length high hazard (%)	<0	92	88	92
Newell Highway (Bohena Creek)	Length (km)	2.6	9	11.1	16.5
	Duration (hours)	45	47	50	58
	Length high hazard (%)	85	99	99	99
Kamilaroi Highway	Length (km)	0	1.1	2.8	13.5
	Duration (hours)	58	69	58	61
	Length high hazard (%)	100	90	66	100

Rail line	Overtopping	20% AEP	5% AEP	1% AEP	PMF
Newell Highway (Narrabri Creek/Namoi River)	Length (km)	0	0.1	1.7	8.7
	Duration (hours)	0	8	43	58
	Length high hazard (%)	0	0	69	100
Other named roads	Length (km)	163	290	461	953
	Duration (hours)	111	96	95	99
	Length high hazard (%)	76	90	94	99

Land use

Existing land use within the study area for the flooding assessment is dominated by cropping (48 per cent), grazing and pasture (29 per cent) and production forests (20 per cent). Other land uses, including horticulture, residential, farm infrastructure, transport and infrastructure, account for the remaining 3 per cent. Table B3.5 provides a summary of areas of the key land uses that are subject to inundation for a range of flood events.

TABLE B3.5 SUMMARY OF AREAS OF INUNDATION OF LAND USES (HA)—EXISTING

Land use	Area within study area (ha)	20% AEP	5% AEP	1% AEP	PMF
Production forests	74,386	10,915	16,718	22,585	53,609
Grazing, pasture	107,804	19,757	29,653	36,319	70,443
Cropping	180,115	19,222	30,199	42,332	113,298

Buildings

Table B3.6 provides a summary of impacts on buildings for a range of flood events, as follows:

- Number of buildings subject to above-floor flooding
- Average duration (hours) of buildings on land subject to flooding above 0.5 m
- Number of buildings located on land subject to high flood hazard.

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.

The floor levels of buildings were identified based on actual surveyed floor levels, where available, and existing ground level, plus 300 mm where floor levels had not been surveyed.

The results of modelling predict that there are 117 buildings subject to above-floor flooding in the 20% AEP event, of which 52 are located in a high flood hazard area. The majority of impacted buildings are located near and within Narrabri, with average durations of inundation of up to 20 hours.

The number of impacted buildings increases to about 1,510 in the 5% AEP event and to about 6,110 in the 1% AEP event. The numbers of buildings within high flood hazard areas also increase substantially for the larger flood events. In the 1% AEP event, buildings near and within Narromine and Narrabri are heavily impacted.

TABLE B3.6 SUMMARY OF ABOVE-FLOOR FLOODING OF BUILDINGS—EXISTING

Feature	20% AEP	5% AEP	1% AEP	PMF
Number (above floor flooding)	117	1,510	6,110	12,437
Duration >0.5 m (hours)	0 to 20	0 to 21	0 to 31	2 to 82
Number (high flood hazard)	52	910	5,363	12,208

Further analysis of above-floor flooding for the 1% AEP flood event by building type is provided in Table B3.7. The table 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 B3.7 SUMMARY OF ABOVE FLOOR FLOODING OF BUILDINGS IN THE 1% AEP FLOOD EVENT—EXISTING

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

B3.3 Impact assessment—construction

B3.3.1 Flooding

Key risks

Construction activities, including earthworks, compounds, stockpiles in floodplains and works within watercourses, have the potential to affect flooding behaviour. 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 downstream watercourses through the transport of sediments and construction materials by floodwaters
- Obstruct the passage of floodwater and overland flow, which could exacerbate existing flooding conditions and pose a safety risk to the public.

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. The proposal has been designed to minimise the duration of onsite work in watercourses, which would enable increased flexibility when scheduling works around forecast rain periods. Prior to construction, a flood and emergency response plan would be prepared that sets out measures that are aimed at mitigating the impacts of construction activities on flood behaviour, as far as practicable.

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

The construction phase assessment assumes a worst-case scenario where all temporary construction infrastructure (such as compounds and sediment basins) are in place and construction of the rail formation is complete. 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 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 operational impacts, described in section B3.4.

Potential flooding impacts associated with the key construction infrastructure, including borrow pits, is provided in Part C.

Flooding characteristics

A summary of the key results of the flood modelling undertaken for the assessment is provided below. Further information, included mapping and full modelling results, is provided in Technical Report 3.

During construction, there would be an overall minor decrease in areas of inundation for all modelled flood events, as summarised in Table B3.8. This is due to the following:

- Land that would form part of the rail corridor being excluded from the impacted areas
- Changes in flood behaviour whereby water is temporarily held behind the rail formation, decreasing downstream inundation of land.

Flooding extents for the 1% AEP event during construction are shown in Figure B3.2.

Around Narromine, increased water levels in the 1% AEP event would generally be limited to less than 10 mm. The exceptions to this are localised areas downstream near Narromine and adjacent to the Macquarie River, and upstream near the Mitchell Highway, Main Western Line and Parkes to Narromine Line.

In the 1% AEP event, increases of up to 0.2 m occur both upstream and downstream of the construction footprint, near the Castlereagh River. These are generally limited to upstream areas within 500 m, except for the Castlereagh River where it extends up to 2.7 km upstream.

Near Narrabri, there are a number of areas where flood levels in the 1% AEP event from Bohena Creek are increased, with the most significant increase being a small area immediately to the south of the Narrabri West multi-function compound, where an afflux of greater than 1 m is observed due to the compound (see Part C for further detail). Around the Namoi River and Narrabri Creek, changes in flood levels away from the main channels are typically less than 10 mm, with no significant increases in extents of flooding.

For the majority of other catchments, changes in flooding in the 1% AEP event are typically characterised by:

- Widespread, shallow overland flows with increases up to 10 mm within nearby floodplains
- Increases up to 0.2 m near drainage structures
- Variable increases within the main channels of watercourses.

TABLE B3.8 TOTAL AREAS OF FLOODING AREAS—CONSTRUCTION

Flood event	Area of inundation construction (ha)	Change construction (ha)
20% AEP	51,906	-615
5% AEP	74,704	-2,567
1% AEP	106,550	-14

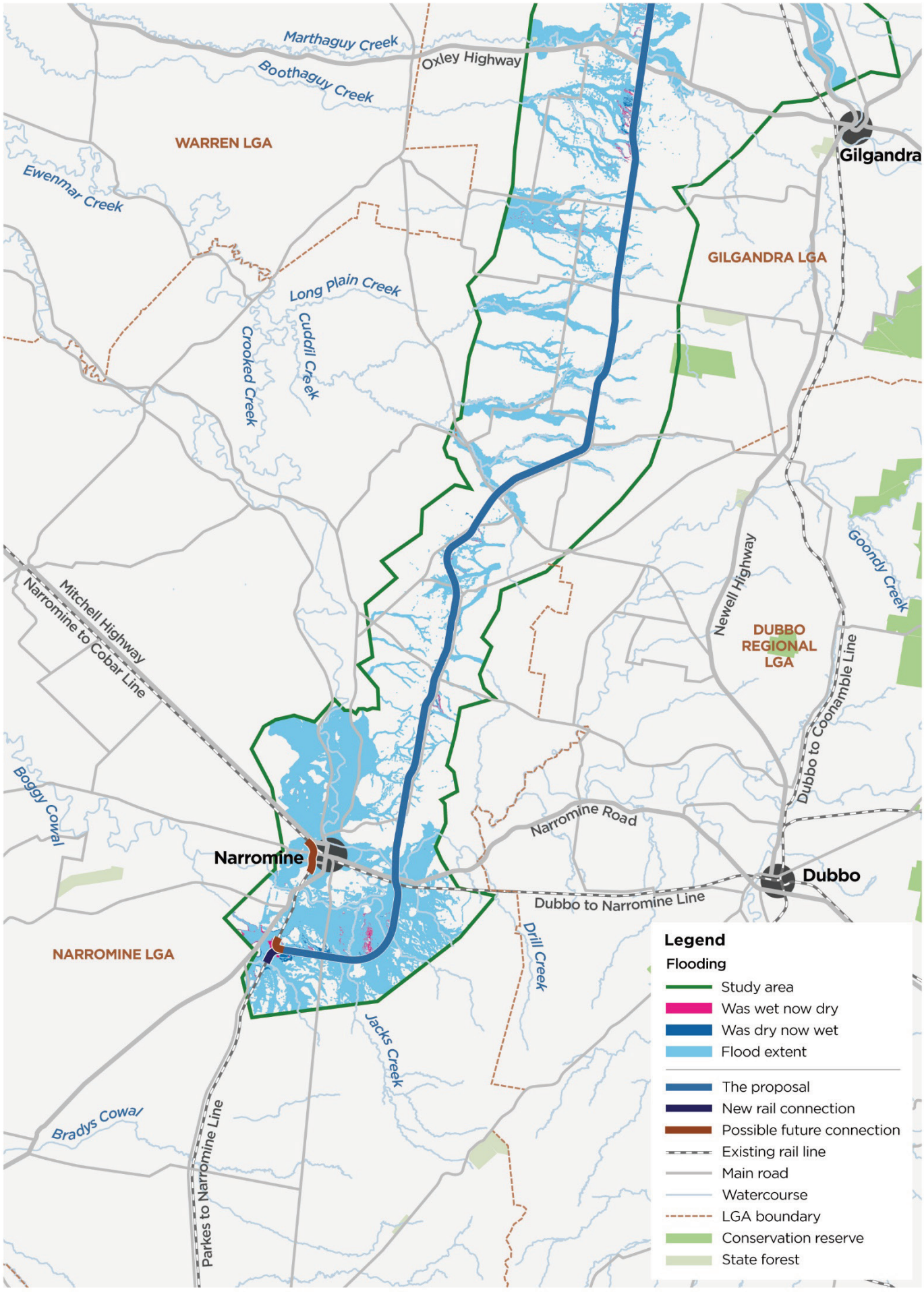

Figure B3.2 **Predicted flooding extents – construction (one per cent AEP event) (map 1)**

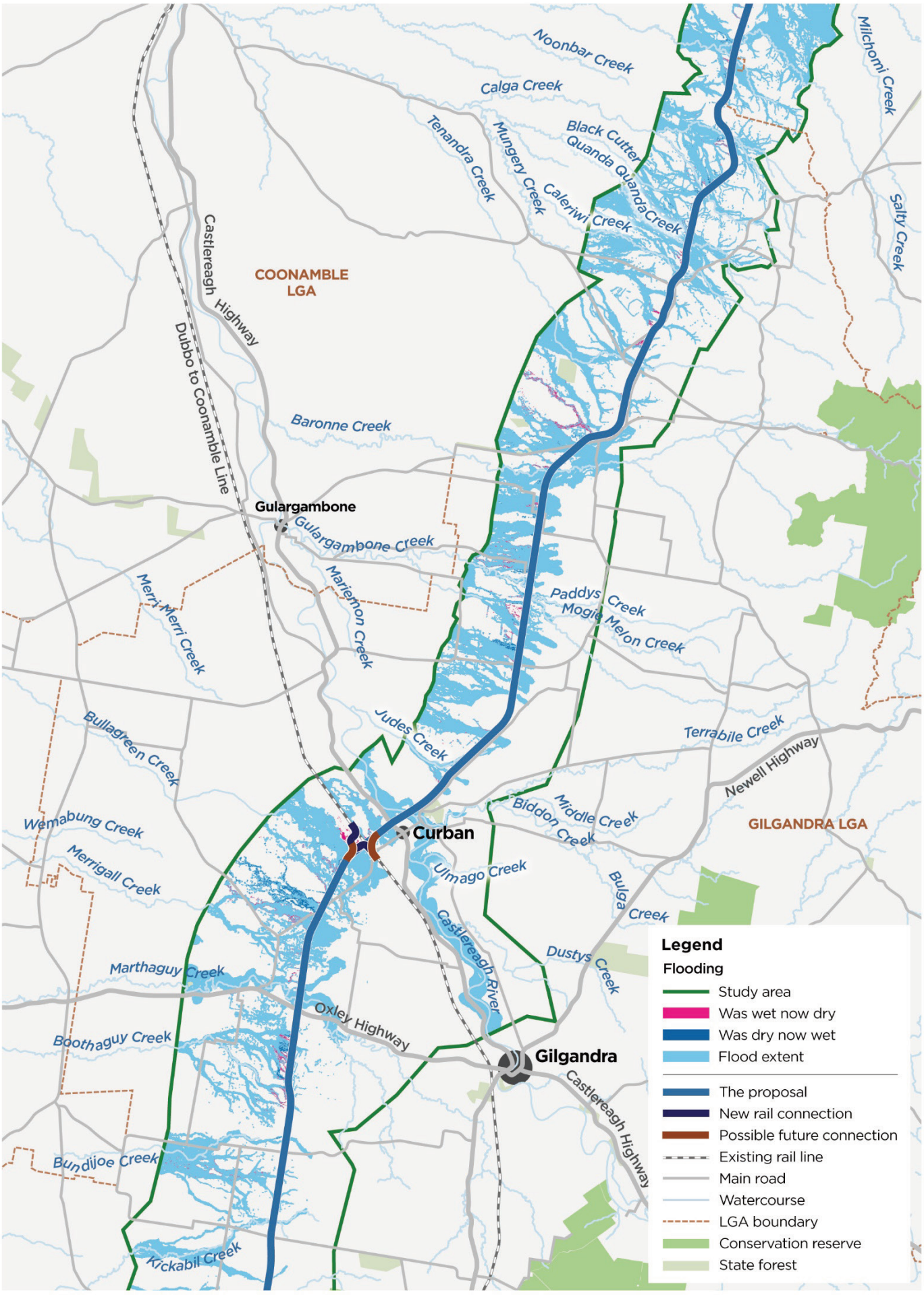

Figure B3.2 **Predicted flooding extents – construction (one per cent AEP event) (map 2)**

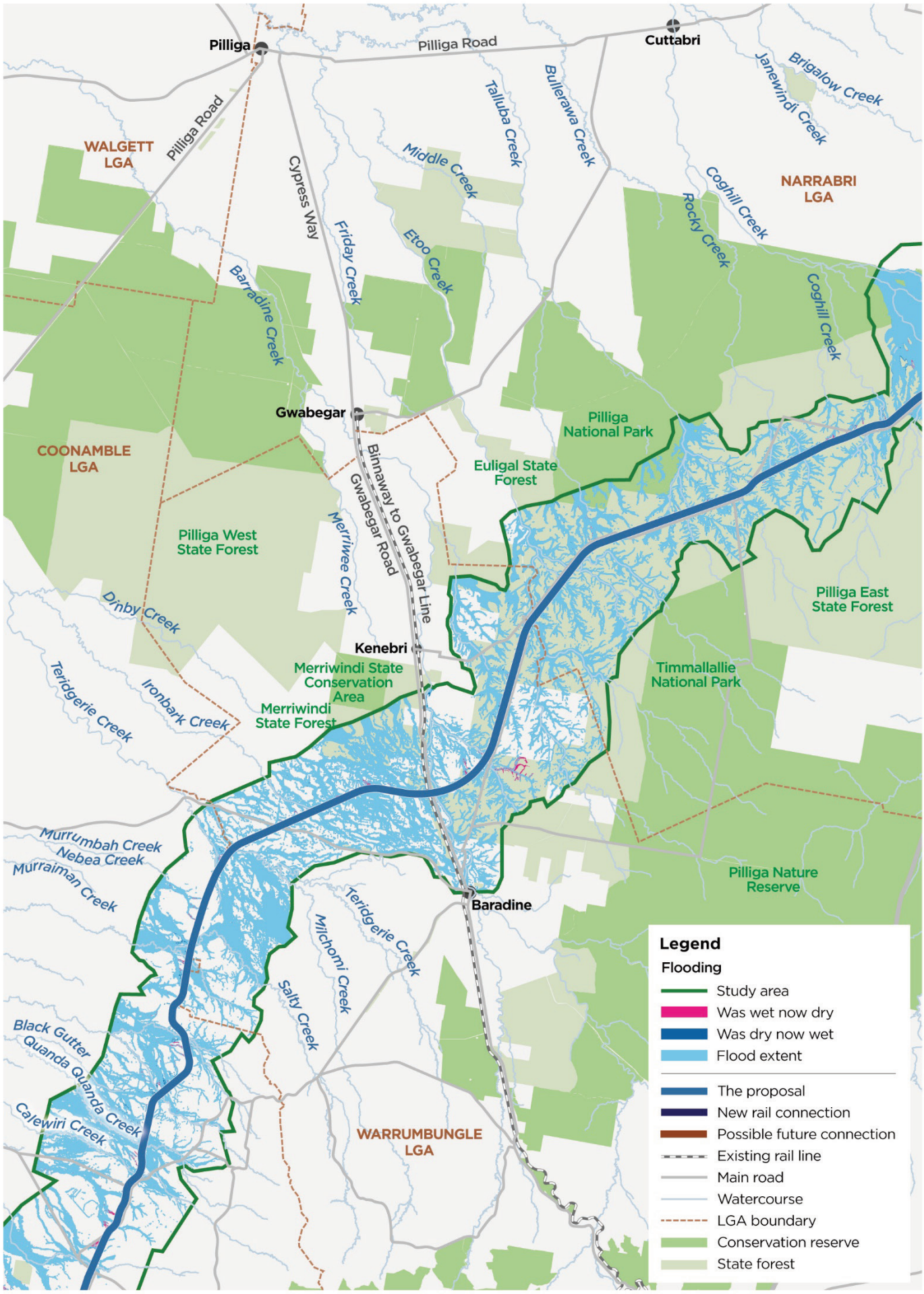

Figure B3.2 **Predicted flooding extents – construction (one per cent AEP event) (map 3)**

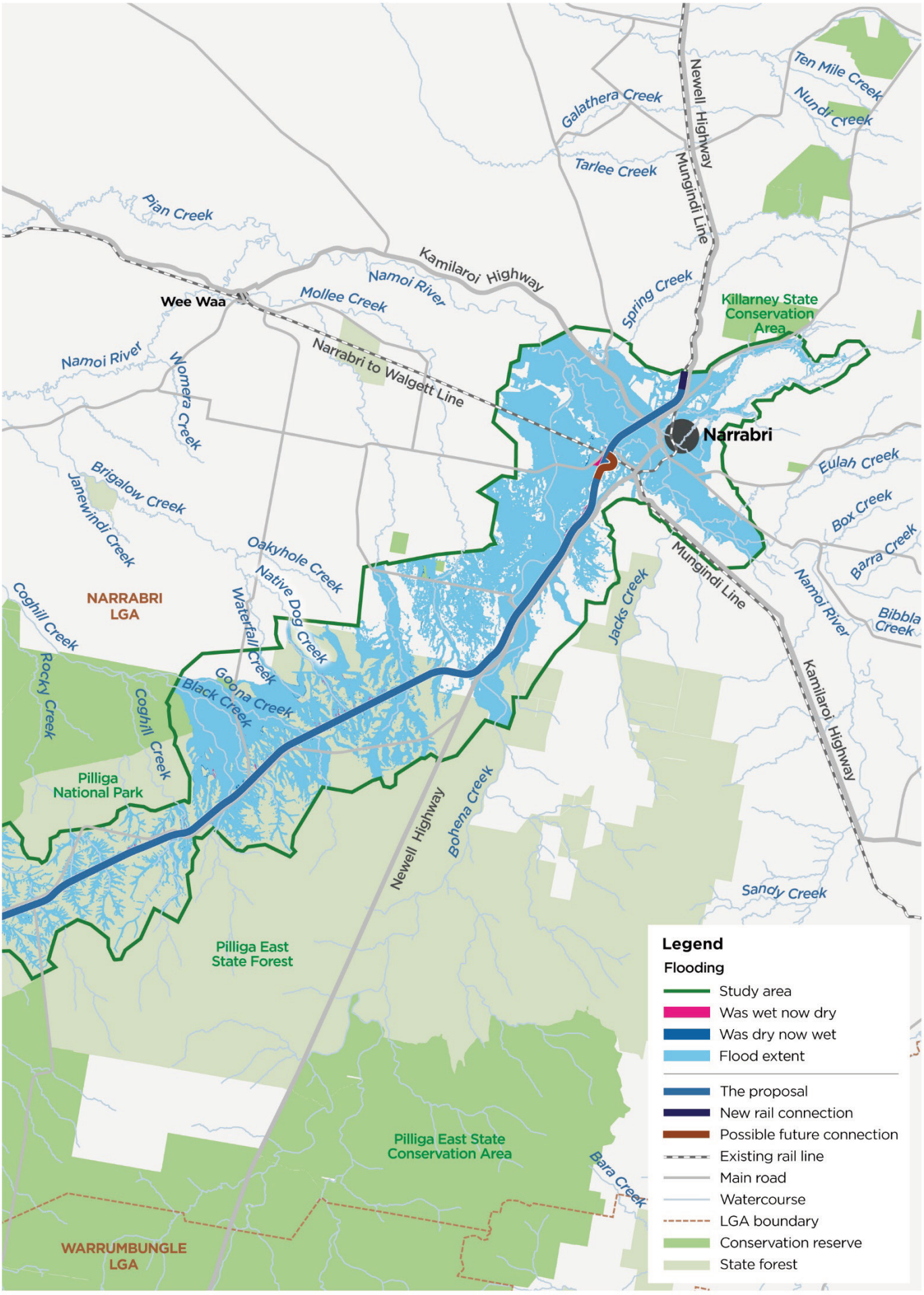

Figure B3.2 **Predicted flooding extents – construction (one per cent AEP event) (map 4)**

Rail lines

Table B3.9 provides a summary of the predicted amount of potential overtopping (change in length as a percentage) of existing rail lines, should a flood event occur during the construction phase.

The results of modelling indicate that potential overtopping lengths for the Main Western Line, Parkes to Narromine Line (reconstructed as part of Inland Rail) and Narrabri to Walgett Line (west of the proposal site) would generally remain unchanged or reduce during construction for all modelled flood events.

In some events, potential overtopping lengths and durations for the Dubbo to Coonamble Line would increase; however, these would be minor additional lengths (up to 130 m) and, as the line is already potentially inundated, it would not affect train operations.

The results of modelling indicate that for the 20% AEP event, the length of potential overtopping of the Narrabri to Walgett Line (east of the proposal site) would increase by 21%; however, the existing potential overtopping length is less than 0.1 km. As such, the change would be negligible and would not affect train operations. The potential duration of inundation of the Parkes to Narromine Line in the 20% AEP event is predicted to increase by a few minutes. This change would be negligible and would not affect train operations. The overtopping length of the Dubbo to Coonamble Line is increased in all events modelled; however, the existing length of overtopping is less than 1 km and less than 1 hour in duration and, as such, the increases are relatively minor and unlikely to impact train operations.

TABLE B3.9 SUMMARY OF POTENTIAL OVERTOPPING OF EXISTING RAIL LINES (PERCENTAGE CHANGE IN LENGTH)—CONSTRUCTION

Rail line	20% AEP	5% AEP	1% AEP
Main Western Line	0%	-63%	1%
Parkes to 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 (west)	0%	-2%	0%
Narrabri to Walgett Line (east)	21%	0%	-3%
Mungindi Line	75%	7%	0%

Roads

No additional lengths of highways would be potentially overtopped in the modelled flood events during the construction phase. There are increases in lengths of high flood hazard on existing overtopped sections of the Oxley Highway in the 20% AEP event and minor increase in duration of inundation on the Oxley Highway and Newell Highway in smaller events. As these highways are already subject to potential flooding in these events, the changes would not result in any noticeable impacts. For other named roads, potential changes would be negligible-to-minor changes in lengths, subject to inundation and flood hazard, and less than 10 per cent increases in duration for most events. It is unlikely that these would be noticeable across the study area.

Land use

During construction, the modelling results predict that flooding of key land uses, including forested lands, grazing areas and cropping lands, would be generally minor in terms of depth and duration of flooding.

Buildings

Table B3.10 provides a summary of the outcomes of modelling in terms of the estimate of total buildings affected (those with above floor flooding and subject to an afflux of greater than 10 mm) should a flood event occur during construction.

The majority of the impacted buildings are located near and within Narrabri and would be subject to afflux of less than 0.05 m. It is predicted that flood hazards would increase from low to high at 12 buildings and surrounds during the 5% AEP and at eight buildings and surrounds during the 1% AEP events. All of these are located near or within Narromine and Narrabri.

It is predicted that the duration of flood inundation at buildings and surrounds would increase by more than 10 per cent at 9, 66 and 134 buildings in the 5%, 20% and 1% AEP flood events, respectively. The majority of these are located near or within Narrabri.

The potentially affected buildings include residences, non-residential buildings such as 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. There is also likely to be localised modifications in existing ground levels and flow paths that would affect floodwater behaviour.

Additional assessment and modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined in section B3.2.2) and determine if the proposal (including the construction methodology) could be modified so that flooding characteristics are not worsened or minimised, as far as practicable, up to and including the 1% AEP event. Further information on the approach to minimising the predicted impacts is provided in section B3.5.

TABLE B3.10 SUMMARY OF BUILDINGS SUBJECT TO ABOVE-FLOOR FLOODING AND AN AFFLUX OF GREATER THAN 10 MM—CONSTRUCTION

	20% AEP	5% AEP	1% AEP
Total buildings affected	7	57	133

B3.3.2 Geomorphology

Key geomorphological risks during construction include activities in the riparian zone that could result in:

- Disturbance of watercourse channels and substrates associated with installation of bridges and culverts, resulting in erosion and changes to flow regimes
- Disturbance of soil, loss of vegetation, increased erosion, runoff from laydown areas and construction access tracks, and changes to water quality or quantity entering the watercourse
- Clearing of riparian vegetation that could reduce the hydraulic roughness and resistance of these surfaces to scour and erosion
- Disturbance of areas resulting in creation of preferred flow paths, potentially triggering further erosional processes and the migration of flow paths away from their existing alignment.

Changes to surface water flow patterns that could result in increased erosion and siltation of watercourses in the proposal site are considered in section B2.3.2. Potential impacts on water quality, including impacts caused by increased sediment loads, are considered in chapter B5.

The majority of watercourses that cross the proposal site are non-perennial and in moderate to poor condition. Where watercourses are perennial, erosion and sedimentation impacts would be mitigated by implementing standard erosion and sediment control measures (see sections B2.5 and B5.5). This would limit the potential for geomorphological impacts.

A geomorphology monitoring program would be developed and implemented to monitor and manage the potential for geomorphological impacts on watercourses. Further information is provided in section B3.5.

B3.4 Impact assessment—operation

B3.4.1 Flooding

Key risks

During operation, the main potential changes in flood behaviour would be as a result of a reduction in flow area associated with the presence of the rail formation across the floodplain, which would interrupt overland flow. Downstream of, and immediately near, the rail formation, flow would be concentrated at bridge and culvert outlets. This could cause increases in velocities and peak flood levels at these locations. These potential impacts have been minimised as far as possible at this stage of the design process by the design features incorporated in the proposal (see section B3.1.4).

Flooding characteristics

General

The proposal has been designed to have a minimum flood immunity for the 1% AEP event. This means that the flood level would remain below the ballast layer.

A summary of the key results of the flood modelling undertaken for the assessment is provided below for the 1% AEP flood event. Further information and full modelling results are provided in Technical Report 3.

During operation, it is predicted that there would be an overall minor decrease in areas of inundation for smaller events and an overall minor increase for larger events, as summarised in Table B3.11. This is due to a combination of land that would form part of the rail corridor being excluded from the impacted areas and changes in flood behaviour whereby water is temporarily held behind the rail formation, decreasing downstream inundation of land. Predicted flooding extents for the 1% AEP event during operation are shown in Figure B3.3. Overall, there is expected to be minimal impact on existing surface flow paths across the proposal site. This is due to the number of bridges and culverts that would be provided, which have been located to maintain existing flow paths as far as practicable. There would be minor changes where existing overland flows are directed to new culverts resulting in localised constrictions of flow.

TABLE B3.11 TOTAL AREAS OF FLOODING—OPERATION

Flood event	Area of inundation operational (ha)	Change operational (ha)
20% AEP	52,108	-413
5% AEP	77,179	-92
1% AEP	106,715	151
1% AEP with climate change	126,264	222
PMF	248,256	2,774

Extents and depths

Around Narromine, it is predicted that flood levels would generally be decreased in the 1% AEP. Minor increases would typically be limited to areas immediately adjacent to the new rail corridor, around the Macquarie River, Wallaby Creek and associated tributaries, and near The McGrane Way.

Near the Castlereagh River, increases of up to 0.2 m are predicted immediately near the rail corridor, extending in decreasing values, out to about 400 m upstream in the 1% AEP event. Downstream of the rail corridor, it is predicted that there would be some areas of shallow overland flooding (less than 0.03 m deep).

In the 1% AEP event, it is predicted that afflux associated with Bohena Creek would occur up to about 1 km upstream of the rail corridor. Afflux values typically range between 10 mm and 0.2 m. It is predicted that afflux associated with Narrabri Creek would be up to about 600 m upstream of the new rail corridor. Predicted afflux values typically range between 10 mm and 0.2 m.

For the majority of other catchments, predicted changes in flooding in the 1% AEP event would be typically characterised by widespread, shallow overland flows, with increases up to 10 mm within nearby floodplains. There would be isolated larger increases near some watercourses, such as Baronne Creek and Baradine Creek, near the rail corridor and within the main channels of watercourses.

Flood hazard

Around Narromine, Curban and Narrabri no significant widespread changes in flood hazard are predicted except for highly localised areas. These areas are typically constrained to areas immediately adjacent to the rail corridor. Predicted areas of increased flood hazard are typically reflective of changes from dry to low flow hazard, representing the minor changes in flood extents. Around the Castlereagh River, some areas of change from low to high hazard are also predicted. For the majority of other catchments, predicted changes in flood hazard would be typically limited to areas immediately adjacent to the rail corridor, with some localised increases from dry conditions to low hazard, and low to high hazard, near watercourses such as Baronne Creek and Baradine Creek.

Flow velocities

Predicted peak flow velocities under operational conditions for a range of flood events, based on hydraulic modelling, are summarised in Table B3.12 for all watercourses (based on the River Styles® framework). The

results show that peak flows for the 20% AEP and 1% AEP events for the Macquarie River, Castlereagh River and Namoi River would be essentially unchanged.

As noted in section B3.2.1, the majority of watercourses are currently in poor to moderate condition and have a moderate to high fragility. This indicates that the majority are 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 significant changes to existing conditions (see section B3.4.2 for further information).

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 Technical Report 3.

TABLE B3.12 SUMMARY OF PEAK FLOW VELOCITIES (METRES PER SECOND)—OPERATION

River style	5% AEP	1% AEP
Confined valley	0.6 to 1.1	1.2 to 2.1
Partly confined valley	0.6 to 2	1–2.8
Laterally unconfined valley	0.4 to 2.1	0.8–2.6
Discontinuous	0.2 to 1.4	0.3–2.2

Inundation time

The results of modelling indicate that near Narromine, changes in flood duration for the 1% AEP event would be variable but widespread across the Macquarie River and Wallaby Creek floodplains. There would be relatively minor increases of between 10 and 20 per cent (relative to existing flood durations of between 40 and 80 hours) where there are minor increases in flood depths, such as near the Mitchell Highway. Apart from some localised increases around the rail corridor near the Castlereagh River, there would be no overall significant changes in flood durations near the Castlereagh River or Namoi River. For the majority of other catchments there would be limited changes in flood durations, apart from some localised areas near watercourses, such as Baronne Creek and Tenandra Creek.

Rail lines

The proposal would have a minimum flood immunity for the one per cent AEP event. This means that the flood level would remain below the ballast. Table B3.13 provides a summary of the predicted potential overtopping of existing rail lines for a range of flood events during operation as follows:

- Change in length (percentage) located on land subject to flooding that could result in overtopping of the rail line
- Change in maximum duration (percentage) where flood levels are more than 0.5 m above ground level and could result in overtopping of the rail line.

For the majority of modelled events, it is predicted that changes to potential inundation lengths and durations would either be minor or negligible increases, or an improvement to the existing conditions.

While increases in lengths of potential overtopping are predicted on the Narrabri to Walgett Line (east of the proposal) and the Mungindi Line in the 20% AEP event, there would be no significant changes in duration of inundation. As such, there would be no expected impacts on train operations on these lines.

For the Parkes to Narromine Line (reconstructed as part of Inland Rail) it is predicted that there would be increases in potential duration of inundation by more than five hours (54 hours under existing conditions) in the 1% AEP event and more than two hours (20 hours under existing conditions) in the 5% AEP event. While this line is already subject to extensive flooding during these events, further refinement would be undertaken during detailed design to minimise the potential increases, as far as practicable, to limit the potential impact on train operations.

For the Dubbo to Coonamble Line, it is predicted that there would be greater than 10 per cent increases in potential duration of inundation in the 20% , 5% and 1% AEP events and greater than 10 per cent increase in length of overtopping in the 1% AEP event; however, under existing conditions, the duration of inundation is less than one hour and overtopping length is less than 1 km and, as such, this would not be expected to impact train operations.

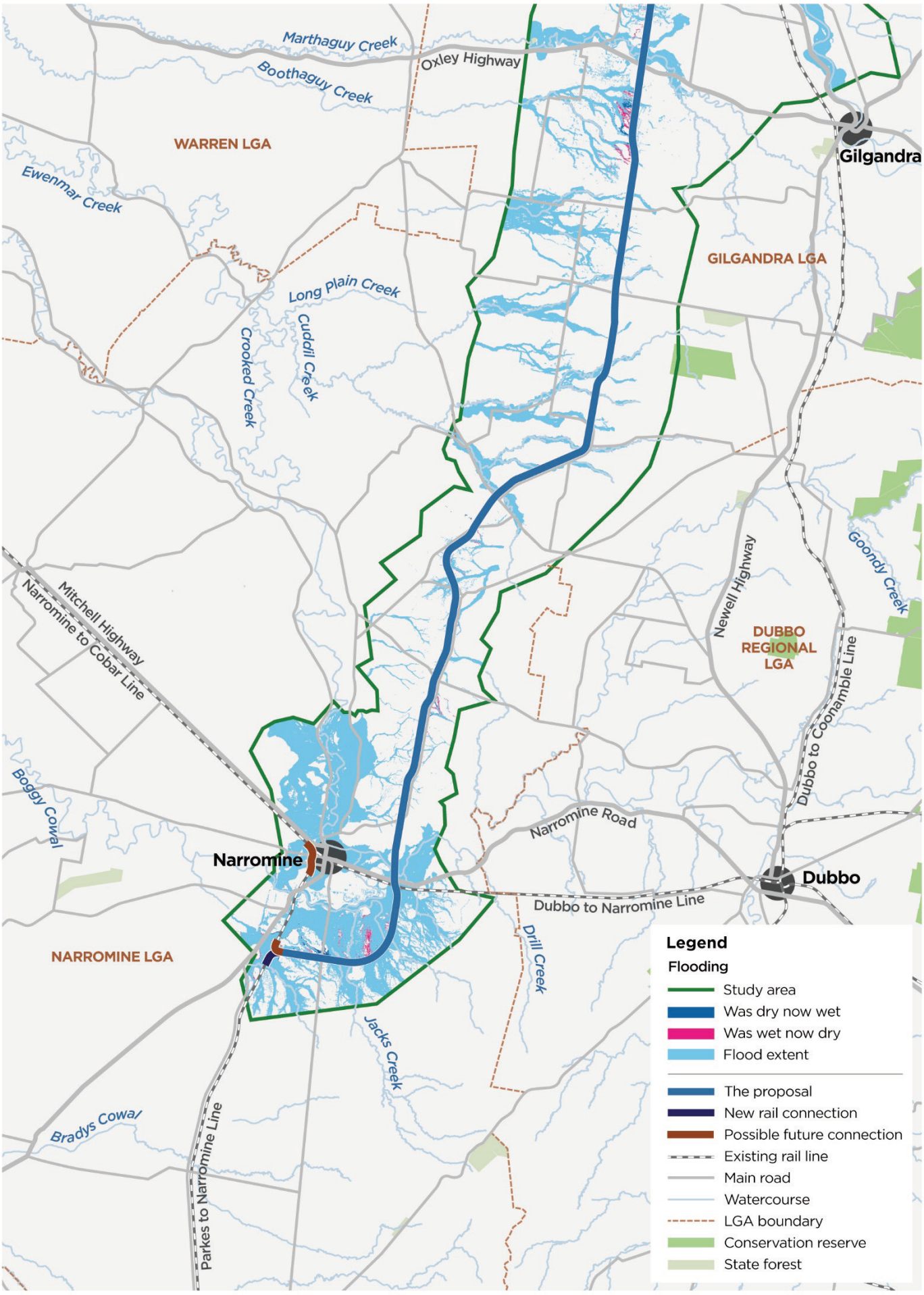

Figure B3.3 **Predicted flooding extents – operation (one per cent AEP event) (map 1)**

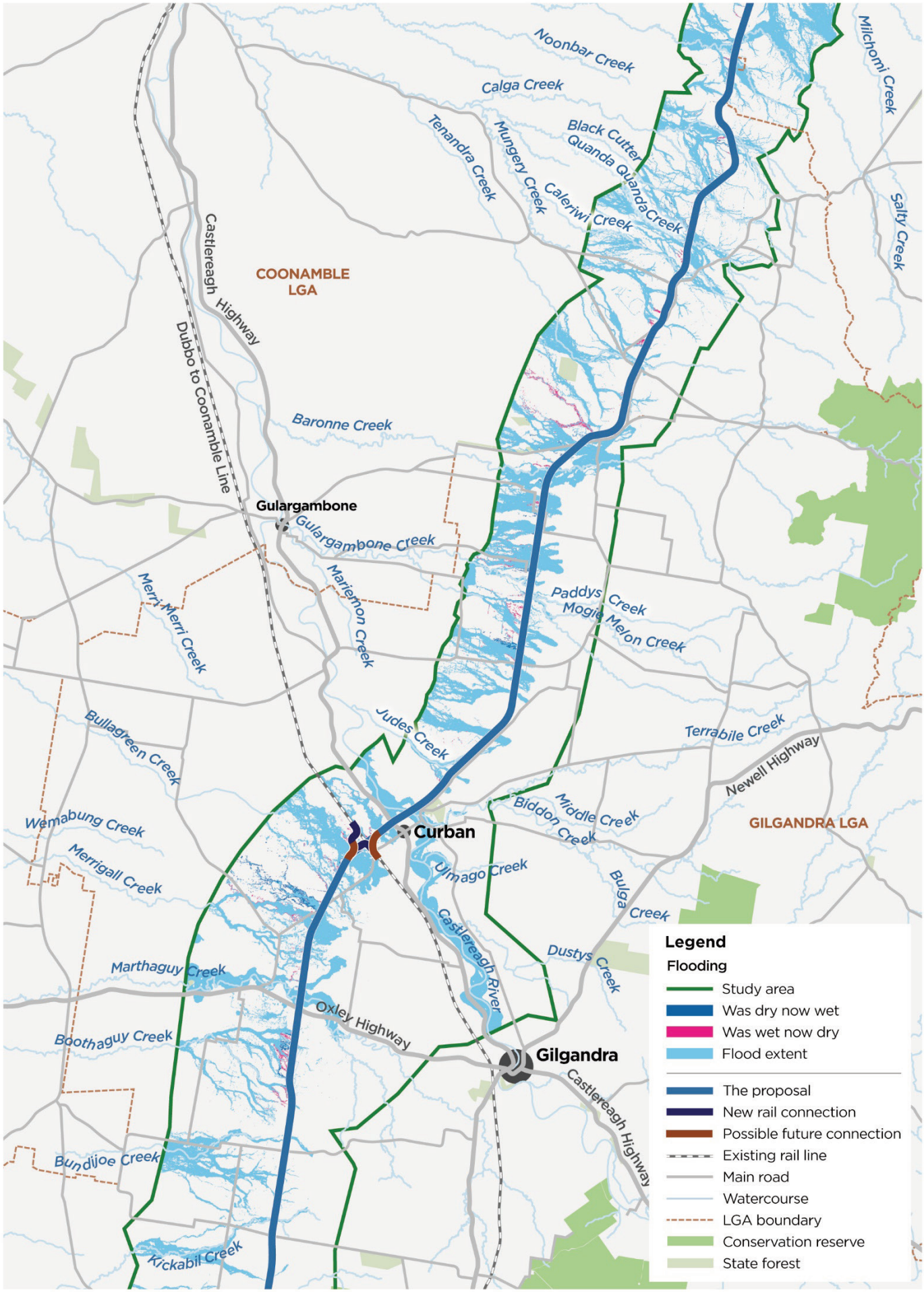

Figure B3.3 **Predicted flooding extents – operation (one per cent AEP event) (map 2)**

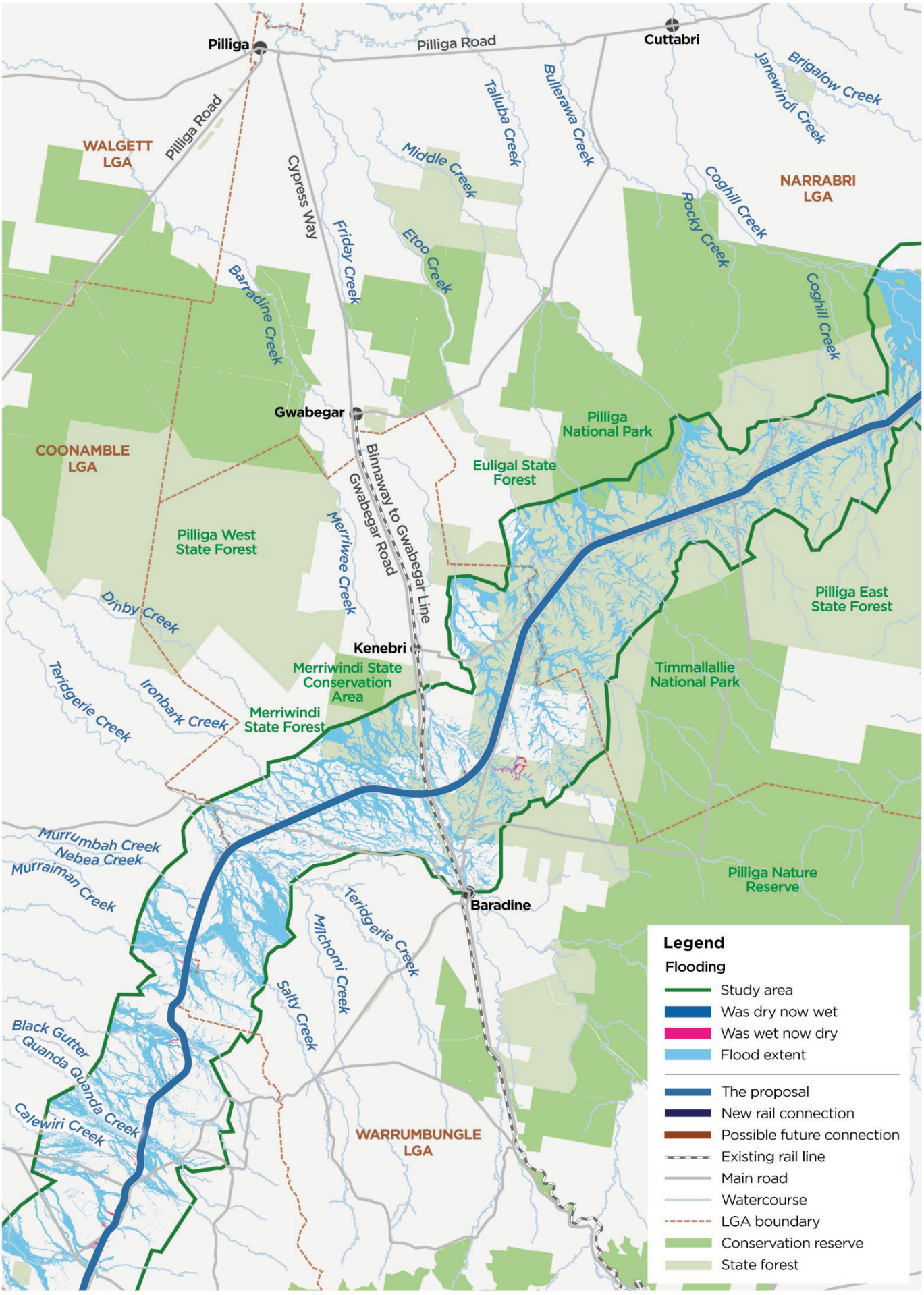

Figure B3.3 **Predicted flooding extents – operation (one per cent AEP event) (map 3)**

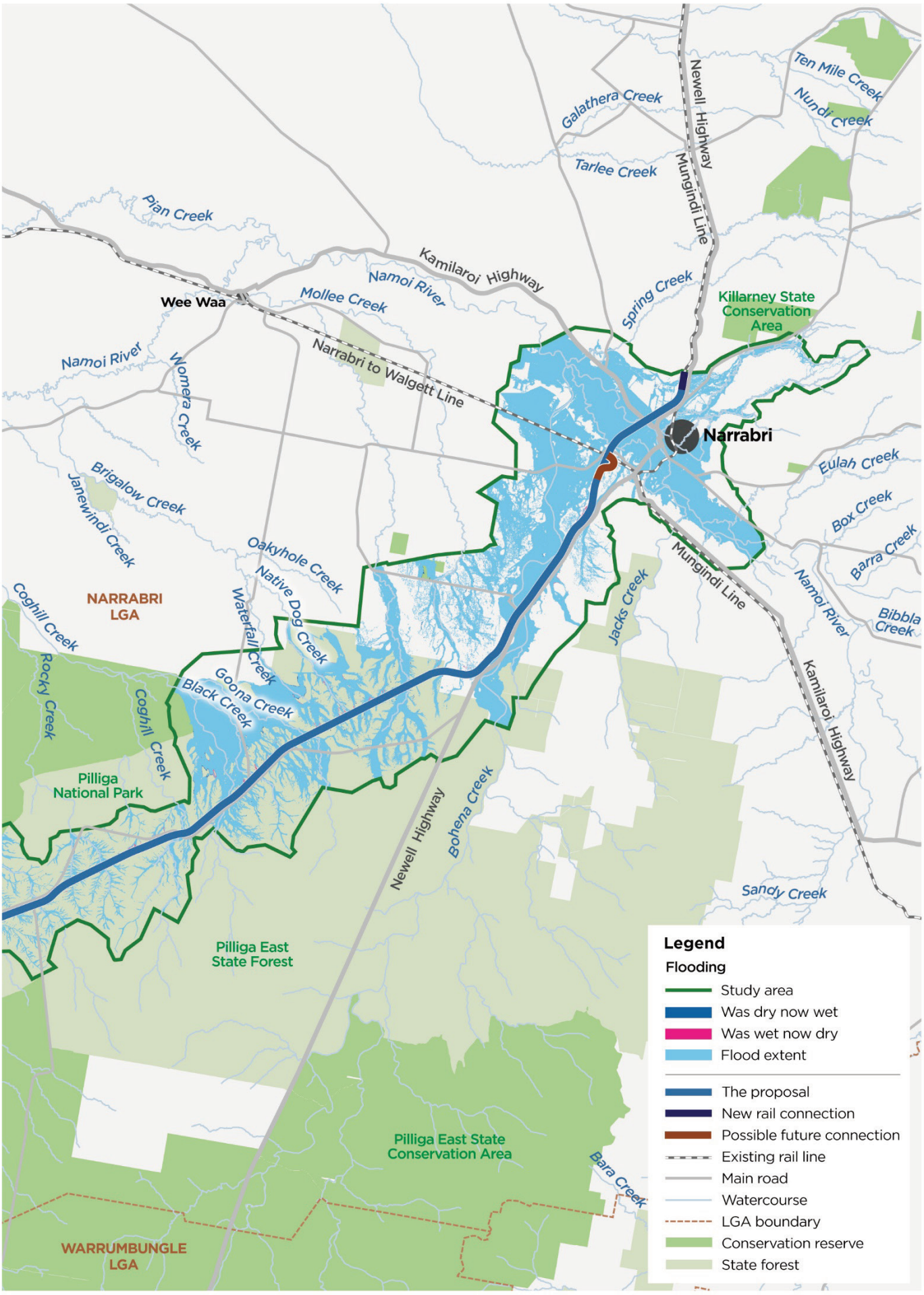

Figure B3.3 **Predicted flooding extents – operation (one per cent AEP event) (map 4)**

TABLE B3.13 SUMMARY OF POTENTIAL OVERTOPPING OF EXISTING RAIL LINES—OPERATION

Rail line	Overtopping	20% AEP	5% AEP	1% AEP	PMF
Main Western Line	Length change (%)	0	0	1	0
	Duration (>0.5 m) change (%)	0	0	<10	<10
Parkes to Narromine Line	Length change (%)	7	6	-7	0
	Duration (>0.5 m) change (%)	<10	>10	>10	<10
Dubbo to Coonamble Line	Length change (%)	-2	6	17	1
	Duration (>0.5 m) change (%)	>10	>10	>10	<10
Binnaway to Gwabegar Line (non-operational)	Length change (%)	1	-7	-2	-4
	Duration (>0.5 m) change (%)	<10	<10	<10	<10
Narrabri to Walgett Line (west)	Length change (%)	0	5	0	1
	Duration (>0.5 m) change (%)	<10	<10	<10	<10
Narrabri to Walgett Line (east)	Length change (%)	21	0	-3	3
	Duration (>0.5 m) change (%)	<10	<10	<10	<10
Mungindi Line	Length change (%)	75	6	-1	0
	Duration (>0.5 m) change (%)	<10	<10	<10	<10

Roads

Table B3.14 provides a summary of the predicted potential overtopping (change in length as a percentage) of existing highways and other roads during operation. The results show that potential impacts would be generally negligible. The only minor exception is in the PMF event for the Newell Highway (Bohena Creek) where an additional 2 km (16.5 km under existing conditions) is predicted to be potentially overtopped. Given the rarity and size of this event, the additional potential overtopping would not result in any noticeable impacts.

TABLE B3.14 SUMMARY OF POTENTIAL OVERTOPPING (PERCENTAGE CHANGE IN LENGTH) OF EXISTING ROADS—OPERATION

Roads	20% AEP	5% AEP	1% AEP	PMF
Mitchell Highway	0%	0%	0%	1%
Castlereagh Highway	0%	0%	0%	0%
Oxley Highway	0%	0%	0%	1%
Newell Highway (Bohena Creek)	-1%	-2%	0%	11%
Kamilaroi Highway	0%	0%	0%	0%
Newell Highway (Narrabri Creek/Namoi River)	<0.1%	0%	0%	8%
Other named roads	0%	0%	0%	-1%

Land use

Table B3.15 provides a summary of the predicted change in the area of inundation of key land uses for a range of flood events. It is predicted that there would be a reduction in inundation for all major land uses. This is due to a combination of land that would form part of the rail corridor being excluded from the impacted areas and changes in flood behaviour whereby water is temporarily held behind the rail formation decreasing downstream inundation of land. As such, there are no expected impacts on existing land uses.

TABLE B3.15 SUMMARY OF IMPACTS ON LAND USE (CHANGE IN AREA OF INUNDATION)—OPERATION

Land use	Area within study area (ha)	20% AEP change (ha)	5% AEP change (ha)	1% AEP change (ha)	PMF change (ha)
Forested lands	74,386	-70	-100	-161	-406
Grazing, pasture	107,804	-51	-608	-131	-2,213
Cropping	180,115	-118	-2,583	-317	-8,498

Buildings

Summary of building impacts for a range of flood events

Table B3.16 provides a summary of the predicted impacts on buildings for a range of flood events during the operation phase as follows:

- Number of buildings subject to above floor flooding with afflux greater than 10 mm
- Number of buildings subject to flooding above 0.5 m where the duration of inundation increases by more than 10 per cent
- Number of buildings located on land where the flood hazard changes from low to high.

TABLE B3.16 SUMMARY OF BUILDING IMPACTS—OPERATION

Feature	20% AEP	5% AEP	1% AEP	PMF
Total buildings (above floor flooding) with afflux >10 mm	1	47	71	7,035
Duration >0.5 m (number change >10%)	3	60	142	256
Number (change from low to high flood hazard)	0	3	1	24

In the 1% AEP event, about 71 buildings would be subject to above-floor flooding with afflux greater than 10 mm. Of these, the majority are located near Narromine (14) and Narrabri (51). This represents about 1 per cent of buildings within the study area already affected by 1% AEP flooding. It is predicted that flood hazard at one building and surrounds near Narrabri would increase from low to high in the 1% AEP event.

It is predicted that the duration of flood inundation at buildings and surrounds would increase by more than 10 per cent at 3, 60 and 142 buildings in the 20% AEP, 5% AEP and 1% AEP flood events, respectively. The majority of these are located near or within Narromine and Narrabri.

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. There are also likely to be localised modifications in existing ground levels and flow paths that could affect floodwater behaviour.

Summary of above floor flooding impacts for the 1% AEP event

Further analysis of above floor flooding for the one per cent AEP flood event by building type is provided in Table B3.17, 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 (as defined in section B3.2.2)—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 B3.17 SUMMARY OF ABOVE-FLOOR FLOODING OF BUILDINGS IN THE ONE PER CENT AEP FLOOD EVENT—OPERATION

	1% AEP	
Building type	**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 subject to above-floor flooding (see Table B3.17), the majority are predicted to experience a negligible change (i.e. less than a 10 mm increase or decrease) to existing conditions.

As shown in Table B3.16, 71 buildings are predicted to be subject to above-floor flooding and experience an afflux of greater than 10 mm. Of these 71 buildings, 22 are sensitive buildings that are predicted to experience an increase of between 10 and 100 mm, of which all but one experience above-floor flooding under existing conditions.

A summary of all buildings subject to greater than 10 mm afflux under operational conditions for the 1% AEP event is provided in Figure B3.4.

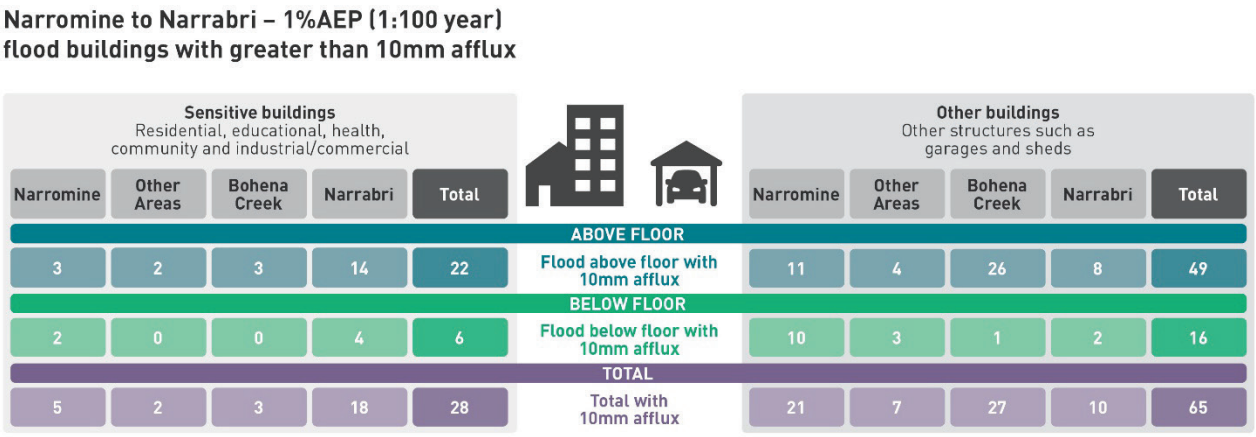

FIGURE B3.4 SUMMARY OF BUILDINGS SUBJECT TO GREATER THAN 10 MM AFFLUX—OPERATION (1% AEP EVENT)

Additional modelling would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined in section B3.2.2) 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. Further information on the approach to minimising the predicted impacts is provided in section B3.5.

Consistency with floodplain management plans

The *Narromine Floodplain Risk Management Study and Plan* and *Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020* are the floodplain management plans that apply to the study area. These plans cover the urban area of Narromine and part of the urban area of Narrabri.

In relation to the *Floodplain Management Plan for the Lower Namoi Valley Floodplain 2020*:

- The plan 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 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 (see section B3.3).

In relation to the *Narromine Floodplain Risk Management Study and Plan*:

- The study recommends implementing development controls such as a flood planning levels for new development set at the 1% AEP flood level with a 0.5 m freeboard. As the proposal would have only a minor impact on the peak 1% AEP flood levels within Narromine, it would not have a significant impact on the extent of the flood planning area and the area of land to which the flood planning controls would apply.
- The study also recommends carrying out feasibility studies for flood mitigation works, including upgrading the existing Narromine river bank levee and the hydraulic capacity of culverts under the Parkes to Narromine Line. The levee bank is proposed to be located to the west of the proposed bridge over the Macquarie River, where minimal changes in peak flood levels are predicted. As a result, the proposal would not limit or preclude the potential future levee bank works. In addition, 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 relevant stakeholders (including local councils; the Department of Planning, Industry and Environment; NSW State Emergency Service; and local emergency management committees (as relevant)) 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 site.

Compatibility with flood hazard and hydraulic functions

Floods can create hazardous conditions, including fast-flowing, shallow water or slow-flowing deep water, in which humans are vulnerable. It is the human interaction with the floodplain and the associated exposure to flood hazards that creates flood risk. Flood hazards can include direct impacts on people (fast currents sweeping them away) or impacts on the built environment, including infrastructure required for the functioning of the community, such as roads and rail.

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 in an iterative manner throughout the design process, as described in Technical Report 3. This included considering existing flood behaviour and high hazard areas where significant flow conveyance occurs, and sizing of bridges and culverts through multiple modelling runs to minimise hydraulic impacts.

With the exception of Narromine and Narrabri, the majority of the proposal site generally passes through rural land, with land uses that are less sensitive to flood hazards, as there are less people and infrastructure with the potential to be impacted. Additionally, the modelling indicates that flood hazards to buildings and roads across the proposal site would not be expected to significantly change.

Emergency management arrangement impacts

There are a number of local flood plans relevant to the proposal site that 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 proposal has the potential to affect 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, 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. As described in section B3.2.2, there are about 6,110 buildings in the study area subject to above-floor flooding in the existing 1% AEP event, of which about 5,758 are located in Narromine and Narrabri. The proposal would cause a minor increase in depth of flooding to a small proportion (about 1 per cent) of buildings already affected by the 1% AEP event but would not cause any significant increase in the number of buildings affected by flooding; therefore, no significant impacts on the existing property protection measures identified in the relevant local flood plans are expected as a result of the proposal.

There are no dedicated flood evacuation routes identified within the study area and existing highways and roads would be used to evacuate the community. It is predicted that the proposal would result in negligible to minor impacts on the length and duration of flooding to highways and roads; as a result, it would not result in any significant impacts on existing flood evacuation, road traffic control and road closure arrangements.

For large-scale evacuation from Narrabri, existing options include air, rail and road. The proposal has a flood immunity for the 1% AEP event and would potentially provide an alternate evacuation option.

Social and economic impacts of flooding

Social impacts of flooding relate to 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 can have to daily life, such as restricted vehicular access; potential isolation; property damage; odour associated with flood water debris and rubbish; sewage spills; the risk of infection; clean-up work; reduced access to supplies; ponding and slow drainage (time of inundation) after the flood event.

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 have the potential for some minor impacts associated with increased depth and duration of flooding to a number of buildings, the majority of which are within Narromine and Narrabri, which are already affected by flooding. These impacts would be minimised, as far as practicable, through further design refinement during detailed design.

The socio-economic impacts of flooding on agricultural land and production can be both positive and negative and depend on the activity being undertaken on a property. Positive impacts include replenishment of groundwater and surface irrigation water sources, which can have a beneficial impact in future years for grazing and cropping. Negative impacts include stock losses, crop damage, environmental damage (e.g. growth of woody weeds and loss of some species) and interrupted management, including damage to fencing and roadways. The flood modelling shows that the overall changes in flood behaviour across rural lands within the study area would be minor and are therefore unlikely to significantly affect overall agricultural operations.

The potential impact on flooding to roads and rail infrastructure would be generally negligible, with only minor changes to the length and duration of flooding affecting existing roads and rail lines. As a result, the economic impacts of the proposal on existing road and rail infrastructure damage would also be negligible.

Overall, the proposal would not result in any broad-scale changes in flood behaviour and, as such, would not result in any significant socio-economic impacts.

Risk of rail formation overtopping and failure

The proposal would not be overtopped in the 1% AEP event. For larger events, it is predicted that overtopping would occur in the following events:

- 0.2% AEP event—total of 200 m
- 0.05% AEP event—total of 3 km
- 0.01% AEP event—total of 24 km
- PMF event—total of 26 km.

The maximum depth of overtopping of the proposal is predicted to occur to the south of Webbs Siding Road, to the east of Narromine. The difference between headwater and tailwater level in the PMF event is about 0.1 m, which indicates that the proposal would not act like a dam. As a result, a potential failure of the rail formation would have insignificant consequences to people and property downstream.

The maximum difference in headwater and tailwater level in the PMF event is predicted to be 2.7 m along Eumungerie Road. The proposal would not be overtopped in the PMF event at this location. There are a number of locations along the proposal site where differences in headwater and tailwater levels are predicted to be high and the proposal would be subject to a shallow depth of overtopping over the rail. Under these circumstances, it is expected that some railway ballast would be washed away, depths of overtopping of the rail formation would be reduced and any risk to people and property would not be significant.

B3.4.2 Geomorphology

Key geomorphological risks during operation include:

- Scour at watercourse crossings—increased velocities could lead to potential scouring
- Maintenance/repair of instream structures—removal of sediment, vegetation and wood from instream structures has the potential to change flow regimes, which may impact watercourse condition and stability
- Use and maintenance of access roads—erosion and sedimentation arising from increased runoff from hard surfaces.

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.

The watercourses crossed by the proposal site 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. For Tinegie Creek, Macquarie River and Ewenmar Creek, which were identified as being in good condition, the following changes are predicted:

- Tinegie Creek—velocities would be marginally higher but unlikely to worsen the existing condition
- Macquarie River and Ewenmar Creek—velocities are predicted to decrease.

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 m/s), fine gravels (0.8 m/s) and vegetated surfaces (2 m/s). 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 Technical Report 3.

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 predict 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.

B3.5 Mitigation and management

B3.5.1 Approach to mitigation and management

Approach to mitigation and management

Approach to managing the key potential impacts identified

As described in section B3.1.4, the proposal would incorporate a number of design features to avoid and/or minimise the potential impacts on flooding and watercourses.

Flood modelling has indicated that, despite the implementation of the proposed design features, there may be some impacts on buildings, rail lines and watercourses downstream of bridges and culverts during construction and operation. Additional investigations would be undertaken during detailed design to confirm the floor levels of sensitive buildings (as defined in section B3.2.2). 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 determine if the proposal could be modified such that flooding characteristics with regards to property and buildings 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.

Approach to managing other impacts

A flood and emergency response plan would be prepared and implemented as part of the CEMP. The management plan would include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour, as far as practicable.

A geomorphology monitoring program would be implemented in accordance with the soil and water management plan, as part of the CEMP. The monitoring would seek to identify any changes to the geomorphological stability of the watercourses that may be attributable to the proposal to inform appropriate management responses. The

program would be developed in consultation with relevant stakeholders (including the Department of Planning, Industry and Environment and local councils) and with reference to the Water Quality Guidelines.

Expected effectiveness

ARTC and its contractors have experience managing potential flooding and watercourse impacts associated with the construction and operational phases of rail development projects.

Flood modelling has been undertaken for the proposal in accordance with relevant guidelines, including *Australian Rainfall and Runoff; A Guide to Flood Estimation* (Ball et al., 2019) and flood management planning documents relevant to the study area. Further assessment and refinement during detailed design in accordance with these would be undertaken with the aim of avoiding or minimising, as far as practicable, impacts on sensitive buildings and infrastructure.

Monitoring and auditing would be undertaken during construction to ensure that the CEMP relevant plans and the monitoring program are being implemented. Watercourse condition monitoring would also be undertaken to observe any changes in the geomorphological stability of the watercourses that may be attributable to the proposal and to inform appropriate management responses.

The proposed mitigation measures are expected to be effective in managing the potential impacts on people and property as a result of the proposal.

Interaction between measures

Implementing other relevant measures provided in chapters B2, B4 and B5, and the rehabilitation strategy described in section A8.7, would also assist in minimising the potential for flooding and geomorphology impacts.

The approach to managing potential impacts, including the effects of changed flood behaviour, could in some situations involve developing property-specific measures to manage the requirements at individual properties. This would involve determining requirements, in consultation with individual landholders, for property-level responses during construction and the ongoing operation. These measures, which would include mitigation for specified impacts, would be defined in individual property agreements. Further information is provided in chapter B12.

Mitigation measures to control impacts on flooding and geomorphology may overlap with mitigation measures proposed for the control of water quality, soil and contamination, water resources, air quality and waste management impacts. All management measures would be consolidated and described in the CEMP. The plan would identify measures that are common between different aspects. Common impacts and common mitigation measures would be consolidated to ensure consistency and implementation.

B3.5.2 List of mitigation measures

Measures that will be implemented to address potential impacts on flooding and geomorphology are listed in Table B3.18.

TABLE B3.18 FLOODING MITIGATION MEASURES

Stage	Ref	Impact	Mitigation measure
Detailed design/ pre-construction	FH1	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 B3.4.1 of the EIS. 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.
	FH2	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	FH3	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.
	FH4	Flooding impacts	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.
	FH5	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 watercourses that may be attributable to the proposal and 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).

B3.5.3 Managing residual impacts

Residual impacts are impacts of the proposal that may remain after implementation of:

- Design and construction planning measures to avoid and minimise impacts (see sections A7.2 and A8.1)
- Specific measures to mitigate and manage identified potential impacts (see sections B3.5.1 and B3.5.2).

The key potential flooding issues and impacts originally identified by the environmental risk assessment (see section A9.1) are listed in Table B3.19. The (pre-mitigation) risks associated with these impacts, which were identified by the environmental risk assessment, are provided. Further information on the approach to the environmental risk assessment, including descriptions of criteria and risk ratings, is provided in section A9.1.

The potential issues and impacts identified by the environmental risk assessment were considered as part of the impact assessment, summarised in sections B3.3 and B3.4. The mitigation and management measures (listed in Table B3.18) that would be applied to manage these impacts are also identified. The significance of potential residual impacts (after application of these mitigation measures) is rated using the same approach as the original environmental risk assessment. The approach to managing significant residual impacts (considered to be those rated medium or above) is also described.

TABLE B3.19 RESIDUAL IMPACT ASSESSMENT—FLOODING

Assessment of pre-mitigated risk (see section A9.1 and Appendix E)					Mitigation measures (see Table B3.18)	Residual impact assessment			
Phase	**Potential impacts**	**Likelihood**	**Consequence**	**Risk rating**		**Likelihood**	**Consequence**	**Risk rating**	**How residual impacts will be managed[1]**
Construction	Impact of flooding on unprotected areas during construction resulting in wash-outs or erosion	Possible	Moderate	Medium	FH1, FH3-FH5	Unlikely	Minor	Low	n/a
	Sedimentation and changes to geomorphology in watercourses	Possible	Moderate	Medium	FH3-FH5	Unlikely	Minor	Low	n/a
	Presence of, or change to, structures associated with the proposal could impact upstream and downstream local flood behaviour	Possible	Major	High	FH1, FH3-FH5	Unlikely	Minor	Low	n/a
Operation	Potential changes to road overtopping frequencies and levels impacting emergency service management	Possible	Major	High	FH1	Rare	Moderate	Low	n/a
	Presence of structures associated with the proposal and track height could impact upstream and downstream regional flood behaviour	Likely	Major	Very high	FH1, FH2	Possible	Moderate	Medium	Where localised impacts can't be avoided, further consultation with affected property owners would be undertaken to identify measures that could be implemented to minimise the impacts, as far as practicable.
	Changes to flood characteristics as a result of impacts on the hydraulics of the catchment	Possible	Moderate	Medium	FH1, FH2	Unlikely	Minor	Low	n/a

Note: 1. For residual impacts with a risk rating of medium or above.