CHAPTER 12

Hydrology and flooding

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT

Contents

Figures

Tables

12. Hydrology and flooding

This chapter provides a summary of the assessment of flooding, hydrology and geomorphology for the Inland Rail—Illabo to Stockinbingal project (the proposal). It describes the existing environment, assesses the impacts of construction and operation of the proposal, and provides recommended mitigation and management measures. The full assessment report is provided in Technical Paper 4: Hydrology and flooding (Technical Paper 4) of the EIS.

12.1 Overview

The proposal site crosses a number of watercourses within the Murrumbidgee River and Lachlan River catchments. Watercourses crossed by the proposal are ephemeral, with water flowing only for short durations following rainfall. The study area is located within the upper reaches of the respective catchments and not subject to regional flooding. Isolated flooding occurs within the study area within local catchments. Flood levees have been constructed to mitigate existing impacts of flooding from Dudauman Creek within the township of Stockinbingal.

During construction there is potential for impacts to hydrology and flooding from general construction activities, and these would be considered typical for linear infrastructure projects. This includes the potential for construction activities, plant or equipment to obstruct or block the flow of water or surface water flow paths if not managed appropriately. Staging of construction activities can also have the potential to result in impacts during a flood event. Due to existing impacts from flooding associated with Dudauman Creek, a potential for impact from construction staging has been identified. Further review of the staging of the construction works in the Dudauman Creek floodplain will be completed during detailed design of the proposal.

As described in Chapter 8: Proposal description—construction, the estimated water demand for construction of the proposal is about 797 megalitres (ML). Consultation with a local commercial water supplier (Goldenfields Water) has indicated there would be an adequate supply of water for the proposal. To manage peak water demand and rates of supply, water tanks are proposed to be installed within construction compounds for the temporary storage of water onsite, and ensure an adequate supply is maintained for the duration of construction. The use of other water sources, including recycled water from sewage treatment plants, would also be considered during detailed design.

Once operational, the proposal has been designed to mimic the existing drainage and surface water flow conditions, including directing flows to topographic low points and existing watercourses. The proposal includes one minor drainage diversion within the Ironbong Creek catchment (at approximately chainage 16000), with a longitudinal drainage channel designed to capture the flows and divert them about 600 m to the south. This diversion maintains surface water flows within the Ironbong Creek catchment. As there are no significant changes to hydrologic regimes, impacts are not predicted on the water balance or water availability within the downstream catchments.

Overall, the proposal is predicted to have only localised impacts to hydrology, flooding and geomorphic conditions. These impacts have been minimised and mitigated through the design of the proposal, and flood modelling would be further refined during detailed design. Where exceedances of the adopted criteria, or quantitative design limits (QDL), are predicted to occur, they have been considered in the context of their impact on surrounding land uses and receivers, compared to existing conditions. The proposal is predominantly surrounded by agricultural land, and impacts from QDL exceedances including flood height (afflux), hazard and duration are minor and do not impact the use of this land, as impacts from flooding generally already occur in these locations. Notwithstanding, further design and modelling would be undertaken during detailed design and further consideration would be given to mitigation of flooding impacts, including in consultation with affected landowners.

Exceedances from changes in velocity also occur in areas of agricultural land, and measures such as erosion and scour protection will be implemented at points of discharge. For areas beyond the rail corridor, further consideration of the approach for managing these impacts is required during detailed design. The proposal does not worsen impacts from flooding to buildings, roads or existing rail lines, beyond impacts which occur in existing conditions, and predominantly results in an improvement to flood immunity.

The proposal is not predicted to result in any other significant impacts to flooding during operation, including in the event of extreme flood events, such as probable maximum flood (PMF).

12.2 Approach

A summary of the approach to the assessments is provided in this section, including the legislation, guidelines and/or policies driving the approach and the methodology used to undertake the assessments. A more detailed description of the approach and methodology is provided in Technical Paper 4.

12.2.1 Legislative and policy context

The assessment has been undertaken with reference to the following legislation, policy and guidelines:

- *Natural Resource Access Regulator Act 2017* (NSW)
- *Water Management Act 2000* (NSW) (WM Act)
- *Water NSW Act 2014* (NSW)
- Water NSW Regulation 2013 (NSW)
- *The Australian Rainfall and Runoff Guidelines* (ARR) (Ball et al., 2019)
- *AS/NZS 3100:2018 Risk Management—Principles and Guidelines* (Standards Australia, 2018)
- *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7* (Australian Institute for Disaster Resilience (AIDR), 2017)
- *Climate Change Impacts and Risk Management—A Guide for Business and Government* (Department of Environment and Energy, 2006)
- Practical Consideration of Climate Change, Floodplain Risk Management Guideline (NSW Government, 2007)
- *NSW Floodplain Development Manual and Flood prone land policy* (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005)
- ARTC guidelines, including—*ARTC's Engineering Practices Manual, Civil Engineering, Track Drainage—Design and Construction* (ARTC, 2013)
- *Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies* (NSW Office of Environment and Heritage (OEH), 2019a)

The assessment also referred to local flood policy and plans, including:

- Environmental planning instruments, including the Cootamundra Local Environment Plan 2013, and Junee Local Environment Plan 2012
- Stockinbingal Floodplain Risk Management Study and Plan (FRMS&P) prepared for Cootamundra-Gundagai Regional Council (SMEC, 2002)
- Jeralgambeth Creek at Illabo, Floodplain Risk Management Study and Plan prepared for the NSW former Office of Environment and Heritage, Floodplain Management Branch (Lyall and Associates, 2012).

Under the provisions of the WM Act, Water Sharing Plans (WSPs) define the rules for sharing the water resources of regulated rivers. The following WSPs encompass part or all of the proposal site:

- Lachlan Regulated River Water Source 2016
- Lachlan Unregulated and Alluvial Water Sources 2012
- Lower Lachlan Groundwater Source 2003
- Lower Murrumbidgee Groundwater Sources 2003
- Murrumbidgee Regulated River Water Source 2016
- Murrumbidgee Unregulated and Alluvial Water Sources 2012.

A detailed description of the legislative and policy context for the assessment is provided in Chapter 2 of Technical Paper 4.

12.2.2 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (SEARs) relevant to water quality, together with where they are addressed in the EIS, are provided in Appendix A.

12.2.3 Methodology

12.2.3.1 Study area

The study area for the hydrology and flooding assessment includes surface water catchments impacted by the proposal site, which is defined as the area of drainage by a stream or body of water, or the area of land from which water is collected, and includes areas upstream and downstream of the proposal.

The proposal lies at the catchment divide of the Lachlan and Murrumbidgee River catchments. The Murrumbidgee catchment encompasses about 25 kilometres (km) of the proposal, and the Lachlan catchment covers 14 km. These catchments include the named watercourses of Billabong, Ulandra, Run Boundary, Isobel, Powder Horn and Dudauman Creeks, their tributaries and tributaries of Ironbong, Wattle and Bland Creeks.

12.2.3.2 Key tasks

The key tasks undertaken for the hydrology and flooding assessment included:

- a review of background information relevant to the study area, including previous studies, mapping, survey data, topography and climate data
- a review of sensitive receivers to determine potential impacts
- consultation with council and local landowners to obtain local flooding knowledge
- hydrologic and hydraulic modelling (flood modelling) (discussed further below) to develop a detailed understanding of existing design flood behaviour for the study area
- assessment of proposed changes to the existing hydrologic system and flood behaviour for construction and operation of the proposal
- Identification of mitigation measures to minimise and manage impacts.

Detailed discussion of the methodology for the hydrology and flooding assessment is provided in Chapter 3 of Technical Paper 4.

12.2.3.3 Flooding assessment

Existing flood conditions

The flooding assessment involved identifying existing catchments within the study area, and drainage structures present, to establish the existing flooding conditions. Flood modelling was undertaken to assess existing flooding behaviour within the study area, including impact to the existing rail corridors from flooding. The location of existing drainage infrastructure was considered in the flood modelling of the existing flooding conditions.

A broad range of design rainfall events, varying in severity, were assessed to determine the peak surface water flows within the catchments. Flood modelling was undertaken for a range of design flood events, for durations of 30 minutes through to 24 hours, for all the required annual exceedance probabilities (AEP).

Parameters identified in Table 12-1 have been adopted for use when simulating the design rainfall events; 18.13% (also referred to as the 0.2 exceedances per year (EY)), 10%, 2%, 5%, 1% and 0.05% Annual Exceedance Probability (AEP).

TABLE 12-1: FLOOD MODELLING EVENTS

Design event	Approximate equivalent Average Recurrence Interval (ARI)	Purpose of event analysis
0.2EY	5-year ARI	Low order event for impact assessment.
10% AEP	10-year ARI	Medium event for flood impact assessment and potential lower standard adopted for hydraulic design.
5% AEP	20-year ARI	Medium event for flood impact assessment and potential lower standard adopted for hydraulic design.
2% AEP	50-year ARI	Medium event for flood impact assessment and potential lower standard adopted for hydraulic design.
1% AEP	100-year ARI	Typical standard for hydraulic design.
1% AEP plus climate change	100-year ARI and climate change	Climate change factor of 20% applied to 1% AEP rainfall depths to assess the impact of predicted future climate conditions.
0.05% AEP	2000-year ARI	Extreme event to inform loading for structural stability assessments for bridges (if required).
Probable Maximum Flood (PMF)	NA	Extreme event to understand full extent of flood extent.

A climate change scenario was simulated in the flood models, which involved assessment of a 20 per cent increase in rainfall intensity, based on the ARR2019 recommendation to adopt the CSIRO Representative Concentration Pathway (RCP) of 8.5 as the climate change scenario within the Murray-Darling Basin cluster and an expected design life of 100 years. The 1% AEP rainfall data was factored up by 20 per cent to assess the sensitivity of flood behaviour resulting from climate change-induced rainfall intensity.

A cross-drainage blockage assessment was completed following the ARR2019 risk assessment, including an assumption of up to 25 per cent blockage. For existing culverts, the ARR2019 assessment was applied, except for the Stockinbingal to Parkes rail line and Lake Cargelligo line culverts for which maintenance records and visual inspections during site visits indicated 50 per cent blockage.

It is noted that the hydraulic model has not been established to understand flood behaviour through the urban areas of Stockinbingal for flood risk management and planning purposes. Further model definition with detailed survey of Stockinbingal would be required to adequately model flood behaviour through the urban areas. The models developed for this proposal should not be used to assess the effectiveness of current or proposed flood management measures for Stockinbingal unless updated with detailed survey information.

Operation impact assessment

Potential impacts to flood conditions during operation of the proposal (i.e. as a result of the permanent proposal infrastructure) were modelled by assessing changes in the behaviour of existing flooding conditions as a result of the proposal.

The design of the proposal was used to inform flood modelling, including the proposed vertical alignment, drainage structures and formation. The results of the flood modelling were used to:

- model flood impacts to the identified catchments, including:
  - assessing upstream and downstream flow, level, velocity, hazard and scour potential
  - assessing changes in flood safety risks on private and public land, including roads
- achieve the design immunity (1% AEP at top of formation) that determined the drainage infrastructure required
- identify design requirements for culverts and bridges, including upgrade of existing culverts (where required), to manage surface water flows to achieve compliance with QDLs.

Construction impact assessment

A qualitative construction impact assessment was completed, including review of the construction activities for the proposal. This included considering the existing flood behaviour to estimate where the proposal may interact with flood water, and where changes may occur to flood behaviour as a result of construction activities, plant and equipment.

Flood planning level and rail flood immunity

The proposal has been designed with a flood immunity of 1% AEP. This is consistent with the Floodplain Development Manual (DIPNR, 2005) and other relevant policies and standards. The flood planning level applies to the top of the rail formation (i.e. the earthworks and ballast on which the rail infrastructure is placed).

12.2.3.4 Peer review

A technical peer review of the flood models, including the hydrologic and hydraulic models has been completed. The independent review included an in-depth review of hydrologic and hydraulic model inputs, outputs and assumptions. The findings were 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.

A discussion on comments raised in the review and the responses provided are included in Appendix B of Technical Paper 4.

12.2.3.5 Geomorphological assessment

A geomorphological assessment was undertaken to assess the propensity for scour, erosion and geomorphological changes to occur at watercourses or overland flow paths impacted by the proposal. This assessment included:

- a review of existing conditions, including:
  - aerial imagery and topographic mapping for the study area
  - existing soil mapping and the results of geotechnical investigations completed for the proposal

  - the results of the aquatic biodiversity assessment, including the natural substrate (per cent bedrock, boulder, cobble, clay, etc) identified
  - current farming practices and potential impacts to watercourses, including dams, erosion banks, water capture bunds
  - existing watercourses and outputs from flood modelling (discussed above), including flood velocities, depths and extents
- application of river styles (*River Styles Framework* (DoI Water, 2019)) to define river character and behaviour
- assessment of potential impacts from the proposal based on the proposed change in the hydraulic conditions at and around watercourses and drainage lines, based on proposed drainage infrastructure and changes in velocity and flow distribution.

12.2.3.6 Quantitative Design Limits

The SEARs (at Key Issue 4, Item 2(a)) require the preparation of 'Quantitative Flood Management Objectives' for the proposal. For consistency with other Inland Rail projects, these objectives have been termed 'Quantitative Design Limits' (QDL).

Proposal-specific QDLs have been established through a review of the existing pattern of land uses in the project area, flood immunity objectives applied to development in the locality, and Inland Rail project objectives regarding rail infrastructure flood resilience. Consideration has also been given to other sections of Inland Rail, and a review of other critical infrastructure proposals across greenfield sites, to maintain a consistency of approach. These criteria have then been adapted for the proposal in consultation with the NSW Department of Planning and Environment (DPE), and the Inland Rail North Star to Boarder Project Draft Conditions of Approval as at May 2022.

The QDLs are broken down into the following key flood parameters:

- flood height—change in flood level (afflux) is used as the criterion
- flood velocity—change in the speed of the floodwaters is used as the criteria
- flood flow distribution—changes in the direction and extent of flood flows
- flood duration—the period of time that the floodwaters are present above the ground
- flood hazard—refers to the velocity depth product (v.d), which provides a provisional understanding of the flood hazard, where hazard is flooding that has the potential to cause risk to the community.

In addition to the QDLs, the proposal-specific flood models have been interrogated to understand changes in surface water supply and impacts to geomorphology. Detailed discussion of the design criteria implemented for the proposal is provided in Chapter 4 of Technical Paper 4.

Afflux

Afflux refers to a relative change in flood levels, between an existing scenario and a proposal scenario. The afflux limits (measured as increases) for the proposal are:

- habitable floors and sensitive infrastructure—10 millimetres (mm) (0.01 metres (m))
- non-habitable floors—20 mm (0.02 m)
- agricultural land—200 mm (0.2 m)
- forest, unimproved grazing land—300 mm (0.3 m)
- classified roads managed by TfNSW—50 mm (0.05 m)
- highways and sealed roads with a speed limit of greater than 80 kilometres per hour (km/hr)—50 mm (0.05 m)
- sealed road with a speed limit of less than 80 km/hr—100 mm (0.1 m)
- other land, surrounds of buildings, open space, recreation facilities and infrastructure—100 mm (0.1 m).

Change in flood velocity

The velocity (or speed of the flow of water) limits for the proposal as set by DPE for the proposal are:

- ground surfaces that have been sealed or otherwise protected against erosion—20 per cent increase
- classified roads managed by TfNSW—10 per cent increase in velocity where existing velocity already exceeds 1 m/s

- areas of natural ground surfaces including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas:
  - where existing velocities are less than 0.5 m/s, post development velocity is limited to 0.5 m/s or up to a 20 per cent increase (whichever is lesser)
  - where existing velocities are greater than 0.5 m/s, post development velocities are limited to a 0.025 m/s increase.

Flood flow distribution

Changes in the direction and distribution of flood flows has been considered by assessing changes in flood extent and changes to flood velocities, and by using the criteria set for afflux and velocity. Changes to existing flow diversions are assessed as part of the flood flow distribution assessment.

Flood duration

Flood duration refers to the amount of time for flood waters to dissipate and therefore the length of time that an impact from flooding would occur. The flood duration limits for the proposal are:

- habitable floors, and sensitive infrastructure:
- where existing above-floor flooding is less than 1 hour in flood duration, the post-development flood duration shall not exceed 1 hour
- where existing above-floor flooding is greater than 1 hour in duration, up to 5 per cent increased inundation duration
- where existing below-floor flooding is less than 1 hour in flood duration, the post-development flood duration shall not exceed 1 hour
- where existing below-floor flooding is greater than 1 hour in duration, up to 10 per cent increased inundation duration.
- classified roads managed by TfNSW:
  - no increase in duration of flood inundation to sections of road not already inundated
  - otherwise, 10 per cent increase in inundation duration.
- highways and sealed roads greater than 80 km/hr (operational road area), Sealed roads less than 80 km/h and all unsealed public roads (operational road area)
  - for new on-roadway inundation, or where existing inundation is less than 1 hour in flood duration, the post-development flood duration shall not exceed 1 hour, or as otherwise agreed by the relevant road authority
  - where existing on-roadway inundation is greater than 1 hour in duration, up to 10 per cent increased inundation, or as otherwise agreed by the relevant road authority.
- all other areas:
  - where existing inundation is less than 1 hour in flood duration, the post-development flood duration shall not exceed 1 hour
  - where existing inundation is greater than 1 hour in flood duration, up to 10 per cent increase in duration of inundation
  - no duration performance targets apply to newly flooded land no greater than 1000 m^2 in area.

Flood hazard

Flood hazard is typically defined as a product of the depth and velocity of floodwaters. This performance target is focused on achieving design solutions that do not appreciably alter flood hazard in sensitive/urban areas that are likely to be accessed/accessible by persons during flood events. The performance threshold permits some degree of change, in light of the fact that change is permissible in other flood impact categories (e.g. afflux). The flood hazard limits for the proposal are:

- residential buildings, and commercial, industrial, infrastructure and recreation land uses, highways and sealed roads—10 per cent increase in d.v (a measure of flood depth combined with velocity)
- classified roads managed by TfNSW—10 per cent increase in d.v where this does not result in an increase in hazard category. Otherwise no increase
- all other areas—20 per cent increase in d.v.

12.2.3.7 Consultation

Consultation with the community and key stakeholders has taken place during the reference design and environmental assessment phase of the proposal. This consultation has included meeting with Cootamundra–Gundagai Shire Council and Junee Shire Council, and numerous landowners.

Consultation focused on gaining information about historical and existing flood behaviour from council and landowners, and providing a description of the flood models and an understanding of flood behaviour for the proposal under existing conditions.

The following consultation was undertaken:

- Cootamundra–Gundagai Shire Council meetings occurred in October 2020 and February 2021
- a presentation was given to the Illabo to Stockinbingal Community Consultative Committee (CCC) in November 2020
- ten landowner meetings were conducted in October and November 2020
- in February 2021, two landowner meetings occurred to discuss the location of culverts and bridges across individual properties

The feedback provided by stakeholders during the consultation activities was used, where relevant, to inform the understanding of the hydrology of the area and for calibrating the model. Further information on consultation activities for the proposal is detailed in Chapter 4: Engagement.

Consultation with State Emergency Service (SES) was also completed via correspondence. The response from SES requested review of the final plans to manage potential impacts and did not request any information during development of the technical assessment (Technical Paper 4). Opportunity for feedback from SES will be provided during public exhibition of the EIS.

12.2.4 Risks identified

The environmental risk assessment for the proposal is included in Appendix G. This included an assessment of the potential risks to hydrology and flooding. Risks associated with hydrology and flooding with an assessed risk level of medium or higher included:

- water quality impacts due to spills and erosion during construction and operation
- water quality impacts to watercourses from the discharge of water from temporary water quality basins during construction
- impacts to construction activities due to flooding
- impacts on flood-prone areas from temporary infrastructure during construction
- impacts on flood-prone areas from permanent infrastructure during operation
- flooding impacts on proposal infrastructure and immunity during operation
- impacts on the geomorphology of watercourses.

12.2.5 How potential impacts have been avoided

The option development and assessment process for the proposal is summarised in Chapter 6: Alternatives and proposal options. As noted in Chapter 6, the shortlist of route options was subject to a detailed assessment, and the proposal was refined based on evaluation of key considerations, including impacts to hydrology and flooding.

Potential impacts to hydrology and flooding were included in the list of selection criteria used for the analysis of options (summarised in Chapter 6). This has included consideration of existing flooding. The design of the proposal has been developed to avoid impacts to hydrology and flooding through the QDLs detailed in section 12.2.3.6.

Potential impacts on hydrology and flooding would continue to be avoided through:

- designing, constructing and operating the proposal to further minimise the potential for impacts as far as practicable
- managing the potential impacts to hydrology and flooding in accordance with relevant legislative and policy requirements, as outlined in section 12.2.1

- implementing the mitigation measures provided in section 12.5.5
- implementing other mitigation measures relevant to other issues also relevant to hydrology and flooding.

A range of mitigation measures have been included in the proposal to mitigate potential hydrology and flood impacts, as provided in section 12.6.2. Any residual impacts are discussed in section 12.6.3.

12.3 Existing environment

12.3.1 Climate

The climate of the South West Slopes of the Riverina region is classified as Hot Dry Zone (with cooler winters) climatic zone. The region experiences hot and dry summers, and cold to mild temperatures during the winter months. The nearest weather station (Wagga Wagga Research Centre, site number 074114) records mean daily maximum temperatures from 31.0 degrees Celsius (°C) in January to 12.4°C in July.

Rainfall data from the Stockinbingal (Sunnydale) (station number 73150) at the north of the proposal site shows an average annual rainfall of 484.6 mm. Rainfall data from the Junee Treatment Works (station number 73019) at the south of the proposal site shows an average annual rainfall of 525.4 mm. Rainfall is generally consistent across the year, with slightly higher rainfall from July to October.

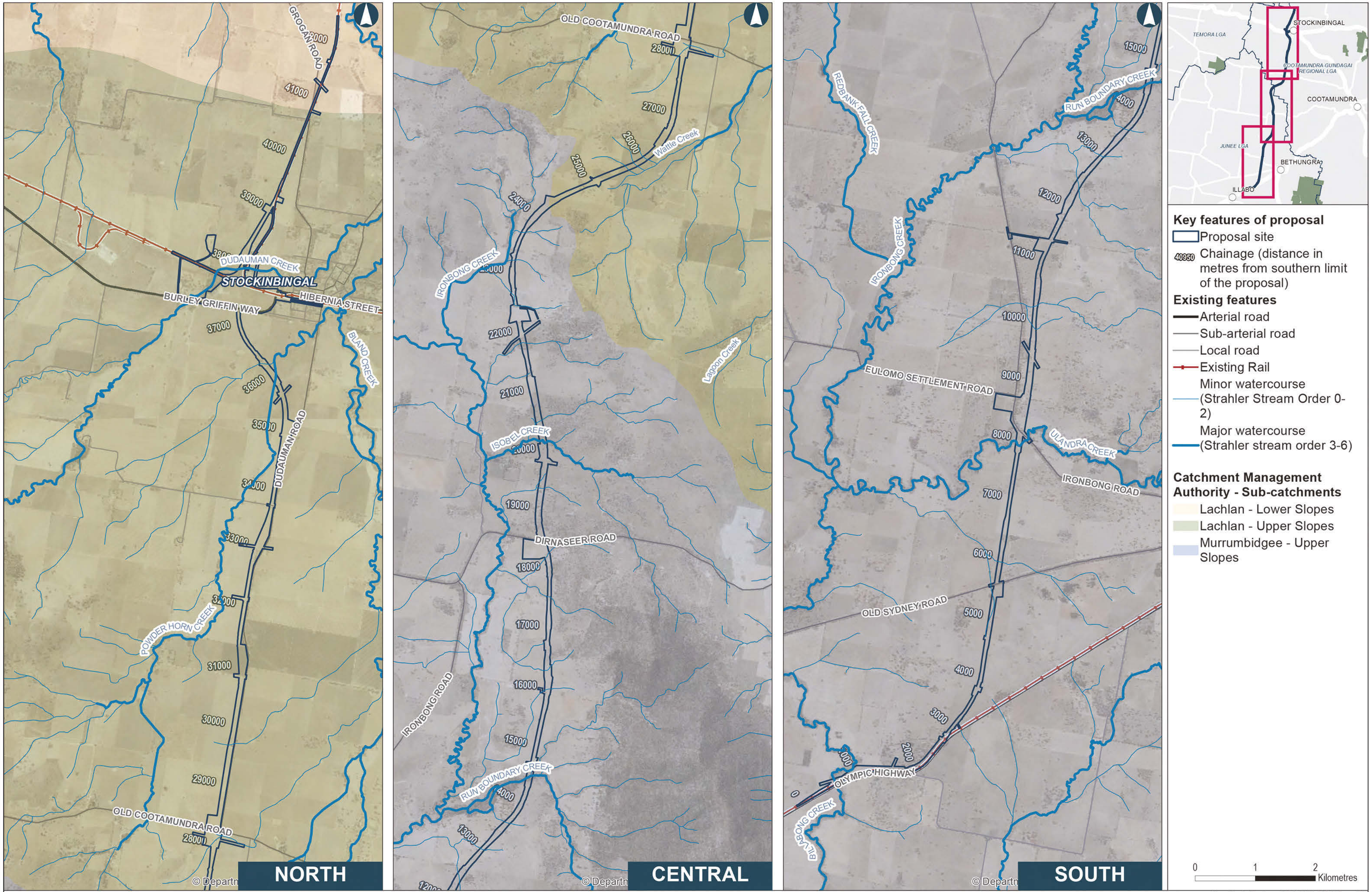
12.3.2 Catchments

The study area is located within two catchments, comprising the Murrumbidgee River catchment and Lachlan River catchment. Both of these catchments are sub-catchments of the Murray-Darling Basin. The study area is located within the upper reaches of both catchments and watercourses within this area are predominantly ephemeral, flowing only during rainfall events. As such, the study area is subject to localised flooding and is not impacted by the regional floodplain for either of the catchments. The catchment boundaries are shown in Figure 12-1.

The majority of the study area is located within the Murrumbidgee River catchment. Regionally, surface water within this catchment flows with the topography, generally in a southerly direction towards the Murrumbidgee River, which is located about 30 km south of the study area.

Surface water flows in the Lachlan River catchment within the study area are to the north, reaching the Lachlan River over 100 km to the north. This catchment includes the township of Stockinbingal.

Flood levees have been constructed in this catchment to mitigate existing impacts of flooding from Dudauman Creek to the west of the township and through the town itself between West Street and Grogan Road (refer to section 12.3.4).



12.1 Catchment areas and key watercourses

Data Sources: ####

12.3.3 Watercourses

12.3.3.1 Hydrology

The proposal site intersects a number of watercourses, including named creeks and unnamed tributaries.

Watercourses intersected by the proposal site are ephemeral (i.e. watercourses that only flow following periods of intense or prolonged rainfall). The hierarchy of watercourses is defined using Strahler stream order system. This system assigns an 'order' to watercourses according to the number of additional tributaries associated with each watercourse, to provide a measure of system complexity. Table 12-2 provides a summary of named watercourses within the study area and their location is identified on Figure 12-1.

TABLE 12-2: KEY WATERCOURSES WITHIN THE STUDY AREA

Catchment	Watercourse	Strahler stream order	Flow conditions	Flow direction and relationship to proposal site
Murrumbidgee	Billabong Creek	6th	Ephemeral	Flows from north to south and intersected by the proposal site.
Murrumbidgee	Ulandra Creek	5th	Ephemeral	Generally, flows from east to west and confluences with Ironbong Creek and intersected by the proposal site.
Murrumbidgee	Run Boundary Creek	3rd	Ephemeral	Flows in a north-westerly direction, before turning south east and confluencing with Ironbong Creek, and intersected by the proposal site.
Murrumbidgee	Isobel Creek	2nd	Ephemeral	Flows from east to west through the study area, confluencing with Ironbong Creek and intersected by the proposal site.
Murrumbidgee	Ironbong Creek	3rd	Ephemeral	Generally flows in a north–south direction, confluencing with Billabong Creek. Ironbong is not intersected by the proposal—at its closest point the main channel is less than 250 m from the proposal site.
Lachlan	Powder Horn Creek	2nd	Ephemeral	Generally flows from south–north and confluences with Bland Creek downstream of the study area, and intersected by the proposal site.
Lachlan	Dudauman Creek	3rd	Ephemeral	Generally flows from south–north, turning east through Stockinbingal within the study area. Flows are influenced by existing road and rail lines, and a number of levees identified near Stockinbingal. Dudauman Creek is intersected by the proposal at two locations.

12.3.3.2 Geomorphology

A geomorphic assessment of watercourses that intersect the proposal site was completed with consideration of overland flow paths, local landscapes and geological conditions.

Soils and geology

Typical soils along the proposal site include solodic soils and red-brown earths consisting of a sandy loam to clay loam topsoil with a heavier textured subsoil. The soil landscapes in the north of the proposal site are mainly alluvium, red-brown earths. The Stockinbingal Formation is located just north of the Dudauman Creek floodplain with solodic soils. These soils are largely alluvial with some areas of solodic soils. The central section of the proposal is mainly Frampton Volcanics, with red podzolic soils and some alluvium and red-brown earths. The southern section of the proposal site are alluvium soils with small outcrops of the Junawarra Volcanics and the Combaning Formation, and some solodic soils. Further details on soils and geology of the proposal site are provided in Chapter 20: Soils and contamination.

Watercourse geomorphology

Many of the watercourses that intersect the proposal site are ephemeral watercourses that flow only after a period of intense or prolonged rainfall. These watercourses do not have defined flow channels and, therefore, their geomorphologic conditions are susceptible to change following an intense or prolonged rainfall. These undefined watercourse catchments are predominantly cleared of remnant vegetation, and farm dams have been constructed to capture overland flows for storage for agricultural purposes. The geomorphic condition of the watercourses with defined channels surrounding or within the proposal site has been analysed using the River Styles Framework Tool (DoI Water, 2019). The River Styles Framework is a system for categorising river types and describe river behaviour.

The geomorphology of the watercourses intersecting the proposal is provided in Table 12-3.

TABLE 12-3: GEOMORPHOLOGY OF EXISTING WATERCOURSES

Watercourse	Flow conditions	Condition	Classification[1]
Billabong Creek	Ephemeral	The watercourse banks are well defined and include low- and high-flow channels immediately upstream of the proposal. There is vegetation both in the base of the watercourse and in the high-flow channels. The floodplain above the top of the bank is largely cleared of vegetation.	River style: Laterally unconfined, continuous channel with low sinuosity sand. High fragility and susceptible to change if the watercourse vegetation and contributing catchment are impacted; however, it has moderate recovery potential.
Ulandra Creek	Ephemeral	Ulandra Creek is highly vegetated within the main defined creekline, with the flood plain above the top of bank largely cleared of vegetation. The main watercourse is 2.3 m deep and 19 m wide.	River style: Laterally unconfined, continuous channel with meandering fine-grained sand. High fragility and susceptible to change if the watercourse vegetation and contributing catchment are impacted; however, it has moderate recovery potential.
Run Boundary Creek	Ephemeral	The main channel is well defined and highly vegetated, being approximately 1.5 m deep and 20 m wide. Land is cleared from the top of bank, and the watercourse becomes less defined downstream where it joins an unnamed tributary.	River style: Laterally unconfined, continuous channel with low sinuosity sand. High fragility and susceptible to change if the watercourse vegetation and contributing catchment are impacted; however, it has moderate recovery potential.
Isobel Creek	Ephemeral	Isobel Creek has a well-defined meandering shape, that is typically 20 m wide between the top of banks and 2.2 m deep. It is highly vegetated to the top of bank, beyond which it has been cleared.	River style: Laterally unconfined, continuous channel with low sinuosity gravel bed, and is in a poor condition. Moderate fragility, which means it has the potential to adjust to changes and impacts locally over small stretches but it has low recovery potential.
Isobel Creek Tributary	Ephemeral	Isobel Creek Tributary is well defined and vegetated, with numerous agricultural dams upstream and downstream of the proposal. Approximately 300 m downstream the watercourse becomes less defined before connecting into the main watercourse alignment.	No river style is available for this watercourse due to the small size of its catchment, but it is likely to be similar to the main Isobel Creek channel.
Powder Horn Creek	Ephemeral	A geomorphic assessment completed in 2001 to accompany the *Stockinbingal Floodplain Management Study* (SMEC) (DPIE, 2002) described active gullying occurring in Powder Horn Creek downstream of Corbys Lane and parallel to Dudauman Road. Powder Horn Creek shows substantial clearing and damming of the natural flow path upstream of the proposal site including diversion drains to direct flow into dams.	River style: Laterally unconfined, continuous channel with channelised fill and is in a poor condition. It has a moderate fragility, which means it has the potential to adjust to changes and impacts locally over small stretches and it has been identified as a site for strategic recovery.
Powder Horn Creek Tributary	Ephemeral	Similar to the main watercourse alignment, Powder Horn Creek tributary's natural creekline has been cleared and realigned for agricultural purposes.	No river style is available for this watercourse due to its small catchment but it is likely to be similar to the main Powder Horn Creek channel.

Watercourse	Flow conditions	Condition	Classification[1]
Dudauman Creek	Ephemeral	A 2001 Geomorphic assessment (Erskine, 2001) described Dudauman Creek at the Burley Griffin Way as having sand and gravel bed material, and that it has been repeatedly disturbed by excavation, and, as such, is in a poor condition in the vicinity of the proposal site.	River style: Laterally unconfined, continuous channel with channelised fill and is in a poor condition. It has a moderate fragility, which means it has the potential to adjust to changes.

1. NSW River Styles spatial layer (DPIE, 2019) & NSW River Styles Database (DPIE, 2019)

12.3.4 Flooding

As discussed above, the study area is located within the upper reaches of the respective catchments and not subject to regional flooding. Isolated flooding occurs within the study area within local catchments. An understanding of the existing flood behaviour for the proposal site is based on all available historic studies and data, anecdotal information, landowner discussions and design flood modelling.

12.3.4.1 Flood management plans

Two flood management plans relevant to the proposal site were identified; Stockinbingal Floodplain Management Study and Plan (SMEC, 2002) and Jeralgambeth Creek at Illabo—Floodplain Risk Management Study and Plan (Lyall and Associates, 2012).

A summary of these plans is provided in the following sections, while consideration of the consistency of the proposal with these plans is provided in section 12.5.5.

Stockinbingal Floodplain Management Study and Plan

The Stockinbingal Floodplain Management Study and Plan was prepared based on the 1999 Stockinbingal Flood Study. The focus of the plan was to provide a flood management strategy for the village of Stockinbingal to manage the flood risk.

The village is located on the combined floodplain of the Bland and Dudauman creeks. The proposal does not cross Bland Creek but intersects many tributaries of Bland Creek including Powder Horn Creek.

The proposed management measures are within the urban areas of the village of Stockinbingal. The plan observes that gully erosion is an issue for Powder Horn Creek. The plan indicates that there is a series of artificial levees along Dudauman Creek between Burley Griffin Way and the Lake Cargelligo Line. The levees are estimated to have a current immunity of between 5% and 10% AEP.

The Stockinbingal Floodplain Risk Management Plan indicates that the two most significant floods occurred in 1956 and 1974. Inundation in Stockinbingal during the 1974 flood event occurred when Dudauman Creek broke its banks in the vicinity of the West Street (downstream of the proposal site) and Wood Street intersection, and at the Geraldra Street crossing.

Jeralgambeth Creek at Illabo—Floodplain Risk Management Study and Plan

No historic flood information was available for the Junee Shire Council area for the proposal except that Jeralgambeth Creek at Illabo Floodplain Risk Management Study and Plan indicates a severe storm occurred in February 2011, which resulted in a flood at Illabo (magnitude of this event is not documented in the report).

Jeralgambeth Creek is the main watercourse in the vicinity of Illabo and is a tributary of Billabong Creek. Jeralgambeth Creek joins Billabong Creek downstream of the proposal and does not impact on the proposal site.

12.3.4.2 Flood emergency arrangements

The rural nature of the proposal site, scarcity of urban development and lack of regional flood-liable land means there are no formal flood emergency management arrangements in place for most of the land in and around the proposal site.

The Cootamundra–Gundagai Shire Council area is in the Murrumbidgee State Emergency Service (SES) region and for emergency management purposes is part of the Southern Highlands Emergency Management District. The Local Flood Plan (LFP) from the previous Cootamundra Shire Council, the Cootamundra Local Flood Plan (NSW SES, 2007) governs flood emergency management arrangements for the urban areas of Stockinbingal. The Cootamundra SES local controller is responsible for dealing with floods. The plan outlines that the Rural Fire Service (RFS) is to provide personnel in rural areas and villages to inform the Cootamundra SES local controller about gauge heights, flood conditions and response needs in their own communities and to disseminate flood information.

12.3.4.1 Flooding at catchments

A summary of the flooding behaviour for the catchments assessed, including flooding extent, velocities and duration, within the study area is provided in Table 12-4. Flood extents for the 1% AEP are shown in Figure 12-2. Further detail is provided in Technical Paper 4.

TABLE 12-4: KEY WATERCOURSES AND EXISTING FLOOD BEHAVIOUR FOR THE 1% AEP

Catchment and watercourse	Flood levels and distribution	Velocity	Critical storm duration
Murrumbidgee			
Billabong Creek	Billabong Creek has a catchment of about 320 km^2 and includes the tributaries of Ironbong Creek and Ulandra Creek. The existing Main South Line acts as a barrier for surface water flows. The floodplain upstream of this control point is up to 1.7 km wide, with depths ranging up to 1.1 m during the 1% AEP.	Up to 1.5 m/s within the channel and floodplain flows of less than 0.5 m/s.	Up to 24 hours, 12 hours for the 1% AEP.
Ulandra Creek	Flooding is generally confined to the channel for flood events up to the 1% AEP. At Ironbong Road the floodplain extends to 1 km in width for the 1% AEP, and depths of up to 3 m in the main channel. Ironbong Road acts as a barrier to surface water flows from east to west. Historical evidence suggests that floodwaters do break the banks and inundate land either sides of the main channel.	Up to 2 m/s within the channel and floodplain flows of less than 0.5 m/s.	12 hours for 1% AEP
Unnamed tributaries between Ulandra and Run Boundary Creek	Flooding is directed by overland flow paths to a number of farm dams. Depths between the farm dams are estimated to be less than 0.1 m for the 1% AEP.	Less than 0.5 m/s except immediately downstream of some farm dams.	Up to 24 hours for 1% AEP
Run Boundary Creek	Flood modelling for Run Boundary Creek indicates that flows are predominantly confined to the channel for the 1% AEP. The width of the floodplain for Run Boundary Creek ranges from 170 m to 350 m at the confluence of Ironbong Creek. Water depths are up to 1.5 m within the channel and 0.7 m across the floodplain.	Up to 4 m/s within the channel and floodplain flows of less than 1 m/s.	Up to 24 hours for 1% AEP
Isobel Creek	A flood extent of Isobel Creek of generally less than 30 m was modelled during the 1% AEP, with depths up to 1.5 m within the channel.	Up to 4 m/s within the channel and floodplain flows lowering to 0.3 m/s.	Up to 18 hours for 1% AEP
Lachlan			
Unnamed tributaries between Isobel and Powder Horn Creeks	The 1% AEP indicates that there is limited channel definition, with limited capacity, and a majority of the 1% AEP flood flow spreading across flat grazing and cropping land. Flood depths are 0.1 m across the majority of the extent, with depths of up to 0.5 m downstream of a farm dam.	Average of less than 0.2 m/s, with some sections peaking at 0.5 m/s.	Up to 24 hours for 1% AEP

Catchment and watercourse	Flood levels and distribution	Velocity	Critical storm duration
Powder Horn Creek	A flood extent of up to 500 m is produced during the 1% AEP, with flood depths ranging from 2 m within the channel, and 0.1 m to 0.5 m at the edge of the floodplain. Flood modelling for Powder Horn Creek indicates it is not impacted by flooding from Bland Creek within the study area.	Up to 1.5 m/s within the channel and floodplain flows of 0.8 m/s.	Up to 18 hours for 1% AEP
Dudauman Creek	Dudauman Creek has a relatively small channel, and modelling indicates that Burley Griffin Way and the Lake Cargelligo Line act as barriers for surface water flows and result in ponding upstream. Flood modelling indicates that flooding during 1% AEP events south of the Burley Griffin Way extends to about 500 m. Flooding extents of up to 750 m occur between the Burley Griffin Way and the Lake Cargelligo Line, which act as upstream and downstream constraints. This flooding results in water depths of up to 2 m within the channel and 0.5 m across the floodplain. Flood extents downstream of the Stockinbingal to Parkes Line is about 200 m and extends out to 500 m immediately upstream of Stockinbingal.	Up to 1.8 m/s within the channel and floodplain flows of less than 1 m/s.	Up to 18 hours through the channels between Burley Griffin Way and the Lake Cargelligo Rail Line, and up to 24 hours downstream of the Stockinbingal to Parkes rail line for the 1% AEP.

Key features of proposal

Proposal site

40950 Chainage (distance in metres from southern limit of the proposal)

Existing features

Sub-arterial road

Arterial road

Existing Rail

Receptor Type

Active Recreation

Commercial

Educational

Place of worship

Residential

Existing flood depth (m)

<= 0.5

0.5 - 1.0

1.0 - 1.5

1.5 - 2.0

> 2.0

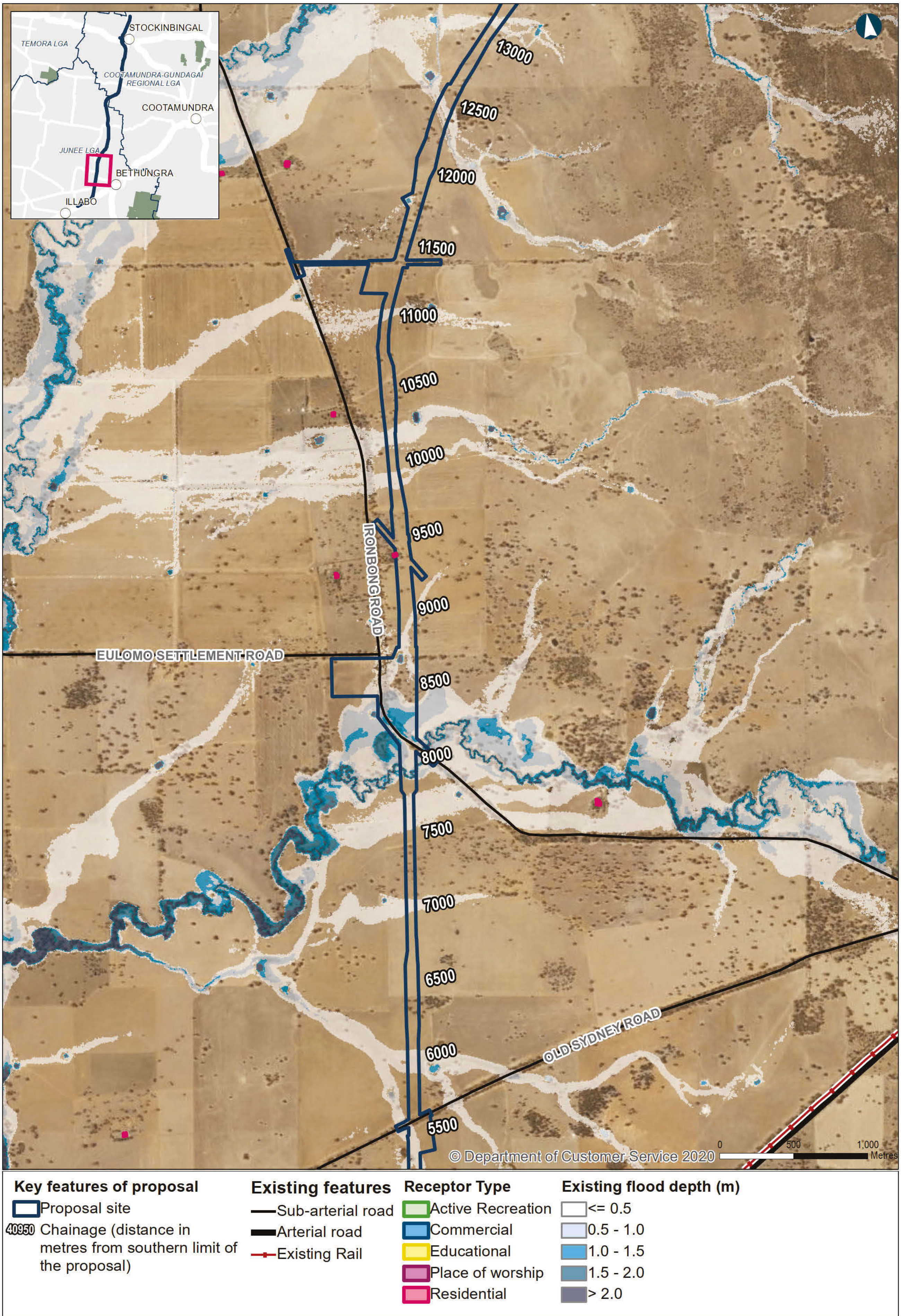
12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000

MAP 1 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd

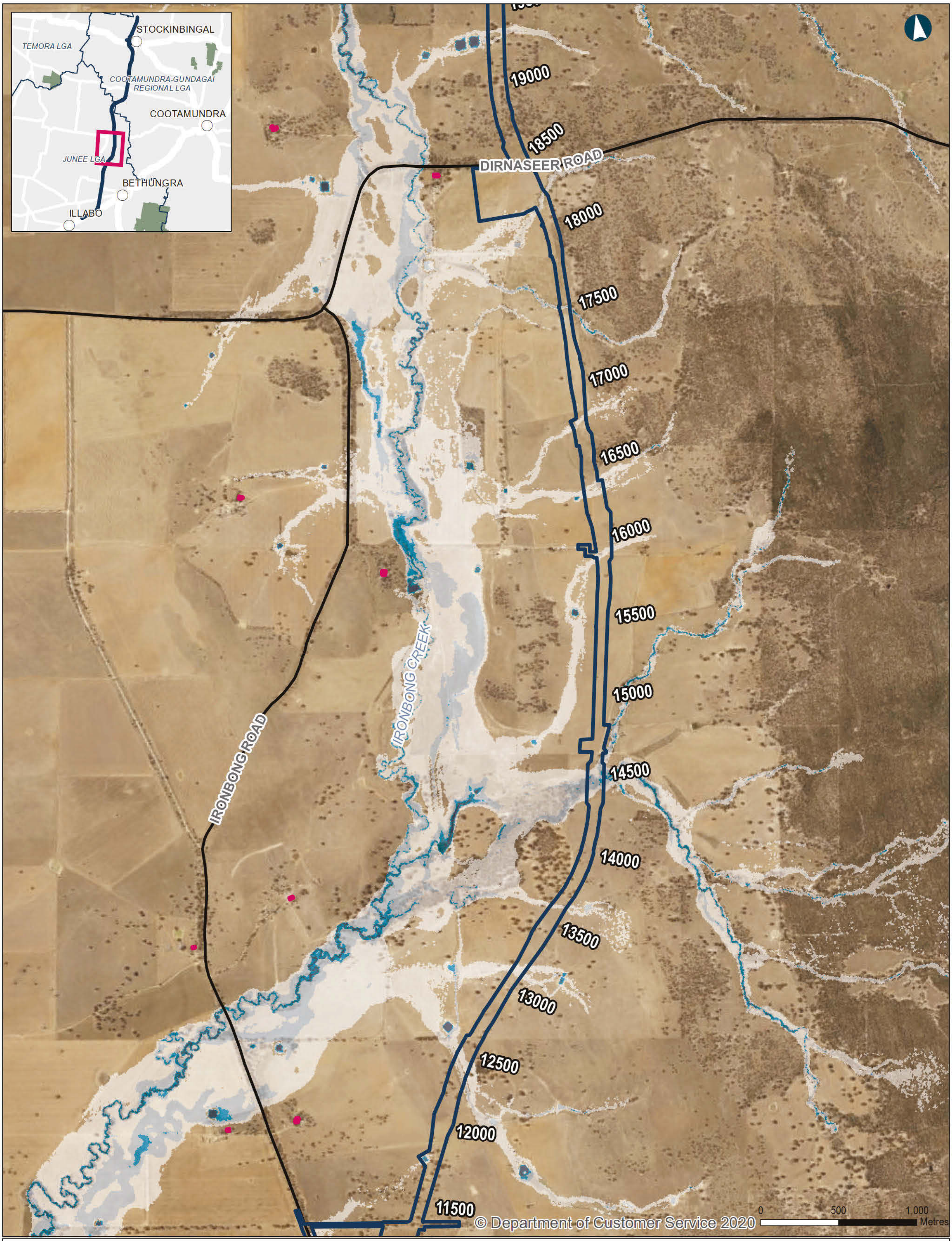


12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 2 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd



Key features of proposal

- Proposal site
- 40950 Chainage (distance in metres from southern limit of the proposal)

Existing features

- Sub-arterial road

Receptor Type

- Active Recreation
- Commercial
- Educational
- Place of worship
- Residential

Existing flood depth (m)

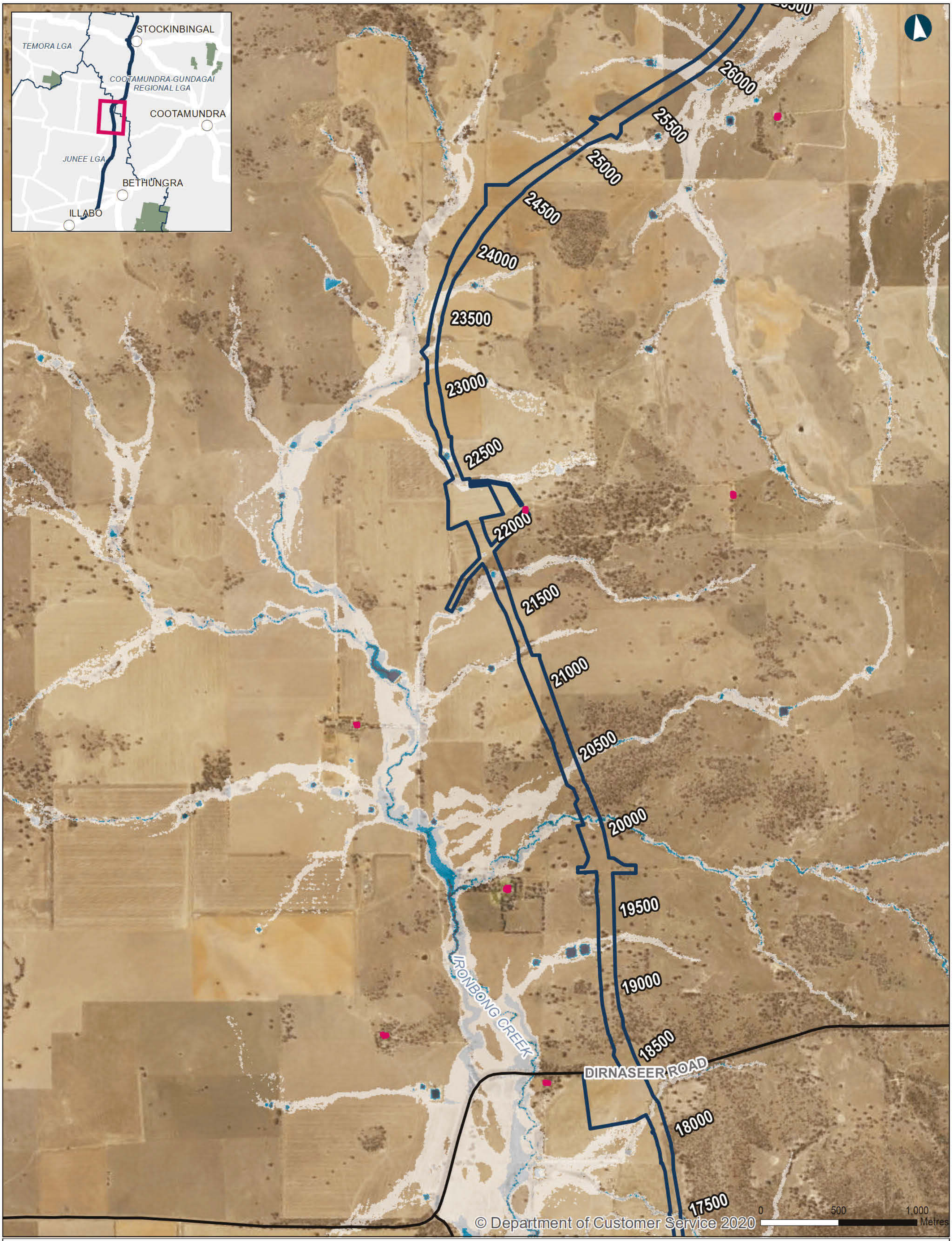
- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 3 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd



Key features of proposal

Proposal site

40950 Chainage (distance in metres from southern limit of the proposal)

Existing features

Sub-arterial road

Receptor Type

Active Recreation
Commercial
Educational
Place of worship
Residential

Existing flood depth (m)

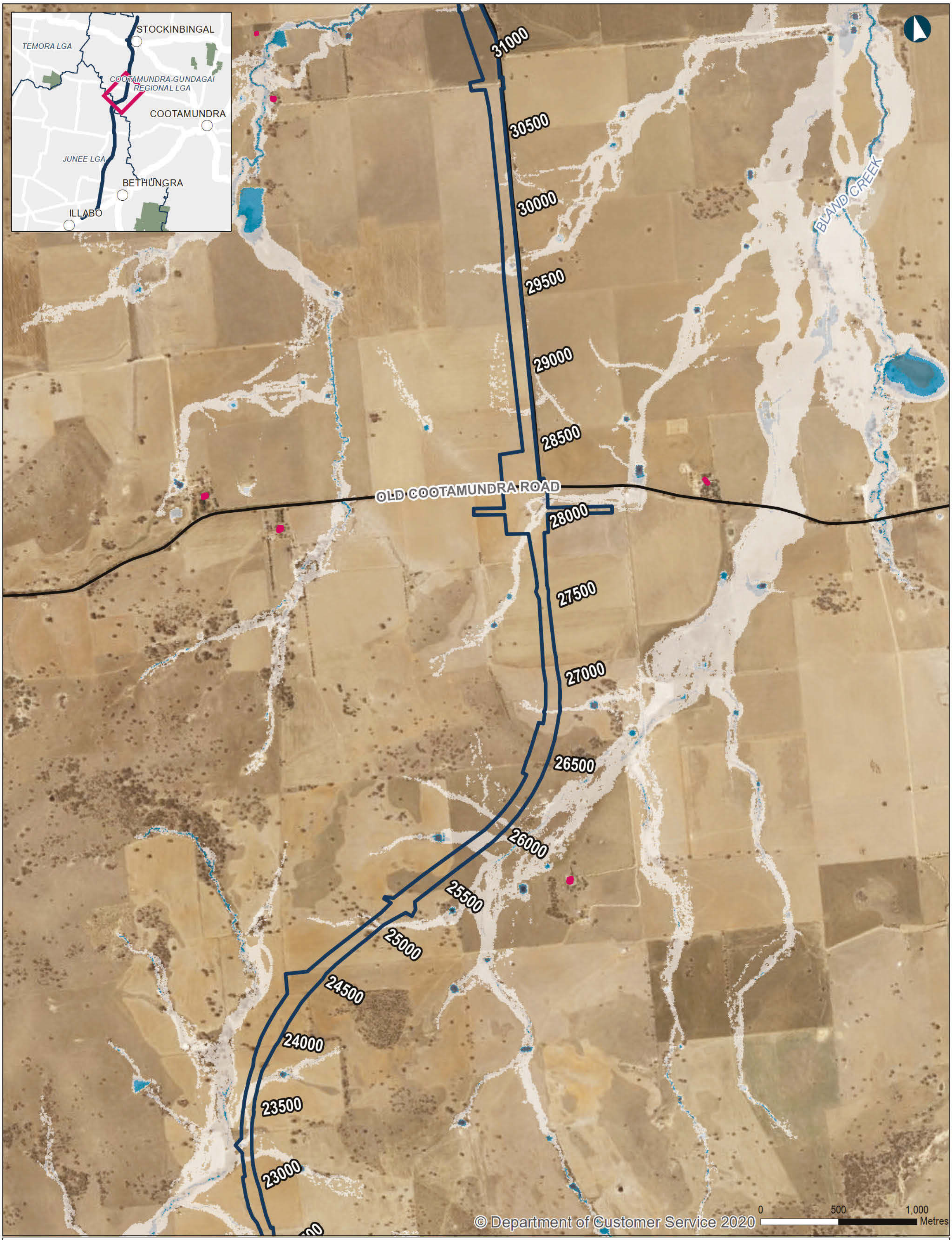
<= 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 4 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd



Key features of proposal
Proposal site
40950 Chainage (distance in metres from southern limit of the proposal)

Existing features
Sub-arterial road

Receptor Type
Active Recreation
Commercial
Educational
Place of worship
Residential

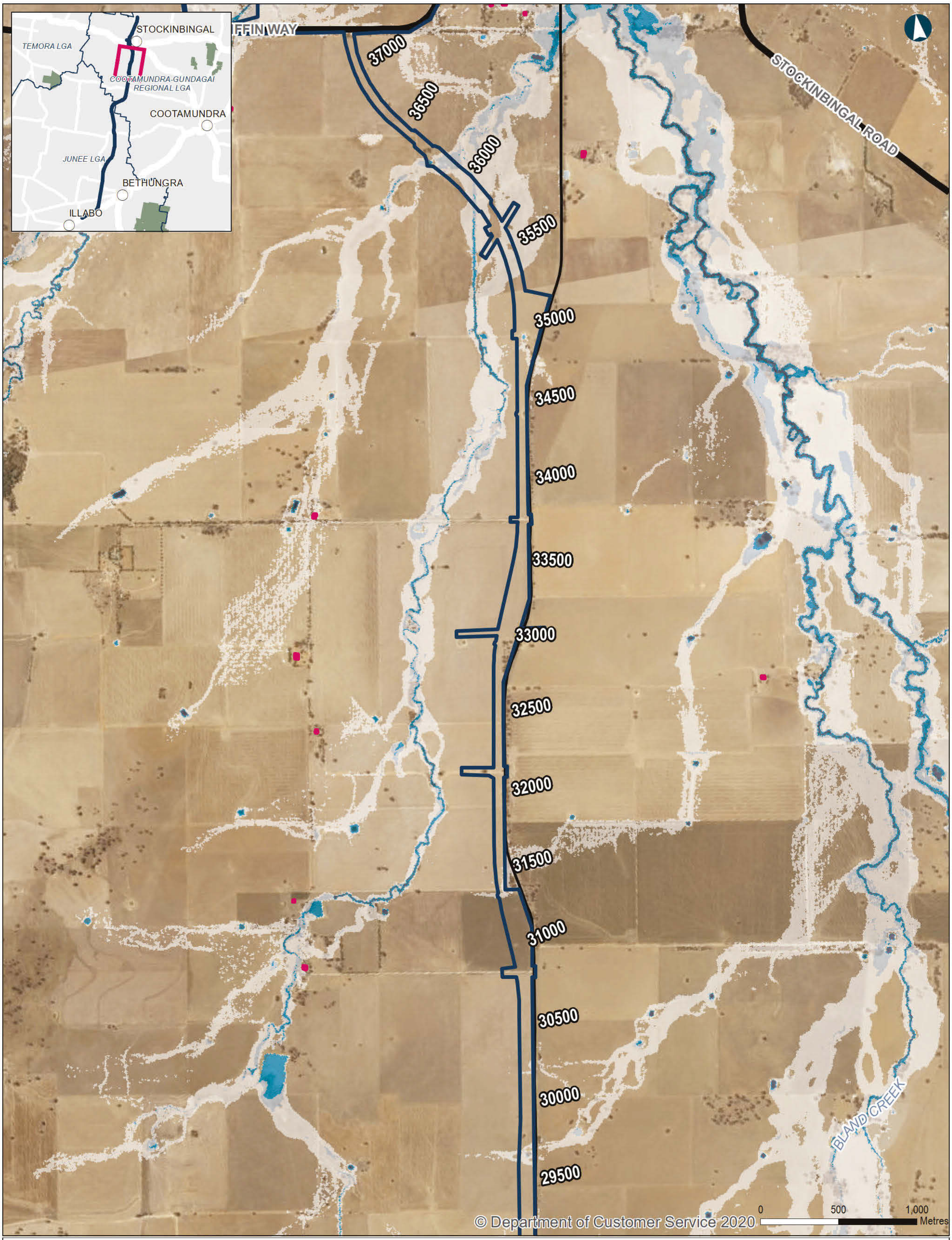
Existing flood depth (m)
<= 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 5 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd



Key features of proposal
- Proposal site
- 40950 Chainage (distance in metres from southern limit of the proposal)

Existing features
- Sub-arterial road
- Arterial road

Receptor Type
- Active Recreation
- Commercial
- Educational
- Place of worship
- Residential

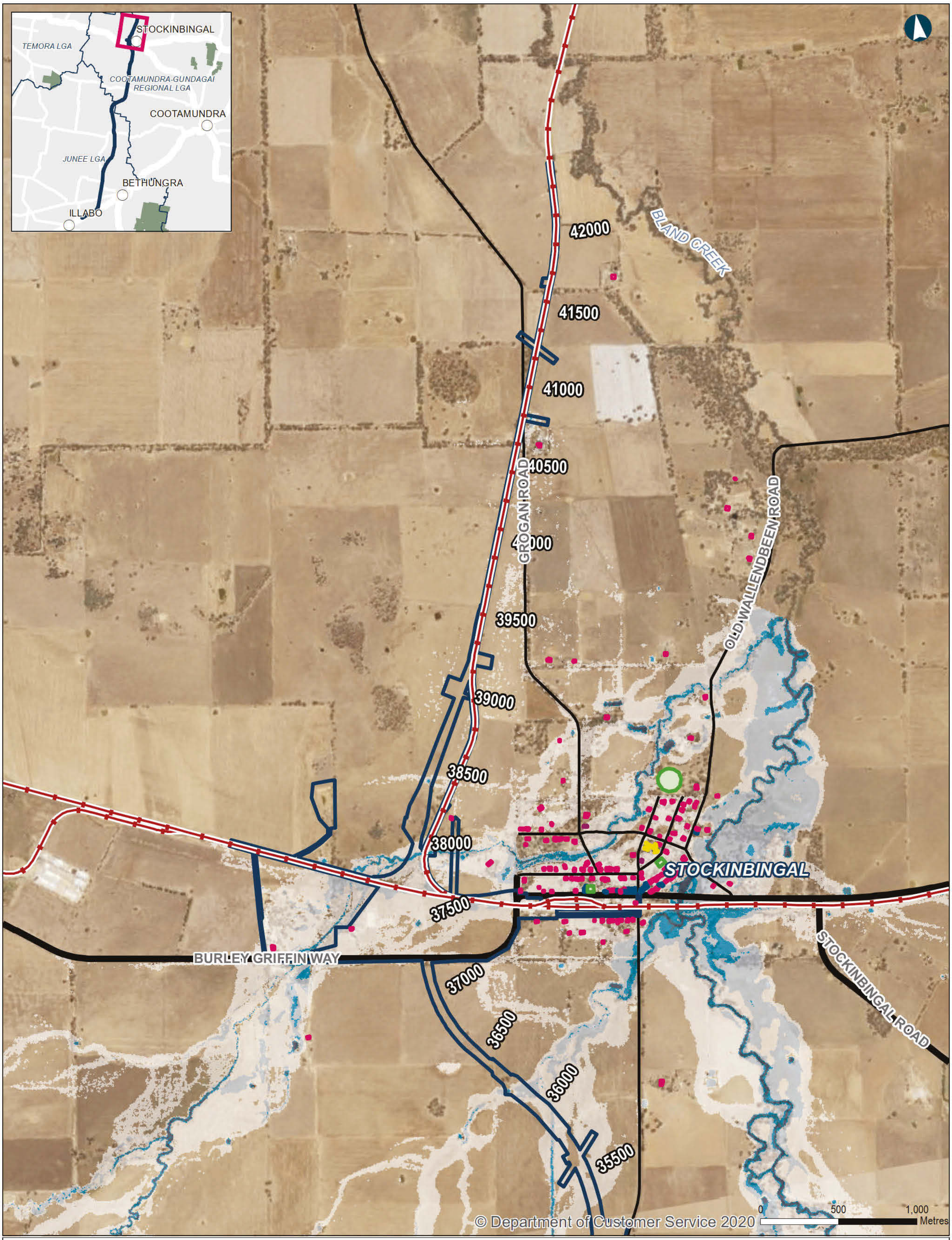
Existing flood depth (m)
- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 6 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd



Key features of proposal

- Proposal site
- 40950 Chainage (distance in metres from southern limit of the proposal)

Existing features

- Sub-arterial road
- Arterial road
- Existing Rail

Receptor Type

- Active Recreation
- Commercial
- Educational
- Place of worship
- Residential

Existing flood depth (m)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

12.2 Existing flood conditions (1% AEP)

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:35,000
MAP 7 of 7

Illabo to Stockinbingal Data Sources: LPI, IRDJV, ARTC

220_0115_EIS_12_2_ExistingFloodConditions_r1v4.mxd

12.3.4.2 Probable Maximum Flood

The Probable Maximum Flood (PMF) 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. This is an extreme event that provides an understanding of the full flood extent.

The Probable Maximum Precipitation (PMP) is the estimated highest rainfall event that could result in a PMF. The PMP and resulting flows were estimated for the larger catchments intersected by the proposal, which consist of Billabong, Ulandra, Powder Horn and Dudauman Creeks.

The effects of a PMP storm event of up to 24 hours were modelled to estimate the critical duration for PMF events. The 24-hour storm has been identified as being critical for Billabong Creek, the 18-hour storm for Ulandra, and the 3-hour storm for both the Powder Horn Creek and Dudauman Creek catchments. The flood maps in Appendix C of Technical Paper 4 present the peak flood levels and depth for the PMF events across these four catchments.

The Billabong Creek floodplain is up to 1.8 km wide in the vicinity of the proposal and flood depths are over 7 m in the main channel and up to 3 m across the floodplain.

The Ulandra Creek PMF extends up to 1.5 km in width at the proposal but most of the flow is still carried by the main watercourse channel, with depths up to 2.5 m.

The Powder Horn and Dudauman Creek floodplains in the vicinity of the proposal have a combined floodplain width of 2.5 km. The majority of the flood flows are still carried by the main channels and the combined floodplain has a depth less than 0.5 m between the Burley Griffin Way and the Lake Cargelligo Line near Stockinbingal.

12.3.4.3 Flooding immunity at existing roads and rail corridors

Flood modelling was used to determine where existing infrastructure, including road and rail, may be subject to overtopping. Where overtopping does not occur, the infrastructure is considered to have flood immunity for that flood event.

Review of survey information has helped in understanding the existing flood immunity of roads that are intersected by the proposal or in the vicinity of the proposal.

Immunity for existing rail is defined as the overtopping event as there are no details on the depth to formation, whereas immunity for proposed rail is up to the formation level of the rail and not the overtopping height.

The Main South Line section of the proposal is estimated to have up to 2% AEP flood immunity and to the west through Illabo, flood modelling of Jeralgambeth Creek indicates the rail is not overtopped by events up to and including the 1% AEP.

Consideration of potential for (or absence of) overtopping of the existing rail lines is provided in Table 12-5. Limited survey of the top of rail was available to confirm the immunity of the rail through Stockinbingal to west of Dudauman Creek along the Lake Cargelligo Line.

TABLE 12-5: CONSIDERATION OF OVERTOPPING OF EXISTING RAIL LINES DUE TO FLOODING UNDER EXISTING CONDITIONS

Rail	Existing flood immunity event (AEP)
Main South Line	▸ 2% AEP flood immunity for the existing rail through the Billabong Creek ▸ 1% AEP to the west through Illabo
Lake Cargelligo Line	▸ 1% AEP
Stockinbingal to Parkes Line	▸ 1% AEP

A summary of potential overtopping of roads within the study area from existing flooding is provided in Table 12-6.

TABLE 12-6: CONSIDERATION OF OVERTOPPING OF ROADS DUE TO FLOODING UNDER EXISTING CONDITIONS

Road	Existing flood immunity event (AEP)
Olympic Highway	▸ 1–2% AEP
Old Sydney Road	▸ 10% AEP
Ironbong Road	▸ Less than 5% AEP to the north and south of Ulandra Creek ▸ 1% AEP at Ulandra Creek
Dirnaseer Road	▸ Road not impacted by flooding
Old Cootamundra Road	▸ Road not impacted by flooding at proposal locations
Dudauman Road	▸ 2% AEP—road is subject to inundation from Powder Horn Creek
Burley Griffin Way	▸ 2% (1% AEP at the bridge crossing of Dudauman Creek) ▸ 10% for Hibernia Street between West Street and Cynthia Street.

12.3.4.4 Existing buildings and properties

Impacts to buildings from existing flooding were determined through a review of aerial imagery and the results of existing flood modelling. The 195 buildings, including houses and other farm structures identified near the proposal site as part of the noise and vibration impact assessment, were used to inform the assessment as detailed site survey has generally not been collected for any of these structures (see Technical Paper 8: Noise and Vibration (Construction). A review of the sensitive receiver locations against the 1% AEP flood extent indicates that up to 74 buildings are inundated, based on the conservative assumption that the floor levels for these buildings are at ground level. Of these, 58 buildings are located within the township of Stockinbingal (refer to Figure 12-2).

The *Stockinbingal Floodplain Risk Management Study and Plan* (SMEC, 2002) estimated 73 properties would experience above-floor flooding in a PMF and 30 in a 1% AEP event (formally known as the 100 ARI) for the existing environment. It is noted that the estimate was based on contour information provided by Cootamundra Shire Council and not detailed survey. Based on the study findings, several houses were recommended for house raising to reduce the impact of flooding. The houses recommended for raising are located at least 600 m away from the proposal site.

12.3.5 Surface water supply

For the rural land surrounding the proposal, surface water supply predominantly comes from rainfall collected via rainwater tanks, farm dams and from the reticulated water network operated by Goldenfields Water. Goldenfields Water operates a reticulated network across the study area that services many of the farms with both stock and domestic supply. In the vicinity of the proposal, the network extends along Burley Griffin Way, Old Cootamundra Road, Dirnaseer Road, Ironbong Road, Eulomo Settlement Road and Old Sydney Road. There are no permanent flowing watercourses near the proposal, so no water is extracted from surface watercourses.

A search of the NSW Water Register (WaterNSW, 2019) was undertaken to identify the number of Water Access Licences (WALs) available for each surface water source. The WALs indicate that the surface water sources intersected by the proposal are potentially used for stock, domestic and town water supply. There are also a number of WALs for extraction of water from unregulated rivers.

Due to the ephemeral nature of the watercourses, there is no permanent water flow; and it is unlikely that there are any WALs utilised as a primary source of water in the vicinity of the proposal site.

Aerial photography and topographic data of the proposal study area indicate that farm dams are typically located along overland flow paths or adjacent to creeks to allow for opportunistic collection of surface runoff. The volume of surface water available has not been estimated. Farm dams are discussed further in the following section.

12.3.6 Farm dams

A total of 137 farm dams have been identified within the catchments both upstream and downstream of the proposal. Within the proposal site there are 14 farms dams. Investigations undertaken as part of Technical Paper 11: Social indicated that landowners considered preservation of flows paths to farm dams to be important. These farm dams are predominantly located on overland flow paths to opportunistically capture surface flows. The condition and volume of these dams is not known. A dam dewatering protocol would be prepared prior to construction, which would consider options for reuse of water in the dam, and identify licensing and approval requirements. This is discussed further in Chapter 13: Water quality. Through meetings with landowners, several contour banks across the proposal have been identified and included in the flood assessment. Contour banks are artificially raised sections of land on agricultural properties to control overland flow. Contour banks are generally established to direct flow towards farm dams or slow flow to reduce erosion.

12.3.7 Stormwater infrastructure

Existing stormwater infrastructure within the study area is limited as the majority of the study area is located on agricultural land.

Stormwater infrastructure has been identified on existing roads, including Burley Griffin Way, Dudauman Road, Ironbong Road, Old Sydney Road and the Olympic Highway, including culverts that convey stormwater runoff under the roads. These culverts are not connected to any other pipe networks but convey flows to open channels either side of the roadway and towards the nearest watercourse.

Stormwater infrastructure around the Main South line consists of open channels running parallel to the rail. One culvert to the west of Billabong Creek has been identified and three to the east. Similar to the roads, these culverts convey flows beneath the rail into open channels.

Stormwater infrastructure for the Stockinbingal–Parkes Rail line includes culverts at the Dudauman Creek crossing. Similarly, the Lake Cargelligo line includes a culvert crossing of Dudauman Creek.

12.4 Impact assessment—construction

The proposal has the potential to result in general construction impacts, which would be considered typical of most infrastructure projects. The proposed 24-month construction timeframe will limit the risks of flooding affecting the construction program due to the low probability of large rainfall events causing flooding. Construction works occurring as part of the proposal that may result in impacts to hydrology and flooding include:

- General impacts, including
  - construction works, or equipment impacting the flow of water or potentially blocking flows within watercourses
  - proposal construction activities with the potential to result in altered surface water flow conditions where the landscape is modified by dam infilling (both partial and complete), construction of new traverse drainage, stockpiling material onsite (including spoil, topsoil, and mulch), and storage of plant and equipment.
- Construction staging, where construction and/or demolition works may impact the distribution of floodwater
- Impacts from use of water during construction
- Impacts to the geomorphology of watercourses.

Potential impacts to hydrology and flooding during construction of the proposal are discussed in the following sections.

12.4.1 General impacts

Impacts to hydrology and flooding from construction activities may include:

- changes in surface water flows increases in the rate of flow in the receiving drainage lines could result in scour and channel erosion, as well as a possible widening of the watercourse through a process of bank erosion
- changes in flooding controls such as levees or controlling structures resulting in downstream impacts
- partial blockage of transverse drainage by debris could result in floodwater surcharging onto the road and surrounding areas during storms
- surface water contamination if chemical storage areas are breached by floodwater and hazardous chemicals migrate offsite flooding of construction areas and ancillary sites, including loss of plant and equipment
- safety risks associated with high-flow velocities and/or deep water, constituting a hazard to personnel and equipment
- inundation and damage to construction plant and equipment
- increased runoff and sedimentation, especially if controls are damaged or become ineffective.

As discussed in section 12.3.7, there is limited stormwater infrastructure within the proposal, and the proposal would not directly discharge to any of the existing infrastructure. With the implementation of mitigation and management measures, the proposal would not result in any impacts to the conveyance capacity (rate of water able to be transferred in a system) of existing stormwater systems.

Further consideration of construction activities for the proposal and potential impacts to hydrology and flooding is provided in Table 12-7.

TABLE 12-7: CONSTRUCTION ACTIVITIES AND STAGING FOR THE PROPOSAL AND POTENTIAL IMPACTS TO HYDROLOGY AND FLOODING

Activity	Potential impacts to hydrology and flooding
Earthworks	Earthworks from across the proposal site may result in changes in flood behaviour during construction. Construction in areas liable to flooding may become inundated, with flood water entering the construction area and flows disrupted by construction of embankments. 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 watercourses.
Work within watercourses and flowpaths	Construction in these areas may be of higher risk of impacts from flooding due higher flow velocities, which may occur in the main channels compared to surrounding areas. Temporary structures required to construct the bridges such as temporary crossings, crane pads, also have the potential to be damaged or washed away during a flood event, which may impact downstream property and infrastructure. These structures may also have an impact on flood behaviour and potentially result in flood impacts if changes are significant. If inadequately managed, works in watercourses have the potential to change the flow regime, impact riparian vegetation and aquatic biodiversity (considered in Chapter 10: Biodiversity), and contribute to erosion, sedimentation and water quality impacts (considered in Chapter 13: Water quality. Given that the majority of watercourses that cross the proposal site are ephemeral, impacts to surface water hydrology and flow regimes as a result of construction would be limited in extent. The staging of excavations and works directly within watercourses and overland flow paths would be planned to occur during dry conditions, as far as practicable, in accordance with soil and water management plan and, therefore, impacts would not be significant but localised and temporary.
Construction access	While construction haulage would be primarily undertaken on existing roads, and within the proposal corridor, some dedicated construction access tracks would be required for movements to and within the proposal site. A number of temporary watercourses crossings would be required to facilitate construction vehicle movements along the length of the proposal site (refer to Chapter 8: Proposal description—construction). New access tracks and temporary watercourse crossings have the potential to result in impacts, including: ▸ loss of vegetative cover leads to an increase in harder impervious surfaces and subsequently more runoff ▸ sediment movements and erosion from increases in hard impervious surfaces ▸ potential temporary blockage of overland flow paths as they cross low points ▸ redirection of overland flow paths and watercourses due to access tracks. Where existing access tracks (within the existing rail corridor) and roads are being used, it is expected that the impacts would be minor.
Construction compounds	Where possible, these sites have been located away from watercourses and overland flows paths. Consideration of potential impacts to hydrology and flooding from the use of these sites is outlined below. Construction compounds potentially impacted by flooding include: sites 1, 2, 4, 5, 16, 17, 21, 25 and 26. Impacts from flooding may include changes in flood behaviour due to the obstruction of flows, or damage to construction compounds and risk of injury due to inundation of these areas. Construction planning at these locations would consider the likelihood of flooding, evacuation routes, warning times and potential impacts from the compound flooding.

12.4.2 Construction staging

The staging of the construction of culverts, bridges and longitudinal drainage may result in temporary impacts during a significant rainfall event; however, the staging of excavations and works directly within watercourses and overland flow paths is likely to only occur during dry conditions.

The staging of the construction works in the Dudauman Creek floodplain will need to be further reviewed during detailed design. The proposal will not impact any of the existing structures; however, flood modelling has identified the complex nature of flooding in the vicinity of the Lake Cargelligo and Stockinbingal to Parkes rail lines due to existing structures, embankments and flood levees. It is estimated that there is potential for change in flood behaviour in the vicinity of the proposal; however, the main Dudauman Creek channel would not be impacted. Potential changes are expected across the eastern floodplain between the construction compounds 26 and 27.

If the staging of construction works in the Dudauman Creek floodplain is not managed, then the temporary changes to flood behaviour may result in increased flood risk to the urban area of Stockinbingal. An increased flood risk may occur due to increased flood flows through the town or increased flood velocities.

12.4.3 Construction surface water supply

As described in Chapter 8: Proposal description—construction, water would be required for rail and road formation works, dust control, site compaction and reinstatement during construction. Based on the current design and anticipated construction duration, the estimated water demand would be about 797 megalitres (ML).

Initial consultation for water supply requirements with Goldenfields Water, who are responsible for water supply functions within the local government areas Junee, Temora, and parts of Cootamundra-Gundagai, has indicated there would be adequate supply to meet the needs of the proposal. The available flow rates are yet to be confirmed; however, it is understood that daily water demand of the proposal would exceed flow rates available from Goldenfields. To address this, water tanks are proposed within construction compounds to ensure that water can be accumulated prior to substantial construction commencement. This would ensure an adequate supply throughout construction. The use of recycled water from sewage treatment plants would be considered during detailed design as per EMM reports prepared for ARTC (Inland Rail Program—NSW water procurement option analysis, 2020).

12.4.4 Geomorphology

As discussed above, the proposal would involve works within and around ephemeral watercourses, resulting in altered surface water flow conditions where the landscape is modified by:

- dam infilling, both partial and complete along the proposal site
- construction of new traverse drainage
- stockpiling material onsite, including; spoil, topsoil, mulch
- storage of plant and equipment
- installing erosion protection measures in accordance with the CEMP
- construction of culverts or bridges as described in Chapter 8: Proposal description—construction
- rehabilitating the disturbed area once works are complete.

During construction there may be some localised re-direction of overland flows, which could have impacts to the geomorphology of watercourses; however, these are likely to be temporary and would not impact long-term sources of surface water.

12.5 Impact assessment—operation

Operation of the proposal could result in potential changes to the flood behaviour from establishment of the rail formation, which may interrupt overland flow of surface water.

Upstream and downstream of, and immediately near to, the rail formation, overland flows 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.

12.5.1 Flooding

12.5.1.1 Impacts from flooding and compliance with quantitative design limits for each catchment

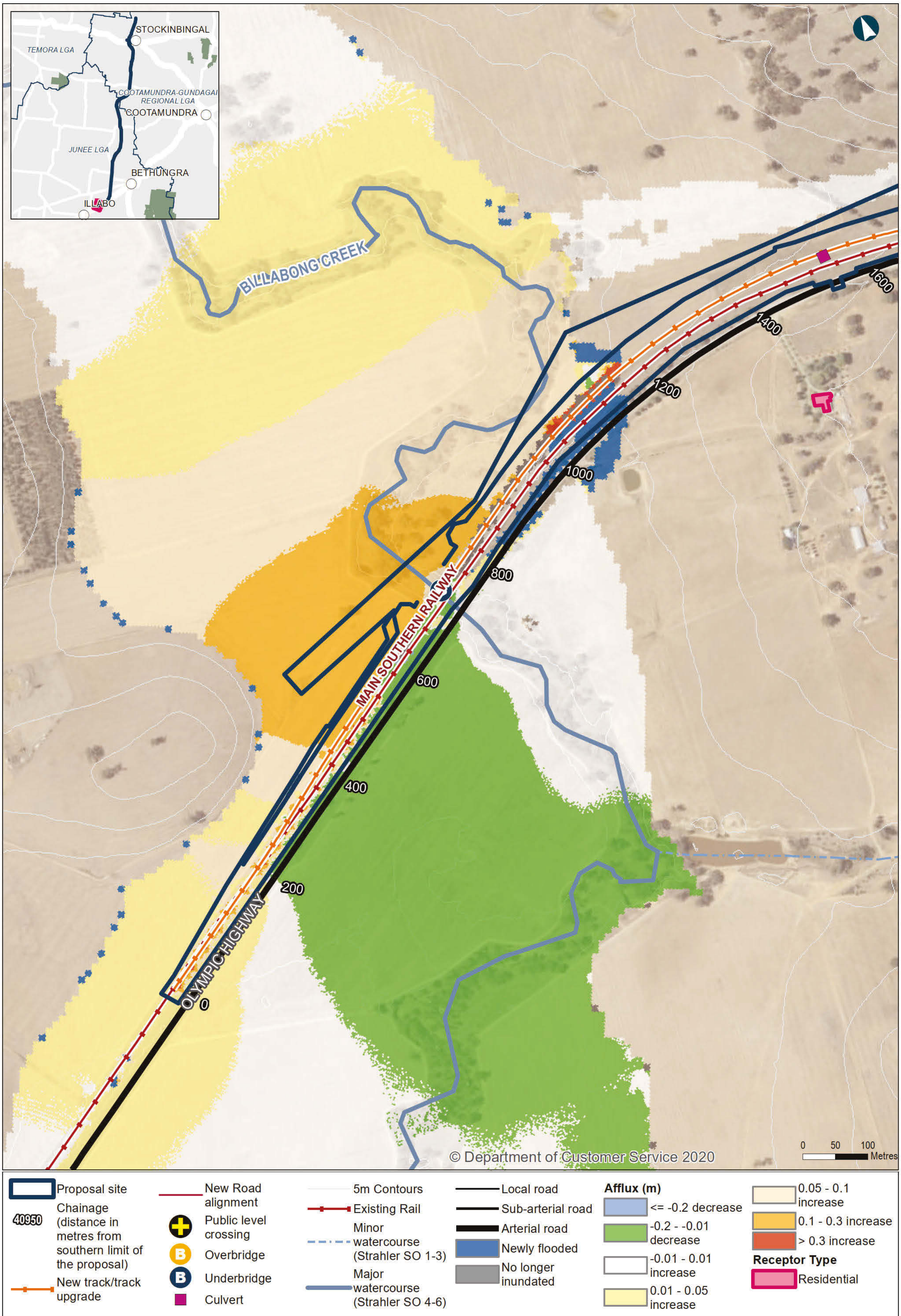
A summary of flooding impacts for each catchment is assessed, and compliance with QDLs is provided in Table 12-8, and discussed further in the following.

Maps of the predicted changes in afflux during the 1% AEP are shown in Figure 12-3 to Figure 12-8. Further detail of flooding impacts is provided in Chapter 6: Alternatives and proposal options and Appendix C of Technical Paper 4. The proposal does not impact flooding at Ironbong Creek.

TABLE 12-8: MODELLED FLOODING IMPACTS DURING OPERATION OF THE PROPOSAL

Catchment	Change in distribution	Afflux (flood levels)	Flood velocity	Duration	Hazard
Billabong Creek	No significant change in flood distribution.	• For the 1% and 2% AEP flood events, the flood modelling indicates that there would be a minor change in flood levels within the QDL. • No change in peak flood level is estimated for the other flood events.	For the 1% AEP: • Up to 10% increase at tie in point and across the floodplain at Billabong Creek. • At chainage 6000, increase up to 20% to 0.72m	During the 0.2 EY event, an increase in duration occurs from 7 hours to 14 hours across agricultural land to the south of the Olympic Highway. This impact is not noted to occur in less frequent (larger) flood events.	Around chainage 210 an increase in hazard above the QDL of 20% for agricultural land.
Ulandra Creek	No significant change in flood distribution.	Afflux of 330 mm on localised area between realigned Ironbong Road and the proposal. During the 0.2EY event, afflux reduces to 280 mm. Unnamed tributaries between Ulandra Creek and Run Boundary Creek do not have a change in flood levels.	For the 1% AEP: • Less than 10% increase at one area of the floodplain 400 m downstream of proposal. Design velocities less than 1.0 m/s and less area impacted and more frequent events • Increase of >20% at other cross-drainage locations.	Increase of duration at the location of culverts at chainage 12500 up to 30 hours during the 5% and 1% AEP events, but not more frequent events. Increase of duration at the location of culverts at chainage 13100 of up to 24 hours for the 5% and 1% AEP events, but not more frequent events.	No change in hazard.
Run Boundary Creek	No significant change in flood distribution.	For the 1% AEP and more frequent flood events, the proposed bridge structure across Run Boundary Creek is sufficient to meet afflux criteria of less than 0.2 m increase beyond the proposal boundary. The 0.05% AEP event afflux is up to 0.2 m and extends up to 100 m upstream of the bridge crossing but beyond this the impact is minimal.	For the 1% AEP: • Isolated increase <20% at Run Boundary Creek • Isolated increase of up to >20% at other cross-drainage locations.	No significant change in duration.	No change in hazard.
Isobel Creek	No significant change in flood distribution.	No significant afflux for the 1% AEP or more frequent events, including unnamed tributaries between Isobel Creek and Powder Horn Creek.	For the 1% AEP: • Increase up to 10% within creek. Existing velocities >1.5 m/s • At Chainage 23.2 km, isolated increase >20%. Design velocities <0.7 m/s	No significant change in duration.	No change in hazard.

Catchment	Change in distribution	Afflux (flood levels)	Flood velocity	Duration	Hazard
Powder Horn Creek	No significant change in flood distribution.	No significant afflux for the 1% AEP or more frequent events.	For the 1% AEP: ▸ Localised increases <20% downstream of proposal. Velocity 1.0 m/s in channel and <1.0 m/s in floodplain ▸ At chainage 28200, Isolated increase >20%. Due to concentration of flows and location of farm dam at edge of proposal.	Increase of duration at the location of culverts at chainage 26200, upstream of Powder Horn Creek, of up to 24 hours for the 5% AEP event, but not other events.	No change in hazard.
Dudauman Creek	No significant change in flood distribution.	For the 1% AEP event: ▸ Afflux of 320 mm on unimproved grazing land between the between the realigned Lake Cargelligo line and the realigned Burley Griffin Way within extent of proposed basin ▸ Afflux of up to 380 mm upstream of the Dudauman Creek bridge ▸ Afflux of up to 380 mm upstream of the alignment south of Dudauman Creek bridge. Smaller QDL exceedances occur between the realigned Lake Cargelligo line and the realigned Burley Griffin Way within extent of proposed basin during more frequent events.	For the 1% AEP: ▸ Increase >10% in channel downstream of Wood Street. Increase >20% upstream of proposal and at Burley Griffin Way western tie in point	No significant change in duration.	Exceedance of QDL at chainage 37700, where velocity depth product is 0.7 m^2/s.

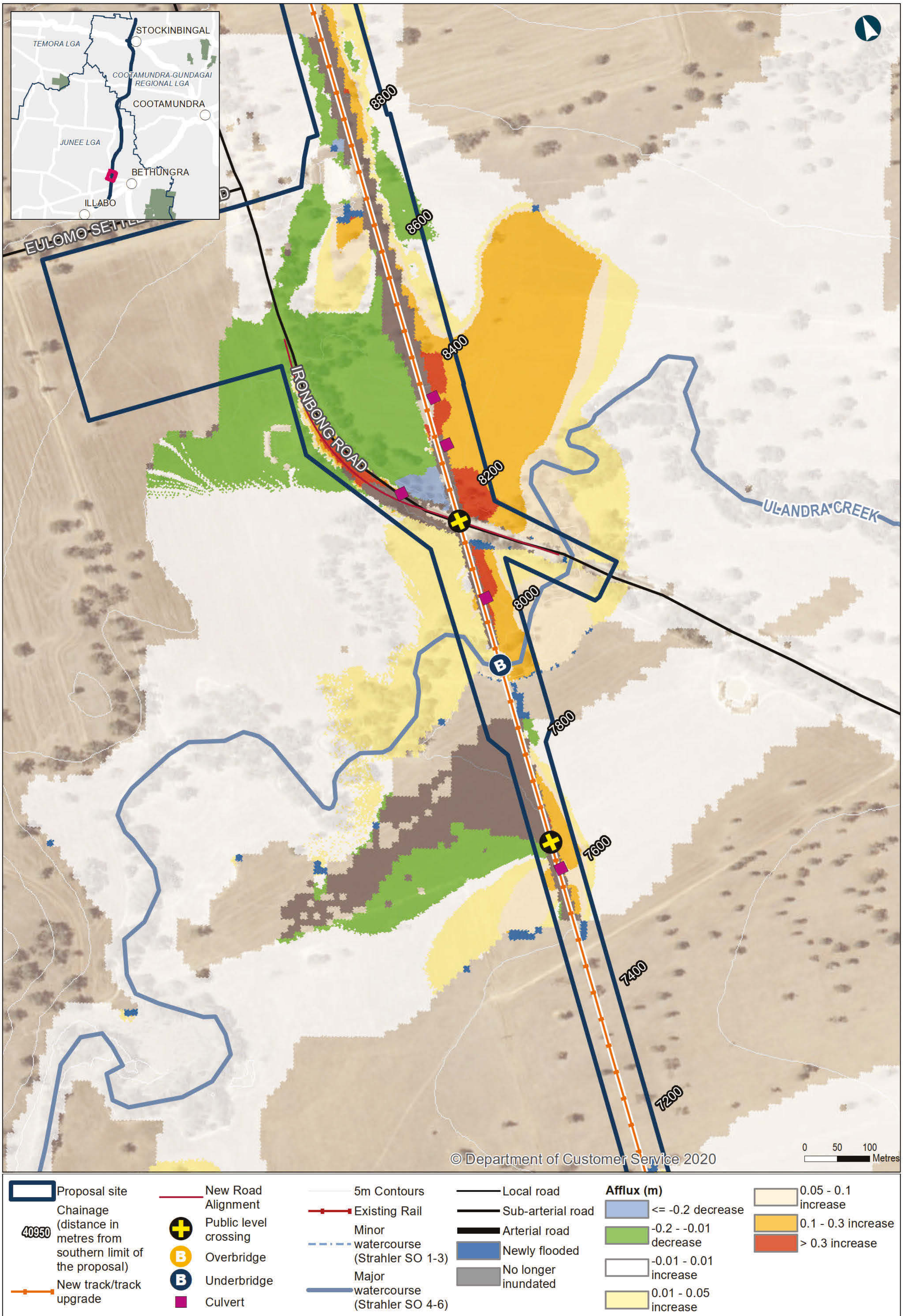


12.3 1% AEP Flood Afflux - Billabong Creek

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:8,000

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_3_1AEPAfluxBillabong_r1v3.mxd



12.4 1% AEP Flood Afflux - Ulandra Creek and Ironbong Road

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_4_1AEPAffluxUlandra_r1v5.mxd

Proposal site
40950 Chainage (distance in metres from southern limit of the proposal)
New track/track upgrade
Overbridge
Underbridge
Culvert
5m Contours
Existing Rail
Minor watercourse (Strahler SO 1-3)
Major watercourse (Strahler SO 4-6)
Local road
Sub-arterial road
Arterial road
Newly flooded
No longer inundated

Afflux (m)

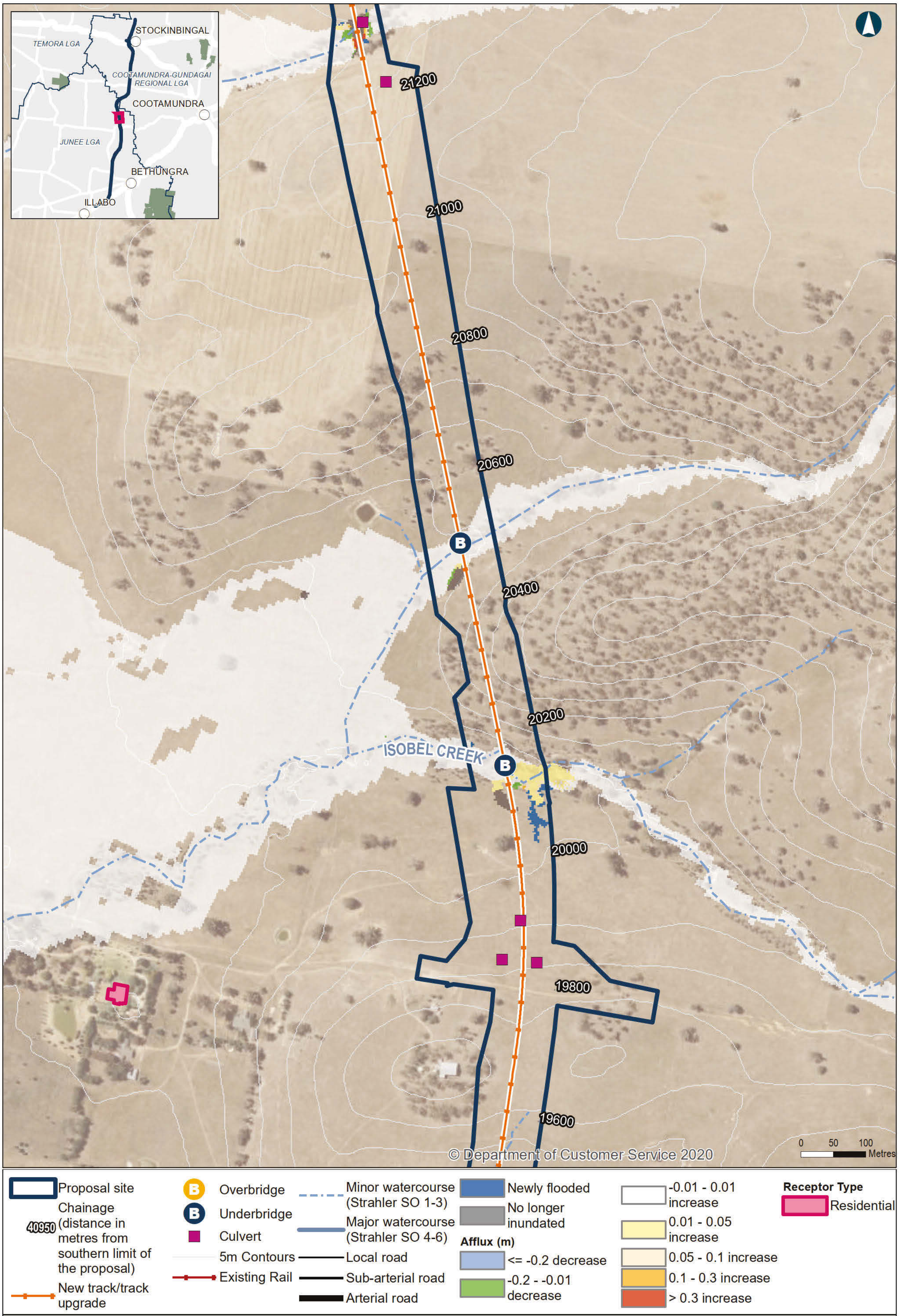
<= -0.2 decrease
-0.2 - -0.01 decrease
-0.01 - 0.01 increase
0.01 - 0.05 increase
0.05 - 0.1 increase
0.1 - 0.3 increase
> 0.3 increase

12.5 1% AEP Flood Afflux - Run Boundary Creek

Coordinate System: GDA 1994 MGA Zone 55
Date: 7/13/2022 Paper size: A4 Scale: 1:10,000

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_5_1AEPAffluxRunBoundary_r1v3.mxd

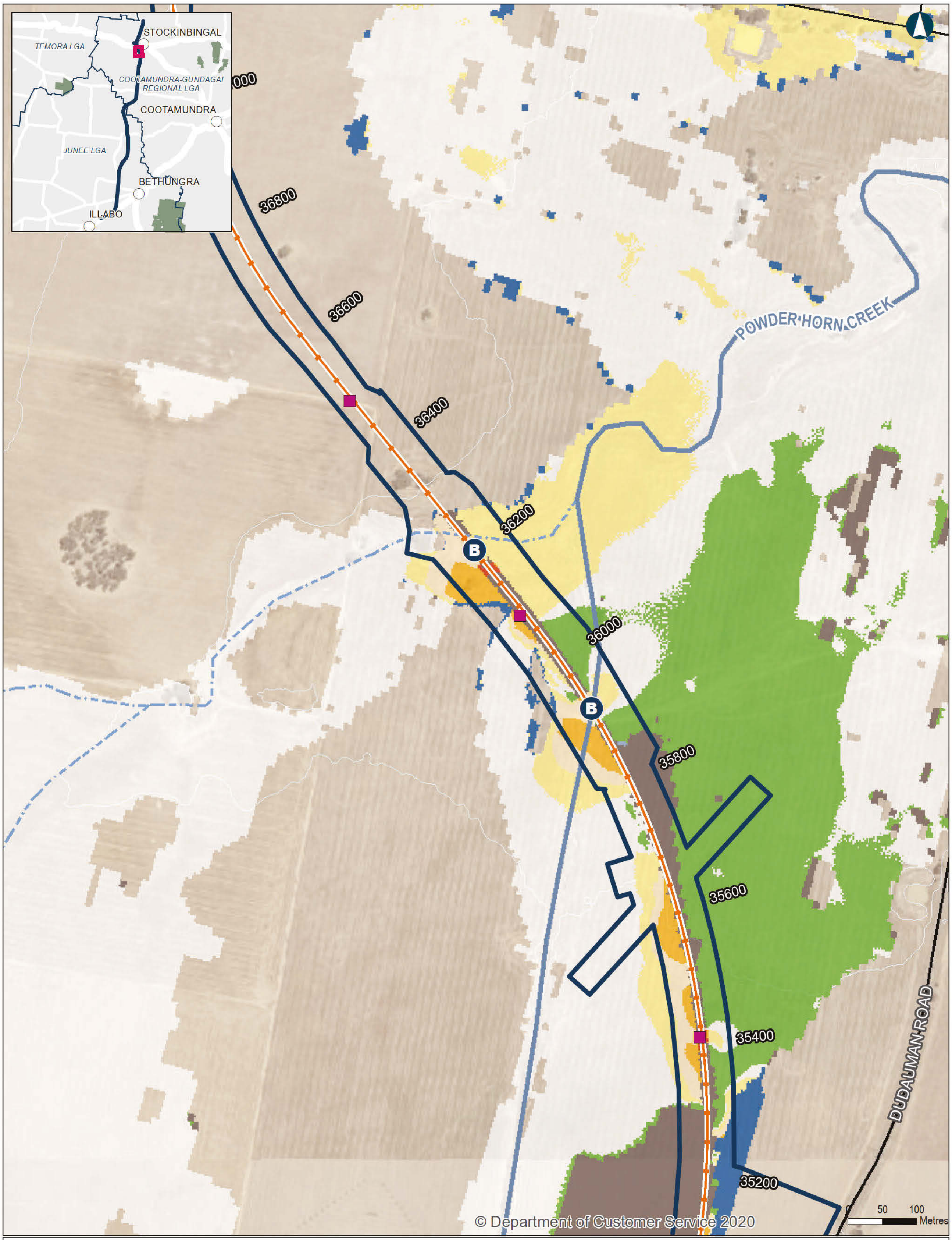


12.6 1% AEP Flood Afflux - Isobel Creek

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:8,000

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_6_1AEPAffluxIsobel_r1v4.mxd



Proposal site
40950 Chainage (distance in metres from southern limit of the proposal)
New track/track upgrade
Overbridge
Underbridge
Culvert
5m Contours
Existing Rail
Minor watercourse (Strahler SO 1-3)
Major watercourse (Strahler SO 4-6)
Local road
Sub-arterial road
Arterial road
Newly flooded
No longer inundated

Afflux (m)

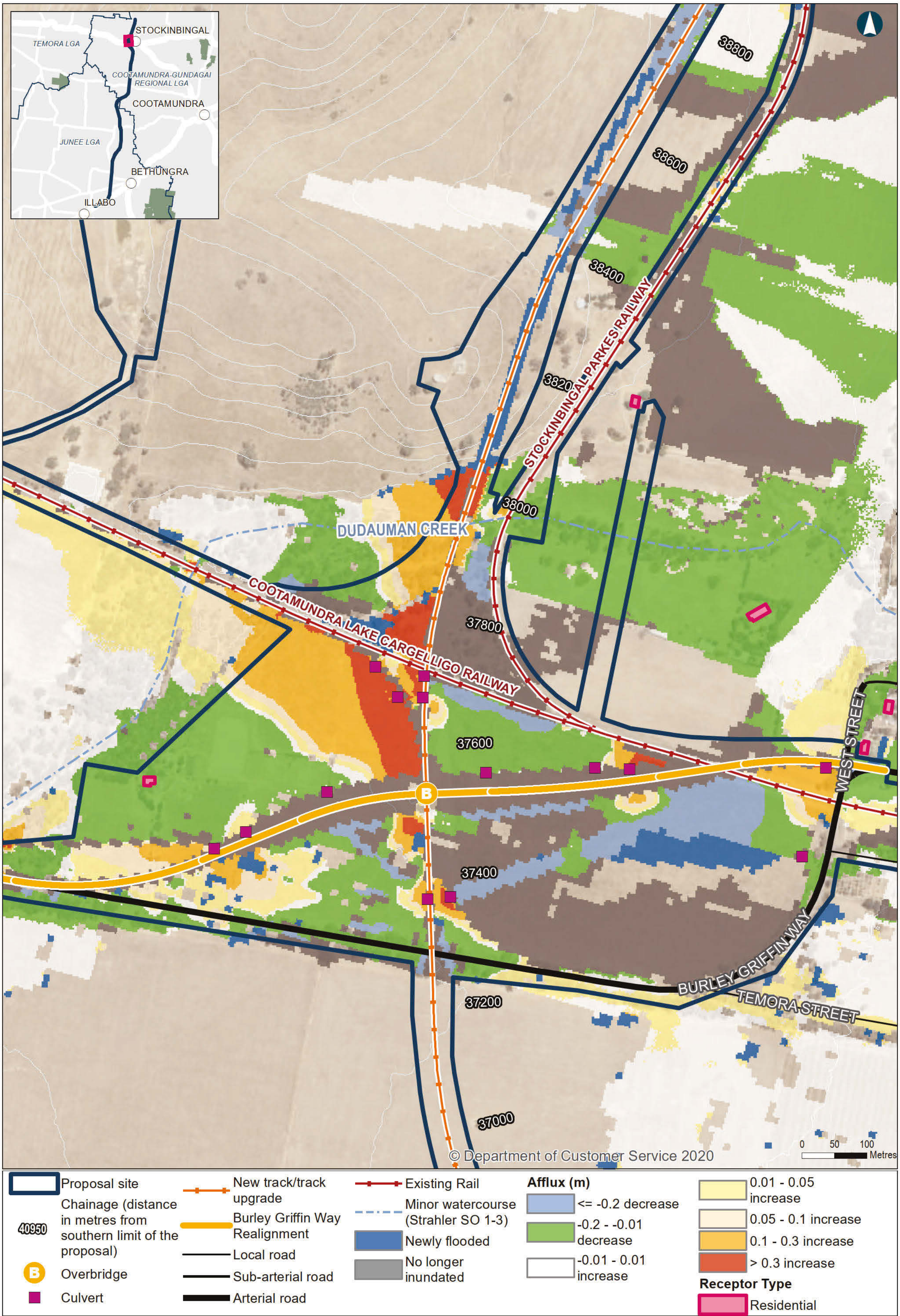
<= -0.2 decrease
-0.2 - -0.01 decrease
-0.01 - 0.01 increase
0.01 - 0.05 increase
0.05 - 0.1 increase
0.1 - 0.3 increase
> 0.3 increase

12.7 1% AEP Flood Afflux - Powderhorn Creek

Coordinate System: GDA 1994 MGA Zone 55
Date: 7/13/2022 Paper size: A4 Scale: 1:8,000

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_7_1AEPAffluxPowderhorn_r1v4.mxd



12.8 1% AEP Flood Afflux - Dudauman Creek

Coordinate System: GDA 1994 MGA Zone 55
Date: 8/8/2022 Paper size: A4 Scale: 1:8,000

Illabo to Stockinbingal Data Sources: IRDJV, ARTC, LPI

220_0115_EIS_12_8_1AEPAffluxDudamaun_r1v7.mxd

12.5.1.2 Summary of impacts from flooding

The flood impact assessment is based on the proposal-specific flood models for key watercourses identified in section 12.3.4.1.

Where exceedances to the QDLs occur, the design of the proposal, including flood modelling, will be refined during the detailed design stage to mitigate these impacts, where practical. Where relevant, mitigation will include consultation with landowners of properties potentially impacted by these exceedances, to determine appropriate mitigation measures.

Flood distribution

The proposal would result in changes to local topography to achieve desired gradients and placement of formation for the track. The proposal design features, such as culverts, bridges and longitudinal drainage channels, would direct existing surface runoff from one side of the proposal to the other to maintain existing flow distribution. All the proposed cross-drainage structures have been located at topographic low points or watercourses. The proposed sizes of the structures have been governed by the other QDLs to minimise impacts.

The proposal includes one drainage diversion at the topographic low point at chainage 16000. The proposal formation drains to the south so the longitudinal drainage channel parallel to the alignment has been designed to capture the flows and divert them to the south. A culvert is located at around 15400, which can direct flows from the diversion channel to the west and back into the Ironbong Creek catchment.

The proposal would impact one contour bank within the proposal site but the proposed location of culverts in the vicinity of this bank would have no impact on flow behaviour across the proposal.

All changes in flood distribution are minor and within the QDLs.

Flood afflux

The predicted afflux as a result of the proposal are generally compliant with the QDLs in section 12.2.3.6. Areas where afflux exceeds QDLs for the 1% AEP includes:

- Ulandra Creek:
  - afflux of 330 mm on localised area between realigned Ironbong Road and the proposal
- Dudauman Creek:
  - afflux of 320 mm on unimproved grazing land between the between the realigned Lake Cargelligo line and the realigned Burley Griffin Way (within the proposal site)
  - afflux of up to 380 mm upstream of the Dudauman Creek bridge
  - afflux of up to 380 mm upstream of the proposal, south of Dudauman Creek bridge.
  - a general improvement (reduction in flood levels) within the township of Stockinbingal.

Flood velocities

As indicated in section 12.5.1, the existing velocities across much of the proposal site are less than the 0.5 m/s QDL for a 1% AEP and more frequent events. As discussed in section 12.2.3.6, where existing velocities exceed 0.5 m/s, a conservative QDL of a 0.025m/s increase has been adopted. It is noted that this QDL is conservative, and the potential for impact would be subject to the actual susceptibility of soils to erosion. Soils across within the study area generally comprise silty clays or clays, which are typically non-dispersive and tend to have low erosion potential, further soil sampling would be completed during detailed design for the proposal to confirm the erosion potential for soils.

Discussion of QDL exceedances for velocity for the 1% AEP flood event is provided in Table 12-9. A number of exceedances of the QDL for velocity occur around the inlets and outlets of some culverts and in some locations these exceedances propagate downstream or upstream into the adjacent land beyond the rail corridor. Mitigation and management measures to address impacts from erosion and scour are discussed in section 12.6.

TABLE 12-9 DISCUSSION OF QDL EXCEEDANCES FOR VELOCITY FOR THE 1% AEP FLOOD EVENT.

Cross Drainage Location	Discussion of QDL exceedances for velocity for the 1% AEP flood event.
Billabong Creek	Up to 10% increase at tie in point and across the floodplain
Chainage 6000	Increase up to 20% to 0.72 m/s

Cross Drainage Location	Discussion of QDL exceedances for velocity for the 1% AEP flood event.
Ulandra Creek	Less than 10% increase at one area of the floodplain 400 m downstream of proposal. Design velocities less than 1.0 m/s and less area impacted and more frequent events.
Chainage 8200	Increase of >20% occurs between proposal and realigned Ironbong Road.
Chainage 8600	Isolated increase >20% due to removal of farm dam but less extent than more frequent events
Chainage 10200	Increase >10% due to concentration of sheet flow path.
Chainage 11000 (downstream of Ironbong Road)	Increase >10% due to concentration of sheet flow path.
Chainage 12300	Increase >10% due to concentration of sheet flow path and existing contour banks. Design velocity <0.8 m/s
Chainage 13100	Increase >10% due to concentration of sheet flow path.
Run Boundary Creek	Isolated increase <20%
Chainage 16400	Isolated increase >20% due to farm dam and landowner contour banks.
Chainage 17600	Isolated increase >10% with existing velocities >1.5 m/s.
Isobel Creek	Increase up to 10% within the watercourse. Existing velocities >1.5 m/s.
Chainage 23200	Isolated increase >20%. Design velocities <0.7 m/s
Chainage 28200	Isolated increase >20%. Due to concentration of flows and location of farm dam at edge of proposal.
Powder Horn Creek	Localised increases <20% downstream of proposal. Velocity 1.0m/s in channel and <1.0 m/s in floodplain.
Dudauman Creek	Increase >10% in channel downstream of Wood Street. Increase >20% upstream of proposal and at Burley Griffin Way western tie in point.

Flood hazard

Flood hazard is a risk categorisation for flood behaviour based on flood water depths, flood water speed (velocity) and emergency management considerations such as warning time, access to high ground and duration of inundation. Flood risk is associated with human exposure to flood hazard, including access in and out of flooded areas. The proposal site generally passes through rural land, with land uses that are less sensitive to flooding due to sparse population and proximity to infrastructure likely to be impacted.

While flood modelling for the proposal has identified changes in flood depths and velocities, this is not expected to impact the existing flood hazard across a majority of the proposal site, with the exception of:

- In the Billabong Creek catchment between chainage 210 and 540—there is an increase in hazard above the QDL (20 per cent increase for agricultural land), due to the increase in flood depths at this location. Current flood depths are over 1.0 m for existing conditions which creates a high hazard situation, and the increase in flood depths does not change use of the land as it would currently be unusable during a flood event due to deep water.
- A culvert at chainage 23290 (within the Murrumbidgee River catchment) —there is a localised increase in velocity depth product above the QDL. At this location, the velocity depth product is 0.6 m^2/s, which is unsafe for people and vehicles.
- Culverts at chainage 37700 (located between the realigned Lake Cargelligo line and the realigned Burley Griffin Way)—at this location the velocity depth product is 0.7 m^2/s, which is unsafe for people and vehicles.

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. Due to the nature of flooding across the proposal there are no widespread changes in flood hazard or hydraulic function as a result of the proposal, and estimated changes are highly localised and do not impact access or use of the land.

Flood duration

The drainage infrastructure for the proposal has been sized and located to minimise impacts to flood behaviour. Impacts to duration of inundation with the proposal is generally compliant with the QDL, with the exception of:

- Chainage 3100—an increase in duration from 7 hours to 14 hours for a 0.2 EY event. However, the increase in duration does not impact use of the land for grazing as it occurs within an existing overland flow path that is subject to inundation. This impact is not noted to occur in less frequent (larger) flood events.
- Chainage 12500—an increase in duration of 23 per cent during a 1% AEP event, up to 30 hours. The extent of this impact extends beyond the proposal site, for about 100 m downstream of the proposal at a location where there are several contour banks designed to control overland flow.
- Chainage 13100—an increase in duration of 23 per cent during the 1% AEP, up to 25 hours. The extent of this impact is less than 30 m from the proposal site and occurs due to contour banks and farm dams upstream of a culvert directing overland flows and the position of the culvert
- Chainage 26200—an increase in duration of 13 per cent, to over 24 hours for the 5% AEP only. The extent of this impact is 200 m from the proposal site.

12.5.1.3 Potential impacts during extreme flood events

The extreme event considered to be relevant to operation of the proposal is the 0.05% AEP event, which has a return period of approximately 2,000 years. The 0.05% AEP event is used to inform the structural design of bridges, which are designed to withstand hydraulic loading and scour conditions under this event. The PMF event was also simulated to assess the potential impacts of the proposal under an extreme flood event.

A potential impact during extreme flood events is washout of the rail. Washout refers to the washing away of the rail embankment as a result of a flood event that reaches or exceeds the ballast level. Impacts to property downstream are considered the highest risk as a result of washout. The only properties downstream of the proposal within a floodplain are in the urban areas of Stockinbingal. The assessment of washout considered scenarios with embankment failures of varying widths in the flood model. For a PMF event, the results indicate that up to 11 properties in Stockinbingal will experience a minor increase in hydraulic hazard as a result of a washout of the formation. One location was predicted to experience an increase in hydraulic hazard of 22 per cent, which results in a hydraulic hazard category change considered unsafe for vehicles, children and the elderly.

Qualitative consideration of washout at other locations during a PMF event identified:

- Billabong Creek—overtopping of the rail occurs for about 1.6 km, with depths varying from 0.1 m at the extents of the floodplain to depths of up to 2.5 m in the immediate western overbank of Billabong Creek. The proposal, the existing Main South Line, and Olympic Highway act as a significant barrier to flood flows during extreme events. There are no residential properties downstream of the proposal at this location. It is also noted, during the 1% AEP, a section about 400 m in length is overtopped by depths in the order of 0.2 m.
- Powder Horn Creek—overtopping of the rail occurs for about 230 m on the eastern side of the main channel with overtopping depths in the order of a maximum of 0.1 m. The proposal is a barrier to flood flow, with water levels up to 2 m higher upstream of the proposal. The nearest residential house is 700 m downstream of the proposal and no impact from overtopping was considered likely at this location.

12.5.1.4 Culvert blockage

Afflux for the 1% AEP event considering blockage factors of 25 per cent indicate changes to afflux of ±10 mm.

12.5.1.5 Emergency management arrangements

Impacts to emergency management arrangements can occur when flood behaviour changes including change in timing of flood peaks, change in hazard, change in duration and change in flood extent. The rural nature of the proposal site means there are no formal flood emergency arrangements in place for most of the land around the proposal site.

The proposal has minimal impact to flood behaviour for all watercourses and overland flow paths except for Ulandra Creek and Dudauman Creek. At Ulandra Creek, it is predicted that the proposal would not impact use of Ironbong Road as a main emergency management route.

For the Dudauman Creek floodplain, the modelling does not predict changes to flood behaviour in the town of Stockinbingal but flood emergency management arrangements would need to be prepared for the re-aligned Lake Cargelligo Line and the Inland Rail Line.

In accordance with NSW guidelines, vehicles can become unstable when flood depths on roads exceed a depth of 0.3 m (NSW Government, 2005). As such, this is adopted as the level requiring road closures, and consideration of impacts to community evacuation and emergency management routes may be required.

12.5.2 Erosion and scour

The design of all culvert inlets and outlets includes scour protection to protect the structures from being undermined due to scour during large flood events and progressive erosion over time. The scour protection measures have been designed in accordance with industry standards. Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses (refer to section 12.5.4) is not anticipated for the proposal.

The culvert design includes inlet and outlet concrete aprons. Additional rock scour protection is provided beyond the concrete aprons, with the rock size and extent determined by the velocity regime (including topography) and dimensions of the culvert. Consideration of scour protection in an area of steeper topography at Chainage 18300 (an unnamed watercourse within the Murrumbidgee catchment), indicates the width of scour protection required is approximately 18 m.

Generally, there is sufficient room within the permanent footprint of the rail corridor to establish scour protection measures; however, as discussed in section 12.5.1.2, flood modelling has predicted a number of exceedances for velocity, which may require installation of scour protection measures that extend beyond the rail corridor. Due to the minor nature of these exceedances, the approach for managing these impacts will include detailed survey at these locations to inform refinement of the design of the longitudinal channels, and scour design to suit the existing conditions and overland flow paths to reduce this impact. Consultation will also be undertaken with landowners where QDLs on adjacent land cannot be achieved (refer to section 12.6). Any requirement for construction of measures beyond the current proposal boundary would be subject to assessment and further approvals if required.

12.5.3 Flood immunity

12.5.3.1 Buildings

The property impact assessment was based on the relative change in flood level, where floor levels have assumed to be at ground level, which provides a consistent basis for assessment that gives a cautionary identification of impacted structures; however, one property in the Dudauman Creek floodplain, close to the proposal was surveyed to provide detailed information on the building floor levels. Of the 195 residential buildings considered in the assessment, QDL exceedances for afflux up to the 1% AEP flood event are not predicted to occur at any buildings. Additional survey of floor levels and, where appropriate, surrounding fill or levees, will be completed at detailed design to refine the understanding of the impacts.

Table 12-10 summarises the number of properties exceeding the flood management objective for events larger than the 1% AEP. For events less than the 1% AEP, there are no buildings identified above the quantitative design limits.

TABLE 12-10: NUMBER OF BUILDINGS IMPACTED BY AFFLUX ABOVE QUANTITATIVE DESIGN LIMITS

Storm event	Number of properties (habitable) impacted by afflux above QDL criteria	Afflux above QDL for other buildings (non habitable)
PMF	35	2
0.05% AEP	9	2
1% AEP (plus climate change)	8	2
1% AEP	0	2
2% AEP	0	2
5% AEP	0	1
10% AEP	0	0
0.2EY	0	0
Total number of individual buildings during any event	41	4

12.5.3.2 Roads

Flood modelling only predicts changes to inundation at Ironbong Road.

At Ironbong Road, flood modelling predicts the road will have 1% AEP immunity at the level crossing. The immunity is predicted to improve to the north, with the western edge of the super elevated road having 1% AEP immunity. The eastern edge of the realigned Ironbong Road will be inundated in a 1% AEP event and the depth of inundation will be less than currently experienced by the existing road. Figure 12-9 shows that the upstream side of the road is inundated but the downstream side is flood free for the 1% AEP event, with the new road obstructing flows.

In existing conditions, Ironbong Road is the hydraulic control for the flood height upstream of the proposal. As the proposed road embankment is constructed offline this creates a new hydraulic control just downstream of the existing road embankment, obstructing flood flows and creating the afflux of 0.5 m, between the two road embankments, as shown in Figure 12-9. This increase in flood elevation will be isolated between the existing and proposed road embankments and separated from private land due to the new and old road corridors (east, west and north) and the rail corridor (to the south), with no other means of access.

At Ironbong Road, the model predicts the road will have 1% AEP immunity at the level crossing and to the north the immunity is predicted to improve. Under these conditions, north of the level crossing will experience depths up to 400 mm, and the hazard will be H2 with isolated sections of H3. The duration of inundation is predicted to be up to 20 hours, which is similar to existing conditions. The current hazard category for Ironbong Road is H4 but the realigned road will have an improved category of H3 due to the reduced depths.

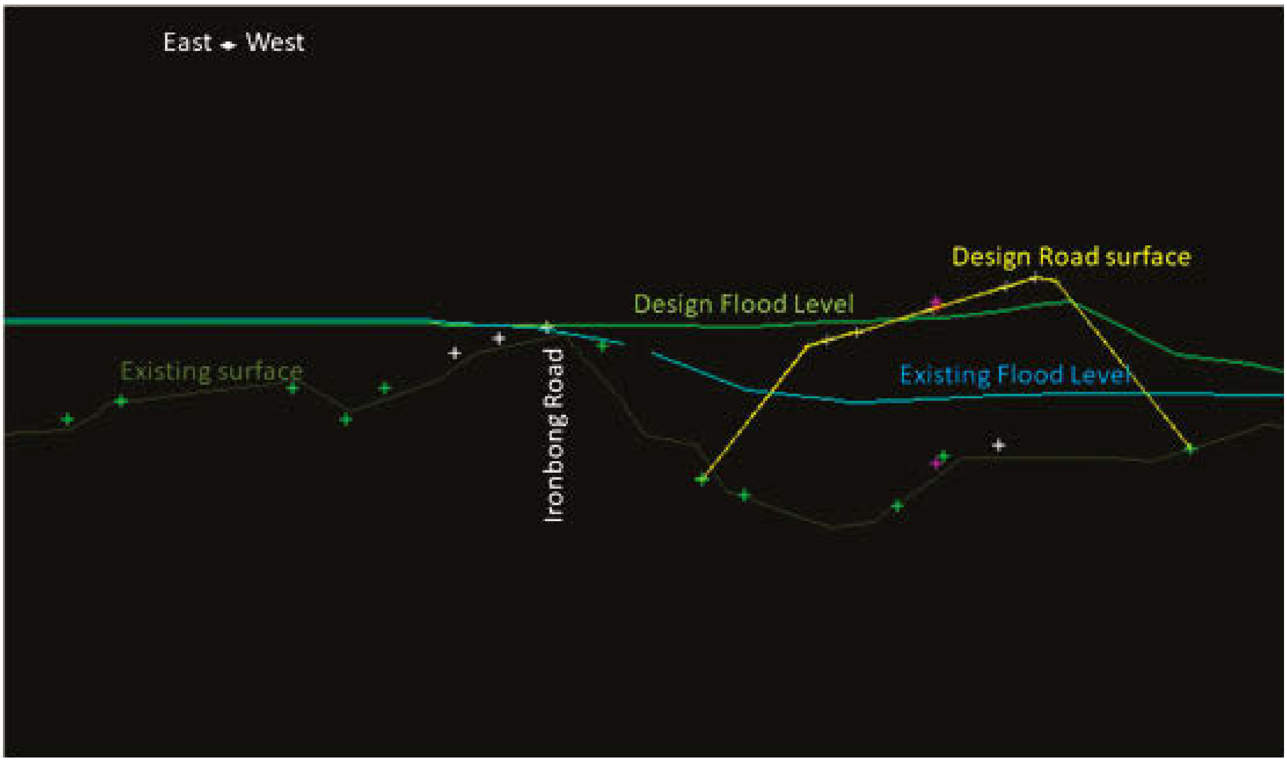


FIGURE 12-9: CROSS-SECTION OF IRONBONG ROAD (DESIGN ROAD SURFACE IN YELLOW)

No changes to flood immunity are predicted for Old Sydney Road for the full range of flood events; however, road users travelling from the east to the west via the proposed level crossing would need to be warned of potential flood waters on the western site of the level crossing as there is unlikely to be visibility of flood waters on the road until the vehicle is crossing the top of the rail embankment.

Afflux of 58 mm is predicted for the Burley Griffin Way, at Dudauman Creek; however, the Hazard category does not change for this section of road and remains at H1. In other sections of the Burley Griffin Way, the proposal is predicted to result in an improvement to flood immunity, or no change to immunity beyond the proposal site.

12.5.3.3 Rail

The 1% AEP peak flood levels have been assessed against the design formation level across the proposal in line with the design requirements. The design formation level is above the 1% AEP design flood level across the proposal, with the exception of a section of the proposal approximately 400 m in length on the western side of the floodplain experiences overtopping with depths in the order of 0.2 m. The height of the rail in this location is controlled by the tie in point to the Main South Line.

Washout is discussed in section 12.5.1.3.

12.5.4 Geomorphology

The geomorphic impact assessment has focused on the changes to flood levels and velocities. Over time, the ephemeral watercourses and overland flow paths around the proposal have developed a channel form in equilibrium with historical flood levels, flow velocities and landscape conditions. For many overland flow paths, the channel form or lack of channel has been influenced by agricultural land uses and farm dam construction. The proposal would not change the contributing catchment areas to any of the watercourses or overland flow paths (except for the two diversions that are discussed in section 12.5), which means the magnitude and recurrence of flows (and flood level) that developed the channels and overland flows paths would not change.

The proposed culverts have been sized and located to minimise impacts to flood levels and velocities, and for many of the culverts the change to flood levels and velocities is minor and localised to immediately upstream and downstream of the culvert. Mitigation measures have been proposed to reduce velocities to below erodible levels, which would also keep impacts local (refer to section 12.5.5).

As indicated in section 12.3.3.2 and Table 12-3, river types and behaviour of the river is described using the NSW River Styles Framework. The geomorphic impact assessment has focused on the watercourses with bridges that also correspond to fish passage requirements. A summary of the geomorphological impacts is provided in Table 12-11 and provided in full in Chapter 7 of Technical Paper 4.

As discussed in the Aquatic Ecology Assessment (Technical Paper 2), the study area includes limited aquatic connectivity due to the ephemeral nature of watercourses in the area. Small refuge pools were identified in Isobel Creek, a tributary of Isobel Creek and Billabong Creek. The potential minor impacts to the geomorphology of these watercourses discussed in Table 12-11 would not result in impacts to access to habitat for spawning and refuge.

TABLE 12-11: POTENTIAL GEOMORPHOLOGICAL IMPACTS

Watercourse	Potential impact
Billabong Creek	The proposal is expected to have a negligible impact on geomorphic conditions downstream as the watercourse is already influenced by the existing rail and road bridges. Upstream of the proposal, the expected impact to geomorphic conditions would be local; as the low flow channel would not be obstructed by the proposal, there would be minimal removal of vegetation in the watercourse and there would be no changes to the flow regime as there would be no change to catchment conditions as a result of the proposal.
Ulandra Creek	Modelling indicates that the proposal would have some impact on geomorphic conditions downstream and peak flood levels would increase. There would be no change to catchment conditions so the frequency and volume of channel-forming flows would not change. Upstream of the proposal, the expected impact to geomorphic conditions would be localised and only continue as far as Ironbong Road. Upstream of Ironbong Road the watercourse form is influenced by existing land-use practices and the Ironbong Road culverts. The connection of the main channel to the floodplain would not be impacted due to the location of the bridge, so changes to geomorphic conditions as a result of the proposal would be minor as the impacts would be local and not impact the watercourse beyond the proposal boundary.
Run Boundary Creek	The proposal is expected to have a minor impact on the geomorphic conditions in Run Boundary Creek. There would be no changes to the frequency or peak flood flow magnitudes that form the channel but the minor impact in flood level upstream is predicted to influence the size of the upstream channel and potentially make it more defined. Any changes downstream of the proposal would be local as the key channel-forming influences of flow and frequency would not be changed.
Isobel Creek and Isobel Creek tributary	The proposal would not be located in the main watercourse channel for either of these watercourses and, as such, the expected impact to geomorphic conditions would be minor. There are no changes to peak flood levels or velocities in the vicinity of the proposal. There are no changes to catchment areas or the frequency of flooding so the impact to the geomorphic condition would be local. Upstream of the proposal the watercourses become overland flow paths with no vegetation and several farm dams across the catchment. As such, while the proposal's impacts would be minor, the upstream land uses have the largest impact on geomorphic form for Isobel Creek and tributary.

Watercourse	Potential impact
Powder Horn Creek and tributary	The predicted changes to geomorphic conditions are likely to be increased erosion within the channels of the watercourse and tributary watercourse due to the increased velocities predicted at the bridge. These changes may propagate upstream but would be influenced by upstream land uses, including a farm dam in the tributary channel and unsealed access tracks. Downstream of the proposal, the catchment contains more farm dams and some vegetation before crossing under Dudauman Road. The impacts of the proposal are likely to be minimal and contained to the area immediately downstream of the proposal but would not propagate beyond Dudauman Road.
Dudauman Creek and tributary	The flood modelling predicts changes to peak flood levels in and around the proposal for the full range of flood events. Peak velocities are also predicted to change by varying amounts. There would be no change to the overall contributing catchment but there would be a redistribution of flows between Burley Griffin Way and the existing Lake Cargelligo rail line. The extent of impact to geomorphic conditions would be limited to the existing Burley Griffin Way culverts upstream of the proposal as there is significant vegetation in an around the channels at Burley Griffin Way. Downstream of the proposal, the potential change to geomorphic conditions would be confined to the Stockinbingal–Parkes Line and potentially a small section of the channel downstream but would not propagate beyond West Street. Noting that this channel is already influenced by farm dams and adjacent land-use practices before being confined by flood levees through the urban area of Stockinbingal.

12.5.5 Surface water availability and supply

The proposal has included sufficient bridges and culverts to maintain existing flow paths and therefore not impact local surface water supplies. There are also not expected to be impacts to environmental water availability as the proposal would not be capturing or storing water permanently.

There are currently no WALs in the study area and the operation of the proposal would not require permanent water supply. It is therefore determined that there would be no impacts to licences across the proposal study area.

As discussed in section 12.3.7, there is limited stormwater infrastructure within the proposal, and the proposal would maintain existing surface water flows and not result in any impacts to the conveyance capacity of existing stormwater systems.

12.5.6 Consistency with relevant policy and guidelines

The adopted model development followed the recommended industry best practice of ARR 2019 (it is noted that at the time the models were first built, ARR 2016 was the current industry best-practice guideline. ARR 2016 has been updated from draft to final in ARR 2019. There are no significant changes to the relevant sections used for this assessment between ARR 2016 and ARR 2019).

The *NSW Floodplain Development Manual* (DIPNR, 2005) is the latest manual for floodplain development in NSW. The supporting *Floodplain Risk Management Guide, incorporating 2016 Australian Rainfall and Runoff in studies* (NSW OEH, 2019a) has been considered in this assessment, and site-specific data and recommended methods for regional flood frequency analysis (RFFE) have been adopted.

Both ARR 2019 and the Floodplain Risk Management Guide recommend the use of local data to calibrate and validate flood models. One gauge was relevant to the proposal, the Wattle Creek at Dudauman Gauge (#412134). This gauge was reviewed but was deemed unreliable for large flood events.

Consideration of local planning policy concluded:

- the proposal is consistent with the provisions of the Cootamundra Local Environmental Plan 2013, and the Junee Local Environmental Plan 2012
- Stockinbingal Floodplain Management Study and Plan (SMEC, 2002)—the plan proposes management measures within the urban areas of the village of Stockinbingal and proposed the Flood Planning level for the flood prone land to be set at the1% AEP plus 500 mm freeboard. The proposal will have no impact to peak flood levels across the urban areas of Stockinbingal, and minor isolated changes to flood extent within Stockinbingal. The proposal is therefore considered to have no significant impact on the extent of the flood-planning area or area of land to which the flood-planning controls would apply, and is considered to be consistent with this plan.

The proposal does not impact land relevant to the Jeralgambeth Creek at Illabo, Floodplain Risk Management Study and Plan (Lyall and Associates, 2012).

12.5.7 Social and economic impacts

The proposal is not anticipated to result in significant social and economic impacts from flooding. Where exceedances of QDLs are predicted, these generally occur within the rail corridor, or as minor impacts in the surrounding area. Mitigation and management measures for the proposal would include further flood modelling during detailed design to refine the understanding of these impacts, and the effectiveness of controls.

Existing farm contour banks have been identified and the assessment indicates that only one contour bank would be impacted by the proposal. The proposal has been designed to maintain all but one overland flow path, which will therefore minimise the impact to farm dam flows.

12.6 Mitigation and management

12.6.1 Approach to mitigation and management

The overall approach to managing impacts on hydrology and flooding is, in order of importance, to:

- avoid impacts through the planning and design process
- minimise impacts through the planning and design process
- mitigate impacts using a range of mitigation measures
- where it is not practicable to mitigate impacts to comply with QDLs, negotiations and agreements will be reached with affected landowners.

12.6.1.1 Approach to managing the key potential impacts identified

The design of the proposal has been developed with consideration of the QDLs to avoid and/or minimise the potential impacts on flooding and watercourses. During the development of the design, the outputs from the flood models have been reviewed against the criteria and mitigation measures included in the design to ensure all proposal aspects meet the impact criteria. Where there is estimated non-conformances, or where minimum design standards are not met, then further mitigation measures have been proposed, including refinement of the proposal design and further modelling during detailed design, and discussion with affected landowners.

The proposal site has been extended from the base of the embankment to incorporate all drainage and flooding feasibility design features, including scour protection measures and diversion drains. The proposal has been designed to minimise cut and fill and, as such, follows the existing topography as best as possible. Location of overland flow paths have been identified during the existing conditions flood modelling and measures to maintain the passage of flows to culverts have been proposed.

Scour protection has been designed at the outlets to culverts and along longitudinal channels. For culverts, the limiting velocity of 0.5 m/s was considered for identified locations requiring scour protection. The design of the scour protection at the outlet to culverts has been in accordance with *Guide to Road Design Part 5: Drainage—General and Hydrology Considerations, Section 3.6* (Austroads, 2021). The scour protection included rocks to prevent scouring and protect the ground surface, with increasing rock sizes specified up to 550 mm before shotcrete was considered. At bridges, pier footings and abutments have been designed to account for predicted scour depths from a 0.05% AEP flood flow event through the bridge. Should additional scour protection be required beyond the proposal corridor then it is anticipated that this would be negotiated with the landowner and a suitable range of mitigation measures agreed.

Further modelling, including detailed survey of existing drainage structures, would be undertaken during detailed design and further consideration would be given to mitigation of flooding impacts, where feasible.

12.6.1.2 Approach to managing other potential impacts

Additional mitigation measures are provided in section 12.6.2 to mitigate impacts that are not avoided by the proposal design. This would include implementation of measures specified in the soil and water management sub-plan prepared as part of the CEMP, to minimise the potential impacts on watercourses during construction.

For exceedances to the QDLs from changes in velocity, detailed soil analysis and an erosion threshold assessment will be completed to inform the mitigation approach.

12.6.1.3 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 guideline 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.

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

12.6.1.4 Interactions between mitigation measures

Mitigation measures to control impacts on hydrology, geomorphology and flooding may overlap with mitigation measures proposed for the control of water quality, groundwater, soil and contamination, health and safety, and waste management impacts.

All mitigation measures for the proposal 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.

12.6.2 Recommended mitigation measures

The measures outlined in Table 12-12 would be implemented to mitigate the potential impacts to flooding, hydrology and geomorphology.

TABLE 12-12: MITIGATION MEASURES

Ref	Impact	Mitigation measures	Timing
HF-1	Flooding impacts	The design would continue to be refined where practicable to not worsen existing flooding characteristics at sensitive receivers, up to and including the one per cent Annual Exceedance Probability (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) ▸ contour banks and dams (including survey of these features to ensure continuous operation of these features) ▸ existing rail line, at rail connections ▸ level crossings and road flood levels and extent of flooding along roads ▸ overland flow paths and storage effects of construction and operational infrastructure. 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 and Environment, the NSW State Emergency Service and potentially impacted landowners. Following refinement of the cross-drainage design, where velocity QDL exceedances occur in land adjacent to the corridor that cannot be resolved through infrastructure measures within the corridor, negotiate mitigation measures with the affected landowners for the affected land areas.	Detailed design/ pre - construction
HF-2	Construction water supply	Construction water supply options would continue to be explored during detailed design and would include: ▸ ongoing consultation with Goldenfields Water (or an equivalent commercial water supply operator) to access the local reticulated network ▸ investigation of options to use recycled water from sewage treatment plants ▸ access to groundwater bores where it can be bought on-market ▸ investigation into the use of farm dams for water harvesting and storage.	Detailed design/ pre -construction

Ref	Impact	Mitigation measures	Timing
HF-3	Retaining water flows	Detailed design would consider channelling of water around Ironbong Road level crossing and Burley Griffin Way realignment and the potential formation of detention basins as a means of retaining flows in a similar manner to existing farm dams and flood levees.	Detailed design/ pre -construction
HF-4	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-prone land and flood events where practicable. Following development of the construction methodology, critical stages of the works should be identified and tested in the flood model to identify potential construction-phase flooding impacts. The tests should simulate the following in the model for a number of construction phase scenarios as required: - key stages of temporary embankment opening during demolition/reconstruction that could pass additional flow downstream - location and level of long-term construction facilities (such as compounds, access tracks and stockpiles) that could obstruct and divert flows - location and level of temporary works in waterways and overland flow paths during bridge and culvert construction that could obstruct and divert flows. The construction-phase flood modelling should be iterated through sufficient scenarios to inform planning of the works such that construction-phase flood impacts are identified and managed accordingly. The outcomes of the modelling should be used to inform the construction phase flood emergency response plan (mitigation measure HS-4).	Construction
HF-5	Sedimentation and erosion management	A soil and water management plan would be prepared and implemented as part of the Construction Environmental Management Plan. The plan would include measures, processes and responsibilities to minimise the potential for soil and water impacts (including impacts to groundwater and geomorphology) during construction.	Construction
HF-6	Dewatering of farm dams that require relocation and/or decommissioning	A dam dewatering protocol would be developed as part of the soil and water management plan. It would consider: - options for reuse of water in the dam - licensing and approval requirements, where relevant - the quality and quantity of the water to be released, where relevant - strategies to minimise impacts on native, threatened or protected species - strategies to minimise spread of nuisance flora and fauna species.	Construction
HF-7	Management of flood emergency risks beyond the rail corridor	To mitigate flood risks to life or property beyond the rail corridor at Old Sydney Road, flood risk information would be provided in sufficient detail, e.g. through appropriate signage, so that relevant emergency services personnel and affected third parties are made aware of the potential for flooding west of the proposed raised level crossing.	Operation

12.6.3 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 Chapter 6; Alternatives and proposal options) and Chapter 8; Proposal description—construction))
- specific measures to mitigate and manage identified potential impacts (see section 12.6.2).

The key potential hydrology and flooding issues and impacts originally identified by the environmental risk assessment in Appendix G: Environmental risk assessment and are listed in Table 12-13. 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 Appendix G: Environmental risk assessment.

The potential issues and impacts identified by the environmental risk assessment were considered as part of the hydrology and flooding impact assessment, summarised in sections 12.4 and 12.5. The mitigation and management measures (listed in Table 12-12) 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 and are found in Table 12-13. The approach to managing significant residual impacts (considered to be those rated medium or above) is also described.

Provided the mitigation measures are implemented accordingly, the proposal poses a negligible-to-low risk of impacting the hydrology and flooding behaviour as identified in the risk assessment in Table 12-13.

Table 12-13: Residual impact assessment—hydrology

Phase	Potential impacts	Pre-mitigated risk			Mitigation measures (refer to Table 12-12)	Residual risk			How residual impacts would be managed
		Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating	
Construction	Temporary impact to the behaviour of local surface water systems during construction due to the presence of construction features, including erosion and sedimentation control structures.	Possible	Moderate	Medium	HF-4, HF-5, HF-6	Unlikely	Minor	Low	n/a
	Changes to flow patterns and altered hydrology due to construction in watercourses.	Possible	Moderate	Medium	HF-4, HF-6	Unlikely	Minor	Low	n/a
	Impact of flooding on unprotected areas during construction resulting in washouts or erosion.	Possible	Moderate	Medium	HF-4, HF-5	Unlikely	Minor	Low	n/a
	Sedimentation and changes to geomorphology in watercourses.	Possible	Moderate	Medium	HF-5	Unlikely	Minor	Low	n/a
Operation	Impacts on upstream and downstream drainage due to the introduction of built structures such as embankments, culverts and bridges.	Possible	Major	High	HF-1	Rare	Moderate	Low	n/a
	Potential changes to road overtopping frequencies and levels impacting emergency service management.	Possible	Moderate	Medium	HF-1, HF-3	Unlikely	Minor	Low	n/a

Phase	Potential impacts	Pre-mitigated risk			Mitigation measures (refer to Table 12-12)	Residual risk			How residual impacts would be managed
		Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating	
	- Presence of, or change to, structures associated with the proposal could impact upstream and downstream local flood behaviour.	Likely	Moderate	High	HF3-HF4, HF-6	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	HF-1	Unlikely	Moderate	Low	n/a
	- Flooding impacts on proposal infrastructure and immunity during operation.	Likely	Moderate	High	HF-4, H-7	Unlikely	Minor	Low	n/a