TECHNICAL PAPER 04

Hydrology and Flooding Impact Assessment

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT

Technical and Approvals Consultancy Services: Illabo to Stockinbingal

Technical Paper 4 – Hydrology and Flooding Impact Assessment

August 2022

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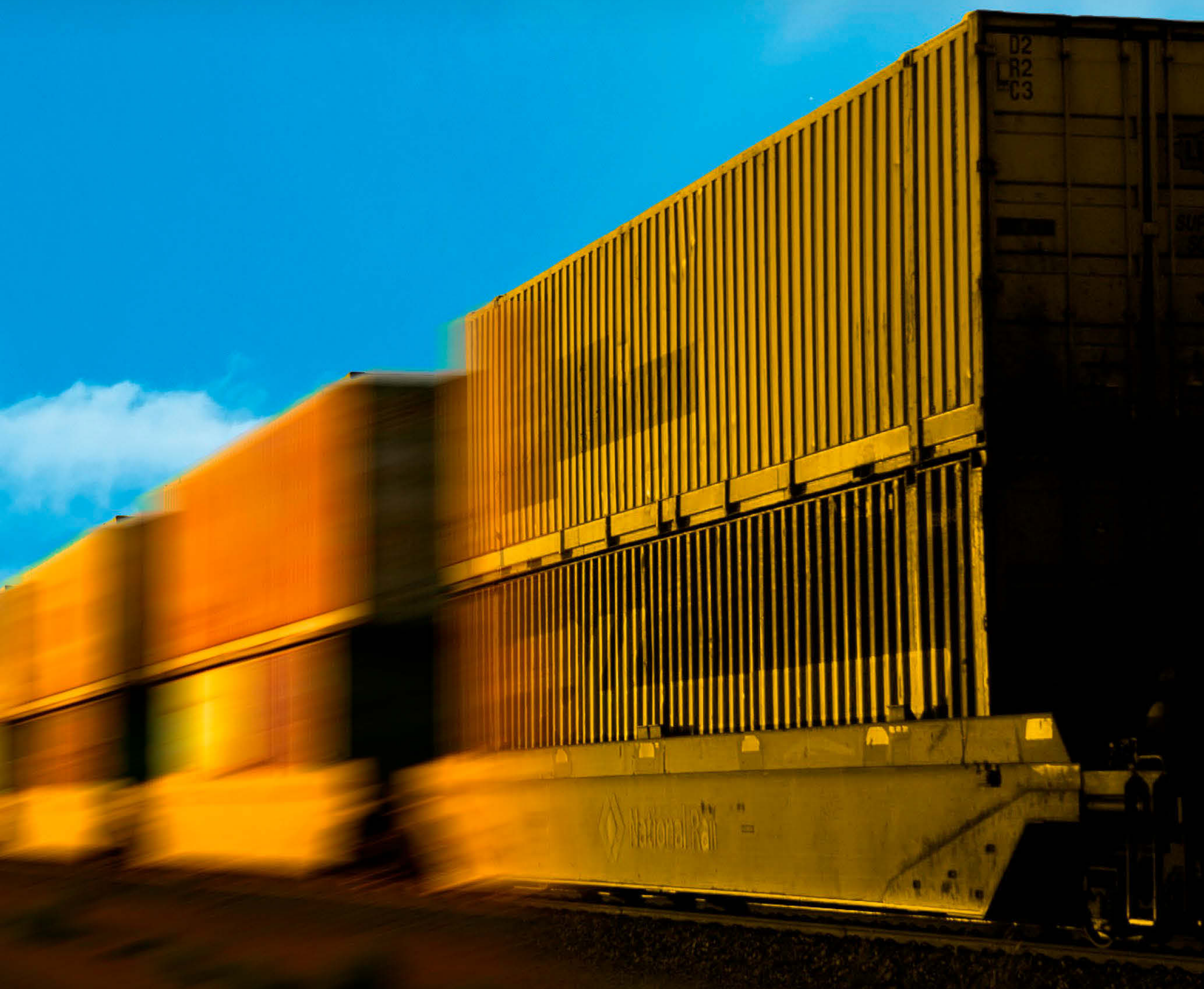

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Glossary and abbreviations

Term	Definition
AEP	Annual Exceedance Probability. The probability that a design event (rainfall or flood) has of occurring in any 1 year period.
Afflux	With reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels, between an existing scenario and a proposal scenario.
AHD	Australian height datum
Alignment	The geometric layout (e.g. of a road) in plan (horizontal) and elevation (vertical).
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Average Recurrence Interval
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff (Ball et al, 2019)
ARTC	Australian Rail and Track Corporation
BOD	Basis of Design
BoM	Bureau of Meteorology
Catchment	The area drainage by a stream or body of water or the area of land from which water is collected.
CEMP	Construction Environmental Management Plan
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCP	Development Control Plan
Design Rainfall	Design rainfalls are based on the statistical analysis of historical rainfall data to determine the design rainfall depth (mm) or design intensity (mm/hr) corresponding to selected durations and frequencies (BOM, 2015).
DD	Detailed Design
DEM	Digital Elevation Model
DITRDC	Department of Infrastructure, Transport, Regional Development and Communications
DPIE	Department of Planning, Industry and Environment (NSW)
EY	Exceedances per year. Used to define the frequency of occurrence of more frequent rainfall or flood events. It is used to express the probability of events more frequent than 50% AEP, where expressing frequency in terms of annual exceedance probability (AEP) is not meaningful and misleading. For example, a design event (rainfall or flood) that has a chance of occurring once during every 6 month period is expressed as having 2 Exceedances per Year (2EY).
ELVIS	Elevation Information System
Earthworks	All operations involved in loosening, excavating, placing, shaping and compacting soil or rock.
Embankment	An earthen structure where the road (or other infrastructure) subgrade level is about the natural surface.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
FFA	Flood Frequency Analysis

Term	Definition
FRMSP	Floodplain Risk Management Study and Plan
Flood Planning Level (FPL)	The FPL is the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) selected for floodplain risk management purposes. For the Inland Rail the FPL is set as the 1% AEP at the shoulder of the formation capping.
Flood prone land	Land susceptible to flooding by the probable maximum flood. Note that the flood prone land is also known as flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. It is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is inundated by floods up to and including the probable maximum flood event (i.e. flood prone land).
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as ‘greenhouse’ and climate change.
GIS	Geographic information systems
Hydrology	The study of rainfall and surface water runoff processes.
HPC	Heavily Parallelised Computations
IL	Initial Loss (rainfall) – a XP-RAFTS model parameter
Impact	Influence or effect exerted by a proposal or other activity on the natural, built and community environment.
IR	Inland Rail
IRDJV	Inland Rail Design Joint Venture – A joint venture of WSP and Mott MacDonald.
km	kilometres
LEP	Local Environmental Plan
LGA	Local government area
LiDAR	Light Detecting and Ranging
MNES	Matters of National Environmental Significance
m	metres
mAHD	Metres above Australian Height Datum
m2	square metres
m3	cubic metres
m/s	metres per second
m3/s	cubic metres per second
mg/L	milligrams per litre
NARCliM	NSW and ACT Regional Climate Modelling

Term	Definition
N/A	Not applicable
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW Government) (now a department of NSW Department of Planning, Industry and Environment called Environment, Energy and Science)
OEMP	Operation Environment Management Plan
1D	One Dimensional
PMF	Probable maximum flood. The flood that occurs as a result of the probable maximum precipitation on a study catchment. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The probable maximum flood defines the extent of flood prone land (i.e. the floodplain).
PMP	Probable Maximum Precipitation
Peak discharge	The maximum discharge occurring during a flood event.
Peak flood level	The maximum water level occurring during a flood event.
Probability	A statistical measure of the expected chance or likelihood of occurrence.
Proposal site	Defined as the area that would be directly impacted by the construction and operation of the proposal. Varies in width, approximately 40–130 metres (m), typically incorporating a buffer of up to 50m around the permanent proposal footprint.
Proponent	The person or organisation that proposes to carry out the proposal or activity. For the purpose of the proposal, the proponent is ARTC.
QDL	Quantitative Design Limit
RCBC	Reinforced Concrete Box Culvert
Reference Design	70% Reference Design – Initial basis for determining flood impacts to be further refined 100% Reference Design – Final design assessed and mitigation provided for as part of the proposal.
Risk	Chance of something happening that will potentially have an undesirable effect. It is measured in terms of consequence and likelihood.
RFFE	Regional Flood Frequency Estimation
Runoff	The amount of rainfall that ends up as streamflow, also known as rainfall excess.
SEARs	Planning Secretary’s Environmental Assessment Requirements
SES	State Emergency Services
SSI	State significant infrastructure
Spoil	Surplus excavated material.
Staging	Refers to the division of the proposal into multiple contract packages for construction purposes, and/or the construction or operation of the overall proposal in discrete phases.
Stockpile	Temporary stored materials such as soil, sand, gravel, spoil/waste.
Stream order	A classification system which assigns an ‘order’ to waterways according to the number of additional tributaries associated with each waterway, to provide a measure of system complexity.

Term	Definition
Surface water	Water flowing or held in streams, rivers and other wetlands in the landscape.
TA	Technical Advisor
TfNSW	Transport for NSW
TIN	Triangular irregular networks
TUFLOW	Water Flow modelling software (www.tuflow.com)
2D	Two Dimensional
WM Act	Water Management Act 2000 (NSW)
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).
XP-RAFTS	XP Runoff Analysis and Flow Training Simulation Software. A comprehensive software program to simulate runoff hydrographs at defined points throughout a watershed based on a set of catchment characteristics and specific rainfall events.

Executive summary

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing an interstate freight rail corridor between Melbourne and Brisbane. Inland Rail involves the design and construction of a new inland rail connection, about 1,700 kilometre (km) long, between Melbourne and Brisbane. Inland Rail is a major national proposal that will enhance Australia's existing national rail network and serve the interstate freight market.

The Illabo to Stockinbingal section of Inland Rail ('the proposal') includes a total extent of about 42.5 kilometres (km), and consists of about 39km of new, greenfield single track standard gauge railway and associated infrastructure between Illabo and Stockinbingal.

This technical paper focuses on the hydrology, flooding and surface water aspects of the environment in which the proposal will interact with. The proposal lies in the upper Murrumbidgee and Lachlan River catchments and is not subject to main river flooding from either the Murrumbidgee or Lachlan Rivers. The proposal intersects many minor overland flow paths and upper catchment tributaries including Billabong, Ulandra, Run Boundary and Isobel Creeks in the Murrumbidgee catchment and Powder Horn and Dudauman Creeks in the Lachlan catchment. At the catchment divide the topography is fairly steep with Run Boundary and Isobel Creeks having steep catchments. The Ulandra and Billabong Creeks catchments have steep upper sections but they flatten out near the proposal. Powder Horn and Dudauman Creek catchments are fairly flat for most of their length and flow in a north east direction towards the town of Stockinbingal before joining the larger Bland Creek in the Upper Lachlan River catchment.

The proposal will involve fill embankments and bridges and culverts across overland flow paths and ephemeral creeks and cuttings at the catchment divide. Bridges have been included at Billabong, Ulandra, Run Boundary, Isobel, Powder Horn and Dudauman Creeks. Culverts have been included for all but one overland flow path, where the proposal will divert a small catchment 500m south to a culvert under the proposal and re-join its original flow path some 30 metres from the edge of the proposal. The proposal design was iterated to attempt to avoid the diversion but it was not possible due to engineering constraints. The proposal's intersection with flood prone land is relatively minor compared to the length of the proposal so much of the construction can be kept clear from waterways. Construction works in creeks will be considerate of existing flow behaviour and done to minimise impacts to sediment movement and changes in flows.

The design immunity for the proposal is the 1% Annual Exceedance Probability (AEP) design flood event to the shoulder of the formation of the rail embankment. This criterion has been met across the proposal for all greenfield sections but is not possible at the connection to the existing Main South line where the formation has a 2% AEP design flood immunity. Flood models have been developed to understand the existing flood behaviour across the proposal and in the catchments around the proposal. The flood modelling was used to inform the Reference Design which has been iterated to mitigate and manage impacts of the proposal on flood behaviour, hydrology and geomorphology. The flood models were also used to understand the potential for overtopping of the rail during extreme flood events.

Hydrologic models were developed using the XP-RAFTS software program and, in the absence of reliable steam gauge information for calibration of the models, the flows generated from the models were verified against flows estimated using the Australian Rainfall and Runoff 2019 Regional Flood Frequency Estimation method.

Murrumbidgee catchment and Lachlan catchment hydraulic models were developed using the TUFLOW software program. TUFLOW allows for the simulation of flooding in major rivers, overland flow paths and piped networks with 2-dimensional modelling used for overland flow paths and floodplains where flow is multi-directional and 1-dimensional modelling for hydraulic structures such as rail and road culverts and drainage systems. The hydraulic models were established using the latest topographic information for the proposal and surrounding catchments and detailed survey at key locations, including the levees through the town of Stockinbingal. The proposal was then incorporated into the hydraulic models with the formation included as a change to the topographic surface with the proposed culverts, bridges and drainage structures represented in the models.

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

The hydraulic models were used to estimate peak flood depths, levels, velocities, duration of inundation and flood hazard (defined as the product of velocity and depth) for a range of design storm events including the 0.2 Exceedances per Year (EY), 10% Annual Exceedance Probability (AEP), 5% AEP, 2% AEP, 1% AEP, 1% AEP with allowance for climate change, 0.05% AEP and the probable maximum flood (PMF). The results were then used to inform the design and minimise or mitigate the impact of the proposal. The results of the modelling were used to locate culverts at overland flow paths intersected by the proposal and identify if scour and erosion protection measures were required around drainage structures and bridges. The modelling supplemented with the NSW River Styles information, Technical Paper 2 – Aquatic biodiversity impact assessment, site visit information and geotechnical information informed the location and size of culverts and bridges to minimise changes to hydraulic and geomorphic conditions. With a culvert or bridge proposed at every overland flow path or creek and no diversion of flow out of or between sub-catchments it is predicted that there will be no impact on surface water supplies or uses upstream and downstream of the proposal.

Overall, the proposal is predicted to have only localised impacts to flood behaviour, hydrology and geomorphic conditions. These impacts have been minimised and mitigated through the design. Bridges will allow for fish passage, with round piers to minimise hydraulic disturbance and geomorphic changes to the channels. Culverts have been located to maintain existing overland flow paths and will incorporate scour protection measures to manage the transition of flow into and out of the drainage structures. Construction work will be located away from flood prone areas or where this is not possible in the Dudauman Creek floodplain will be appropriately managed to minimise risks to the environment. The proposal will not significantly change the existing flood behaviour for the land around the proposal nor will it impact on the use of the land and surface water resources around the proposal.

1 Introduction

1.1 Overview

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane. Inland Rail involves the design and construction of a new inland rail connection, about 1,700 kilometre long, between Melbourne and Brisbane. Inland Rail is a major national proposal that will enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Illabo to Stockinbingal section of Inland Rail ('the proposal'), which has a total extent of about 42.5 kilometres (km), and consists of about 39km of new, greenfield single track standard gauge railway and associated infrastructure between Illabo and Stockinbingal.

The proposal requires approval from the NSW Minister for Planning and Public Spaces under Division 5.2 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Minister for the Environment.

This report has been prepared by Inland Rail Design Joint Venture (WSP/Mott Macdonald) as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to accompany the application for approval of the proposal, and addresses the Secretary's Environmental Assessment Requirements (SEARs) from the Secretary of the Department of Planning, Industry and Environment (DPIE), issued on 30 April 2021.

1.2 The proposal

The proposal is located between Illabo and Stockinbingal within the Riverina region of NSW. The location of the proposal is shown in Figure 1.1.

1.2.1 Key features

The key features of the proposal (which would be confirmed during detailed design) are shown in Figure 1.2 and includes:

- a total extent of about 42.5km, including about 39km of new, greenfield single track standard gauge railway between Illabo and Stockinbingal, including:
  - a combination of track vertical alignments on existing ground level, on embankments and in cuttings
  - 8 new bridges at watercourses, two road overbridges and one grade separated (road over rail) at Burley Griffin Way
  - one crossing loop and associated maintenance siding
  - construction of new and upgrades to existing level crossings (including public roads and private accesses)
  - stock underpasses and other vehicular crossings on private land to allow for the movement of livestock and vehicles across the rail line
  - installation and upgrade of about 88 new and existing cross drainage culverts below the rail formation and 27 cross drainage culverts below level crossings
  - removal of redundant sections of track along the existing Stockinbingal to Parkes line and Lake Cargelligo line at Stockinbingal

- upgrades of about three km of existing track for the tie-in works to the existing Main South rail line at Illabo, and tie ins to the Stockinbingal to Parkes rail line at Stockinbingal
- construction of about 1.7km of new track to maintain the existing connection of the Lake Cargelligo rail line either side of the proposal
- realignment of a 1.4km section of the Burley Griffin Way to provide a road over rail bridge at Stockinbingal
- realignment of Ironbong Road to allow for safe sight lines at the new active level crossing.

Associated infrastructure would include signalling and communications, signage, fencing and services and utilities. The construction of the proposal would also require the following works:

- construction access roads and access tracks
- watercourse crossings
- temporary changes to the road network
- construction compounds.

1.2.2 Vertical alignment

The proposal has been designed to minimise cut and fill and as such follows the existing topography where possible. From Billabong Creek the alignment rises out of the Billabong Creek catchment to the north east to a peak at about chainage 2.6km. From here the proposal deviates away from the existing main southern line and heads north on a filled embankment across Old Sydney Road and across minor low points before cutting through the Ulandra Creek catchment divide at about 6.4km. Past the cutting the proposal is in fill across Ulandra Creek and Ironbong Road.

The proposal then continues on a steady rise up to Dirnaseer Road at chainage 18.4km. It alternates between cut and fill between 6.4 and 18.4km and crosses many overland flow paths and Run Boundary Creek. North of Dirnaseer Road the proposal flattens and gently rises across numerous overland flow paths and low points with both cut and fill up to the Murrumbidgee and Lachlan River catchment divide at chainage 24.2km. From here the proposal continues to traverse minor overland flow paths and low points but has a gentle downward slope across cut and fill sections. At approximately chainage 35.6km the proposal mimics existing surface slopes to cross the Powder Horn Creek floodplain. The proposal is in fill across the floodplain but relatively close to the surface to reduce fill depths. The proposal continues at the flat grade toward Dudauman Creek before going into cut at approximately 38km. From the northern side of the cutting the proposal gently slopes down across the existing surface to meet the existing Stockinbingal to Parkes rail line at the proposal’s northern extent.

1.2.3 Timing and operation

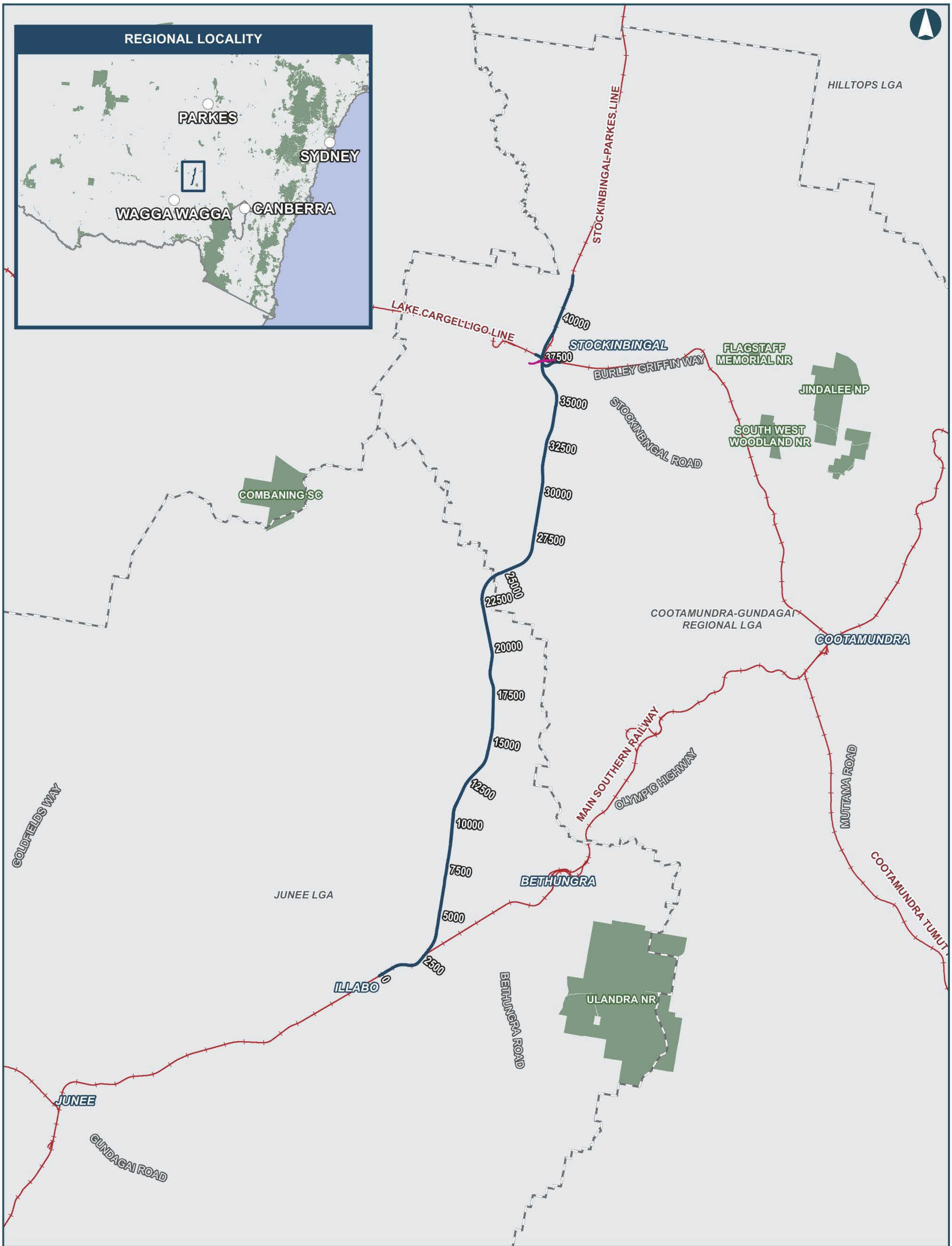
Subject to approval of the proposal, construction of the proposal is planned to start in mid-2024 and is expected to take about 24 months. Construction is expected to be completed by mid-2026.

The proposal would form part of the rail network managed and maintained by ARTC. Train services would be provided by a variety of operators. It is estimated the Illabo to Stockinbingal section of Inland Rail would be trafficked by an average of 6 trains per day (both directions) from commencement of operations in 2026, increasing to about 11 trains per day (both directions) in 2040.

The new rail line will be a faster, more efficient route that bypasses the Sydney rail network and will enable the use of double stacked trains (up to 6.5m high) along its entire length.

The trains would be diesel powered, and would be a mix of grain, intermodal (freight), and other general transport trains up to 1,800 metres in length.

The proposal is expected to be operational, as part of Inland Rail as a whole, once all 13 sections are complete, which is estimated to be in 2027.



ILLABO TO STOCKINBINGAL 1.1 Location of the proposal

0 2 4 6 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 7/23/2021 Paper: A3
Author: IRDJV Scale: 1:200,000

Data Sources: ARTC, NSWSS, ESRI

Key features of proposal

- Key features of proposal
- 40950 Chainage (distance in metres from southern limit of the proposal)
- Burley Griffin Way realignment

Existing features

- Local Government area boundary
- Existing rail
- Parks and reserves
- Sub-arterial road
- Arterial road

INLAND RAIL ARTC

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

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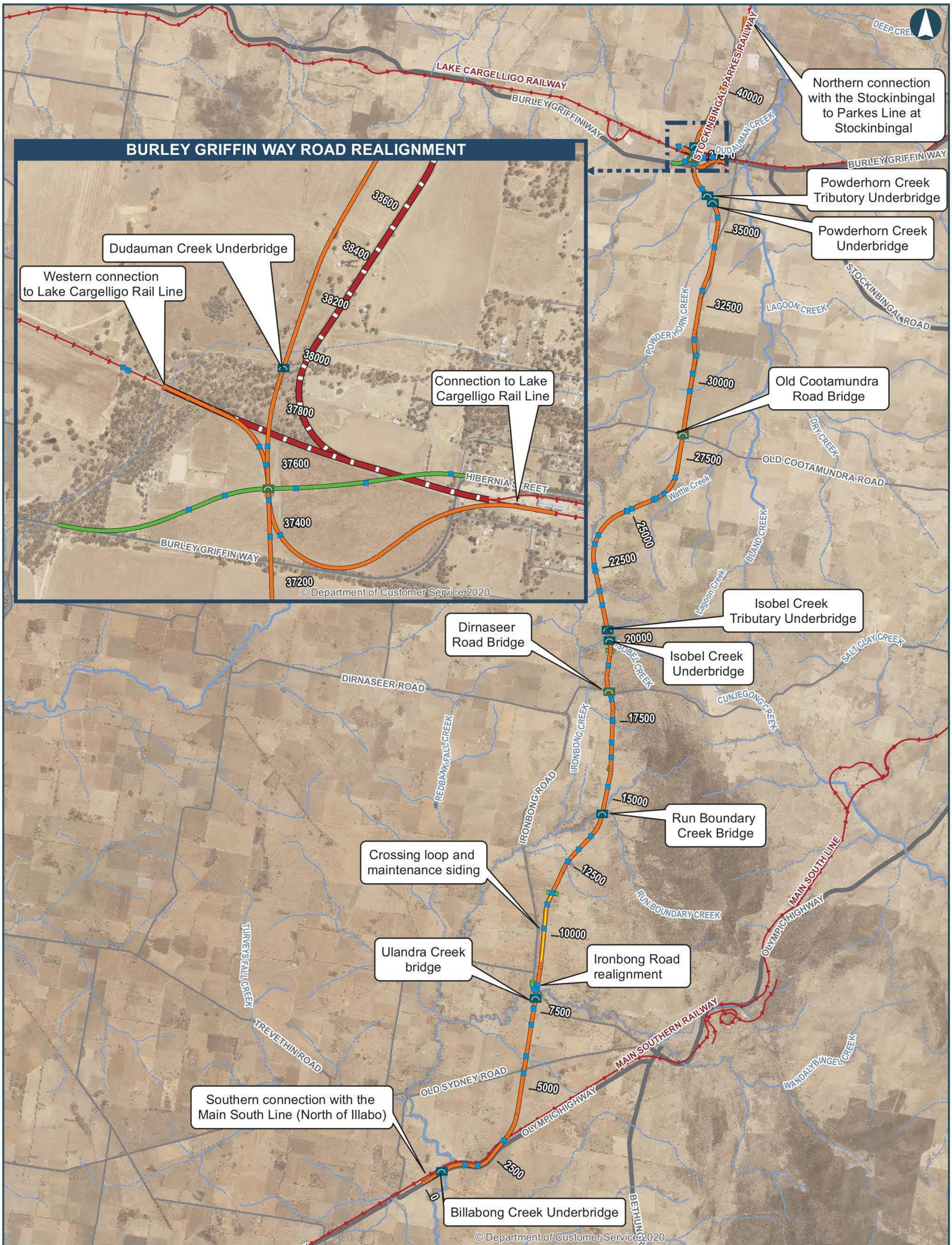


ILLABO TO STOCKINBINGAL 1.2 Key features of the proposal

0 1 2 3 km

Coordinate System: GDA 1994 MGA Zone 55

Date: 7/23/2021 Paper: A3
Author: IRDJV Scale: 1:120,000
Data Sources: ARTC, NSWSS, ESRI

Key features of proposal
- New track/track upgrade
- 40950 Chainage (distance in metres from southern limit of the proposal)
- Crossing Loop & Maintenance Siding
- Burley Griffin Way Road realignment
- Culvert
- Bridge (road crossing)
- Bridge (water crossing)

Existing features
- Sub-arterial road
- Arterial road
- Existing Rail
- Major Watercourse
- Minor Watercourse
- Redundant sections of rail to be decommissioned

INLAND RAIL ARTC

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

1.3 Study area

The study area for this assessment is defined as the catchment areas that contribute flows to watercourses that intersect the proposal. The proposal lies at the catchment divide of the Lachlan and Murrumbidgee catchments. The Murrumbidgee catchment encompasses about 25km of the proposal, and the Lachlan catchment covers about 14km. 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.

The assessment has included definition of catchments associated with these watercourses in order to model hydrology and flooding processes within and around the proposal site. The catchment boundaries are shown in Figure 6.1.

1.4 Scope and purpose of the report

The scope of the flooding and hydrology impact assessment is to document the existing flood behaviour in the surface water catchments surrounding the proposal; the changes to these conditions caused by the proposal; and management and mitigation measures required to ensure that these changes do not adversely affect adjacent property and land use and to ensure that the new rail line meets ARTC's flood immunity requirements.

The flooding and hydrology impact assessment has been prepared to specifically address the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning and Environment (DPE) on 30 April 2021. Table 1.1 summarises the SEARs relevant to flooding, hydrology and geomorphology, and identifies the relevant sections of which address these requirements.

Table 1.1 Secretary's Environmental Assessment Requirements

Key issue	Requirement	Where addressed in this report
4. Flooding, Hydrology and Geomorphology	1) Description of topographic and hydrologic conditions of the site and surrounding area, including:	
	a) Assessment of the existing hydrology and flooding characteristics of all watercourses within and adjacent to the proposal area. This includes locating and assessing flowpaths emanating from existing culverts, pipes and bridges under the rail formation, or from overtopping of the existing formation in flood events.	Section 6.8
	b) Description of the existing and proposed topography in all areas that could be potentially affected by floodwaters. This includes the spatial location, and the horizontal and vertical dimensions of all spoil mounds	Sections 1.2.2 and 6.3.1
	c) Carrying out of investigations to assess the propensity for scour, erosion and geomorphological changes to occur within any watercourses or overland flowpaths affected by the proposal.	Sections 6.9, 7.2.5, 7.2.9 and 8.1.1.3
	2) Design parameters and features, including:	
	a) Description and justification of quantitative flood management objectives for flooding, hydrological and geomorphological changes resulting from the proposal. These objectives are to consider land use and include for afflux, velocity, extent, duration, hazard, and scour potential.	Chapter 5. For consistency with other Inland Rail projects, these objectives have been termed "Quantitative Design Limits" (QDL).

Key issue	Requirement	Where addressed in this report
	b) Description and justification of the proposed flood planning level (FPL) for the proposal including the annual exceedance probabilities (AEPs) of the floods which will overtop the formation and rail. When establishing the appropriate FPL, consider any impacts on adjacent infrastructure and any alteration works required to improve flood immunity of affected infrastructure.	Sections 5.2 and 7.2.1
	c) Description of the location and size of all existing and proposed pipes, culverts and bridges, and the locations and AEPs of floods that overtop the existing formation and rail.	Sections 6.8.8 and 7.2.1.2 and Figure 1.2
	d) Preliminary engineering designs of the velocity dispersal velocity attenuation and other velocity mitigation works that are proposed to avoid adverse scouring on the land downstream of the proposal area, adjacent to locations where pipes, culverts or bridges are proposed or where the rail formation may be overtopped.	Sections 4.4.2.2 , 6.9, 7.2.2.2 and 8.1.1
	e) At locations along the rail route, identification of the width of land between the toe of the formation and the downstream boundary of the proposal area, that is available for the construction of these mitigation works. Where there is insufficient width of proposal land available for these works, clear identification of the extent of additional land beyond the proposal area that may be required, including the locations where easements over land or acquisition of land may be required.	Sections 7.2.1
	3) Operational phase impacts of the proposal on flood behaviour for a full range of flood events up to and including the PMF (including consideration of the impacts of climate change and differencing storm durations), including:	Addressed in section 7.2 and Appendix D
	a) utilisation of 2D hydrologic and hydraulic models that are consistent with ARR and current best practice and utilise topographic and infrastructure data that is of sufficient spatial coverage and accuracy to ensure the resultant models can accurately assess existing and proposed water flow characteristics;	Section 4.3
	b) identification of allowance for blockage of all cross-drainage structures to be made in accordance with ARR	Section 4.3.5
	c) having these models independently peer-reviewed with the results published in the EIS;	Section 4.3.7 and Appendix B
	d) assessing any changes to the potential flood affectation, scouring or geomorphological changes to other properties, assets and infrastructure, over a full range of flood durations and flood frequencies against the proposed quantitative flood management objectives;	Section 7.2
	e) assessing changes in upstream and downstream flow paths (location, discharges and velocities, including overland flow);	Section 7.2
	f) where the existing rail infrastructure has an adverse flood impact on property or people, the flood assessment must consider the extent to which the proposal alleviates or exacerbates these existing impacts;	N/A – there is no existing rail infrastructure
	g) assessing impacts of extreme floods up to the probable maximum flood (PMF) including consideration of flood risks to people and property resulting from failure of the formation or washouts of ballast;	Sections 4.3.3, 7.2.8, Appendix D
	h) assessing consistency (or inconsistency) with applicable Council or DPIE Water floodplain management plans; The requirements of these plans must be discussed with DPIE Water and the relevant Council;	Section 7.2.11

Key issue	Requirement	Where addressed in this report
	i) assessing whether each component of the proposal is compatible with the flood hazard of the land and the hydraulic functions of flow conveyance and flood storage of the land;	Section 7.2.2.6
	j) assessing impacts on farm dam, agricultural infrastructure, crops and activities associated with altered hydrology including volumetric changes in water flows;	Sections 7.2.2.3 and 7.2.10
	k) assessing any impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Service and applicable the council; and	Section 7.2.7 and Chapter 4 of the EIS
	l) Evaluating any social and economic impacts that the proposal may have on the community as a consequence of changes to flooding and hydrology including dividing or fragmentation of property and changes to property management which could lead to the loss of viability.	Section 7.2.12 and refer to the Technical Paper 11 – Social and Technical Paper 12 – Economic
	4) Construction impacts on the proposal including:	
	a) typical construction methodology and programming that may affect flood impacts	Section 7.1.1
	b) structures and plant located on the floodplain during construction;	Section 7.1.2
	c) land uses and infrastructure in the vicinity of the proposal susceptible to flood impacts that may arise during the construction phase;	Section 7.1.2
	d) acceptable impacts having regard to the nature and duration of various construction activities within the floodplain, and the probabilities of a range of flood events occurring over the duration of the construction period; and	Sections 7.1.1 and 7.1.2
	e) measures to mitigate risks of construction impacts occurring	Section 8.1
	5) In the event that operational impacts do not comply with the nominated quantitative flood management objectives, provide measures to ensure the proposal's detailed design complies with the quantitative objectives. Alternatively:	
	a) demonstrate that design changes to meet objectives at a given proposal location are not practicable; and	Chapter 8
	b) describe how broad flooding objectives will still be met at a given location; and	Section 7.2
	c) detail procedures to ensure that the flood performance is acceptable to affected parties.	Section 7.2.12 and 7.2.11

Key issue	Requirement	Where addressed in this report
9. Water – Hydrology	1) Describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the proposal, including stream orders, as per the BAM.	Sections 6.1 and 6.8 and Technical Paper 6 – Groundwater
	2) Prepare a conceptual water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Construction and operation of the proposal will not involve catchment diversions nor extraction of surface water. Therefore, a surface water balance is not required for the assessment. Water supply options for the construction phase are discussed in Sections 7.1.3 and 7.2.10. The Technical Paper 6 – Groundwater includes a detailed water balance for groundwater
	3) Surface and groundwater hydrology impacts of the construction and operation of the proposal and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Chapter 7
	a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Sections 7.2.2, 7.2.9 and Technical Paper 2 – Aquatic biodiversity
	b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement	Technical Paper 6 – Groundwater
	c) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Section 7.2.10
	d) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Section 7.2.2.2, 7.2.9
	e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Sections 7.1.1, 7.2.2, 7.2.10 and 8.2

Key issue	Requirement	Where addressed in this report
	f) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation including an assessment of the availability of water where water entitlement is required to be purchased.	Surface water take is not proposed, as such a detailed water balance is not required. Technical Paper 6 – Groundwater includes a detailed water balance for groundwater.
	4) Identification of any requirements for baseline monitoring of hydrological attributes.	Section 8.1

1.5 Structure of this report

This structure of this report is outlined below:

- **Chapter 1 – Introduction** – introduction and overview of the proposal including the SEARs.
- **Chapter 2 – Legislation and policy context** – identification of relevant legislation, policies and guidelines that inform the technical aspects of this assessment.
- **Chapter 3 – Available data –** notes the key datasets used in the assessment.
- **Chapter 4 – Methodology** for the assessment, including defining the technical study area, how the impact assessment was completed and identification of mitigation measures.
- **Chapter 5 – Quantitative design limits** – includes defining the objectives for the technical assessment and providing justification for the objectives.
- **Chapter 6 – Existing conditions** – describes the existing conditions for the technical study area.
- **Chapter 7 – Impact assessment** – outlines the assessment of impacts for the construction and operational stages of the proposal.
- **Chapter 8 – Mitigation and management measures** – identified mitigation and management measures which will be implemented to minimise the impact of the proposal.
- **Chapter 9 – Conclusions**
- **Chapter 10 – References**.

2 Legislation and policy context

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The objective of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is to protect and manage prescribed Matters of National Environmental Significance (MNES). Under the EPBC Act, proposed ‘actions’ that have the potential to significantly impact on MNES, the environment of Commonwealth land, or that are being carried out by a Federal Government agency, must be referred to the Federal Minister for the Environment for assessment.

As a result of the potential for impacts on protected matters, the proposal was referred to the (then) Australian Minister for the Environment in June 2018 (EPBC Referral No 2018/8233). On 6 August 2018, the Australian Government Department of the Environment and Energy notified that the proposal is a controlled action, with the controlling provisions being ‘listed threatened species and communities’ (under section 18 & 18A of the EPBC Act).

No impacts to MNES have been identified as part of this assessment.

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) and Environmental Planning and Assessment Regulation 2021 (EP&A Regulation) establish a framework for the assessment and approval of developments in NSW. They also provide for the making of environmental planning instruments, including state environmental planning policies (SEPPs) and local environmental plans (LEPs), which determine the permissibility and approval pathway for development proposals and form a part of the environmental assessment process. In accordance with the provisions of the EP&A Act, the proposal is State Significant Infrastructure (SSI).

SSI may also be declared to be critical State significant infrastructure (CSSI) in accordance with section 5.13 of the EP&A Act, if it is of a category that, in the opinion of the Minister for Planning and Public Spaces, is essential for the State for economic, environmental or social reasons. The proposal was declared as CSSI in 2021.

Under section 5.14 of the EP&A Act, the approval of the Minister for Planning and Public Spaces is required for State significant infrastructure (including CSSI), and an EIS has been prepared under Division 5.2 of the EP&A Act.

The proposal requires approval from the NSW Minister for Planning under Division 5.2 of the NSW EP&A Act. Section 5.23 (1) (g) of the act outlines specific approvals are not required for state significant proposals, but the following acts are considered for reference.

2.2.2 Natural Resources Access Regulator Act 2017 No 64

Natural Resources Access Regulator (NRAR) has been established through the Natural Resources Access Regulator Act 2017 No 64. The NRAR has been established to be an independent regulator with total carriage of the compliance and enforcement of water management legislation in NSW. The NRAR is responsible for water access licences and associated approvals required for state significant proposals. So if licences or approvals are required for the proposal then the NRAR will be the application authority for a water access licence.

2.2.3 Water Management Act 2000

The *Water Management Act 2000* (WM Act) recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with access to water. The main tool the WM Act provides for managing the state's water resources are water sharing plans (WSP). The relevant WSP for the proposal are the Lachlan Unregulated River Water Sources 2012 and Murrumbidgee Unregulated River Water Sources 2012. The WM Act focuses on protecting, enhancing and restoring water resources and encouraging best practice management and use of water.

A water use approval under section 89, a water management work approval under section 90, or an activity approval (other than an aquifer interference approval) under section 91 of the WM Act is not required but should be considered if the proposal changes significantly. These are not required because the proposal is a State Significant Proposal as indicated in section 2.2.1 above and is not intending to source surface water from the catchments surrounding the proposal.

2.2.4 Water NSW Act 2014 No 74

The *Water NSW Act 2014* creates the corporation of WaterNSW which replaces the State Water Corporation. The principal objectives of WaterNSW are:

1. to capture, store and release water in an efficient, effective, safe and financially responsible manner
2. to supply water in compliance with appropriate standards of quality
3. to ensure that declared catchment areas and water management works in such areas are managed and protected so as to promote water quality, the protection of public health and public safety, and the protection of the environment
4. to provide for the planning, design, modelling and construction of water storages and other water management works
5. to maintain and operate the works of WaterNSW efficiently and economically and in accordance with sound commercial principles.

Relevant key functions for the proposal include:

- to protect and enhance the quality and quantity of water in declared catchment areas
- to manage and protect declared catchment areas and water management works vested in or under the control of WaterNSW that are used within or for the purposes of such areas
- to undertake flood mitigation and management.

WaterNSW are responsible for the provision of stream gauges across NSW including maintenance and monitoring the stream gauge data network. The stream gauge data utilised in this assessment has been sourced from a WaterNSW site.

2.2.5 Water NSW Regulation 2013

The *Water NSW Regulation 2013* restricts access to lands immediately adjacent to the storages used for drinking water supplies. It also provides for regulatory powers to manage pollution activities that impact water quality.

The *Water NSW Regulation 2013* (which operates under the *Water NSW Act 2014*) provides WaterNSW with the power to legally enforce access restrictions. WaterNSW has enforcement powers under the *Protection of the Environment Operations Act 1997* to penalise polluting activities in the catchment that may impact on water quality. WaterNSW keeps a public register of all notices issued under the *Protection of the Environment Operations Act 1997*.

There are no drinking water catchments or declared catchments identified near the proposal study area or the contributing catchments surrounding the study area.

2.3 Local planning policy

2.3.1 Cootamundra Local Environmental Plan 2013

For the proposal site the Cootamundra Local Environmental Plan 2013 is the relevant local planning regulation that the proposal should align with to ensure consistency beyond the proposal. Part 6, Clause 6.2 Flood Planning. This is relevant for land at Stockinbingal. While the proposal is not required to comply with local planning requirements it does need to ensure it does not impact local flood planning conditions. For the remainder of the proposal outside of the area of Stockinbingal the principles established in the Floodplain Development Manual (NSW Government, 2005) in respect to the location and permissible impacts of development proposals apply.

2.3.2 Junee Local Environmental Plan 2012

Part 6.2 of the Junee Local Environment Plan 2012 outlines the flood planning requirements for the Junee local government area. The requirements of Part 6.2 are applicable to land identified as “flood planning land”. The proposal does not occur within any area identified as “flood planning land” so the provisions of Part 6.2 do not apply.

2.4 Relevant guidelines and policy

There are no local flood management guidelines that apply to the study area but the guidelines and references documented below inform the hydrology and flood assessment and the design of the proposal with respect to hydrology and flooding.

2.4.1 Australian Rainfall and Runoff Guidelines 2019

Australian Rainfall and Runoff Guidelines 2019 (ARR 2019) (Ball et al, 2019) is a national guideline for the estimation of design flood characteristics in Australia. The aim of the guide is to provide the best available guidance and information on design flood estimation in a manner suitable for use by Australian practitioners to be able to estimate the design flood problem, flood processes, and engineering hydrology. ARR 2019 has national application and is essential for policy decisions and proposals in areas as diverse as:

- infrastructure such as roads, rail, bridges, dams and storm water systems
- town planning
- mining
- developing flood management plan for urban and rural communities
- flood warnings and flood emergency management
- operation of regulated river systems
- prediction of extreme flood levels.

ARR 2019 includes recent advances in knowledge regarding flood processes, the increased computational capacity available, expanding knowledge and application of hydrologic information technology, improved information about climate change and the use of stochastic inputs and Monte Carlo methods.

The estimation of flood flow, velocity and water levels and the models were developed following procedures in accordance with ARR 2019 but were prepared using the methods outlined in Australian Rainfall and Runoff 2016 (ARR 2016) (Ball et al, 2016). ARR 2019 is a final published version ARR 2016 with minor edits and corrections but no substantial changes to procedures used for this assessment.

2.4.2 AS/NZS 3100:2009 Risk Management – Principles and Guidelines

AS/NZS 3100:2009 provides principles and generic guidelines on risk management. The principles outlined in the document can be used to assess flood risk and this standard forms the basis of the AIDR Handbook 7 approach to flood risk management.

2.4.3 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7

The Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Handbook 7 (AIDR, 2017) has been developed to provide guidance on the national principles supporting disaster reliance in Australian through the management and publication of this Handbook and others for other types of hazards. This Handbook is supported by six additional guidelines that cover specific aspects of flood risk management and a practice note to assist with land use planning.

The Handbook is intended to provide broad advice and guidance on all important aspects of managing flood risk in Australia and it provides guidance on the best practice principles.

This Handbook has been considered when developing criteria for managing flood risk from the proposal and compliments the NSW Floodplain Development Manual (DIPNR, 2005) by outlining current best practices for flood risk management.

2.4.4 Climate Change Impacts and Risk Management – A Guide for Business and Government

The Climate Change Impacts and Risk Management – A Guide for Business and Government (Department of Environment and Energy, 2006) provides a framework for considering and managing risk due to climate change. It suggests a planning horizon of 25 years to suit strategic business planning timeframes. The framework is based on AS3100:2009 and has been considered in the application of the climate change projections and the potential change to flood risk as a result of these projections (Australian Rainfall and Runoff, Geoscience Australia, 2019).

This is a national guideline for the estimation of design flood characteristics in Australia. The aim of the guide is to provide the best available information on design flood estimation in a manner suitable for use by Australian practitioners to be able to estimate the design flood problem, flood processes, and engineering hydrology. It is an important component in the provision of reliable and robust estimates of flood risk. Consistent use of Australian Rainfall and Runoff (ARR) ensures that development does not occur in high risk areas and that infrastructure is appropriately designed.

2.4.5 NSW Floodplain Development Manual and Flood Prone Land Policy, DIPNR, NSW Government, 2005

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

- the passage of floodwaters is unobstructed
- temporary pondage of floodwaters is maintained.

The primary objective of the Flood Prone Land Policy as outlined in the manual (DIPNR, 2005) is to “reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods where possible.” This includes a merit based approach to assessing development in the floodplain and the consideration of both mainstream and overland flooding.

2.4.6 Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in Studies, NSW Government, 2019

The Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in Studies (NSW Office of Environment and Heritage, 2019) was developed this guide to assist councils to transition from the 2005 Floodplain Development Manual to ARR 2019 when managing their flood risk through the development and implementation of floodplain risk management plans using the process outlined in the Manual.

2.4.7 Practical Consideration of Climate Change, Floodplain Risk Management Guideline, NSW Government, 2007

The Floodplain Risk Management Guideline on the Practical Considerations of Climate Change (NSW Office of Environment and Heritage, 2007) was developed to provide advice on how to include projected climate changes in the Floodplain Risk Management process as outlined in the NSW Floodplain Development Manual and Flood Prone Land Policy (see section 2.4.5). The guideline provides the following advice to assist in considering climate change in managing flood risk which includes assessing climate change impacts through modelling sensitivity analyses.

The projected climate changes are based on the Intergovernmental Panel on Climate Change (IPCC) 2007 assessment report and indicate sensitivity analysis of rainfall increases of 10%, 20% and 30% should be considered.

2.4.8 Australian Rail Track Corporation Guidelines

ARTC maintain minimum design criteria and construction practices for the planning, design, construction and operation of rail proposals. These documents include the Engineering Practice Manual which has subdocuments on Track Drainage (RTS3432). The manual and sub documents have been considered during the design of the proposal and to inform design criteria as part of this assessment. A specific sub document includes, Track and Civil Code of Practice – Section 10 Flooding – Technical Note ETC 10-02.

2.4.9 Australian Railway Standard AS 7637 Hydrology and Hydraulics

AS7637 Hydrology and Hydraulics (Rail Industry Safety and Standards Board, 2014) describes the hydrologic and hydraulic requirements (functions, performance, design constraints and risk attributes) for the design and assessment of railway infrastructure in flood-prone areas. This document has also been considered during the design of the proposal.

3 Available data

This chapter notes the key datasets used in the assessment.

3.1 Key information sources

The adopted approach to describe existing conditions has been to gather information from previous assessments completed for the proposal, local government agencies, state government agencies and other local stakeholders. Sources of information and information received have included:

- Phase 1, Melbourne-Brisbane Inland Rail Hydrologic and Hydraulic Modelling Illabo to Stockinbingal and North Star to Yelarbon (SMEC, 2016):
  - documented the previous modelling completed to inform the alignment selection and concept design for the proposal.
- Cootamundra-Gundagai Regional Council:
  - current flood planning levels for Stockinbingal provided and the Stockinbingal Floodplain Risk Management Study and Plan (FRMS&P) (SMEC 2002). The FRMS&P included geomorphic information for Powder Horn and Dudauman Creeks and information on the number of flood prone properties in Stockinbingal.
- Junee Shire Council (Junee Local Environment Plan 2012, Flood Planning Map - Sheet FLD_003):
  - flood planning information for Illabo
  - Olympic Highway culvert locations.
- NSW former Office of Environment and Heritage, Floodplain Management Branch:
  - Jeralgambeth Creek at Illabo, Floodplain Risk Management Study and Plan, (Lyall and Associates 2012).
- Australian Soil Resource Information System (Atlas of Australian Soils):
  - soil atlas mapping.
- Review of other technical reports for information relevant to the assessment of surface water and flooding, including Technical Paper 2 – Aquatic biodiversity.
- Visual survey of sensitive receivers up to 2km either side of the proposal, completed using a combination of property registration records, review of aerial photography and field validation. The 1% Annual Exceedance Probability (AEP) flood extent was used to identify flood prone properties under existing conditions. It is noted that floor level survey was not generally available to confirm flood liability of buildings and structures and therefore ground levels at buildings determined from the topographic data were used to estimate floor levels in the assessment. One property in the Dudauman Creek floodplain, close to the proposal was surveyed to provide detailed information on the building floor levels. Both residential and non-residential buildings were identified through the use of aerial photographs.
- Goldenfields Water – water supply pipeline information across the proposal area.

3.2 Topographic data

The topographic datasets used to inform the understanding of the terrain in and around the proposal site. for the assessment included:

- Light Detection and Ranging (LiDAR) survey for the study area (2015) – 0.2m resolution covering approximately a 10km wide strip along the proposal corridor, with an accuracy of 0.15m vertical and <0.5m horizontal (23378A_AAM_LiDAR_Readme.pdf).
- NSW Land Registry Services (formerly Department of Land and Property Information) data – elevation grid data with 20m resolution – adopted to supplement the surface model outside of the LiDAR extent.
- Topographic survey (RPS, January and February 2019), including the following watercourses:
  - Billabong Creek – which included survey of the channel and floodplain – up to 135m upstream and 20m downstream of the existing rail bridge
  - Ulandra Creek – existing culvert and channel cross sections and Ironbong Road – up to 16m upstream and 32m downstream of the existing Ironbong Road crossing
  - Old Sydney Road – existing culverts (size, inverts) and top of road
  - Dudauman Creek – existing culverts (Size, length, inverts) under Stockinbingal to Parkes Railway line, existing culverts under the Lake Cargelligo Line and abandoned rail embankment and a small section of the creek.
- Topographic survey (DeWitt Consulting, March 2022) – survey of floor levels on habitable and non-habitable structures for buildings in the vicinity of the proposal.
- Stockinbingal Levee, Levee Owners Manual, (NSW DPE, 2019) – included create level survey data of the levees through Stockinbingal from West Street through to O’Brien Street.

A site visit was completed in July 2018 to verify desktop information on topographic conditions, land uses, watercourses and existing hydraulic structures.

3.3 Hydrologic data

Historic rainfall data and flow gauge data from the nearest gauges have been collated and reviewed to help understand historic flood events and magnitudes for the proposal site. Design rainfall data has been sourced from the Bureau of Meteorology (BOM) and is based on the most up to date estimates for design rainfall information which was released in 2016 (2016 Intensity–Frequency–Duration (IFD) design rainfalls, BOM 2016). Key data used included:

- WaterNSW:
  - stream and rainfall data for the Wattle Creek at Dudauman gauge # 412134 (Water NSW, 2020).
- Bureau of Meteorology Australia:
  - rainfall, evaporation and temperature data from the Junee Treatment Works gauge (station number 73019), Stockinbingal (Sunnydale) gauge (station number 73150) and Wagga Wagga gauge (station number 72150) (BOM, 2019)
  - design rainfall depths for the proposal site (BOM, 2016).
- The Australian Rainfall & Runoff Data Hub (Ball et al, 2019):
  - design rainfall temporal patterns, areal reduction factors, rainfall losses, climate change factors.

4 Methodology

4.1 Overview

The methodology for the hydrology and flooding impact assessment included the following key tasks:

- background data review and compilation, including review of all available existing flooding information in and around the proposal site (refer Chapter 3)
- consideration of relevant legislation, policy and current guidelines, basis of design documents, design objectives and impact assessment criteria for the proposal
- describe and document existing conditions including climate, topography, watercourse conditions, stream order, geomorphic conditions using NSW River Styles, land uses, soils, interaction with groundwater and flood behaviour for a range of design rainfall events to inform the definition of baseline conditions for the proposal study area
- utilise hydrologic and hydraulic models to develop a detailed understanding of existing design flood behaviour for a range of flood events in the vicinity of the proposal, including extreme events and climate change
- consideration of changes to surface water system balance and surface water supply by reviewing existing aerial photographs, agronomist reports and topographic information
- identification of sensitive receivers and analysis of the impacts to these receivers
- utilise the hydrology and hydraulic models to estimate the proposed changes to the existing hydrologic system and flood behaviour for construction and operation of the proposal
- identify mitigation measures to minimise impact to acceptable levels and the land available for these measures
- summarise findings from investigation
- commission a peer review of the hydrologic and hydraulic models.

4.2 Consultation

Consultation with the community and key stakeholders has been completed by ARTC through the design of the proposal and completion of the EIS (refer to Chapter 4 Consultation of the EIS). This consultation has included meeting with Cootamundra-Gundagai Regional Council and Junee Shire Council and relevant landowners specifically to discuss flood behaviour in the study area.

Where relevant information has been available this has been utilised to inform the understanding of the hydrologic environment for the proposal, including updating the flood models to better reflect known flood behaviour. Refer to section 6.8.2 for further information on consultation and specific information gained during this process which has informed this report.

4.3 Flood model development

4.3.1 Overview

Flood models have been established to understand the baseline or existing conditions flood behaviour and to test the impact of the proposal on the flood regime within the proposal site and adjacent land. Flood models are tools used to replicate flood behaviour and include hydrologic and hydraulic analysis. The hydrological model simulates rainfall-runoff processes within the whole catchment upstream of the proposal and generates the flow patterns for the range of flood events that are input to the hydraulic model. The hydraulic model is focused around the proposal area and suitable distances upstream and downstream and uses a more sophisticated computational method to determine detailed flooding patterns and hydraulic parameters around the proposal site.

The following process was used in development of proposal flood models:

- Hydrological modelling and analysis provide a means for identifying contributing catchment areas and estimation of runoff and streamflow generated by the catchment areas upslope of the proposal area. The hydrologic modelling was completed using the software XP-RAFTS. The XP-RAFTS hydrologic model outputs are used as inputs into the hydraulic model.
- Hydraulic modelling and analysis are used to estimate water level, velocity and other hydraulic parameters that result from application of the hydrologically derived flood flows to the detailed topographic features around the proposal site. The TUFLOW software has been used to undertake the hydraulic modelling. The hydraulic models were used to establish an understanding of existing flood extents, depths, velocity, flow distribution, flood inundation and flood hazard. The models were also used to represent the proposal conditions to inform design and so that any flood impacts could be identified and understood.

The model development, calibration and validation methodology is summarised in the following sections, with further information provided in Appendix A. Model calibration involves the testing of the model against measured or observed flood flow and/or level data and variation of the model parameters to obtain a reasonable fit to the measured or observed data. Model validation is the process whereby the calibrated model is used to simulate an independent flood event to provide a check on the reliability of the calibration process. A peer review of the models has been completed and this is provided in Appendix B and summarised in section 4.3.7.

4.3.2 Hydrologic modelling

The XP-RAFTS software has been used for hydrological modelling for the assessment. XP-RAFTS uses the Laurenson non-linear runoff routing (a widely used approach across the industry) procedure to develop a stormwater runoff hydrograph from either historic rainfall data or design rainfall data. The 2018.1 version of the software utilises the latest ARR Data Hub design rainfall information.

Catchment delineation is a key input to the hydrologic models and includes defining the watercourse catchments using the available topographic data to identify the high points and all areas that flow towards the watercourse.

Tributaries of Wattle Creek intersect the proposal and the NSW Department of Industry – Water operate a rainfall and flow gauge on Wattle Creek at Dudauman (gauge number 412134) that records instantaneous rainfall and water levels, with water levels used to generate flow estimates based on a rating curve developed for the gauge site. An extensive data review was completed and a calibration process was attempted using data from this gauge. This analysis concluded that the Wattle Creek gauge rating curve underestimates flows for large flood events, which is a typical limitation of stream gauges and their rating curves, and ultimately could not be used in model calibration (further details provided in Appendix A).

Model validation relied on the ARR 2019 Regional Flood Frequency Estimation (RFFE) method. Modelled catchment losses were adjusted in the XP-RAFTS model and adopted based on a review of RFFE flows against modelled Billabong Creek catchment flows. Billabong Creek is the largest catchment in the study area at 318 square-kilometres (km^2). It incorporates 25km of the 37km new rail track as well as four of the waterway bridges required for the proposal.

The validation process determined that the following XP-RAFTS model parameters gave the best fit to flow estimates from the RFFE method:

- Mannings 'n': 0.07
- Reach lag time: average flow velocity along stream lines extracted from the hydraulic model
- Initial rainfall loss: 30 millimetres (mm)
- Continuing rainfall loss: 1.72 millimetres per hour (mm/hr).

The roughness value of 0.07 was adopted following validation. The roughness value defines the characteristics of the surface of the catchments including topographic irregularity, obstructions, and vegetation and is a key parameter in determining the catchment runoff response to rainfall.

A value of 0.6m/s was adopted for the hydrologic model reach lag parameter based on the hydraulic model results. This parameter determines the travel time for the passage of floodwaters through the watercourses and floodplains.

The initial and continuing losses adopted were based on testing a range of values based on previous flood studies and ARR2019 (refer to section 2.4.1) guidelines. The losses represent the amount of rainfall that infiltrates into the ground and does not contribute to surface runoff.

The simulated design events cover a range of recurrence intervals to inform an overall understanding of flood risk from frequent to rare events. The events simulated include the 0.2 Exceedances per Year (EY) and the 10%, 5%, 2% and 1% AEP events.

4.3.3 Modelling of extreme 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 0.05% AEP design rainfall data available from BOM was utilised for modelling of this extreme event. For most of the proposal catchments critical durations of less than 24 hours were relevant for the extreme event modelling.

Modelling of the Probable Maximum Flood (PMF) was also completed. The Probable Maximum Precipitation (PMP) rainfall depths are derived with the procedures outlined by the BOM with ensemble temporal patterns derived from Jordan et al (2005). The proposal site lies within the Inland Zone for the Generalised Short Duration Method (GSDM) which is applicable for durations up to six hours and areas up to 1000km^2 (Bureau of Meteorology, 2003) and the Generalised Southeast Australia Method (GSAM) is used for durations up to 96 hours and areas up to 100,000km^2 for the region of Australia where tropical storms are not the source of the greatest depths of rainfall (Bureau of Meteorology, 2006).The following steps outline the methodology has been undertaken to determine the PMF flood event:

- determination of PMP depths and temporal patterns from the GSDM methodology for short duration events and GSAM for long duration events
- generation of an envelope of the GSDM and GSAM PMP depths, and extrapolated data points for the intermediate storm durations
- simulation of the PMP in the hydrological model with an initial loss of 0mm and a continuing loss of 1mm/h to generate the PMF flows.

4.3.4 Climate change

A climate change scenario was simulated in the flood models which involved assessment of a 20% increase in rainfall intensity, based on the ARR 2019 recommendation to adopt the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Representative Concentration Pathway (RCP) of 8.5 as the climate change scenario within the Murray Basin cluster and an expected design life of 100 years.

The 1% AEP rainfall data was factored up by 20% to represent the 1% AEP climate change scenario. This scenario was used to assess the sensitivity of the proposal’s flood immunity and impacts on adjacent land to climate change.

The 20% increase is based on the CSIRO modelling which used the 2013 IPCC climate assessment data and is the middle sensitivity value as recommended by the NSW Floodplain Risk Management guidelines on the Practical Consideration of climate change (refer to section 2.4.7).

4.3.5 Hydraulic modelling

Hydraulic models have been used to simulate the interaction between runoff hydrographs generated by the hydrological models, catchment topography and hydraulic controls and infrastructure associated with the proposal. Two dimensional (2D) hydraulic models have been developed using the TUFLOW hydraulic modelling software program. The models have been built using the 2020 version of TUFLOW Heavily Parallelised Computations (HPC) solver. TUFLOW is a grid based 2D hydrodynamic free-surface flow solver that is well suited for modelling floodplains with the ability to fully integrate bridges, culverts and other drainage systems which are represented as 1-dimensional (1D) elements.

A Quad-tree modelling approach was adopted as it achieved a balance between sufficient resolution across the proposal study area, whilst providing increased resolution at locations of interest. The quad-tree approach allows for smaller grid sizes to be used to define the topography of the floodplain at points of interest and where the ground levels vary over short distances. A 10m grid was adopted as the first grid level, with a second level of 5m and a final third level of 2.5m. The extent of the 2.5m grid is approximately a distance of 50m upstream and downstream of design culverts/bridges with the 5m grid roughly 100m upstream and downstream and laterally covering the flood extent for the PMF event. A 5m grid was adopted to appropriately represent the Stockinbingal levees, with top of bank data used to define the overtopping levels.

Two hydraulic models have been developed using this approach: one covering the Murrumbidgee catchment area and one covering the Lachlan catchment area, similar to the hydrologic model breakdown. The extents of the models have been based on the available LIDAR dataset and the proposal study area and are presented in Appendix A.

The proposal footprint has been extended from the base of the proposed rail embankment to incorporate all drainage design features, including scour protection measures and longitudinal drains. This is typically a width of 20m but extends to 50m at some locations where the topography requires more space within the rail corridor to accommodate the drainage infrastructure. Existing and proposed culverts were included in the hydraulic model. Only bridges required for cross drainage of watercourses and overland flow paths have been included in the hydraulic modelling, such that bridges required for road crossings are not included because they do not intersect watercourses. No permanent spoil mounds will be required within flood prone land and therefore have not been included in the modelling.

A cross drainage blockage assessment was completed following the ARR2019 risk assessment for blockage process. This determined values from 0% blockage to 25% blockage would be applicable. The determined values were adopted for the design culverts but a sensitivity test was also completed to understand the sensitivity of the estimated peak flood heights to blockage. Therefore an additional two scenarios for blockage were tested and compared against the base assumption of the ARR2019 assessment estimated values:

1. clear or 0% blockage
2. double the ARR 2019 determined values for proposed culverts up to a minimum of 25% blocked.

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% blockage. Further details are provided in Appendix A.

The proposal flood modelling assumed the existing Stockinbingal to Parkes, Lake Cargelligo and Main South rail lines would all remain, and only redundant sections removed to facilitate the proposal. No changes to existing heights of these existing rail lines and no removal of existing culverts and water structures were assumed as part of the flood modelling.

The models were not able to be calibrated due to the lack of historic flood level data, however, checks of model results were completed based on a comparison of flood extents against levels from historic flood photographs, discussions with landowners and approximate 1% AEP flood extents obtained from Cootamundra-Gundagai Regional Council. Further details of this are provided in section 6.8.

4.3.6 Model limitations

The most up to date data has been used to build the hydraulic models. It is however acknowledged that the results are limited by the inputs. The models are deemed to be an accurate representation of the study area and suitable for use to inform the assessment with acknowledgement of the following limitations:

- The hydraulic model has not been established to understand flood behaviour through the urban areas of Stockinbingal for flood risk management planning purposes. The intent of the hydraulic model is to establish and understand flood behaviour in the rural areas of the proposal and understand the impact of the proposal in both rural and urban areas. Further model definition with detailed survey of Stockinbingal would be required to adequately model flood behaviour through the urban/built-up areas. The model results for Stockinbingal are therefore limited by the accuracy of the topographic data and levee survey data available. 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 information for the urban areas of Stockinbingal.
- The quadtree grid was adopted to represent more accurately the bathymetry of the main waterway crossings to improve the understanding of existing flood behaviour and the impacts of the proposed cross drainage at a finer resolution of a 2.5 m grid. Where possible the quadtree areas were defined with an appropriate buffer to avoid boundary effects that would impact the modelled results.
- It is noted that there are a considerable number of farm dams across the study area. The influence of these on flood model results has not been tested but the conservative approach of assuming that the dams are full prior to a flood event is considered suitable for Reference Design.

4.3.7 Peer review

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

The independent peer review was completed by WMA Water and found that generally the hydrological and hydraulic modelling undertaken for the proposal is consistent with the relevant guidelines and is appropriate for the Reference Design phase of the proposal.

The peer review made the following recommendations for further model refinement at the detailed design stage:

- For Billabong Creek, peak flow estimated by the TUFLOW model closely matches the RFFE expected peak flow. For detailed design a review of the peak flow timing and flood hydrograph volume will need to be completed to ensure the TUFLOW model includes the full flood volume.
- Sensitivity testing on blockage of culverts. ARR2019 Book 6, Chapter 6 (Ball et al, 2019) outlines the most up to date guidance for the estimation of the risk of blockage of culvert structures. The approach considers a range of site specific factors to understand the risk and then calculate the estimated percentage blocked for a structure. ARR2019 suggests that there are several factors that most influence the likely blockage of bridge and culvert structures. For the Reference Design, the ARR2019 approach for blockage determined values from 0% blockage to 25% blockage. For existing culverts the same 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% blockage. Subsequently, a uniform blockage factor of 15% was applied to all new culverts. Sensitivity testing at detailed design should investigate the effects of higher blockage factors.

A log of comments raised in the review and responses provided is included in Appendix B.

4.4 Flood impact assessment

4.4.1 Construction phase

The construction impact assessment is qualitative and based on the proposed construction footprint. The expected temporary construction activities for the proposal were reviewed to identify all works on flood prone land. The construction footprint has been compared against the existing flood behaviour and qualitative impacts assessed to estimate where changes may occur to flood behaviour as a result of construction works.

4.4.2 Operational phase

The flood impact assessment has been based on comparing the model predictions of key hydraulic parameters for the design case against those for the existing conditions with the use of GIS mapping.

The hydraulic models developed for the Reference Design have included all proposed bridges, culverts, drainage systems, rail formation and road works and undergone several iterations to ensure the design meets ARTC's required level of flood immunity and the Quantitative Design Limits (QDLs) which define the flood impact criteria for the proposal – refer to Chapter 5 for further discussion of the QDLs. Sections 4.4.2.1 and 4.4.2.2 below provide further details of the design iteration approach adopted and how this related to flood impact assessment.

Impacts of the proposal on flood levels, flow velocities, flood hazards and duration of inundation were assessed against the QDLs for these parameters at sensitive receivers and infrastructure.

Mitigation measures such as flood relief culverts, flood relief channels and basins and scour protection have been included in the design to minimise impacts to flood behaviour, surface water supplies and watercourse geomorphology. Flow and flow diversions have been minimised and existing levees considered as part of the assessment of impacts to surface water supply.

4.4.2.1 Cross drainage design

The design process included detailed flood modelling to identify the necessary locations for cross drainage structures, scour protection, longitudinal drainage and land take to meet the adopted QDLs as outlined in Chapter 5. The design approach to sizing the structures was as follows:

- Identify key waterway features and drainage paths where cross drainage structures are likely to be required. Each structure was then optimised by varying the size/number of cells and culvert floor level until the following two criteria were met:
  - the required minimum formation flood immunity was achieved; and
  - afflux satisfied the QDL and were reasonably balanced upstream and downstream of the corridor and across the range of events.
- Once the afflux was balanced, the velocity was then checked upstream, through the structure and downstream. If the structure was found to generate velocities that exceeded the QDL over land downstream of the corridor then additional cells were added to increase the waterway area and reduce the velocity, and scour protection within the corridor was included to prevent against scouring. Site specific erosion threshold values (ETVs) were not available so a default ETV of 0.5m/s has been adopted for unprotected surfaces. Refer to section 5.3.
- The flood duration impacts were then checked and impacts across all parameters were checked for the full suite of design events (0.2EY, 10%, 5%, 2% and 1% AEP events) and the design was re-balanced where necessary to address any localised areas of non-compliance with QDLs.

4.4.2.2 Scour protection design

Scour protection has been designed at culvert inlets and outlets and along longitudinal channels where required by the hydraulic conditions. The detailed extents and transitions of scour protection and associated earthworks to the receiving drainage lines will be determined at the detailed design stage when survey data is available.

The design of the scour protection has been undertaken in accordance with Austroads Guide to Road Design Part 5: Drainage – General and Hydrology Considerations. The scour protection takes the form of rock aprons/channel lining with well graded interlocking rocks over geotextile and bedding layers to allow sub-soil drainage and provide a stable foundation for the rock aprons. The rock aprons are designed to withstand flow velocities that occur up to and including the 1% AEP event.

4.5 Water availability and supply

Data on existing water availability and supply was reviewed through 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 in the vicinity of the proposal. Information on the reticulated water network was provided by Goldenfields Water.

The estimated water demand of the proposal was reviewed for construction and operation. Water supply options were also reviewed in the Construction Water Plan prepared for the proposal (Golder, 2020) and Inland Rail Water Procurement Options Analysis (EMM, 2020) prepared to inform decisions about approval or procurement processes related to construction water.

Farm dams were identified through a review of aerial photography and topographic data for the study area. Impacts to water availability from farm dams was considered, including direct loss of farm dams within the proposal, and changes to overland flow paths potentially impacting farm dams as a result of the proposal.

4.6 Geomorphology assessment

The geomorphology of watercourses and floodplains can be defined as the form that the landscape takes in response to long term dynamic interactions between catchment runoff processes, vegetation and underlying soils and geology. Sedimentation and erosion processes are the key catchment runoff processes that affect geomorphology, and disturbance of these processes as a result of new infrastructure has the potential to adversely impact the geomorphic conditions by destabilising the landscape and causing new or increased sedimentation and erosion. The proposal will intersect many overland flow paths and watercourses which have been formed from the flow of water across the surface including sheet flow and concentrated flow and has the potential to affect the geomorphic conditions within these systems.

To assist with understanding the baseline geomorphic conditions, the results of geotechnical investigations completed for the proposal, topographic data, aerial photographs, site visits and Technical Paper 2 – Aquatic biodiversity have been reviewed. A Geomorphic Assessment (SMEC, 2002) that was completed in 2001 to accompany the Stockinbingal Floodplain Management Study was also used to inform understanding of the baseline geomorphology.

The NSW River Styles mapping (NSW OEH, 2012) provides information on the existing geomorphic conditions of many waterways across NSW. This dataset has been used for this assessment and has been supplemented with flood velocity and flood depth results from the flood models. The geomorphic assessment has focused on the nine named watercourses crossed by the proposal (refer to Figure 6.1):

- Billabong Creek
- Ulandra Creek
- Run Boundary Creek
- Isobel Creek
- Isobel Creek Tributary
- Powder Horn Creek
- Powder Horn Creek Tributary
- Dudauman Creek
- Dudauman Creek Tributary.

Other watercourses crossed by the proposal are subject to sheet flow and do not have defined channels that have a River Styles classification.

The potential for the proposal to impact the geomorphology of the adjacent watercourses and floodplains was assessed by determining the existing and future velocity regimes from the hydraulic model results. Areas where the proposal may change the velocity regime and the associated sedimentation and erosion processes were then identified.

5 Quantitative design limits

5.1 Overview

The SEARs (at Key Issue 4, Item 2(a) included in section 1.4) require the preparation of "Quantitative Flood Management Objectives". For consistency with other Inland Rail projects, these objectives have been termed "Quantitative Design Limits" (QDL).

Proposal specific QDLs or impact criteria, have been derived from the Inland Rail project North Star to Boarder Draft Conditions of Approval as at May 2022. The QDLs have been established through a review of the existing pattern of land uses in the proposal 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 the Inland Rail proposal and from a review of other critical infrastructure proposals across greenfield sites to maintain a consistency of approach.

The land use is predominantly rural agriculture with a focus on grazing of stock outside of the urban area at Stockinbingal. The urban area of Stockinbingal lies immediately downstream of the northern end of the proposal. The urban area of Illabo is to the west of the southern end of the proposal, but not within catchments affected by the proposal. Infrastructure within the study area includes the Burley Griffin Way, existing Lake Cargelligo railway line at Stockinbingal, Ironbong Road, Olympic Highway and other local roads between Stockinbingal, Illabo, Cootamundra and Temora.

5.2 Proposed flood planning levels and rail flood immunity

The flood planning level for the proposal has been determined based on ARTC's desired level of service and maintenance requirements, as defined by the Inland Rail Programme Business Case (ARTC, 2015) and Service Offering which requires a high level of reliability as appropriate for a competitive freight transport solution. For the greenfield sections of the Inland Rail program (including this proposal) the required flood immunity is the top of formation to have 1% AEP immunity. This is consistent with the Floodplain Development Manual (DIPNR, 2005), AS/RISSB 7637:2014 Railway Infrastructure – Hydrology and Hydraulics (Australian Standard, 2014) and ARTC Code of Practice – Track and Civil Section 10 Flooding (Technical Note ETD-10-02) (ARTC, 2010).

The flood planning level requirements for land beyond the proposal boundary are set by the local government. For infrastructure beyond the proposal boundary there is no specific requirements for flood planning level. But the proposal has considered impacts to flood behaviour via changes to afflux as outlined in section 7.2.2.

5.3 Quantitative Design Limits

The QDLs adopted for this proposal are presented in Table 5.1 below.

Table 5.1 Quantitative Design Limits

Parameter	Land-use or setting/scenario	Desired performance outcome	Proposed QDL for I2S
Afflux	Habitable floors [1]	To minimise increases in the depth of inundation of habitable floors which are affected by flood events	10mm increase for levels above floor level [2]
	Non-habitable floors [1]	To minimise increases in inundation of non-habitable floors which become inundated in flood events	20mm increase

Parameter	Land-use or setting/scenario	Desired performance outcome	Proposed QDL for I2S
	Sensitive infrastructure	To minimise increases in inundation affecting sensitive infrastructure	10mm increase
	The surrounds of residential buildings, and land used for urban activities, open space and recreation facilities and infrastructure (excluding sensitive infrastructure areas)	To avoid adverse flood level impacts on these urbanised land-types across the floodplain, recognising their use	100mm increase
	Agricultural land	To avoid adverse impacts on agricultural land due to changes in flood level	200mm increase
	Forest, unimproved grazing land, other non-urban land and rural roads (excluding the operational road area)	To avoid adverse flood level impacts on the nominated land uses due to changes in flood level	300mm increase
	Classified roads managed by TfNSW	To minimise the risk to traffic movement	50mm increase on areas flooded under existing conditions. Otherwise, no increase
	Highways and sealed roads >80km/hr (operational road area) [3]	To minimise the risk to traffic movement and/or to minimise the risk of introducing new areas of non-trafficable roadway that severs traffic movement at a network level (where not already severed or isolated) i.e., due to changes in flood level	No afflux where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase
	Sealed roads < 80km/h and all unsealed public roads (operational road area) [3]	To minimise the risk to traffic movement and/or to minimise the risk of introducing new areas of non-trafficable roadway that severs traffic movement at a network level i.e., due to changes in flood level	100mm increase
Velocity	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads and most urban, commercial, industrial, recreational and forested land.	To maintain existing velocities or minimise increases in velocity	up to a 20% increase in maximum post-development velocity
	Classified roads managed by TfNSW	To maintain existing velocities or minimise increases in velocity.	10% increase in velocity where existing velocity already exceeds 1m/s

Parameter	Land-use or setting/scenario	Desired performance outcome	Proposed QDL for I2S
	Areas of natural ground surfaces including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	To maintain existing velocities or minimise increases in velocity	Where existing velocities are < 0.5m/s, post development velocity is limited to: • 0.5m/s • up to a 20% increase in maximum post-development velocity Where existing velocities are > 0.5m/s, post development velocities are limited to a 0.025m/s increase
Flood Hazard (refer to section (1))	Residential buildings, and commercial, industrial, infrastructure and recreation land uses Highways [3] and sealed roads [3] *Does not apply to locations where post-development case dv product is < 0.1m²/s.*	To minimise changes in flood hazard in sensitive areas that are more likely to be accessed/accessible to persons during flood events	For all ARR19 Hazard Classifications: a 10% increase in d.v.
	Classified roads managed by TfNSW		10% increase in vd where this does not result in an increase in hazard category. Otherwise no increase
	Elsewhere *Does not apply to locations where post-development case dv product is < 0.1m²/s.*	To minimise changes in flood hazard in non-sensitive areas that are less likely to be accessed/accessible to persons during flood events (e.g., agricultural land)	For all ARR19 Hazard Classifications: a 20% increase in d.v.
Flood Duration	Habitable floors [1], and sensitive infrastructure	To minimise changes in the duration of flooding affecting 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 • greater than 1 hour in duration, up to 5% 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 • greater than 1 hour in duration, up to 10% increased inundation duration.
	Classified roads managed by TfNSW		No increase in duration of flood inundation to sections of road not already inundated. Otherwise 10% increase in inundation duration.

Parameter	Land-use or setting/scenario	Desired performance outcome	Proposed QDL for I2S
	Highways and sealed roads greater than 80km/hr (operational road area) [3] Sealed roads less than 80km/h and all unsealed public roads (operational road area) [3]	To minimise changes in flood duration that may affect trafficability, access and egress on roads during flood events	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% increased inundation, or as otherwise agreed by the relevant road authority.
	Elsewhere	To minimise changes in the duration of flooding affecting other land, including agricultural land, grazing land, forested land, etc.	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% increase in duration of inundation No duration performance targets apply to newly flooded land no greater than 1000m^2 in area
Flood Flow Distribution & Surface Water Supply	All areas	To minimise impacts from any changes to direction and distribution of flood flows Protect farm dam water supply	Afflux and velocity criteria will be used to identify and assess changes in the direction and distribution of flood flows Avoid of flow diversions where they would impact on the hydrological regime of the farm dams.

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

(2) 10mm has been set to provide a margin for modelling uncertainties/tolerances. The intent of this requirement is that existing flood levels above floor level do not increase.

(3) Including where located within CSSI corridor

5.3.1 Flood hazard

Flood hazard is the depth-velocity product (d.v.) of the flood event and has the potential to cause damage or harm to the community. The main characteristics of interest typically are the flow depth and the flow velocity. The depth-velocity product is used to define hazard vulnerability curves, which can be used as a general classification of flood hazard on a floodplain. ARR19 (refer to section 2.4.1) Hazard Classifications are presented in Figure 5.1.

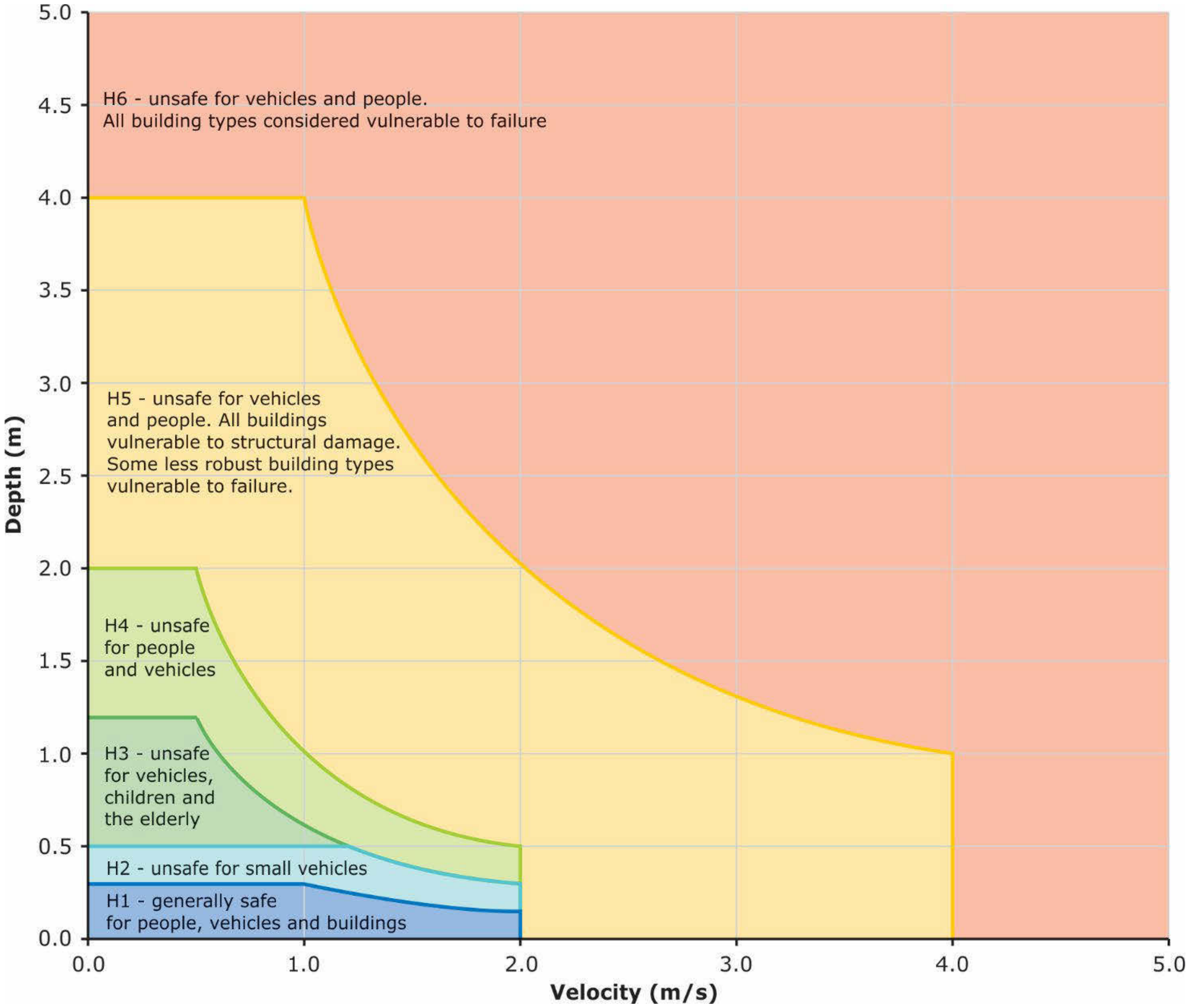


Figure 5.1 ARR2019 Hazard classification curves

5.3.2 Flood flow distribution and surface water supply

The importance of farm dams for agricultural water supply was highlighted in the discussions with landowners. To protect existing farm water supplies general performance criteria relating to avoidance of diversion of sub-catchment flows, whether through overland flow paths or drainage lines, have been adopted. In combination with the other QDLs for agricultural land, the avoidance of flow diversions will ensure minimal impact on the hydrological regime of the farm dams.

Changes in the direction and distribution of flood flows will be considered by assessing changes in flood extent and changes to flood velocities and will utilise the criteria set for afflux and velocity. Changes to flood flow distribution can also be identified through defining the flood conveyance (or floodway areas) of the floodplain. Flood conveyance area are those areas of the floodplain where a significant flow of water occurs during floods. They are often aligned with naturally defined channels. Flow conveyance paths are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels (AIDR, 2017).

Flood flow diversions will be identified or changes to existing flow diversions will be assessed as part of the flood flow distribution assessment.

6 Existing conditions

6.1 Catchment and watercourses

The proposal is located within the Murrumbidgee and Lachlan catchments, which are sub-catchments of the Murray-Darling Basin. The catchment divide lies closer to Stockinbingal and therefore most of the proposal site is within the Murrumbidgee catchment.

Watercourses within the study area are ephemeral (i.e. they are watercourses that only flow following periods of intense or prolonged rainfall). For at least 10km downstream of the proposal site the larger (catchment areas greater than 200 square kilometres) receiving watercourses of Bland Creek and Billabong Creek do not have permanent water flow. Figure 6.1 shows the catchment areas and the key watercourse within the proposal site.

The Straher stream order for watercourses crossed by the proposal is also illustrated in Figure 6.1. The Strahler stream order classification is a "top down" system in which rivers of the first order are the outermost tributaries. If two streams of the same order merge, the resulting stream is given a number that is one higher. If two rivers with different stream orders merge, the resulting stream is given the higher of the two numbers.

First to third order streams are called headwater streams. Streams classified as fourth through sixth are medium streams are streams that are seventh order or larger are a river.

The proposal site is a significant distance (>25km) from the Lachlan River and Murrumbidgee River and is not affected by mainstream/river flooding or regional scale floodplain processes.

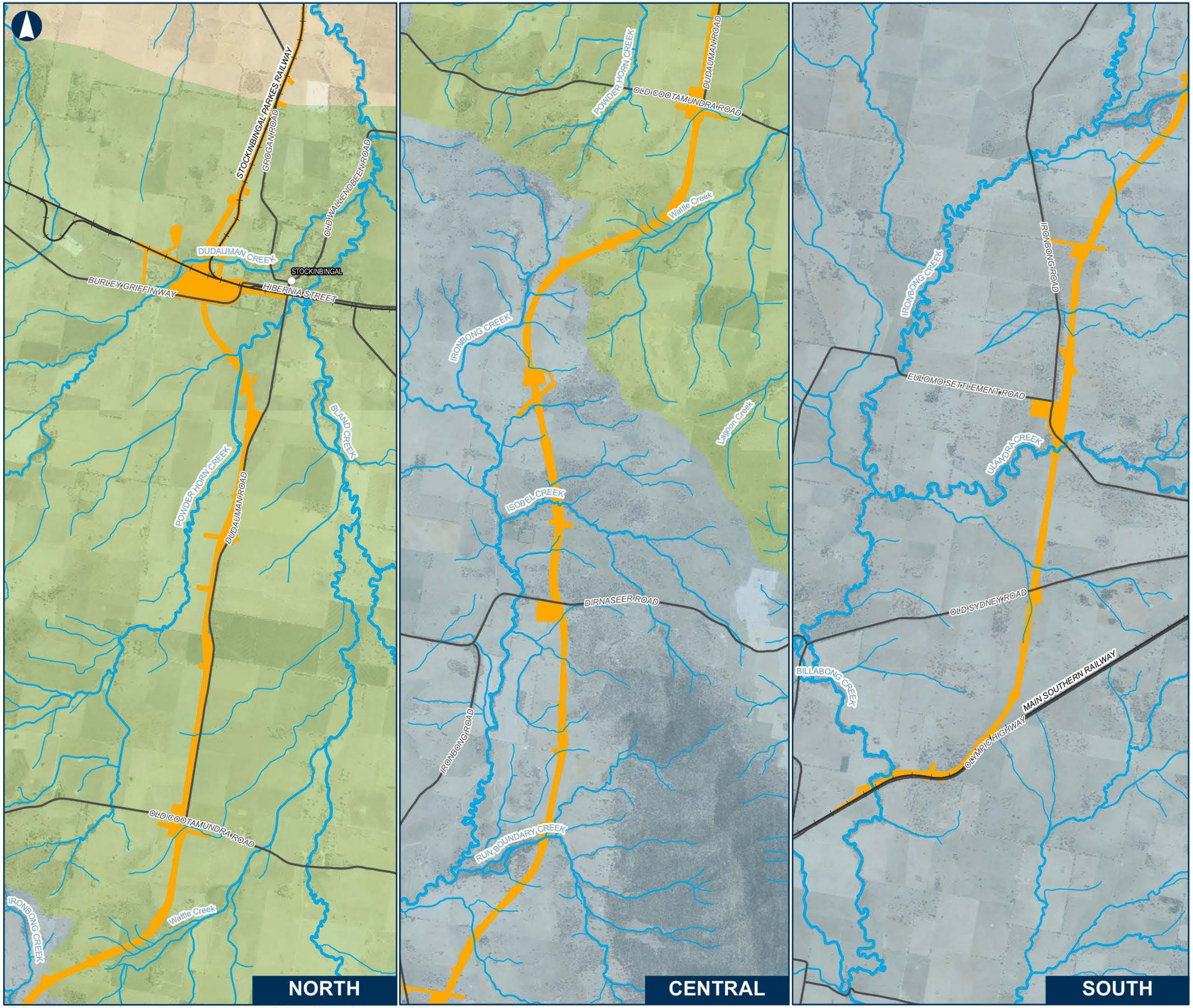
The catchments and watercourses crossed by the proposal are discussed further in the following sections.

6.1.1 Murrumbidgee catchment

The proposal site is located within the upper portion of the Murrumbidgee catchment. About 25km of the proposal site north of Illabo lies within the Murrumbidgee catchment. Named watercourses within the Murrumbidgee catchment that intersect the proposal include:

- Billabong Creek
- Ulandra Creek
- Run Boundary Creek
- Isobel Creek.

The flood behaviour in this area is dominated by three watercourses, Billabong, Ironbong and Ulandra Creeks and the remaining watercourses are tributaries of these three or tend to convey localised overland flow. Ulandra Creek is a tributary of Ironbong Creek which then becomes Billabong Creek at the Main South Line and Olympic Highway crossing. Billabong Creek then flows south for a further 35km before converging with the Murrumbidgee River upstream of Wagga Wagga.



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ILLABO TO STOCKINBINGAL

Figure 6.1 Catchments and waterways

Township

State Roads

Existing Rail

Proposal site

Strahler Stream Order

0

1

2

3

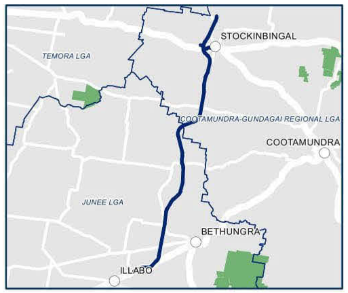
4 - 6

Catchment Management Authority - Sub-catchments

Lachlan - Lower Slopes

Lachlan - Upper Slopes

Murrumbidgee - Upper Slopes



0 0.5 1 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 7/6/2021
Author: IRDJV
Data Sources: IRDJV, ARTC, LPI

Paper: A3
Scale: 1:60,000

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6.1.2 Lachlan catchment

The remaining 16km of the proposal site is in the Lachlan Catchment and lies at the very upper reaches of the Lachlan River valley. Watercourses in the Lachlan catchment that intersect the proposal include:

- Powder Horn Creek
- Dudauman Creek.

The proposal also intersects unnamed tributaries of Wattle Creek, which is in the southern part of the catchment and forms the headwaters of Bland Creek. Powder Horn and Dudauman Creeks are tributaries of Bland Creek. Bland Creek forms to the south east of Stockinbingal, runs north and discharges into Lake Cowal. Lake Cowal overflows into the Lachlan River floodplain during high flows.

The flood behaviour in this area is dominated by Powder Horn Creek across the farming areas to the south of Stockinbingal. Dudauman Creek flows through the developed areas of Stockinbingal and is controlled by flood levees running west to east before joining Bland Creek to the east of town. All other areas of the proposal are subject to local overland flows.

6.2 Climate and rainfall

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. (BOM, 2018) The Junee Treatment Works (station number 73019) at the south of the proposal site measures air temperature as well as rainfall data and has recorded mean daily maximum temperatures 32.4 degrees Celsius (°C) in January to 13.2°C in July.

Rainfall data from the Junee Treatment Works (station number 73019) shows an average annual rainfall of 525.4mm. At the north of the proposal site there is a gauge which only records rainfall, the Stockinbingal (Sunnydale) gauge (station number 73150). Data from this gauge shows an average annual rainfall of 484.6mm. Rainfall is generally consistent across the year, with slightly higher rainfall from July to October.

6.2.1 Design rainfall data

Design rainfall data are based on the statistical analysis of historical rainfall data to establish the design rainfall depth (mm) or design intensity (mm/hr) corresponding to selected storm durations and frequencies. The Bureau of Meteorology maintains a Rainfall Intensity–Frequency–Duration (IFD) Data System, based on the most up to date estimates for design rainfall information from which this data can be obtained for any location across Australia (2016 Intensity–Frequency–Duration (IFD) design rainfalls, BOM 2016).

Design rainfall data across both the Murrumbidgee and the Lachlan catchments within the vicinity of the proposal site and surrounding catchments were reviewed and found to be almost identical across the full range of storms. This indicates that the rainfall climatic influences (such as elevation, landforms and wider climate processes) are common across the proposal site. Design rainfall depths for the proposal site are presented in Table 6.1 (BOM, 2016).

Table 6.1 Design rainfall depths (mm)

Duration (hours)	Design rainfall depth (mm)				
	0.2EY	10% AEP	5% AEP	2% AEP	1% AEP
3	37.3	43.8	50.8	60.4	68
6	46.3	54.3	62.8	74.4	83.5
9	52.6	61.5	71.1	84.1	94.3
12	57.5	67.2	77.5	91.7	103
18	64.9	75.7	87.3	103	115
24	70.4	82	94.6	112	125

6.2.2 Evaporation

Actual evaporation data was obtained from the Wagga Wagga (72150) station. Daily evaporation data is greatest in the summer months of December, January and February with evaporation of 9.4, 10.1 and 9.0mm/day respectively. The months of May, June and July show the lowest evaporation rates with 1.3mm/day observed for July and presented in Figure 6.2 below.

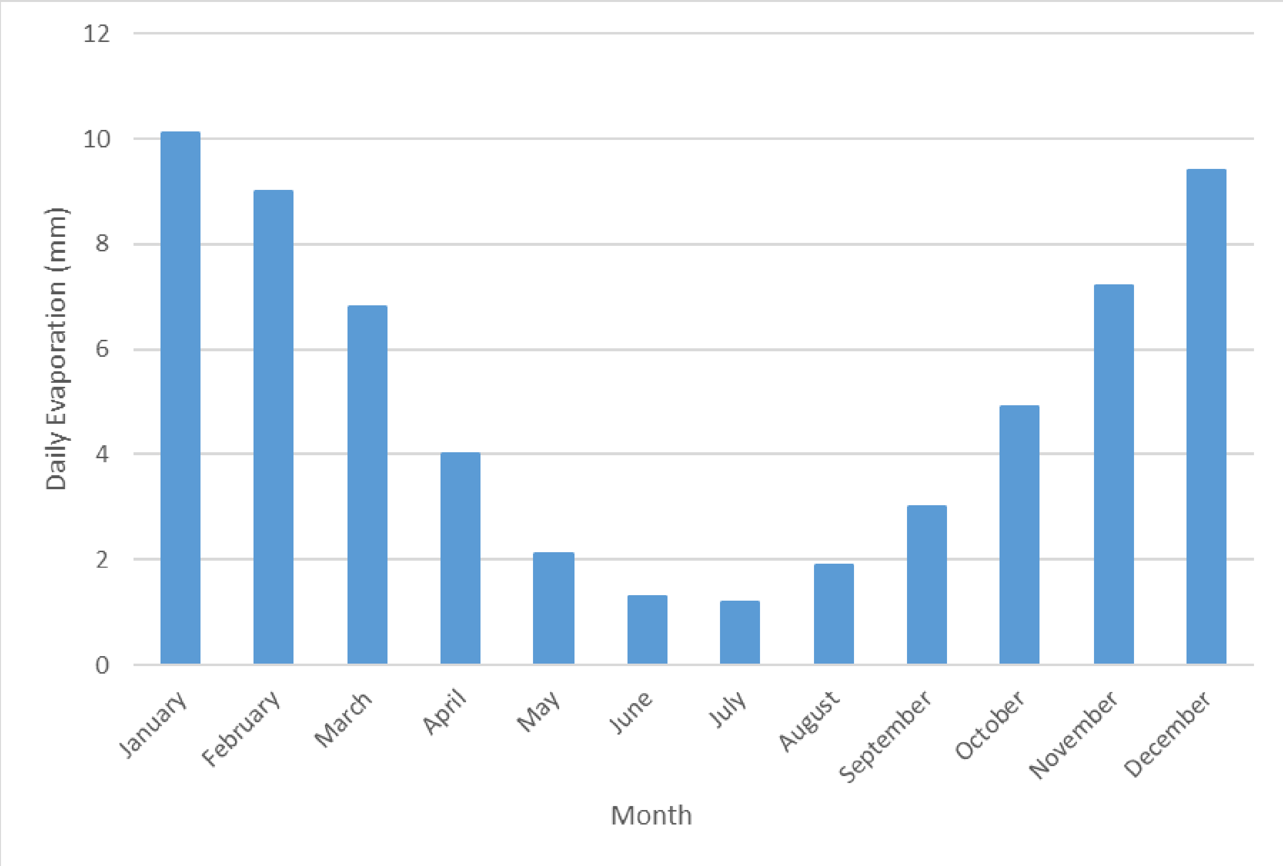


Figure 6.2 Daily average evaporation at Wagga Wagga (mm)

6.2.3 Climate change

There are several sources of information to provide projected climate change estimates for the proposal. They focus on changes in annual and seasonal rainfall totals and are summarised below.

NSW and ACT Regional Climate Modelling (NARCliM) suggests that mean annual precipitation in the Southern Tablelands region (in which the proposal is located) may increase by up to 1.4% by 2070 with the results varying across the seasons from 11% increase in autumn and 11% decrease in spring (DPIE, 2021).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Climate Futures tool (CSIRO, 2021) indicates that for the annual rainfall for the high emission scenario of Representative Concentration Pathway (RCP) 8.5 and the projection year of 2070 the rainfall is likely to experience very little change. The 2090 projection year however indicated significant drying and up to 15% less annual rainfall totals. The NARCliM modelling projection and CSIRO projections for 2070 are similar with likely no change to annual rainfall totals.

ARR 2019 Data Hub makes use of the CSIRO information to estimate a projected change in rainfall intensity. For the proposal horizon 2090 and the RCP 8.5, ARR2019 recommends an increase in rainfall intensity of 20% be considered in climate change assessments.

6.3 Topography

The proposal site is located at the catchment divide between the Lachlan and the Murrumbidgee catchments.

Within the Murrumbidgee Catchment, the southern section of the proposal site generally slopes toward the lower reaches of Ironbong Creek and Billabong Creek. Billabong Creek is relatively flat at the southern end of the proposal, but the creek channel is well defined with both low flow and high flow channels before a sudden change (reduction) in slope as it flows into the floodplain and agricultural land.

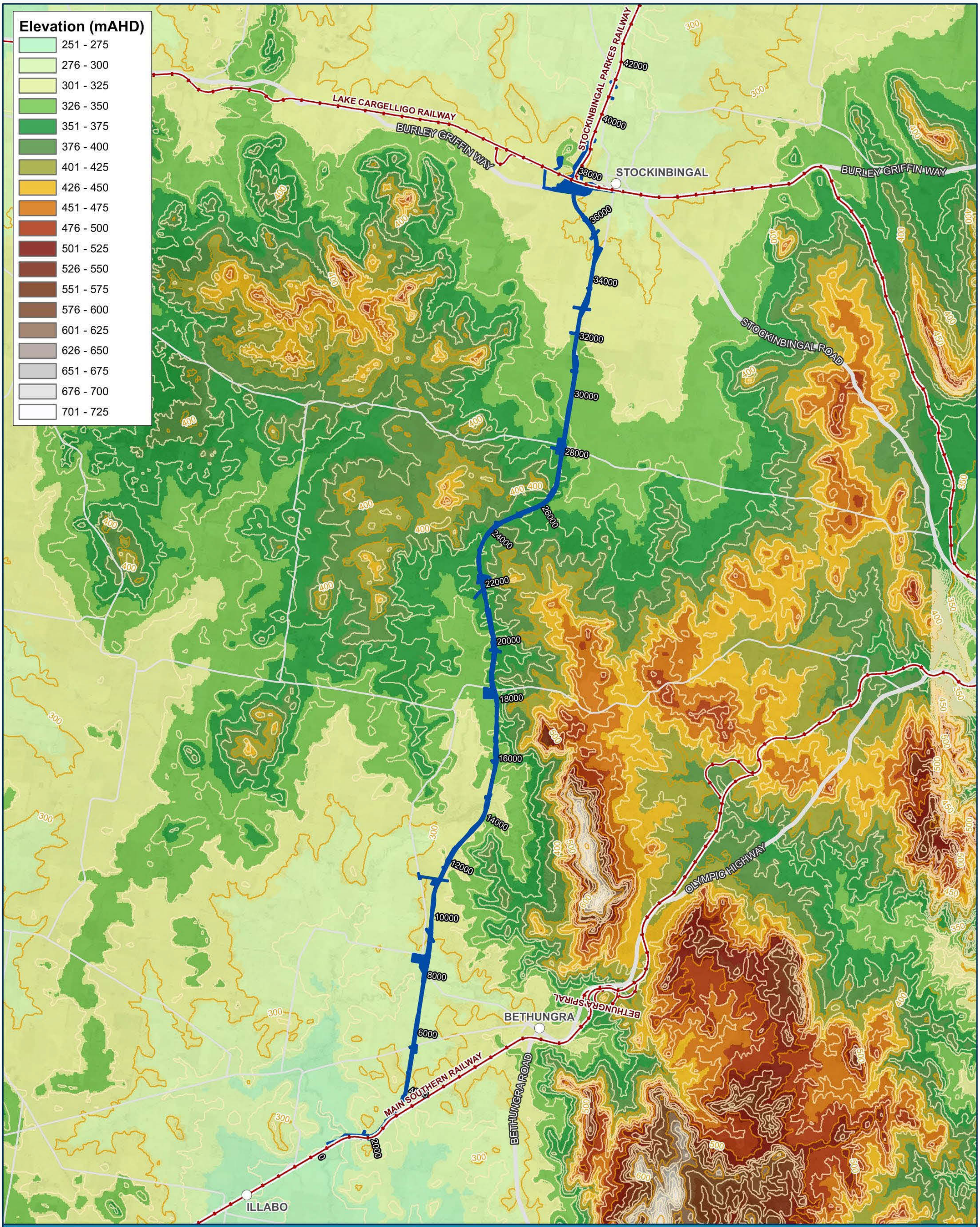
A short section of the proposal to the south of Ulandra Creek and Old Sydney Road slopes towards the south east and into a minor tributary of Billabong Creek which drains under the proposal site and then the Olympic Highway. This area is typical of upper catchment areas with no defined channels, areas of scattered vegetation and farm dams intercepting overland flows.

The Ulandra Creek floodplain is located at the intersection of Ironbong Road and the proposal with its catchment to the east and south east of the proposal. Bethungra Dam is located in the upper reaches of the Ulandra Creek catchment. The dam covers an area of 14.65 hectares (ha) and holds 600 megalitres (ML) of water but is only used for recreational purposes. Its upper catchment area is steep but flattens out before intersecting the proposal site. Ulandra Creek is a well-defined channel, but its floodplain expands in the vicinity of Ironbong Road.

The central part of the proposal crosses the catchment divide between Ironbong Road and Old Cootamundra Road and passes through moderately undulating terrain west of Lighthouse Hill, the Twins Range and east of the Bethungra Range. The terrain is cut by numerous topographic depressions and watercourses associated with Ironbong Creek and its associated tributaries. Slopes across this section range from 0.5% to over 8% in the upper reaches of Run Boundary and Ironbong Creeks.

Within the Lachlan Catchment from south of Old Cootamundra Road the sub-catchments are steep with no permanent watercourses and topographic depressions (overland flow paths) are formed from rainfall runoff and contain numerous farm dams. From Old Cootamundra Road heading north through to Stockinbingal, the sub-catchments of Powder Horn Creek and Dudauman Creek are flat and tend to meander across flat agricultural land.

Figure 6.3 shows the topography of the proposal site and surrounds.



ILLABO TO STOCKINBINGAL 6.3 Topography of the proposal site and surrounds

0 2 4 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 7/6/2021 Paper: A3
Author: IRDJV Scale: 1:120,000
Data Sources: IRDJV, ARTC, LPI

Proposal site
Existing Rail
Sub-arterial road
Arterial road
Major Contour (50 metres Australian Height Datum)
Minor Contour (10 metres Australian Height Datum)

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6.3.1 Contour and levee banks

The natural topography of the study area has been modified by landowners in isolated areas to capture surface runoff. Consultation with landowners has helped identify contour banks across the catchments that capture surface runoff and direct flows to farm dams for storage or divert surface flows as part of farm operations. The available LiDAR used to generate the contours presented in Figure 6.3 was not able to identify these contour banks as they tend to be of minimal height above the surrounding ground and are therefore very minor features in the topography. The contour banks have been manually identified to improve the understanding of existing topographic conditions.

Levee banks have been constructed around the Dudauman Creek channel from upstream of Burley Griffin Way and they follow the creek through the urban area of Stockinbingal. These levees modify the topography of the creek floodplain by containing flood flows to the creek channel. The levels of these levees have been informed through use of a 2019 survey completed by NSW Public Works (NSW DPE, 2019).

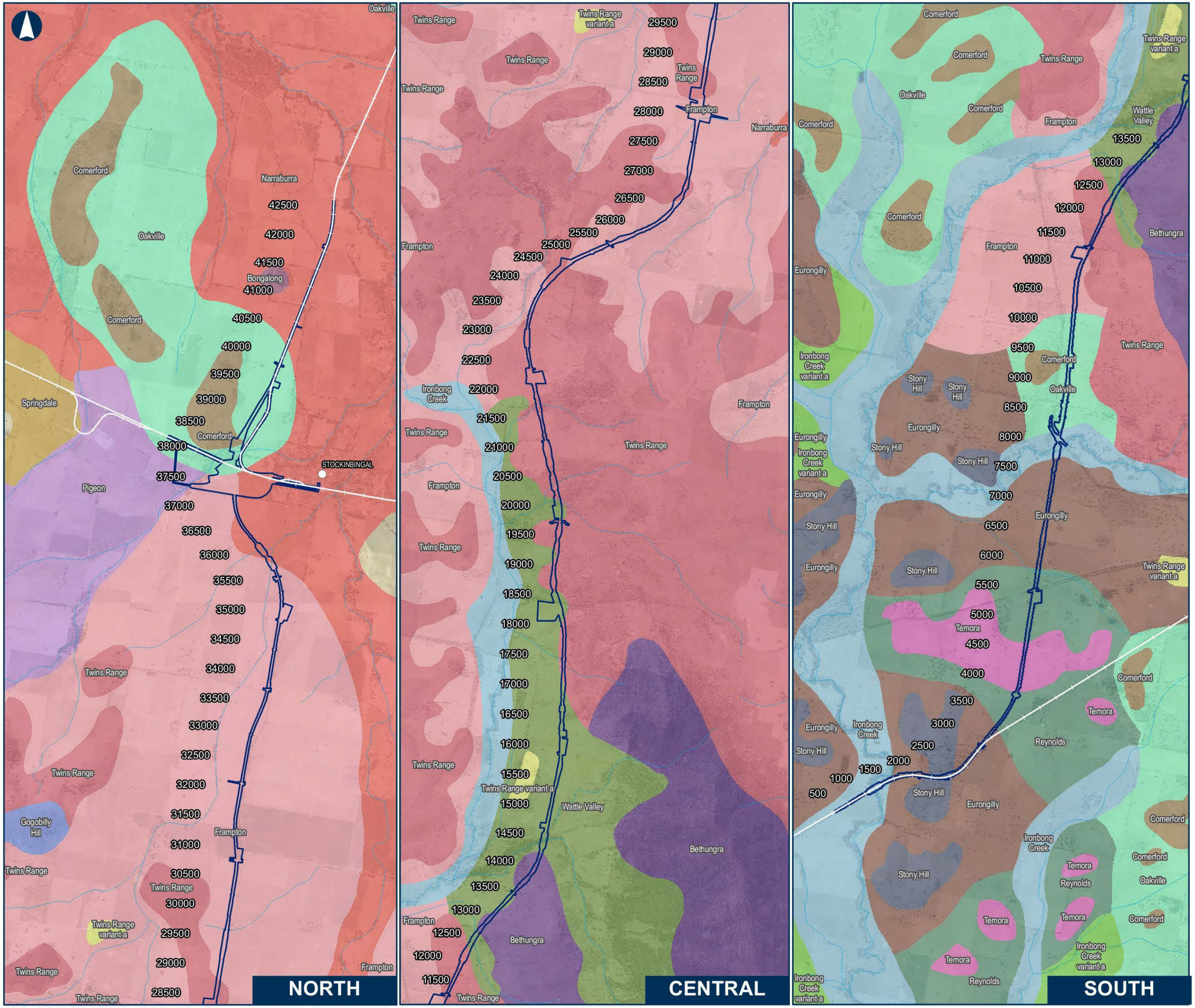
6.4 Soils and geology

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 pH of the top-soil is typically in the range of 5.5 to 6.5.

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 are 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.

Figure 6.4 shows the soils landscapes within the proposal site.

The soils along the proposal site are typically non-dispersive in nature with the alluvium and residual soils predominantly found to be silty clays or clays. Non-dispersive soils tend to have low erosion potential and rill and sheet erosion is generally minimal, as was observed during the geotechnical site investigations. However, site investigations did observe gully and bank erosion in several overland flow paths and in Isobel Creek.



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6.4 Soil landscapes

Proposal site
Existing Rail
Watercourse

Soil Landscape

- Bethungra
- Bongalong
- Comerford
- Eurongilly
- Frampton
- Gogobilly Hill
- Ironbong Creek
- Ironbong Creek variant a
- Narraburra
- Oakville
- Pigeon
- Reynolds
- Springdale
- Stony Hill
- Temora
- Twins Range
- Twins Range variant a
- Wattle Valley

0 1.5 3 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 7/6/2021
Paper: A3
Author: IRDJV
Scale: 1:60,000
Data Sources: IRDJV, ARTC, LPI

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6.4.1 Acid sulfate soils

A review of the Australian Soil Resource Information System – Acid Sulfate Risk map (CSIRO, 2013) identified that the proposal is located within an area described as low probability of acid sulfate soil.

6.5 Land uses

The available aerial photographs and published land use maps have been used to inform the understanding land uses in and around the proposal site. The proposal traverses undeveloped rural areas used primarily for grazing and agriculture. The major industries in the area include livestock, wool and wheat. Most of the land within the proposal site has been cleared and disturbed for agricultural activities, however some patches of remnant vegetation remain. Figure 6.5 shows the published land use mapping for the proposal site.

The nearest urban areas are Illabo in the south and Stockinbingal in the north. The urban areas of Illabo lie well away from the proposal site. Stockinbingal lies at the confluence of Dudauman, Powder Horn and Bland Creeks and has urban development between these creek channels. The urban areas of Stockinbingal lie immediately downstream of the proposal crossings of Dudauman and Powder Horn Creeks.

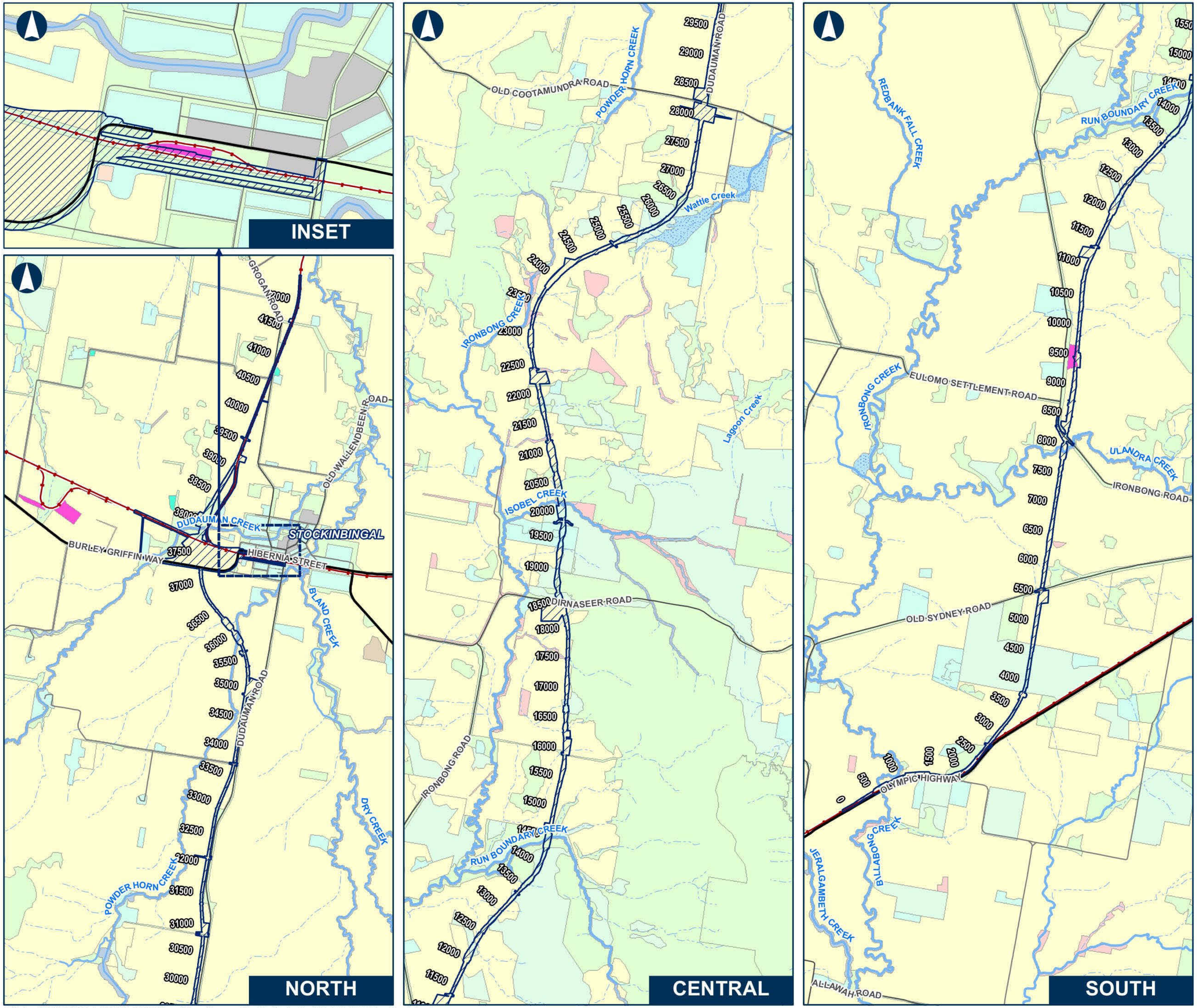
Within the southern section, from Billabong Creek through to Old Sydney Road, land uses are dominated by grazing for sheep but landowners are known to use some paddocks for crops in alternate years. There are a significant number of farm dams across both sides of the proposal site and the proposal will continue to convey overland flow beneath the rail embankment through culverts and bridges so there will be no change to catchment areas.

From Old Sydney Road to Ulandra Creek and Ironbong Road the land uses include cropping and grazing. Overland flows are from east to west with most of the flood flows carried by Ulandra Creek. Water supply for the crops does not involve permanent irrigation infrastructure but is reliant on rainfall and supply from nearby above ground storages.

In the central section across the catchment divide from Ironbong Road to Old Cootamundra Road the topography of the land steepens, and grazing is the dominant land use. Overland flows are opportunistically captured by many farm dams which are the dominant water supply for the stock through the area. There are some areas of cropping or pasture improvement that would be dependent on rainfall for water supply.

For the northern section from Old Cootamundra Road through to Burley Griffin Way the land flattens out and cropping and grazing dominate the land use, but surface water dams continue to be the main source of water supply.

To the immediate west of the urban areas of Stockinbingal, the land use includes grazing land, with farm dams located between Burley Griffin Way and the Lake Cargelligo railway line. The land use surrounding the proposal site returns to grazing land but is restricted by the Stockinbingal to Parkes railway and the Lake Cargelligo railway.



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6.5 Land uses

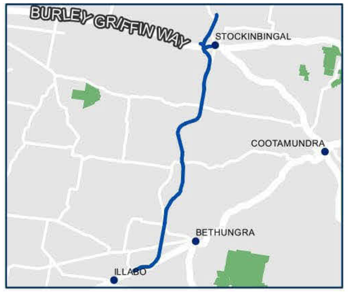
- Proposal site
- Existing Rail

Existing features

- Arterial road
- Sub-arterial road
- Local road
- Major Watercourse
- Minor Watercourse

Land Use Mapping (ABARES 2017)

- 1.1.0 Nature conservation
- 1.2.0 Managed resource protection
- 1.3.0 Other minimal use
- 2.1.0 Grazing native vegetation
- 3.2.0 Grazing modified pastures
- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 4.4.0 Irrigated perennial horticulture
- 5.1.0 Intensive horticulture
- 5.2.0 Intensive animal production
- 5.3.0 Manufacturing and industrial
- 5.4.0 Residential and farm infrastructure
- 5.5.0 Services
- 5.7.0 Transport and communication
- 5.8.0 Mining
- 5.9.0 Waste treatment and disposal
- 6.1.0 Lake
- 6.2.0 Reservoir/dam
- 6.3.0 River
- 6.4.0 Channel/aqueduct
- 6.5.0 Marsh/wetland



0 0.5 1 1.5 2 2.5 3 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 7/6/2021
Author: IRDJV
Data Sources: ARTC, NSWSS, ESRI
Paper: A3
Scale: 1:12,500

6.6 Sensitive receptors

Sensitive receptors include both human related and environment related receptors. The following section provides a description of the receptors that may be impacted by changes to the flooding regimes.

6.6.1 Residential dwellings and other structures

All dwellings and other farm structures have been identified. Detailed survey of one dwelling and associated farm structures within the property has been provided. But no detailed site survey has been collected for any other structures, and as such the floor levels are assumed to be at ground level, which provides a consistent and conservative basis for assessment of potential flood impacts on the buildings. A total of 195 residential buildings have been identified. Figure 6.6 shows the residential buildings located near the proposal site.

An additional 81 structures have been identified through review of the aerial photography and these are largely farm related structures such as sheds.

6.6.2 Farm dams

A total of 137 farm dams have been identified within the catchments both upstream and downstream of the proposal, of which 14 are located in the proposal site. These farm dams are predominantly located on overland flow paths to opportunistically capture surface flows. The condition and capacity of these dams is not known, however, the capacity has been estimated in the hydraulic models through inclusion of LiDAR data which includes the dams as topographic features subject to LiDAR accuracy limitations.

6.6.3 Stormwater infrastructure

Stormwater infrastructure relevant to the proposal site conveys flows around and across existing infrastructure, discharging to overland flow paths and surrounding watercourses.

Local stormwater infrastructure has been identified on Burley Griffin Way, Dudauman Road, Ironbong Road, Old Sydney Road and Olympic Highway. These structures are culverts that convey stormwater runoff under the roads and 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.

6.6.4 Road and rail infrastructure

There are a number of existing roads and rail lines that are located near the proposal. Roads include Olympic Highway, Old Sydney Road, Ironbong Road, Dirnaseer Road, Old Cootamundra Road, Dudauman Road and Burley Griffin Way. Rail infrastructure includes the Main South Line, Lake Cargelligo Line and Stockinbingal to Parks Rail line.

6.6.5 Wetlands

Four wetlands of International Importance (Ramsar wetlands) in the region were identified through a desktop investigation. These listed wetlands are located more than 400km north of Stockinbingal and are not expected to be impacted by the proposal.

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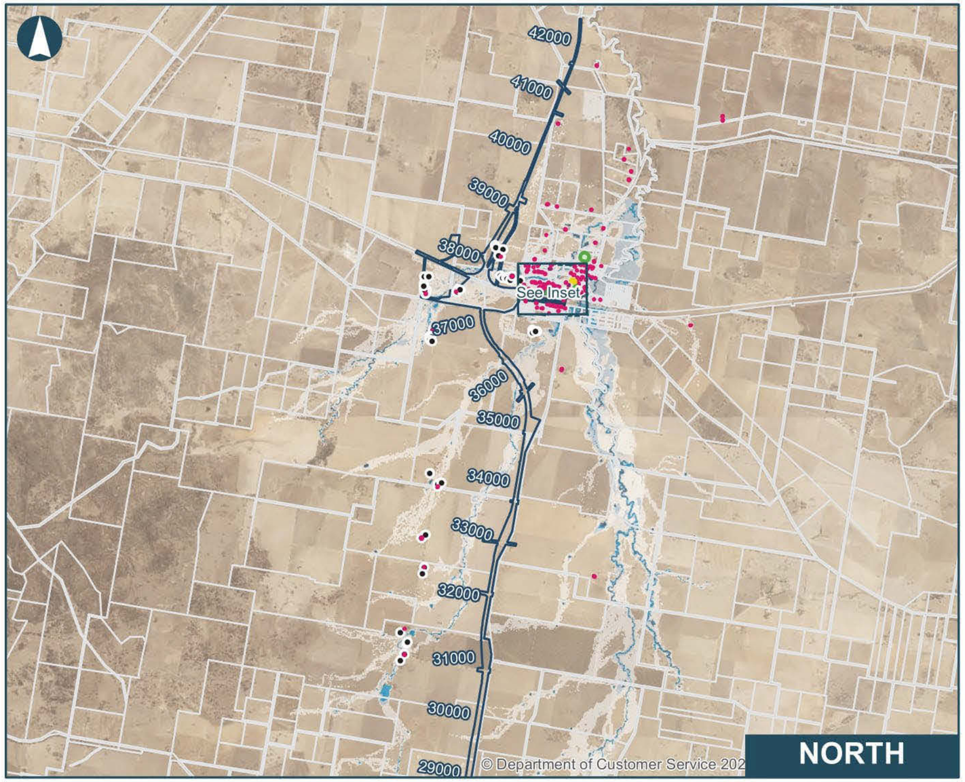
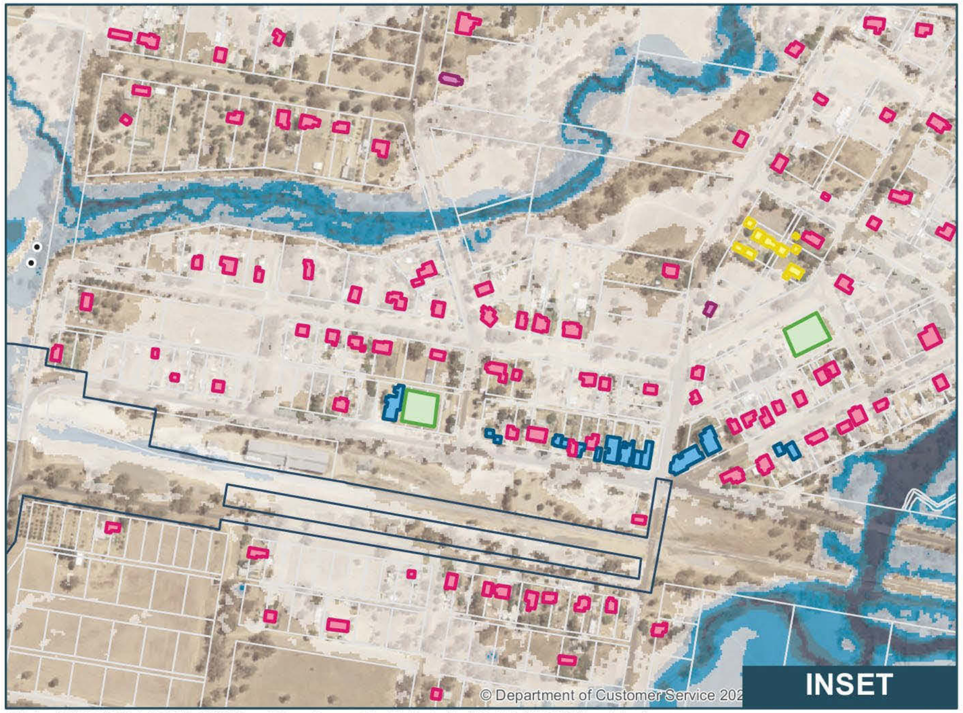
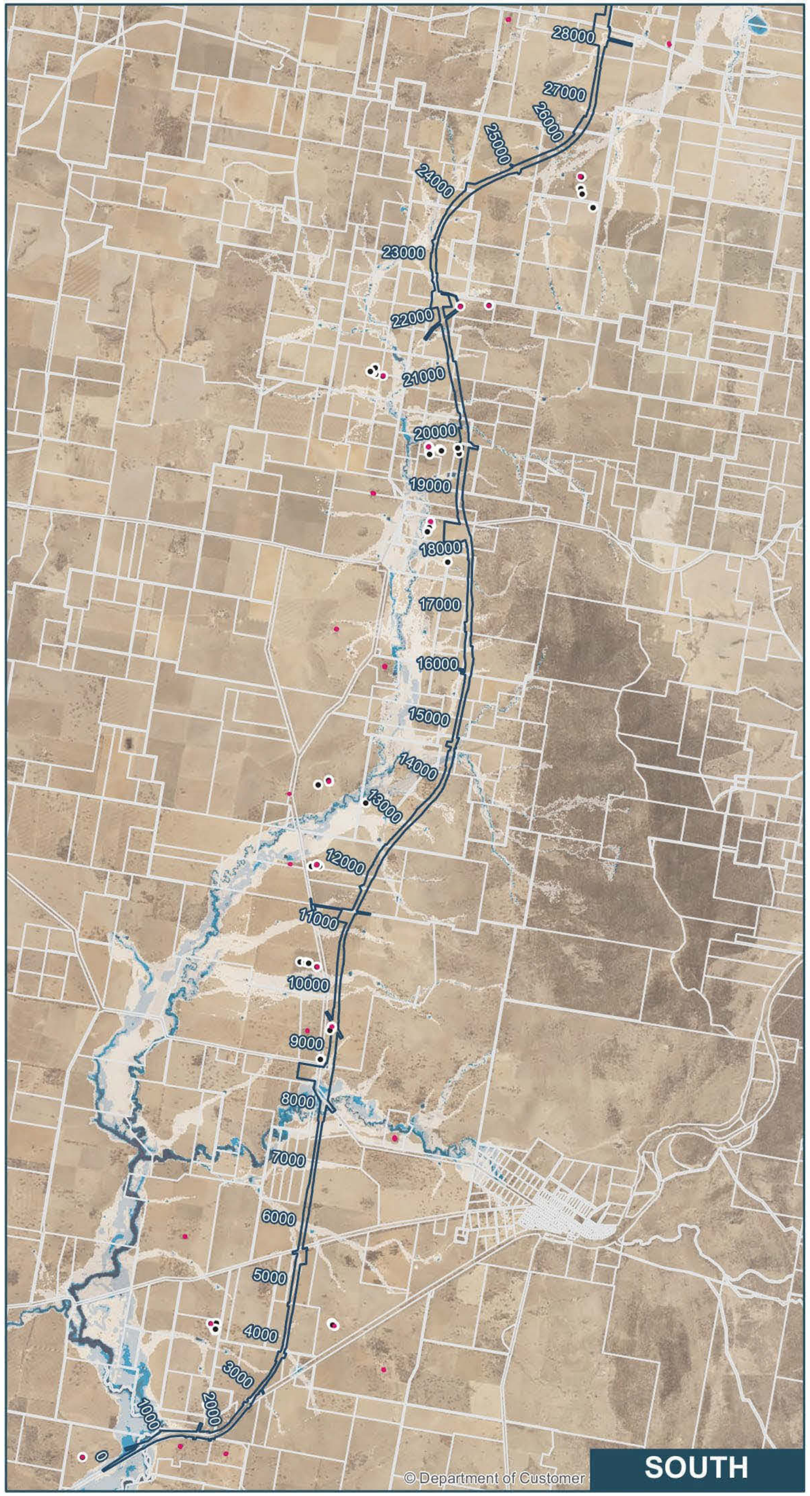
6.6 Buildings







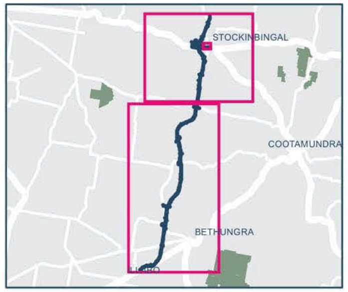
Buildings/farm infrastructure
Proposal site
Cadastre

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



0 1 2 3 4 5 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 8/18/2022
Author: IRDJV
Data Sources: IRDJV, ARTC, LPI
Paper: A3
Scale: 1:90,000

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6.6.6 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms that depend on groundwater for survival. A GDE may be either entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998).

GDEs include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems (BOM, 2017).

Nine ecosystems have been identified near the proposal site that rely on the subsurface presence of groundwater. The location of these GDEs relative to the proposal are further discussed in the Ground Water Impact assessment and presented in Figure 4.9 of that report. GDE's relevant to the proposal include:

- four high potential aquatic (river) GDEs were identified intersecting the rail alignment, Billabong Creek, Dudauman Creek, Ironbong Creek and Ulandra Creek
- four high potential terrestrial (vegetation) GDEs were identified, Blakelys Red Gum, Yellow Box, Western Grey Box and White Cypress Pine.

Refer to Technical Paper 6 – Groundwater for further discussion.

6.7 Water availability

6.7.1 Water supply

For the rural land surrounding the proposal, surface water supply predominantly comes from a reticulated water network operated by Goldenfields Water that services many of the farms with both stock and domestic water supply as well as from rainfall collected via rainwater tanks and farm dams. In the vicinity of the proposal the Goldenfields Water reticulated network extends along Burley Griffin Way, Old Cootamundra Road, Dirnaseer Road, Ironbong Road, Eulomo Settlement Road and Old Sydney Road.

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. The LIDAR data allows the farm dams to be represented in the flood models subject to accuracy limitations associated with the data.

6.7.2 Licensed water extraction

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 in the vicinity of the proposal. WALs can be obtained (subject to restrictions outlined within the relevant Water Sharing Plan) through purchasing or trading of an existing WAL. The information available on the NSW Water Register does not identify the location of the Water Access Licence and does not provide any information regarding licences issued under the *Water Act 1912*.

The WALs indicate that the surface water sources in the vicinity of the proposal are potentially utilised for stock, domestic and town water supply. There are also a number of water access licences for extraction of water from unregulated rivers.

Since none of the intersected water courses have permanent water, it is unlikely that there are any WALs for surface water in the vicinity of the proposal site.

6.8 Existing flooding behaviour

An understanding of the existing flood behaviour for the proposal site has been developed based on a review of available historic studies and data, anecdotal information, landowner discussions and flood modelling. This understanding is presented below first for the Murrumbidgee catchment and then the Lachlan catchment.

Due to the predominantly greenfield nature of the study area and predominant agricultural land uses there are no existing flood studies or surveyed or marked historic flood data available. It is noted that the community has been consulted on flood behaviour and all information available for this assessment has been provided voluntarily and included in the understanding of flood behaviour without specific reference to landowners or properties. Refer to section 6.8.2 which discusses the consultation process and the information provided to inform this assessment.

6.8.1 Flood studies and flood information

6.8.1.1 Stockinbingal Floodplain Management Study and Plan

The Stockinbingal Floodplain Management Study and Plan (SMEC, 2002) 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 plan observed that gully erosion is an issue for Powder Horn Creek.

The proposed flood management measures within the plan were located within the urban areas of the village of Stockinbingal. The plan indicates that there is a series of artificial levees along Dudauman Creek between Burley Griffin Way and O'Brien Street on the northern side of Stockinbingal. The plan also describes flood mitigation works along Dudauman Creek between West Street and O'Brien Street and recommends maintaining the levee between Burley Griffin Way and O'Brien Street. Works include levees, stabilising creek banks, culverts under Geraldra Street and channel enlargement. These works were designed to prevent the 1% AEP event in Dudauman Creek flowing through the village. The levees are estimated to have a current immunity of between 5% and 10% AEP.

The Stockinbingal Floodplain Risk Management Plan (SMEC 2002) 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.

6.8.1.2 Cootamundra-Gundagai Regional Council flood information

Cootamundra-Gundagai Regional Council have provided flood level data for the village of Stockinbingal. This information is limited to 1% AEP flood lines. The source and background modelling used to produce these flood lines is not known and they are likely to be approximated from observations/ anecdotal information from historic flood events.

The Cootamundra-Gundagai Regional Council 1% AEP flood lines have been compared against the flood extent predicted by the flood model developed for this assessment (see section 6.8.5 below for further details of flood model results). As seen in Figure 6.7, there is a reasonable agreement between the modelled flood extent and the Council flood lines.

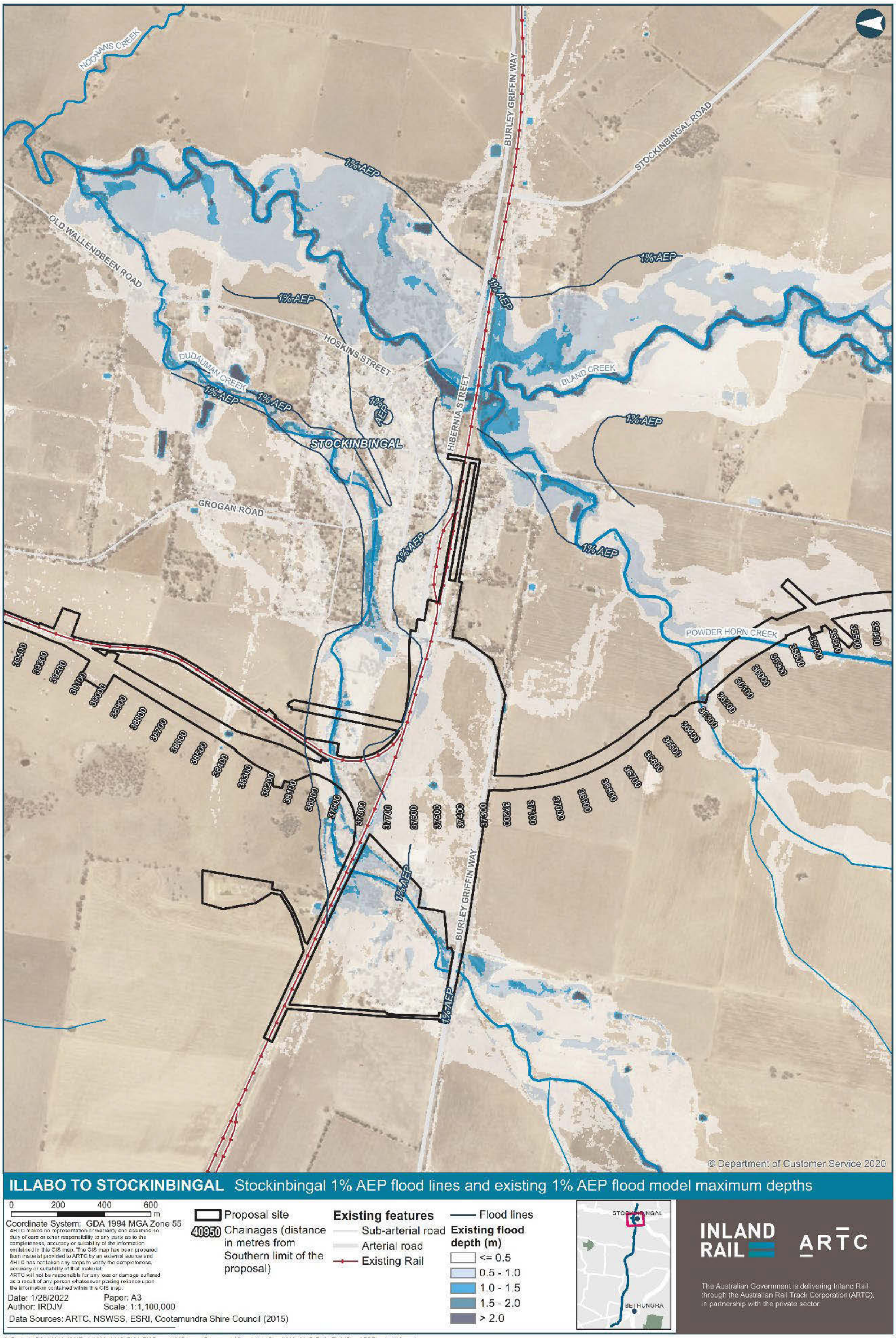

Figure 6.7 Comparison of Stockinbingal flood data against the existing study

6.8.1.3 Junee Shire Council flood information

At the southern end of the proposal, no historic flood information was available for Billabong Creek.

To the immediate west of the proposal site is the town of Illabo for which Junee Shire Council have flood information available for Jeralgambeth Creek. Jeralgambeth Creek is the main watercourse in the vicinity of Illabo and is a tributary of Billabong Creek. It joins Billabong Creek downstream of the proposal, however it does not interact with the proposal. The Jeralgambeth Creek at Illabo Floodplain Risk Management Study and Plan, (Lyall and Associates, March 2012) 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).

No historic flood information was available within the Junee Shire Council area for the proposal site.

6.8.1.4 Wattle Creek at Dudauman Gauge 412134

Wattle Creek is a minor tributary of Bland Creek of which Dudauman and Powder Horn Creeks are also tributaries. WaterNSW operate a gauge on Wattle Creek that has been reviewed to provide more information on historic flood behaviour. Three minor overland flow paths intersected by the proposal drain into Wattle Creek with the gauge approximately 600m from the proposal site.

The Wattle Creek at Dudauman gauge (number 412134) was installed as part of the flood warning network for Cootamundra Shire Council (WaterNSW Site Summary Report, 9 May 2018). The site summary report indicates that 75 manual records of peak flood height and velocity have been taken between 19 May 1988 and 12 January 2021 (WaterNSW Site Summary Report, 12/02/2021). These manual recordings have been used to develop a rating table for the gauge.

All the available recorded data from the Wattle Creek at Dudauman gauge was reviewed and sorted to identify the highest water levels recorded and the highest six recorded water levels are presented in Table 6.2 below. The location of the gauge is shown in Figure 6.8.

An extensive data review process has been completed using data from the Wattle Creek gauge looking to make use of the gauge data for calibration of the flood models (further details in Appendix A). Unfortunately, this analysis concluded that the Wattle Creek stage discharge curve is underestimating flows for larger flood events and ultimately could not be used in model calibration.

Table 6.2 Wattle Creek at Dudauman 412134 maximum recorded rainfall, water level and discharge

Date	Rainfall (mm) (daily total)	Level (m)	Discharge (m^3/s)
9 December 2010	46.5	1.21	5.5
3 March 2012	44.5	1.135	4.3
21 September 2016*	46	1.043	2.9
4 March 2012#	18	1.021	2.6
1 October 2016*	4.5	0.994	2.3
13 May 1995	34.13	0.983	2.2

The rainfall on 3 March 2012 would have created a wet catchment which would have contributed to the high flood level on 4 March 2012. This event is therefore not likely to be independent of the 3 March 2012 event.

* September 2016 was wettest month on record and the wet catchment contributed to a high flow in October despite low rainfall in that month.

ILLABO TO STOCKINBINGAL 6.8 Location of Wattle Creek gauge

0 100 200 300 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 8/26/2021 Paper: A3
Author: IRDJV Scale: 1:10,000
Data Sources: ARTC, NSWSS, ESRI

Proposal site

40950 Chainages (distance in metres from Southern limit of the proposal)

Existing features

Sub-arterial road

Minor Watercourse

Gauge: 412134 Wattle Creek at Dudauman

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6.8.2 Consultation

Consultation with the community and stakeholders was undertaken for the proposal through a number of meetings. The intent was to collect information on historical flood behaviour to inform the understanding and model representation of existing flood behaviour and to understand perceptions of the community and stakeholders on potential impacts of the proposal on flood and surface water behaviour. The meetings and feedback from this consultation, is summarised below and has been considered in the flood modelling and design undertaken for the proposal.

6.8.2.1 Local councils

Cootamundra-Gundagai Regional Council meetings occurred in October 2020 and February 2021. The October 2020 meeting, to Council staff, including the Local Emergency management officer, presented information about the development of the flood models for the proposal and a description of existing flood behaviour. The meeting included a request for information relating to the flood event of 2016 and any additional survey of culverts and drainage for the town of Stockinbingal.

Key information gathered from the meeting included:

- people complain about poor drainage through Stockinbingal
- poor soil in Stockinbingal which results in stormwater draining quickly
- Dudauman Creek flooding has resulted in water over road south of Burley Griffin Way and at the back of showground
- Powder Horn Creek – Troy Street residents identified in previous flood study to be inundated in the 1 in 100 years but Council have not identified this area as at risk of flooding
- Bland Creek – no known flood risk, and was not inundated in 2016, water seen under causeway but not over road, SES was prepared for this event to flood houses but this did not occur
- culverts under the Stockinbingal to Parkes line appear to be regularly cleared of sediment that builds up
- Inland Rail to be invited to the Local Emergency Management meetings.

The February 2021 meeting included a presentation to the Mayor, Deputy Mayor, Councillors and Council staff on the proposed design features relevant to hydrology and flooding and a brief description of the estimated flood behaviour with the proposal.

The key information discussed at this meeting included:

- Council indicated that there is no more land proposed for development at Stockinbingal
- the existing rail embankments at Stockinbingal are part of the levee system and are not proposed to be changed or removed
- there are concerns in the Stockinbingal community that no more water should be channelled into town.

Junee Shire Council engineering staff were met with in October 2020 and the meeting included a description of the flood models developed for the proposal and a description of flood behaviour in the vicinity of the proposal. Historic flood data and culvert data were requested from Council to improve the flood models. Council were able to provide culverts data for the Olympic Highway which they maintain on behalf of Transport for NSW and information on the culvert upgrades following the September 2016 rainfall event.

Key information from the meeting:

- For flooding of the Olympic Highway and main roads, Junee Shire Council and the Local Emergency Management Officer are the first call.
- Junee Shire Council have the contract with TfNSW for maintenance of State and Regional roads so they can provide culvert data of these roads for the proposal.
- Ironbong Road – the road gets closed for flooding at Ironbong Creek, the area does flood, water goes over road frequently, and was closed in 2016 due to a significant rainfall event. Restoration works were required after flood damage across most roads in the area and the Ulandra lagoon was full for months.

- Dirnaseer Road –closed only during large flood events, hasn't been closed in the last 2 years, closed in 2016 due to Ironbong Creek. It has a large floodplain, but most of it stays in the defined channel however at flat areas water breaks out of channel.
- No objections or disagreement with flood model mapping.

6.8.2.2 Community consultative committee

Two presentations were given to the Illabo to Stockinbingal Community Consultative Committee, one in November 2020 and a follow up one in February 2021. At the November meeting a description of the flood models was presented and an understanding of flood behaviour for the proposal under existing conditions was provided.

The February 2021 meeting included an updated presentation and questions on the following topics:

- Climate change – the flood models are using the latest information from the CSIRO (refer to section 6.2.3 of this paper).
- Software used for flood modelling – commercially available software is being utilised (refer to section 4.3.1).
- Peer review – a peer review will be completed as required by the SEARs.
- Flood impact criteria – flood impact criteria (now known as Quantitative Design Limits) have been developed to inform the design (refer to Chapter 5).
- Detailed responses for each of these topics would be included in the EIS technical paper.

6.8.2.3 Landowners

Ten landowner meetings were conducted in October and November 2020 in which the hydrology and flooding team were involved. The meetings included a short description of the flood models developed and then a description of existing flood behaviour. Historic flood events were discussed, with specific reference to September 2016 representing approximately a 10% AEP event. Landowners were asked to describe flood behaviour and consider the information presented from the models and identify potential inaccuracies in the model predictions of flood behaviour.

Additional landowner meetings were conducted in November 2020 by the proponent, in which landowners were also shown 10% AEP flood mapping for the existing conditions. During the meetings landowners were asked to provide their views on the level of accuracy of the flood mapping.

Most of the landowners confirmed reasonable accuracy of the flood mapping, three landowners identified the need for partial updating of flood mapping which included the need to include contour banks that have been constructed to capture and direct surface flows into farm dams and two landowners requested revision/updating of flood mapping due to the presence of contour banks (that were not included in the first version of the flood model) impacting surface flows.

Information that has been provided by stakeholders includes:

- photographs and short videos of historic flood events for Billabong and Ironbong Creeks
- anecdotal information about historic flood events at residents, properties and local roads, including information on flood waters entering buildings (residents, sheds etc)
- anecdotal information about overland flow paths and where they flow during rainfall events
- identification of wet/waterlogged areas
- location and use of contour banks (earth mounds) to direct and capture water into on site storage dams.

In February 2021, two landowner meetings occurred to discuss the location of culverts and bridges across individual properties. The local overland flow conditions were discussed for each culvert location and the impacts of the changes discussed with each landowner.

6.8.2.4 NSW State Emergency Service

Two points of contact were made with the NSW State Emergency Services and the SES have indicated a need to understand the final plans to manage impacts and did not request any information during the reference or EIS stage of the proposal. It has been agreed that copies of the final plans will be provided to be able to understand the impacts and improve management of future flood events.

6.8.3 Existing conditions flood model results

Figures showing existing conditions flood modelling results for peak flood levels and depths, peak velocities, duration of inundation and hazard are included in Appendix C for the 0.2EY, 10%, 5%, 2%, 1% and 0.05% AEP and 1% AEP plus climate change and PMF design events. Each map series has 9 maps that show results from south to north across the proposal. For reference Table 6.3 provides a summary of the contents of each map with a full listing provided in Appendix C, including:

- Appendix C.1 – peak flood level and depth
- Appendix C.2 – peak flood velocity
- Appendix C.3 – duration of inundation
- Appendix C.4 – flood hazard.

Table 6.3 Summary of flood maps for existing conditions

Map number in series	Approximate chainage (km)	Named watercourse (chainage km)
1 of 9	0 to 5	Billabong Creek (0.739)
2 of 9	4.8 to 9.4	Ulandra Creek (7.9)
3 of 9	8.4 to 13.4	*Unnamed tributaries*
4 of 9	13 to18	Run Boundary Creek (14.468)
5 of 9	17 to 22.2	Isobel Creek (20.142)
6 of 9	22 to 27.6	*Unnamed tributaries*
7 of 9	27.2 to 32.2	*Unnamed tributaries*
8 of 9	32.8 to 38.2	Powder Horn (35.9) and Dudauman Creek (37.94)
9 of 9	37 to 42.2	Dudauman Creek (37.94)

6.8.4 Murrumbidgee Catchment flood behaviour

6.8.4.1 Billabong Creek

Refer to Map Set 1 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

Billabong Creek has a catchment area of approximately 320km^2. The majority of the catchment is made up of Ironbong Creek which is approximately 250km^2 in area including Ulandra Creek (71km^2). The hydrologic modelling indicates that the critical storm duration for the catchment immediately upstream of the existing railway is 12 hours for the 0.2EY and 10% AEP events, 12 hours for the 5%, 2% and 1% AEP events and 24 hours for the 0.05% AEP event.

For the 1% AEP event, the hydraulic modelling indicates that the existing rail embankments act as a barrier to flows travelling south and the width of flooding upstream of the existing rail is up to 1.7km wide. Survey of the top of rail indicates the level to be between 259mAHD and 261.8mAHD. Peak 1% AEP flood levels range from 262.0mAHD at Billabong Creek to 260mAHD towards the western edge of the floodplain with depths of between 0.6m and up to 1.1m across this western floodplain. This indicates that the existing top of rail is overtopped which would therefore indicate that the formation (assumed to be 0.6m below top of rail) does not have 1% AEP flood immunity.

The 1% AEP maximum velocity is approximately 1.5m/s in the main channel upstream of the proposal which reduces across the floodplain to less than 0.5m/s.

The duration of inundation in the main channel is estimated to be greater than 24 hours due to the contributing catchment areas upstream. Across the western floodplain adjacent to the Main South Railway, the duration of inundation for the 1% AEP event varies from less than 12 hours to up to 20 hours. This variation is due to the uneven nature of the ground with low points taking longer to drain.

The flood hazard for the site indicates the main channel experiences a velocity depth product greater than 4.0m^2/s. The western floodplain experiences depth greater than 0.5m but the velocity depth product is estimated to be up to 1.0m^2/s which means the area is unsafe for vehicles and people.

The 1% AEP plus climate change scenario results in a peak flood level of 262.4mAHD at the rail bridge which is approximately 0.4m higher than the present day climate flood level.

PMF levels in the creek are approximately 265.7mAHD at the bridge and 263.4mAHD across the western side of the floodplain and the width is approximately the same as the 1% AEP at the rail embankment.

6.8.4.2 Ulandra Creek

Refer to Map Set 2 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

The Ulandra Creek channel is fairly well defined as can been seen on the peak flood level maps (Chainages 7.0 to 7.8km). The hydrologic modelling indicates that the 9 hour storm duration is critical for the catchment. In the vicinity of Ironbong Road Ulandra Creek flows below the road via a 3-span bridge as can be seen in Photo 6.1 below with a peak water level of 285.9mAHD. In the vicinity of the proposal the peak water level for the 1% AEP event is 285.4mAHD with depths of up to 3m in the main channel.

The modelling results indicate that upstream of Ironbong Road large flood events break out from the channel and the floodplain becomes extensive. At Ironbong Road the floodplain in the 1% AEP event is almost 1km in width with depths of up to 1m and velocities less than 1m/s. The detailed survey of Ironbong Road and the Ulandra Creek bridge indicates that the road is largely flood free in the 1% AEP event near the proposal but this event does encroach on the road reserve and there are some sections of the road (not included in the detailed survey) that will be overtopped in the 1% AEP event. Overall, Ironbong Road acts as a barrier to flows travelling from east to west. The historic flood images presented in Photo 6.2 would support this behaviour predicted by the model.

Photo 6.1 Ulandra Creek bridge at Ironbong Road

Historical evidence suggests that floodwaters do break the banks and inundate land either side of the main channel. Photo 6.2 below shows a selection of photos from a flood event. It is noted the date of the photos could not be verified by the landowner who provided them.

Landowner discussions indicated the presence of a lagoon in the right overbank downstream of Ironbong Road. Photo 6.2 (top right) shows the lagoon adjacent to Ironbong Road. The modelling also indicates the presence of the lagoon with deep water and lower velocities. Modelling shows that the flood velocities across the lagoon are less than 0.5m/s but the main channel velocities are up to 2m/s for the 1% AEP event.

The flat nature of the area supports the flood model results that indicate the duration of inundation to be up to 24 hours in the main channel, across the floodplain and in the lagoon.

Flood hazard results for Ulandra Creek and its floodplain indicate a velocity depth product of 1.0m^2/s which would be due to the deep water and isolated areas of high velocities. This area would be considered unsafe for vehicles and people during a 1% AEP flood event.

The 1% AEP plus climate change scenario results in a peak flood level of 286.1mAHD at Ironbong Road bridge and 285.5mAHD at the proposal which is approximately 0.2m higher than the present day climate flood level.

PMF levels in the creek are approximately 287.2mAHD at the Ironbong Road bridge with velocities in the channel and across the floodplain of approximately 1.1m/s. The PMF extent is up to 100m beyond the existing 1% AEP flood extent upstream of Ironbong Road.

Photo 6.2 Flooding at Ulandra Creek near Ironbong Road (received from landowner, date unknown)

6.8.4.3 Unnamed tributaries between Ulandra and Run Boundary Creek

The unnamed tributaries in Map Set 3 are all minor overland flow paths that contribute flow to Ironbong Creek, located to the west or Ironbong Road. Farm dams dominate these overland flow paths with depths between the farm dams estimated to be less than 0.1m for the 1% AEP event. Existing velocities are largely less than 0.5m/s except immediately downstream of some farm dams.

Existing hazard is less than 0.3m^2/s due to the low depths and velocities.

6.8.4.4 Run Boundary Creek

Refer to Map Set 4 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

Run Boundary Creek is a tributary of Ironbong Creek and joins Ironbong Creek downstream of the proposal study area. It flows in a north-west direction and has several smaller tributaries. A significant portion of the eastern catchment is forested and much of the creek channel has scattered vegetation. The 1% AEP event existing conditions modelling indicates that the peak flood level is 310.9mAHD at the proposal site. The modelling indicates that the 6-hour storm produces the highest flows across the catchment with velocities up to 2m/s in the channel upstream of the proposed alignment and flood depth up to 1.5m in the channel and 0.7m across the floodplain. The duration of inundation is up to 24 hours in the channel and the floodplain is up to 170m wide at the alignment and spreads to 350m width as it joins with Ironbong Creek approximately 1km downstream of the proposal. Upstream of the proposed alignment the flood extent is up to 100m in width for the 1% AEP event.

Flood hazard estimates for the main channel and tributary to the north indicate a velocity depth product up 4.0m^2/s with the floodplain at 1.0m^2/s and less.

The 1% AEP plus climate change scenario results in a peak flood level of 311.1mAHD at proposal which is approximately 0.2m higher than the present day climate flood level.

The PMF level in the creek is approximately 312.4mAHD at the proposal site with velocities in the channel of approximately 2.3m/s. The PMF extent is significantly beyond the existing 1% AEP flood extent upstream of the proposal with widths of up to 500m.

6.8.4.5 Isobel Creek

Refer to Map Set 5 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

Isobel Creek is an upper tributary of Ironbong Creek and flows in a westerly direction, crosses the proposed alignment and joins Ironbong Creek. It has several dams in its catchment and some within the creek line and vegetation is generally sparse. The 1% AEP event modelling indicates that the flood extent is generally 30m or less for much of the creek upstream of the alignment with a peak flood level of 342.4mAHD. The 6 hour storm event produces the peak flows within the catchment resulting in velocities of up to 2m/s approaching the proposed alignment and depths of up to 1.5m in the channel. The duration of inundation for this catchment is less than 18 hours with most sections of the channel experiencing less than 12 hours.

Flood hazard estimates for the main channel and tributary to the north indicate a velocity depth product up 4.0m^2/s that quickly dissipates to less than 0.3m^2/s.

The 1% AEP plus climate change scenario results in a peak flood level of 342.9mAHD at the proposal which is approximately 0.5m higher than the present day climate level.

The PMF level in the creek is approximately 344.0mAHD at the proposal with velocities in the channel of approximately 2.3m/s. The PMF extent is significantly beyond the existing 1% AEP flood extent upstream of the proposal with widths up to 200m.

6.8.5 Lachlan Catchment flood behaviour

6.8.5.1 Unnamed tributaries between Isobel and Powder Horn Creeks

Refer to Map Sets 6 and 7 in Appendix C for the existing conditions flood maps for these creeks and sub-catchments in the vicinity of the proposal.

The unnamed tributaries between Isobel and Powder Horn Creek flow into Wattle Creek in Map Set 6 are shallow, with the 1% AEP event having less than 0.1m depths over the majority of the extent, except where water is being captured in a farm dam. The flood water spreads across flat grazing and cropping land. The 1% AEP event modelling indicates that there is limited channel definition, with limited capacity and a majority of the 1% AEP flood flow is sheet flow across the floodplain. This excludes a farm dam in one of the five flow paths. The typical depths in the flow paths vary from 0.5m downstream of the farm dam to less than 0.02m for the majority of the area in the 1% AEP Event. Within these tributaries the floodwaters flow freely over the surface with no defined water courses.

The flood hazard in this area is very low due to low depths and low velocities, excluding downstream of the farm dams where a higher hazard is created due to the faster flow over the dam edge and higher depths typically experienced just downstream. The average velocity for the 1% AEP event is less than 0.2m/s, with some sections peaking at 0.5m/s.

The unnamed tributaries flowing west to east across Dudauman Road into Wattle Creek shown in Map Set 7 are shallow, with the 1% AEP event predicted to have less than 0.1m depths in the overland flow paths. The majority of the tributaries do not have well defined channels with flow spilling across flat, open grazing land. The second to northernmost unnamed tributary has a farm dam just upstream of the existing road, with the road acting as the barrier.

The flood hazard in this area is very low due to low depths and low velocities, excluding some channel sections. The average velocity for the 1% AEP event is less than 0.1m/s, with some sections peaking at 0.5m/s.

6.8.5.2 Powder Horn Creek

Refer to Map Set 8 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

Powder Horn Creek and tributaries meander across the flat grazing and cropping land to the west of Dudauman Road between Old Cootamundra Road and the town of Stockinbingal. The 1% AEP event modelling indicates that the channel has limited capacity and a majority of the 1% AEP flood flows spill from the channel into the floodplain.

The 1% AEP critical duration is the 6 hour storm which produces a flood extent of up to 500m in the vicinity of the proposal with a peak level of 299.0mAHD. The duration of inundation is up to 18 hours across the floodplain. Upstream of the proposal there are two distinct channels with the main Powder Horn Creek channel coming from a southerly direction. The main channel depths are up to 2m from the proposal through to the Temora Street at the southern end of town. Depths across the floodplain vary from 0.5m to 0.1m along the edge of the floodplain. The channel meanders significantly in the general south west to north east direction before reaching the developed areas of Stockinbingal. Main channel velocities are up to 1.5m/s with 0.8m/s across the floodplain in the vicinity of the proposal.

Due to the very flat nature of floodplain and channels, only the Powder Horn Creek channel is estimated to have a velocity depth product of up to 4.0m^2/s with all the floodplain flows and the tributary estimated to have a value of 0.6m^2/s or less. This means that much of the floodplain could be accessed during a flood event by vehicle.

The existing conditions modelling and the previous flood study (refer to section 6.8.1) confirmed that Powder Horn Creek is not affected by flood behaviour of Bland Creek in the vicinity of the proposal area. Powder Horn Creek joins Bland Creek at the Stockinbingal to Cootamundra rail line and results indicate that the floodplains interact and join upstream of the railway but this interaction does not propagate as far upstream as the proposal.

The 1% AEP plus climate change scenario results in a peak flood level of 299.2mAHD at the proposal which is approximately 0.2m higher than the present day climate flood level.

The PMF level in the creek is approximately 299.8mAHD at the proposal with velocities in the channel of approximately 1.4m/s. The PMF extent is significantly beyond the existing 1% AEP flood extent upstream of the proposal and the modelling indicates the PMF extent for Powder Horn Creek joins with the Dudauman Creek across Burley Griffin Way and with Bland Creek across Dudauman Road.

6.8.5.3 Dudauman Creek

Refer to Map Set 9 in Appendix C for the existing conditions flood maps for this creek and sub-catchments in the vicinity of the proposal.

The flood modelling for Dudauman Creek indicates that the main channel is relatively small and large flood events break out from the channel upstream (south) of the Burley Griffin Way culvert and bridge. Upstream (south) of Burley Griffin Way the flood modelling indicates that the 1% AEP flood extent is approximately 500m which increases to approximately 750m between the Burley Griffin Way and the Lake Cargelligo rail line. The modelling also indicates that the main channel has depths of approximately 2m for the 1% AEP event. At Burley Griffin Way the main channel is on the right as indicated by the bridge (Photo 6.3) and a secondary channel is on the left (Photo 6.4). This main channel then heads north and crosses under the Lake Cargelligo line through the left of the two structures (Photo 6.5). A breakout channel crosses under the Lake Cargelligo line on the right (Photo 6.6). Photo 6.7 shows the crossing of Dudauman Creek by the Stockinbingal to Parkes rail line downstream of the proposal.

The modelling indicates that Burley Griffin Way and the Lake Cargelligo line impact flood extents and cause ponding of flood waters upstream of each alignment. The site visit to the area in July 2018 revealed several levees in the vicinity of Dudauman Creek upstream of the Lake Cargelligo line, between the Lake Cargelligo line and Stockinbingal to Parkes rail line and through the residential area of Stockinbingal. As best as possible these have been included in the model build but detailed survey is required to improve the understanding of their impact on flood behaviour. The site visit and flood modelling indicate that flood behaviour for Dudauman Creek in the vicinity of the proposal is constrained by the Lake Cargelligo line, the Stockinbingal to Parkes rail line and Noonans Hill to the north east.

The 6 hour storm duration is critical for the 1% AEP event. The flood modelling indicates that the Lake Cargelligo line is not overtopped in the 1% AEP event. Dudauman Creek has two distinct channels downstream of the Lake Cargelligo line which carry flows up to 2m in depth at velocities of up to 1.8m/s for the 1% AEP event. The overbank areas have depths of less than 0.5m and velocities of less than 1m/s. The two channels combine and flow through the 14 culverts under the Stockinbingal to Parkes rail line with a peak flood height of 303.2mAHD. The flood extent downstream of the Stockinbingal to Parkes rail line is approximately 200m and increases to 500m immediately upstream of the residential area of Stockinbingal (in the vicinity of West Street). The main channel through this section has depths of close to 1.5m with less than 0.5m depths across the floodplain.

The modelling indicates the duration of inundation to be in the order of 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.

Provisional flood hazard assessment for the area indicates the main channels have a velocity depth product of 4.0m^2/s in isolated sections downstream of Burley Griffin Way, downstream of the Stockinbingal to Parkes rail line and downstream of West Street through the urban areas of Stockinbingal. The remainder of the floodplain areas are less than 0.6m^2/s meaning they are generally safe for vehicles and people.

The 1% AEP plus climate change scenario results in a peak flood level of 303.7mAHD at the proposal which is approximately 0.5m higher than the present day climate flood level.

The PMF level in the creek is approximately 304.7mAHD at the proposal with velocities in the channel of approximately 1.4m/s. The PMF extent is significantly beyond the existing 1% AEP flood extent upstream of the proposal, and the modelling indicates the PMF extent for Dudauman Creek joins with Powder Horn Creek across Burley Griffin Way.

Photo 6.3 Burley Griffin Way Eastern Crossing looking downstream

Photo 6.4 Burley Griffin Way Western Crossing looking downstream

Photo 6.5 Lake Cargelligo Rail line western crossing of Dudauman Creek

Photo 6.6 Eastern Culvert bank under Lake Cargelligo line

Photo 6.7 Stockinbingal to Parkes rail crossing of Dudauman Creek

6.8.6 Existing flood affectation at buildings

A total of 195 residential and commercial buildings and 81 other structures that have been identified near the proposal site (refer to section 6.6.1 and Figure 6.6). Flood modelling under existing conditions shows that 74 currently experience inundation during a 1% AEP flood event with the majority (58) being located in Stockinbingal. Table 6.4 shows buildings that are affected by depths greater than 0m in each modelled design event. It is noted that the floor levels are assumed to be at ground level, which is based on the available LIDAR (refer to Section 3.2) except for one property where the floor levels were surveyed to inform the assessment.

Table 6.4 Existing flood affected buildings

Existing flood event	Residential and commercial buildings with depths > 0m	Non-habitable buildings with depths > 0m
0.2EY	6	0
10AEP	11	6
5AEP	14	21
2AEP	17	31
1AEP	21	53
1AEPCC	26	86
0.05AEP	30	116
PMF	41	136

6.8.7 Existing road flood immunity and flood behaviour

The road flood immunity refers to the design flood event at which the road is overtopped by floodwaters. Detailed survey of selected roads was available which has helped inform the understanding of existing flood immunity. These roads included Old Sydney Road and Ironbong Road at Ulandra Creek. For the other roads intersected by the proposal or in the vicinity of the proposal the LIDAR was the best available information. A summary of existing flood immunity is provided in Table 6.5 below.

From the information presented in the table below, Old Sydney Road is the most vulnerable to flooding. The contributing catchment at this location is small and the duration of inundation is less than half a day.

Table 6.5 also presents the existing hazard information for each road and the length over which the hazard category occurs.

Table 6.5 Flood immunity of roads near the proposal

Road name	Existing flood immunity event AEP)	Comments	Hazard category 1% AEP (length of hazard (m))
Olympic Highway	1 to 2% AEP	Assessment based on LIDAR of road surface.	H4 (40m) with depths less than 0.5m and VD <1.0m^2/s
Old Sydney Road	10% AEP	Detailed survey of road and existing culverts included in model for the section of road at the proposal. It is noted that Old Sydney Road is has 5 overland flow paths and Ironbong Creek between Ironbong Road and Warrens Lane in the west.	H1 (45m) at proposal crossing point

Road name	Existing flood immunity event AEP)	Comments	Hazard category 1% AEP (length of hazard (m))
Ironbong Road	Less than 5% AEP near proposal 1% AEP at Ulandra Creek	Detailed survey of Ironbong Road available at Ulandra Creek crossing. Immunity less than 5% AEP to the north and south of Ulandra Creek based on LIDAR level of road surface.	H4 (15m) with depths less than 0.5m and VD<1.0m^2/s
Dirnaseer Road	Not applicable	Road not impacted by flooding.	NA
Old Cootamundra Road	Not applicable	Road not impacted by flooding at proposal locations.	NA
Dudauman Road	2% AEP	Road is subject to inundation from Powder Horn Creek. Assessment based on LIDAR.	H2 (40m) with depths less than 0.1m
Burley Griffin Way	2% AEP	At the bridge crossing of Dudauman Creek the road has a 1% AEP immunity. To the east of the crossing a 35m section of road inundated up to 0.13m in the 2% AEP event. The remainder of the road has at least 1 lane flood free for the 2% AEP.	H1 (400m) with depths than 0.2m east of the Dudauman Creek crossing
	10% AEP	At Hibernia Street between West and Cynthia Street the road in inundated up to 150mm for the 10% AEP event at the level crossing and reduces to 100mm around the corner. For the 1% AEP peak flood depths are 400mm at the level crossing but reduce to 300mm at the corner on Hibernia Street and further reduce to 100mm near the bowling club.	H3 and VD approximately 0.6m^2/s at the level crossing with depths greater than 0.5m. H2 (500m) from level crossing to Gerald Street with depths decreasing from 0.4m to 0.1m.

6.8.8 Existing rail flood immunity

The immunity of the existing rail lines in the vicinity of the proposal is estimated and presented in the Table 6.6. Flood events greater than the immunity event will therefore flow over the top of the existing rail.

Table 6.6 Existing rail flood immunity

Rail line	Existing top of rail flood immunity (AEP)	Comments
Main South Line	2% AEP	Assessment based on LIDAR of rail surface.
Lake Cargelligo Rail Line	1% AEP	At the proposal crossing based on survey of the top of the rail.
Stockinbingal to Parkes Rail Line	1% AEP	At Dudauman Creek based on survey of the top of the rail.

6.8.9 Flood emergency management arrangements

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

The flood problem as discussed in section 6.8.1 at Stockinbingal means that flood emergency management arrangements are in place for the town.

The Cootamundra-Gundagai Regional 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 from the (former) Cootamundra Shire Council, The Cootamundra Local Flood Plan (SES, 2007) governs flood emergency management arrangements for the urban areas of Stockinbingal. 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. The Cootamundra Local Flood Plan indicates that ARTC are to close and re-open railway lines as necessary and advise the Cootamundra SES Local Controller.

The plan indicates that no formal flood warnings are provided for the Cootamundra Shire Council area by the BOM. The available rain gauges in the catchment are used to provide a warning based on the Flash Flood Warning Directive developed by the BOM (BOM, 2019). Upstream of Stockinbingal a gauge at Sunnydale (gauge 73150) is utilised as part of the warnings.

Warnings are issued by the Murrumbidgee SES Regional Headquarters which include:

- SES Livestock and Equipment Warnings. Following heavy rain or when there are indications of significant creek or river rises (even to levels below Minor Flood heights)
- Bureau of Meteorology Flood Watches
- SES Local Flood Advice
- Evacuation Warnings
- Standard Emergency Warning Signal (SEWS).

The nearest evacuation centres to the proposal site are:

- Cootamundra Showgrounds, Pinkerton and Berthong Streets
- Stockinbingal Bowling Club, Burley Griffin Way.

The plan describes the history and Nature of Flooding at Stockinbingal.

> *“In the past Bland and Dudauman Creeks have both caused flooding in the village. The two most significant events occurring in 1956 and 1974. Flooding of properties has resulted from water passing through the village from Dudauman Creek towards Bland Creek and from high water levels in Bland Creek inundating land along its banks. Flow from Dudauman Creek generally enters the village from the West/Wood Streets intersection and there is a major outflow in the Geraldra Street road crossing.*
>
> *In 1987/88 flood mitigation works were constructed along Dudauman Creek between West Street and O’Brien Street. Works included artificial levees, channel enlargement and augmenting the culvert under Geraldra Street. To date these works have controlled flooding but are yet to be tested by a major flood.*
>
> *There are a number of residential properties in Stockinbingal that may experience over-flood flooding during major floods. (the numbers of over floor flooding is based on the Flood Study (no date or reference)).”*

The plan also indicates that “Stockinbingal can become isolated for short periods of time with little warning” and Burley Griffin Way may experience inundation.

It is noted that the description of flood behaviour as presented in the Plan is similar to the patterns of flooding predicted by the flood modelling completed for this assessment.

6.9 Geomorphic conditions

As described above, the study area is located around the catchment divide between the Murrumbidgee and Lachlan catchments. Many of the watercourses and flow paths that intersect the proposal site are minor, flow intermittently and do not have well defined channels nor geomorphological characteristics. These ephemeral systems are predominantly cleared of remnant vegetation and farm dams have been constructed to capture overland flows. The more frequently flowing watercourses with defined channels have been considered as part of the geomorphic assessment and are described further in the following sections.

6.9.1 Billabong Creek

Billabong Creek is a 6th Order Strahler stream with minimal fish passage potential, mature trees within the channel and evidence of erosion and exotic grasses. The banks (refer to Photo 6.8) are well defined and include low and high flow channels immediately upstream of the proposal. There is vegetation both in the base of the creek and in the high flow channels with the floodplain above top of bank largely cleared of vegetation. The creek channel meanders both upstream and downstream of the proposal site with the main control being the existing Main Southern Railway (Photo 6.9) and the Olympic Highway.

For approximately 4km upstream of the proposal site the aerial photography indicates cropping is the dominant land use adjacent to the creek (Photo 6.10). The land has therefore been cleared which is likely to have influenced the condition of the creek. No online dams are evident for the section of creek upstream of the proposal site. As can be seen from the photos there was no water present and aquatic habitats are minimal. The NSW River Styles mapping information indicates Billabong Creek has a low sinuosity sand river style.

The information available indicates that the section of Billabong Creek intersected by the proposal has a high fragility which means this section of creek is susceptible to change if the creek vegetation and contributing catchment are impacted. However, it also is noted to have moderate recovery potential.

Photo 6.8 Billabong Creek looking upstream from existing rail bridge

Photo 6.9 Billabong Creek rail bridge upstream, left bank

Photo 6.10 Billabong Creek (vegetation line) and adjacent grazing paddocks upstream of proposal site

6.9.2 Ulandra Creek

Ulandra creek is a 5th order Strahler stream with minimal habitat sensitivity and fish passage potential.

The main creek line is highly vegetated (see Photo 6.11) with the floodplain above the top of bank largely cleared of vegetation (see Photo 6.12). The main channel is 2.3m deep and 19m wide around the proposed alignment locations and meanders both upstream and downstream of the proposed alignment crossing. A bridge for Ironbong Road exists upstream of the proposed alignment crossing and no farm dams exist near the proposed creek crossing location. The small township of Bethungra and Bethungra Dam is upstream of the proposed crossing.

The NSW River Styles mapping information indicates Ulandra Creek has a meandering fine-grained river style. The information available indicates that Ulandra Creek at Ironbong Road has a high fragility which means this section of creek is susceptible to change if the creek vegetation and contributing catchment are impacted. However, it has moderate recovery potential.

Photo 6.11 Ironbong Road bridge across Ulandra Creek, looking upstream

Photo 6.12 Ulandra Creek looking upstream and adjacent floodplain

6.9.3 Run Boundary Creek

Run Boundary creek is a 3rd order Strahler stream with minimal habitat sensitivity and low fish passage potential.

The main creek is highly vegetated and well defined at the proposal crossing, being approximately 1.5m deep and 20m wide. Land is cleared from the top of bank and the creek becomes less defined downstream where an additional tributary joins the alignment. No farm dams exist in the area near the proposed crossing and Run Boundary creek is generally unaffected by development in the area.

The NSW River Styles mapping information indicates Run Boundary has a low sinuosity fine-grained river style, but lacks defined channels through sections of the watercourse. Similar to Billabong and Ulandra Creeks, it has a high fragility and moderate recovery potential.

6.9.4 Isobel Creek

Isobel Creek is a 3rd order Strahler stream with minimal habitat sensitivity and fish passage potential.

Isobel creek has a well-defined meandering shape that is typically 20m wide between the top of banks, is 2.2m deep and is highly vegetated. There are minimal farm dams along the creek alignment. Above the top of bank, the overbank area has been cleared and land reshaped to increase land usability for agricultural purposes. The aquatic ecologist site observations indicated some invasion of exotic species and some areas of re-vegetation and protection from stock access and some areas with no riparian vegetation (Technical Paper 2 – Aquatic biodiversity).

The NSW River Styles mapping information indicates Isobel Creek has a low sinuosity gravel river style and is in a poor condition in the vicinity of the proposal site. It has a moderate fragility which means it has the potential to adjust to changes and impacts locally over small stretches, but it has low recovery potential.

6.9.5 Isobel Creek Tributary

Isobel Creek Tributary is a 2nd order Strahler stream with minimal habitat sensitivity and fish passage potential.

The creek line is well defined and vegetated with numerous agricultural dams upstream and downstream of the proposed alignment. Approximately 300m downstream the creek becomes less defined, before connecting into the main creek 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 (refer to section 6.9.4). Significant degradation of the creek line was observed due to stock access.

6.9.6 Powder Horn Creek

Powder Horn Creek is a 3rd order Strahler Stream with minimal fish passage potential, no native vegetation, no aquatic vegetation and evidence of erosion (Technical Paper 2 – Aquatic biodiversity). A Geomorphic Assessment (SMEC, 2002) completed in 2001 to accompany the Stockinbingal Floodplain Management Study described active gullying occurring in Powder Horn Creek downstream of Corbys Lane and parallel to Dudauman Road. These two roads are near the proposal site.

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. The land is primarily used for agriculture.

The NSW River Styles mapping information indicates Powder Horn Creek has a channelised fill river style and is in a poor condition in the vicinity of the proposal site. 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.

6.9.7 Powder Horn Creek tributary

Powder Horn Creek tributary is a 2nd order Strahler stream with minimal habitat sensitivity and fish passage potential. Similar, to the main creek alignment, the Powder Horn Creek tributary natural creek line has been cleared and realigned for agricultural purposes.

No River Style is available for this creek due to its small catchment, but it is likely to be similar to the main Powder Horn Creek channel (refer section 6.9.6).

6.9.8 Dudauman Creek

Dudauman creek is a 3rd order Strahler stream with minimal habitat sensitivity and fish passage potential. The Aquatic Biodiversity Impact Assessment identified a good cover of juvenile trees, a dam located within 50m of creek line, de-vegetation in some areas, exotic plant invasion, well defined banks however bank degradation evident through erosion and no aquatic vegetation (Technical Paper 2 – Aquatic biodiversity).

A 2001 Geomorphic Assessment (SMEC, 2002) described Dudauman Creek at the Burley Griffin Way as having sand and gravel bed material and has been repeatedly disturbed by excavation of this material from under the bridge. The assessment identified the artificial levees along both banks downstream of the road and the levee system at West Street through town. The creation of the levee system has caused upstream progressive degradation, bank erosion and channel widening upstream of West Street according to the assessment.

The NSW River Styles mapping information indicates Dudauman Creek has a channelised fill river style and is in a poor condition in the vicinity of the proposal site. It has a moderate fragility which means it has the potential to adjust to changes. The River Style assessment supports the 2001 assessment findings.

7 Impact assessment

7.1 Construction phase impacts

Construction of the proposal is planned to start in mid-2024 and is expected to take about 24 months. This section discusses general and specific construction impacts on flooding. Mitigation measures for these impacts are discussed in Chapter 8.

7.1.1 General construction impacts

Typical construction impacts on hydrology and flooding are as follows:

- construction works or equipment impacting the flow of water by blocking flows within watercourses
- alteration of surface water flow conditions where the landscape is modified by:
  - infilling of dams
  - construction of new cross drainage
  - stockpiling material onsite including; spoil, topsoil, mulch
  - storage of plant, equipment
- surface water contamination if chemical storage areas are breached by floodwater and hazardous chemicals migrate offsite
- flooding of construction areas and ancillary sites, including damage to or loss of plant and equipment
- exposure of construction personnel to safety risks associated with high flow velocities and/or deep water
- increased runoff from disturbed areas and associated sedimentation, if erosion and sediment controls are not properly implemented or damaged during a flood event
- earthworks across the proposal site may result in changes in flood behaviour during construction by temporary obstruction of flow paths and/or loss of floodplain storage. The inundation of the earthworks by floodwater also has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving watercourses.

The proposal includes construction of new bridges and culverts, including work within watercourses. 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 and temporary working platforms have the potential to obstruct flows and worsen flooding upstream of the work sites. There is also potential for temporary works to be damaged or washed away during a flood event, which may impact downstream property and infrastructure.

- The proposal would require construction and use of new access tracks (including unsealed access tracks). A number of temporary crossings of watercourses would be required for access. These activities 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 increased 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.

7.1.2 Specific construction impacts

7.1.2.1 Construction staging at key locations

The staging of the construction of culverts, bridges and longitudinal drainage may result in temporary impacts during a significant rainfall event. The staging of excavations and works directly within watercourses and overland flow paths is likely to only occur during dry conditions in accordance with soil and water management plans and therefore impacts will not be significant but localised and temporary.

The staging of the construction works in the Dudauman Creek floodplain will need to be developed through the detailed design. The proposal will not impact any of the existing structures, including two structures on Burley Griffin Way, two sets of culverts for the Lake Cargelligo line and the Stockinbingal to Parkes culverts. But the flood modelling and Reference Design development 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. Based on the available LiDAR and flood modelling it is estimated that there is potential for change in flood behaviour in the vicinity of the proposal but not within the main Dudauman Creek channel. Potential changes are expected across the eastern floodplain between the construction compounds 26 and 27. Refer to section 6.8.5 for a description of existing flood behaviour.

Staging will not need to consider preloading of embankments or culvert locations due to adequate subgrade across the proposal.

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 areas of Stockinbingal.

7.1.2.2 Construction compounds, laydowns and stockpiles

There are up to 29 locations proposed as use for compounds, laydowns and stockpiles (including spoil mounds) to facilitate construction of the proposal. The location and numbering of these areas is discussed in Chapter 8 of the EIS. Where possible, these sites have been located away from watercourses and overland flow paths. Consideration of potential impacts to hydrology and flooding from the use of these sites is outlined below:

- Construction Sites 1 and 2 (Billabong Creek) – Temporary crossing of Billabong Creek will impact flows following a rain event. Temporary blockage of creek will reduce flows reaching downstream catchments which may impact water supply to downstream catchment.
- Site 4 (overland flow path south east of Old Sydney Road) – Temporary redistribution of surface runoff but no change to flood behaviour in the catchment.
- Site 5 (adjacent to Ironbong Road on corner of Eulomo Settlement Road on the edge of the Ulandra Creek floodplain) – This site may cause a localised redistribution of surface runoff. The site will be located on the edge of the floodplain of Ulandra Creek away from the main channel to the south, so it is not expected to cause any changes to flood behaviour in Ulandra Creek but may locally change flows across Ironbong Road and into the extended floodplain to the west of Ironbong Road.
- Sites 16 and 17 (overland flow path south of Old Cootamundra Road) – Potential change in direction of overland flows on the western side of the proposal (site 16) which will impact flows into a farm dam on the eastern side near site 17. Potential increase in runoff volumes and sediment loads due to hard impervious surfaces.
- Site 21 (adjacent to Dudauman Road) – Temporary redistribution of surface runoff but no change to flood behaviour in the catchment.
- Sites 25 and 26 (Dudauman Creek Floodplain, located between Burley Griffin Way and Lake Cargelligo rail line) – The increase in hard stand areas will increase surface water runoff and sediment loads in the surface runoff. It is estimated that there will be minimal to no change in flood behaviour in the main Dudauman Creek channel to the west of these sites as the site drains away from the main channel. There will be potentially an increase in peak flood levels and depths through this area and increased runoff at the Burley Griffin Way level crossing. This may impact flood behaviour through the urban areas of Stockinbingal but will be mitigated through development of a construction environmental management plan (CEMP) (refer to section 8.2).

7.1.3 Construction water supply

Water would be required for a number of construction activities, including rail and road formation works, dust control, spoil compaction and reinstatement works.

A Construction Water Plan Illabo to Stockinbingal (Golder, 2020) has been prepared. The purpose of the plan is to identify specific water supply options for the proposal. Preliminary estimates of water requirements for the proposal indicates that 675 megalitres (ML) of water would be required over the duration of construction. Initial consultation for water supply requirements with Goldenfields Water, who are responsible for water supply functions within the local government areas of 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 water tanks would be placed within construction compounds to ensure flow rates can be maintained.

EMM have prepared the Inland Rail Water Procurement Options Analysis (EMM, 2020) to inform decisions about approval or procurement processes related to construction water. For the proposal the preferred water sources have been identified to include town water supply, purchase from local water utility and reuse of suitably treated wastewater. Sourcing water from private users was not recommended and water sources requiring new infrastructure was also not recommended due to distance to surface water sources, such as the Murrumbidgee River. Groundwater sources were identified as potential sources but availability and yield were estimated as low and therefore not likely to meet demands (Technical Paper 6 – Groundwater).

7.2 Operational phase impacts

7.2.1 Flood impacts on proposal design

7.2.1.1 Rail flood immunity

Flood modelling indicates that the proposal has met the required minimum immunity as the proposed bridges and culverts convey the 1% AEP peak flood flows across the alignment to keep the 1% AEP flood level at or below the shoulder of the formation in all areas that are not constrained by tie-ins to the existing rail line.

7.2.1.2 Proposed cross drainage infrastructure

Engineering features of the proposal that have the potential to impact the flooding and hydrology regime are

- the new rail embankment that may obstruct overland flows and
- cross drainage structures required to pass flood flows carried in watercourses and
- overland flow paths through the rail corridor.

The design process included detailed flood modelling to identify the necessary locations for cross drainage structures, scour protection, longitudinal drainage and land take to meet the adopted QDLs as outlined in Chapter 5. The proposal footprint has been extended from the base of the embankment to incorporate all drainage design features, including scour protection measures and longitudinal drains. This is typically a width of 20m but extends to 50m at some locations where the topography requires more space within the rail corridor to accommodate the drainage infrastructure.

Cross drainage measures are required at 54 overland flows path or watercourse crossing locations along the alignment, and an additional 34 cross drainage culverts are required for level crossings and the realigned Burley Griffin Way. In addition, longitudinal drainage channels are provided to collect and discharge surface runoff from within the rail corridor and also to intercept overland flows and direct them to the nearest cross drainage structure.

The proposed infrastructure includes bridges for all named watercourses. In other locations reinforced concrete box culverts or reinforced concrete pipes are used in the cross-drainage design. The proposed features are presented on Figure 1.2 above and included in Table 7.1 below.

Table 7.1 Cross drainage design features

Feature ID (approximate chainage km)	Feature	Description	Watercourse
0.711	Bridge	56m (4 spans) long bridge with round piers	Billabong Creek
1.539	Culvert	1 x 2.4W x 1.5H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
1.960	Culvert	2 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
3.160	Culvert	2 x 2.1W x 0.75H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
5.377	Culvert	12 x 900Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
5.907	Culvert	34 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
6.907	Culvert	7 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
7.531	Culvert	20 x 2.4W x 1.8H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
7.904	Bridge	56m (4 spans) long bridge with round piers	Ulandra Creek
8.050	Culvert	23 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
8.169	Culvert	25 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
8.375	Culvert	13 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
10.057	Culvert	10 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
10.870	Culvert	3 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
11.400	Culvert	2 x 1.2W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
12.117	Culvert	30 x 1.2 Ø RCP	Drainage line / overland flow path / flood relief crossing
12.980	Culvert	5 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
13.577	Culvert	6 x 900Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
14.422	Bridge	92m (4 spans) long with round piers	Run Boundary Creek
15.400	Culvert	5 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
16.000	Diversion	Earth embankment and channel	Divert to culvert 15.4
16.315	Culvert	9x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
16.800	Culvert	8 x 2.4W x 1.2H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing

Feature ID (approximate chainage km)	Feature	Description	Watercourse
17.500	Culvert	5x 900Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
17.517	Culvert	11 x 1.35 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
18.317	Culvert	14 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
19.269	Culvert	4 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
20.111	Bridge	69m (3 spans) long with round piers	Isobel Creek
20.460	Bridge	69m (3 spans) long with round piers	Isobel Creek tributary
21.29	Culvert	7 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
21.777	Culvert	22 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
22.400	Culvert	5 x 2.4W X 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
22.450	Culvert	11 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
23.205	Culvert	12 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
23,292	Culvert	14 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
23.650	Culvert	20 x1.2Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
25.095	Culvert	10 1.2Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
25.863	Culvert	9 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
25.971	Culvert	4 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
26.050	Culvert	4 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
26.262	Culvert	20 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
26.892	Culvert	3 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
28.232	Culvert	6 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
28.750	Culvert	4 x 1.2W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
29.784	Culvert	4 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
30.294	Culvert	4 x 1.8W x 0.6H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing

Feature ID (approximate chainage km)	Feature	Description	Watercourse
31.567	Culvert	4 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
33.047	Culvert	12 x 2.4W x 1.8H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
34.353	Culvert	42m (3 spans) long with round piers	Drainage line / overland flow path / flood relief crossing
35.471	Culvert	12 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
35.909	Bridge	42m (3 spans) long with round piers	Powder Horn Creek
36.100	Culvert	2 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
36.189	Bridge	10 x 2.1W x 0.9H Reinforced Concrete Box Culvert	Powder Horn Creek tributary
36.500	Culvert	20 x 2.4W x 1.2H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
37.380	Culvert	1 x 2.4W x 1.5H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
37.700	Culvert	28.8m (3 spans) long with round piers	Drainage line / overland flow path / flood relief crossing
37.710	Culvert	1 x 1.2W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
37.930	Bridge	56m (4 spans) long bridge with round piers	Dudauman Creek
39.392	Culvert	1 x 2.4W x 1.5H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 01	Culvert	5 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 02	Culvert	8 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 03	Culvert	6 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 04	Culvert	6 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 05	Culvert	20 x 1.2 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 06	Culvert	8 x 2.4W x 0.9H Reinforced Concrete Box Culvert	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 07	Culvert	17 x 0.9 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing
Burley Griffin Way 08	Culvert	1 x 0.6 Ø Reinforced Concrete Pipe	Drainage line / overland flow path / flood relief crossing

7.2.1.3 Diversion drains

The design requires a number of diversion drains in the vicinity of the Burley Griffin Way realignment, Inland Rail and Lake Cargelligo realignment. These works have been included to manage flood behaviour in the vicinity of the proposal.

7.2.1.4 Detention basin

The detention basin is required to balance flood flows in the vicinity of Burley Griffin Way realignment. The Burley Griffin Way realignment is located in a flood storage area so a shallow basin has been designed to compensate for the loss of flood storage. The basin works with the diversion drains to manage the impacts to below QDLs. The proposed detention basin layout and drainage channels are shown in Figure 7.1.

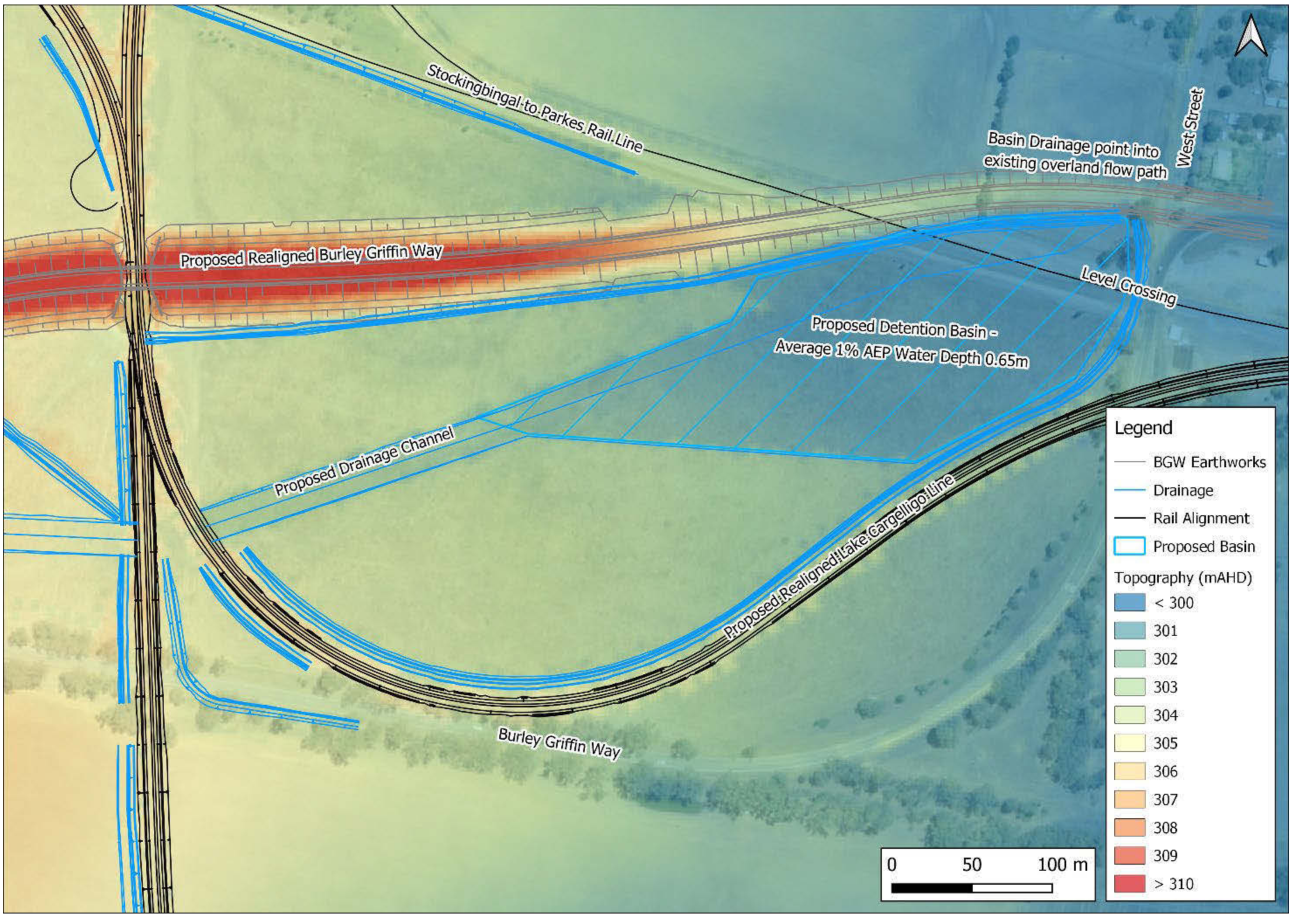


Figure 7.1 Proposed detention basin location

7.2.1.5 Longitudinal drainage

Longitudinal drainage has been included at the base of all fill embankments, along the top of cuttings, through cutting batters and along fill embankments. Where required, longitudinal drains have been designed with sufficient capacity to convey overland flows that enter the corridor to the nearest cross drainage structure. Where longitudinal drains convey external flows, these flows are directed to the watercourse within the same sub-catchment, thereby avoiding diversion of sub-catchment flows and changes to existing drainage patterns.

7.2.2 Operational flood impacts on adjacent land and assets

The proposed design includes an embankment for the proposed rail and realigned Burley Griffin Way, culverts, bridges, longitudinal drainage, level crossing drainage and diversion drains at specific locations. The results indicate that the proposal has not changed flood behaviour in general in the surrounding catchments, as these are associated with minor ephemeral watercourses and there is minimal diversion of existing watercourses due to the proposal. The assessment of the impacts has focused on areas adjacent to the proposal corridor as defined by the permanent works boundary.

Specific impacts are discussed in detail below including reference to the quantitative design limits (QDLs) presented in Chapter 5. Appendix D includes design flood behaviour maps, including:

- Appendix D.1 – design depth and height and afflux
- Appendix D.2 – design velocity and change in velocity
- Appendix D.3 – change in duration
- Appendix D.4 – change hazard
- Appendix D.5 – blockage sensitivity.

There are 9 maps in each map series which includes afflux, percentage change in velocity, percentage change in duration and percentage change in hazard. The maps include aerial imagery, 5m contours, the rail alignment, bridge and culvert locations and proposal specific chainages. A full list of maps is included in the Appendix D and a summary of maps included in Table 7.2 below. It should be noted that in some areas the modelling outputs indicate localised changes well away from the rail corridor and expected influence of the proposed infrastructure. These changes relate to minor model instabilities in these areas and do not represent true impacts of the proposal.

Table 7.2 Summary of design and impact maps

Map number in series	Approximate rail chainages (km)	Named watercourse (chainage km)	Maps – impact assessment
1 of 9	0 to 5	Billabong Creek (0.739)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
2 of 9	4.8 to 9.4	Ulandra Creek (7.9)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
3 of 9	8.4 to 13.4	*Unnamed tributaries*	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
4 of 9	13 to18	Run Boundary Creek (14.468)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
5 of 9	17 to 22.2	Isobel Creek (20.142)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
6 of 9	22 to 27.6	*Unnamed tributaries*	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
7of 9	27.2 to 32.2	*Unnamed tributaries*	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
8 of 9	32.8 to 38.2	Powder Horn (35.9) and Dudauman Creek (37.94)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)
9 of 9	37 to 42.2	Dudauman Creek (37.94)	Afflux, Change in velocity, Change in duration, Change in Hazard (vxd)

7.2.2.1 Afflux

The afflux QDLs are achieved for all areas beyond the rail corridor except at locations identified in Table 7.3.

Table 7.3 Overview and locations of afflux criteria exceedances for general land uses (excluding buildings and roads)

Location	0.2EY	10% AEP	5% AEP	2% AEP	1% AEP
Murrumbidgee Catchment					
Billabong Creek (CH 0.739 km)	No change to flood levels	No change to flood level	No change to flood levels	No exceedances of QDL	No exceedances of QDL
Ulandra Creek (CH7.9 km)	Afflux of 280mm on localised area between realigned Ironbong Road and the proposal	Afflux of 330mm on localised area between Ironbong Road and the proposal	Afflux of 330mm on localised area between Ironbong Road and the proposal	Afflux of 330mm on localised area between realigned Ironbong Road and the proposal	Afflux of 330mm on localised area between realigned Ironbong Road and the proposal
Unnamed tributaries between Ulandra Creek and Run Boundary Creek	No change to flood levels	No change to flood levels	No change to flood levels	No change to flood levels	No change to flood levels
Run Boundary Creek (CH14.46km)	No change to flood levels	No change to flood level	No change to flood levels	No change to flood levels	No exceedances of QDL
Isobel Creek (CH20.142km)	No change to flood levels	No change to flood level	No change to flood levels	No change to flood levels	No change to flood levels
Lachlan Catchment					
Unnamed tributaries between Isobel Creek and Powder Horn Creek	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL
Powder Horn Creek (CH35.9km) and tributary (CH36.2km)	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL	No exceedances of QDL
Dudauman Creek (CH37.94km)	• Afflux of 310mm on un improved grazing land between the realigned Lake Cargelligo line and the realigned Burley Griffin Way within extent of proposed basin	• Afflux of 330mm on un improved grazing land between the between the realigned Lake Cargelligo line and the realigned Burley Griffin Way within extent of proposed basin	• Afflux of 300mm on un improved grazing land between the between the realigned Lake Cargelligo line and the realigned Burley Griffin Way within the extent of proposed basin	• Afflux of 296mm 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 320mm 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 380mm upstream of the Dudauman Creek bridge • Afflux of up to 380mm upstream of the alignment south of Dudauman Creek Bridge

Flood modelling indicates that within the Murrumbidgee River catchment:

- There would be changes in flood levels across the Billabong Creek floodplain but that these would remain within the QDLs.
- In the vicinity of Ulandra Creek, the proposal results in a section of afflux above the QDLs for the 10%, 5%, 2%, 1% AEP and 1% plus climate change events at the Ironbong Road level crossing. These areas of afflux are very localised, largely within the proposal boundary and do not result in a change in the management of the flood prone land. Refer to further discussion in section 7.2.4 flood prone.

Flood modelling indicates that within the Lachlan River catchment:

- Upstream of the Dudauman Creek bridge afflux of up to 380mm is noted for the 1% AEP. Existing flood depths in this area are between 400mm and 700mm. For the 2% AEP event the afflux is confined to the similar locations as the 1% AEP but to a smaller extent, with the 5%, 10% and 0.2EY AEP events having a decrease in flood levels at this location. For the 1% AEP plus climate change event the afflux is up to 500mm for the same area but the rail formation is not overtopped for the 1% AEP plus climate change.
- The section of land between Dudauman Creek and the existing Lake Cardelligo line at chainage 37.8km has an afflux of 400mm in the 1% AEP event only, which exceeds the QDL for unimproved grazing land of 300mm. This land is within the proposal site and relates to the proposed detention basin as discussed in section 7.2.1.4.
- Downstream of the intersection of the realigned Burley Griffin Way and Hibernia Street impacts of up to 180mm (within the QDL for agricultural land) occur in the smaller events 0.2EY, 10%, 5% and up to 100mm for the 2% AEP event. The 1% AEP in this area has impacts of less than 60mm. The impacts of this area are within the creek and overland flow area, with sheds affected by the impacts up to 120mm which is above the QDL of 20mm for a non-habitable building.
- The Stockinbingal to Parkes line and the Lake Cargelligo line to Cootamundra are the hydraulic controls and the modelling indicates minimal change to flood levels through Stockinbingal.

7.2.2.2 Velocity

The existing velocity across the proposal is largely less than the adopted Erosive Threshold Value (ETV) of 0.5m/s. The soils across the proposal study area tend to be silty clays or clays, which are non-dispersive and tend to have low erosion potential. Refer to section 6.4 for a discussion on soils and geology and relevant mapping. However, a soil sampling and testing program to determine the susceptibility of soils to erosion in areas where the proposal will alter the flood velocity regime should be considered for detailed design to further inform the scour and erosion assessment and mitigation measures.

Velocity impacts generally do not exceed the adopted criteria. At locations of exceedances the site specific ETV will be determined during detailed design. A number of exceedances occur above the adopted ETV 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. Outside of these relatively localised areas the velocity regime across the majority of the proposal is unchanged. Some exceedances are noted within the floodplain well away from the rail corridor as a result of minor changes to the velocity regime around the rail corridor that propagate into the floodplain over some distance upstream and downstream and are evident when adopting the very low impact limit of 0.025m/s as specified in the velocity QDL.

Across the study area, velocities are typically less than 1.0m/s with many areas below the ETV of 0.5m/s for the 1% AEP and more frequent flood events. For the larger watercourses where bridges are proposed the velocities are greater than 1m/s, with up to 2m/s for the 1% AEP flood event noted in Billabong Creek, Ulandra Creek, Run Boundary Creek and Isobel Creek and up to 1.5m/s in Powder Horn Creek and Dudauman Creeks but floodplain flows are less at 0.5m/s. The introduction of bridges does not substantially alter the velocity of these watercourses.

The impacts to velocity are summaries in Table 7.4 with further discussion below.

Table 7.4 Overview and locations of velocity criteria exceedances for general land uses (excluding buildings and roads)

Cross drainage location	0.2EY event velocity criteria exceedances	10% AEP event velocity criteria exceedances	5% AEP event velocity criteria exceedances	2% AEP event velocity criteria exceedances	1% AEP event velocity criteria exceedances
Murrumbidgee Catchment					
Billabong Creek (CH 0.739km)	At tie in point up to 20% increase	At tie in point up to 20% increase	At tie in point up to 10% increase	Up to 20% increase at tie in point and across the floodplain	Up to 10% increase at tie in point and across the floodplain
CH6.0km	Increase up to 20% but less than 0.6m/s	Increase up to 20% but less than 0.6m/s	Increase up to 20% but less than 0.6m/s	Increase up to 20% to 0.68m/s	Increase up to 20% to 0.72m/s
Ulandra Creek (CH7.9km)	Up to 20% at one area of the floodplain 400m downstream of proposal. Design velocities less than 1.0m/s	Up to 20% at one area of the floodplain 400m downstream of proposal. Design velocities less than 1.0m/s	Up to 10% at one area of the floodplain 400m downstream of proposal. Design velocities less than 1.0m/s	Up to 10% at one area of the floodplain 400m downstream of proposal. Design velocities less than 1.0m/s and less area impacted	Less than 10% increase at one area of the floodplain 400m downstream of proposal. Design velocities less than 1.0m/s and less area impacted and more frequent events
CH8.2km	Increase of >20% occurs between proposal and realigned Ironbong Road	Increase of >20% occurs between proposal and realigned Ironbong Road	Increase of >20% occurs between proposal and realigned Ironbong Road	Increase of >20% occurs between proposal and realigned Ironbong Road	Increase of >20% occurs between proposal and realigned Ironbong Road
CH8.6km	Isolated increase >20% due to removal of farm dam	Isolated increase >20% due to removal of farm dam	Isolated increase >20% due to removal of farm dam	Isolated increase >20% due to removal of farm dam	Isolated increase >20% due to removal of farm dam but less extent than more frequent events
CH10.2km	Criteria met	Criteria met	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path
CH11.0km (downstream of Ironbong Road)	Criteria met	Criteria met	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path
CH12.3km	Criteria met	Criteria met	Increase >10% due to concentration of sheet flow path and existing contour banks. Design velocity <0.6m/s	Increase >10% due to concentration of sheet flow path and existing contour banks. Design velocity <0.6m/s	Increase >10% due to concentration of sheet flow path and existing contour banks. Design velocity <0.8m/s
CH13.1km	Criteria met	Criteria met	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path	Increase >10% due to concentration of sheet flow path

Cross drainage location	0.2EY event velocity criteria exceedances	10% AEP event velocity criteria exceedances	5% AEP event velocity criteria exceedances	2% AEP event velocity criteria exceedances	1% AEP event velocity criteria exceedances
Run Boundary Creek (CH14.46km)	Isolated increase >20%	Isolated increase >20%	Isolated increase >20%	Isolated increase >20%	Isolated increase <20%
CH16.4km	Isolated increase >20% due to farm dam and landowner contour banks	Isolated increase >20% due to farm dam and landowner contour banks	Isolated increase >20% due to farm dam and landowner contour banks	Isolated increase >20% due to farm dam and landowner contour banks	Isolated increase >20% due to farm dam and landowner contour banks
CH17.6km	Criteria met	Criteria met	Criteria met	Criteria met	Isolated increase >10% with existing velocities >1.5m/s
Isobel Creek (CH20.142km)	Criteria met	Criteria met	Criteria met	Criteria met	Increase up to 10% within creek. Existing velocities >1.5m/s
CH23.2km	Criteria met	Isolated increase >20%	Isolated increase >20%	Isolated increase >20%	Isolated increase >20%. Design velocities <0.7m/s
Lachlan Catchment					
CH28.2km	Criteria met	Criteria met	Criteria met	Criteria met	Isolated increase >20%. Due to concentration of flows and location of farm dam at edge of proposal
Powder Horn Creek (CH35.9km) and tributary (CH36.2km)	Criteria met	Criteria met	Criteria met	Criteria met	Localised increases <20% downstream of proposal. Velocity 1.0m/s in channel and <1.0m/s in floodplain
Dudauman Creek (CH37.94km)	Criteria met	Increase >10% in channel downstream of Wood Street	Increase >10% in channel downstream of Wood Street	Increase >10% in channel downstream of Wood Street. Increase >20% upstream of proposal and at Burley Griffin Way western tie in point	Increase >10% in channel downstream of Wood Street. Increase >20% upstream of proposal and at Burley Griffin Way western tie in point

- Billabong Creek – velocity change is up to 10% except at one isolated location on the edge of the floodplain. This is due to the proposal filling the floodplain and therefore resulting in a small area of land on the existing floodplain now experiencing slightly higher velocities.
- Ulandra Creek – most increases within 10% except for the isolated area in Ulandra Creek 400mm downstream of the proposal. At this location design velocities are less than 1.0m/s.
- Powder Horn Creek – isolated areas of increase downstream of Powder Horn Creek bridge and along Temora Street but very localised.
- Dudauman Creek – increases at Wood Street in channel between Stockinbingal levees, minor local increases in Dudauman Creek upstream of proposal and upstream of Lake Cargelligo rail line and at start of flood diversion channel at the start of the Burley Griffin Way realignment, but velocities remain less than 1.0m/s for design conditions.

7.2.2.3 Flood flow distribution

Changes to flow distribution have been assessed based on changes in flood extent and changes to velocity. All the proposed cross drainage structures have been located at topographic low points or watercourses which therefore minimises impacts to flow conveyance. The proposed sizes of the structures have been governed by the afflux and velocity QDLs to minimise flood impacts and change in flow patterns and flood flow distributions. A minor diversion channel is required as discussed below, however this diversion does not impact the flood flow distribution.

It is proposed that one diversion drain be constructed, upstream of chainage 16.0km to capture flows at the top of a cutting. The proposal alternates between cut and fill between chainage 6.4km and 18.4km and crosses many overland flow paths, one of which occurs in the vicinity of chainage 16.0km. The diversion drain will be located at the top of the cutting to capture surface runoff from entering the cutting and impacting the immunity of the rail. This diversion has been designed as a longitudinal drain to convey flows parallel to the rail and direct flow to the south to culverts at chainage 15.4km. The modelling indicates that there is minimal change to flood levels and velocities between chainage 16km and 15.4km and no noticeable change in the downstream catchment as a result of the diversion.

Downstream of chainage 15.4km there is an increase in peak flood levels of less than 200mm (within the afflux QDL) and a new area of land subject to inundation due to the change in flow from the low point at 16km to 15.4km. The newly flooded land is on the edge of an existing flow path which is over 100m in width. The newly flooded land has a design flood depth of up to 100mm in the 1% AEP event which does not restrict access by stock or vehicles during a flood event. The diversion is within the proposal boundary and functions as a longitudinal drainage channel.

7.2.2.4 Duration

Duration impacts generally do not exceed the adopted QDLs. The following locations are noted to be exceptions to this:

- Chainage 3.1km – for the 0.2 EY event, modelling indicates that there in an increase in the duration of inundation across agricultural land to the south of the Olympic Highway. The proposal includes a longitudinal drain that conveys flows along the toe of the formation and then via a channel to an existing culvert under the Main South Rail line. The flow then travels to a culvert under the Olympic Highway and into the paddock. The overland flow path through the paddock has two dams with the first 160m from the Olympic Highway. The increase in duration occurs in and around both dams with an increase from 7 hours duration to 14 hours duration. This will 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.
- In the vicinity of culverts at chainage 12.5km the modelling indicates an increase in duration of inundation beyond the proposal boundary of up to 25% during a 5% AEP and up to 23% during a 1% AEP event. This change results in a duration of inundation in the order of 30 hours. The increase is not noted to occur for other flood events included in this assessment. The impact occurs for approximately 100m downstream of the proposal at a location where there are several contour banks designed to control overland flow. The increase in duration is due to the culvert being located at a topographic low point but not being in alignment with existing contour banks. It should not affect the use of the land. Refinement of the model in detailed design, supported by further topographic detail and finer resolution of engineering structures including scour protection and energy dissipation is anticipated to reduce these impacts.
- At culvert chainage 13.1km there is an area upstream of the proposal where duration of inundation increased above the QDL for both the 5% AEP and the 1% AEP (but not for other events). The area is less than 30m from the edge of the proposal with some areas beyond the proposal affected by an increase of 24% to a duration of 25 hours for the 5% AEP, and by 23% during the 1% AEP. This impact is due to the contour banks and farm dams upstream of the culvert directing overland flows and the position of the culvert. The culvert has been positioned at the topographic low point, but LIDAR does not have sufficient detail to accurately model the contours and farm dam changes to overland flow paths. The increase in duration should not affect the use of the land but it is due to the obstruction of the overland flows by the proposal. Refinement of the model in detailed design, supported by further

topographic detail and finer resolution of engineering structures including scour protection and energy dissipation is anticipated to reduce these impacts.

- Downstream of the culvert at chainage 26.2km there is an increase in duration as the proposal requires flows to pond behind the embankment before flowing through the culvert rather than the current conditions where flows are less concentrated and spread out before joining a defined overland flow path. Therefore, under proposal conditions the duration of inundation is has increased by 13% to over 24 hours and does not meet the QDL. This impact dissipates within 200m of the proposal to less than 5% change and is only noted to occur during a 5% AEP event.

7.2.2.5 Hazard

Flood hazard changes have been assessed for all events with a focus on the 1% AEP event. For this event the flood modelling indicates that the velocity depth product does not change across the majority of the overland flow paths in both the Murrumbidgee and Lachlan catchments. There are a couple of isolated locations where the hazard has changed above the QDLs:

- In the Billabong Creek catchment between chainage 0.21km and 0.54km there is an increase in hazard above the QDL of 20% for agricultural land. The increase is due to the increase in flood depths at this location. Current flood depths are over 1.0m for existing conditions which creates a high hazard situation. The increase in flood depths are due to the proposal filling in the current overland flow path along the edge of the existing Main South Rail Line which conveys flood flows from the floodplain into Billabong Creek. The increase in hazard however does not change use of the land as it would currently be unusable during a flood event due to deep water. At the culvert at chainage 23.29km (located at that top of the Murrumbidgee River catchment) there is a localised increase in velocity depth product above the QDL. At this location the velocity depth product is 0.6m^2/s which is unsafe for people and vehicles. This area is adjacent to an overland flow path and a number of contour banks which influence flood depths and velocities. The inclusion of the proposal changes the flood behaviour around these features.
- At the culverts at chainage 37.7km (located between the realigned Lake Cargelligo line and the realigned Burley Griffin Way) at this location the velocity depth product is 0.7m^2/s which is unsafe for people and vehicles. This is due to the build up of flood depths along the Lake Cargelligo line in the larger events.

7.2.2.6 Compatibility with flood hazard and hydraulic functions

The compatibility of the proposal with the flood hazard of the land and the hydraulic functions of flow conveyance, floodways and flood storage has been considered throughout the design process. 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. The flood modelling has provided an understanding of existing flow paths and flood behaviour with consideration of high hazard areas where significant flow conveyance occurs. At these locations, bridges were proposed to maintain flow conveyance.

At overland flow paths an iterative approach was adopted to size hydraulic structures to maintain flow conveyance and to limit afflux on the upstream side of the railway in events up to the1% AEP. The design of each bridge and culvert structure developed during reference design ensured flood flow conveyance was maintained and the 1% AEP immunity for the rail formation was achieved.

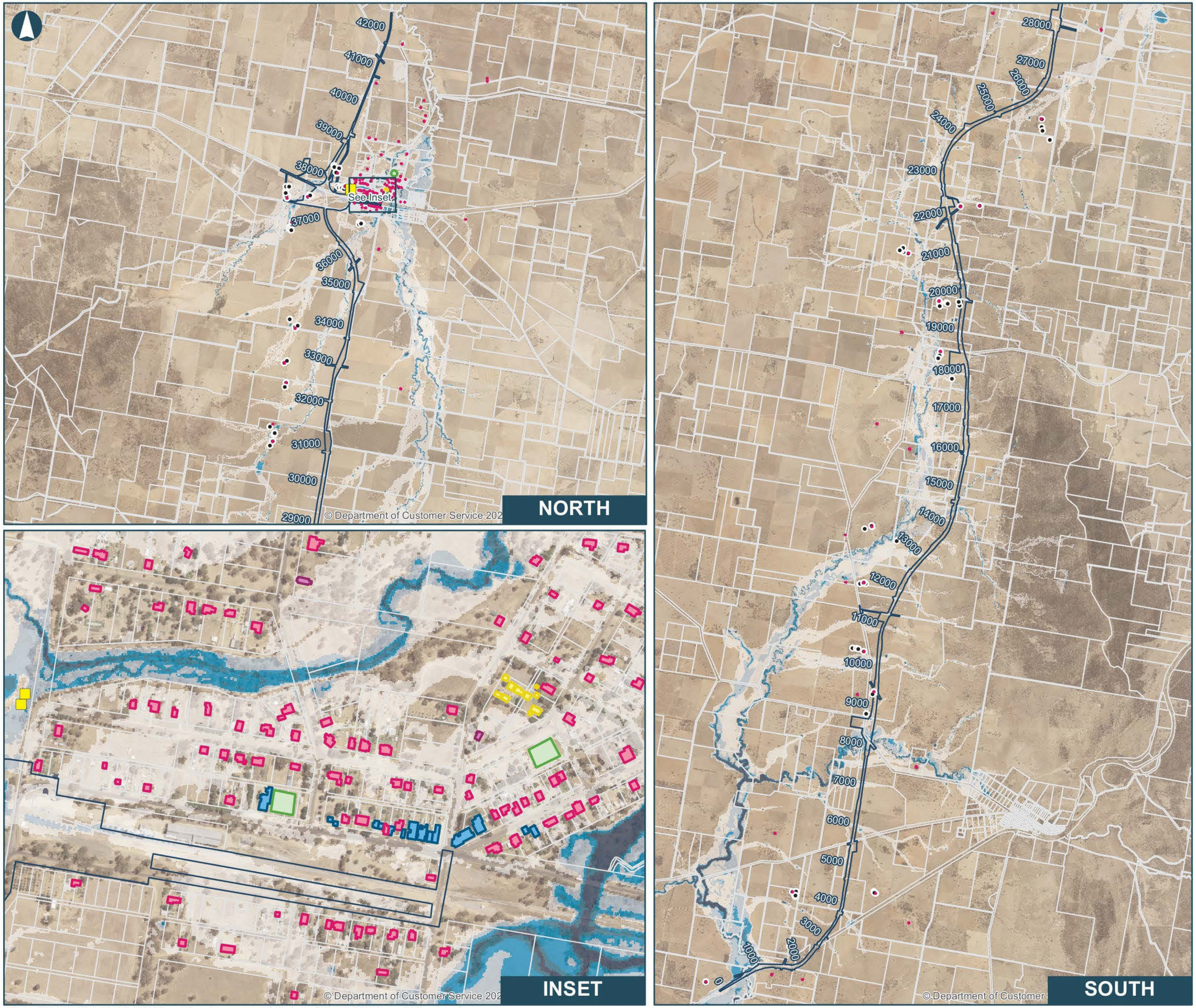
7.2.3 Flood impact on buildings

The property impact assessment was based on the relative change in flood level. Floor levels have been assumed to be at ground level which provides a consistent and conservative basis for assessment. Survey of floor levels, and where appropriate surrounding fill or levees, will be completed at detailed design to refine the understanding of the impact. Of the 195 residential and commercial buildings considered in the assessment, QDL exceedances for afflux up to the 1% AEP flood event are not predicted to occur at any habitable buildings.

Other structures sheds and community halls have also been identified and flood impacts assessed, with two of these identified as being impacted by afflux above the QDL for the 1%AEP event (refer to Figure 7.2). Table 7.5 shows the afflux exceedances for all events.

Table 7.5 Number of buildings impacted by afflux above flood management objectives

Storm event	Number of residential and commercial buildings impacted by afflux above QDL criteria of 10mm	Number of other structures impacted by afflux above QDL criteria of 20mm
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	41	4



INLAND RAIL ARTC

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

ILLABO TO STOCKINBINGAL

Impacted buildings

- Impacted Buildings
- Buildings/farm infrastructure
- Proposal site
- Cadastre

Receiver Type

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

Design flood depth (m)

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

0 1 2 3 4 5 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 8/18/2022
Paper: A3
Author: IRDJV
Scale: 1:90,000
Data Sources: IRDJV, ARTC, LPI

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7.2.4 Flood impact on roads

It is considered that the intent of the QDLs for roads and highways is to ensure that the proposal does not adversely affect the operability of the road network by increasing flood depths, duration and hazard on the pavement and travel lanes. This assessment has therefore focussed on the potential impacts on the operability of the roads and changes to flood risk parameters outside of the travel lanes are not considered to be significant issues but have been fully reported below.

The assessment has categorised the velocity, duration and hazard exceedances into low and high risk, with further examination of the high risk exceedances to determine whether they significantly affect the operability of the roads. No categorisation was applied to the flood level exceedances and instead all exceedances were examined for this key parameter.

The impact assessment for the existing roads is subject to update at the detailed design stage when detailed survey is obtained at the key flood affected sections.

Table 7.6 below presents the findings for the afflux for each of the key roads. Refer to section 6.8.7 to understand existing conditions. Further discussion for selected roads is included below the table.

Table 7.6 Road flood level exceedances for the 1% AEP

Road	Afflux (mm)	Afflux criteria exceedance (mm)	Risk assessment
Olympic Highway	23	0	Maximum of 260mm flooding above pavement level. Flood duration above pavement level is approx. 18 hours. Both travel lanes flooded. **CONCLUSION: No change to hazard or management of the road during a flood event.**
Old Sydney Road	0	0	No flooding above pavement level. **CONCLUSION: No impact on Old Sydney Road at proposal.** It is noted that there will be no change to flood immunity or flood hazard for remainder of Old Sydney Road
Ironbong Road	0	0	The Ironbong Road level crossing is flood free in the 1% AEP event. The realigned section north of the level crossing will have a length of road now flood free in the 1% AEP and further to the north near the tie in point will experience depths up to 400mm for the 1% AEP event on the eastern edge but the western edge will experience depths up to 200mm. Currently the full road width is inundated up to 300mm. But the hazard will be H2 with isolated sections of H3. (Refer to discussion below). The duration of inundation is up to 20 hours for design conditions which is similar to existing conditions. **CONCLUSION: the flooding affectation of Ironbong Road has been improved with the level crossing and realignment and the hazard has been reduced. Flood warning and flood depth markers will still be required.**
Dirnaseer Road	0	NA	It is noted that Dirnaseer Road is subject to inundation along sections away from the proposal.
Old Cootamundra Road	NA	NA	It is noted that Old Cootamundra Road is subject to inundation along sections away from the proposal.
Dudauman Road	0	0	No change in flood hazard and therefore no change to operation of the Dudauman Road at Powder Horn Creek.

Road	Afflux (mm)	Afflux criteria exceedance (mm)	Risk assessment
Burley Griffin Way – at Dudauman Creek	58	8	The increase is localised to a section of road that will be made redundant with the realigned road. **CONCLUSION: The hazard does not change for this section of road and remains at H1. The section of road impacted will not have public access following the realignment of Burley Griffin Way and therefore the increase is not considered material or relevant.**
Burley Griffin Way – at Hibernia Street	0	0	The realigned Burley Griffin Way will not result in an increase in flood depths on the new or existing road pavement. (refer to figure and discussion below.) The intersection of West Street and Hibernia Street will now have a 1% AEP immunity. **CONCLUSION: Improvement to flood immunity and no change to immunity beyond the proposal corridor.**

7.2.4.1 Old Sydney Road

It is noted that 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 will 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.

7.2.4.2 Ironbong Road Impacts

Ironbong Road will be rebuilt and repositioned as a result of the level crossing so this discussion of impacts relates to the realigned road. For the realigned Ironbong Road (chainage 8.1km), the model predicts the road will have 1% AEP immunity at the level crossing. The immunity is predicted to improve along the realigned section to the north of the level crossing, with the western edge of the sloping road having 1% AEP immunity but will be inundated by up to 200mm near the tie in point to the existing Ironbong Road. 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 7.3 shows that the upstream side of the road is inundated, but the downstream side is flood free for the 1% AEP event in a section north of the proposed level crossing. 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.

In existing conditions Ironbong Road is the hydraulic control for the flood height upstream of the proposal. As the proposed road embankment is to be constructed offline this will create a new hydraulic control just downstream of the existing road embankment, obstructing flood flows and creating the afflux of 500mm between the two road embankments as shown in Figure 7.3. 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) but will actually result in a reduction in 1% AEP flood depths as can be seen in Figure 7.4.

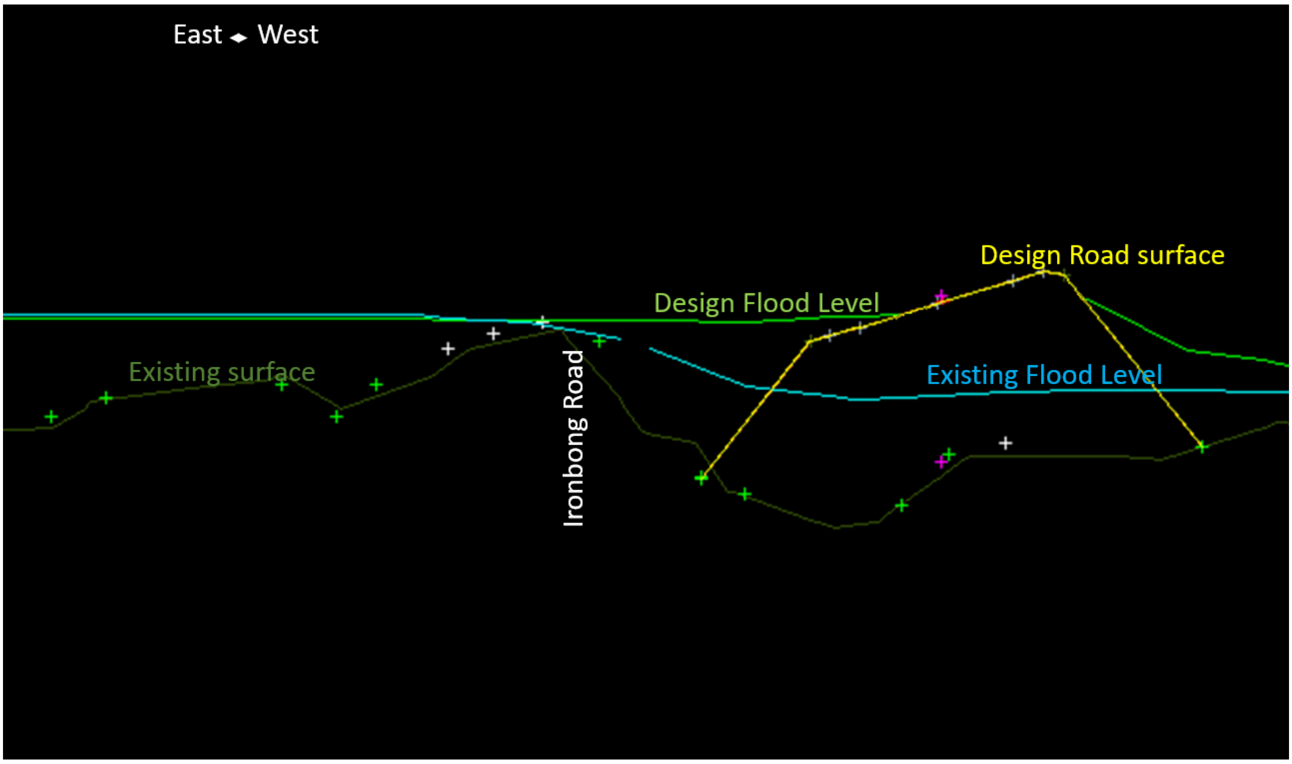

Figure 7.3 Cross section Ironbong Road (design in yellow)

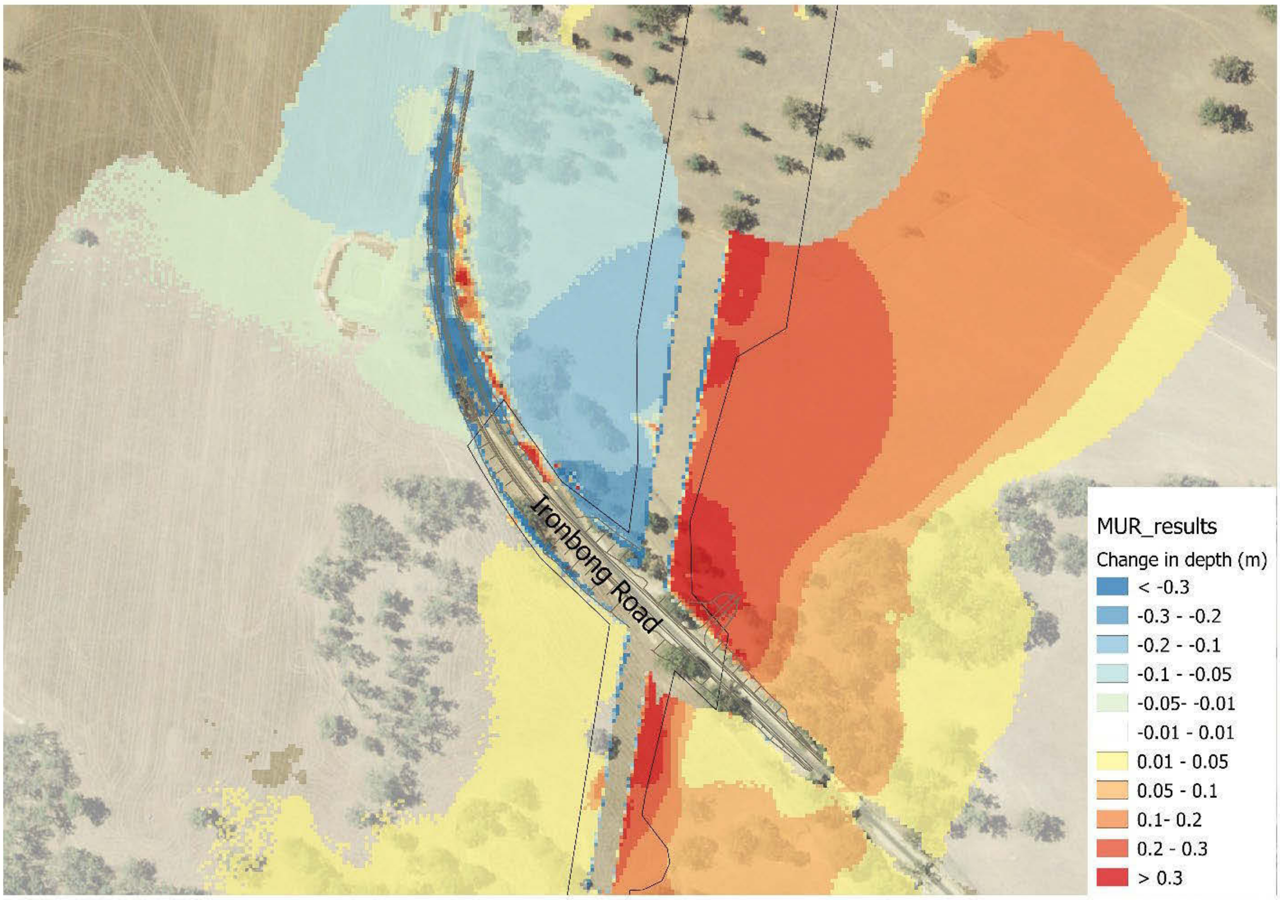

Figure 7.4 Change in peak flood depth for the 1% AEP at Ironbong Road and Ulandra Creek

7.2.4.3 Burley Griffin Way – Hibernia Street

The realigned Burley Griffin Way will provide a 1% AEP flood immunity to the intersection with West Street. Figure 7.5 shows that there will be a slight reduction in peak depths along Hibernia Street beyond the proposal boundary that will result in a reduction in flood hazard category for some sections from H2 to H1. The modelling also shows that Hibernia Street to the east of the proposal corridor now has a 2% AEP immunity through to Gerald Street which is an improvement on the current 10% AEP immunity (refer to Section 6.8.7). The modelling also indicates that there will be no change in duration for Hibernia Street for the 1% AEP flood event.

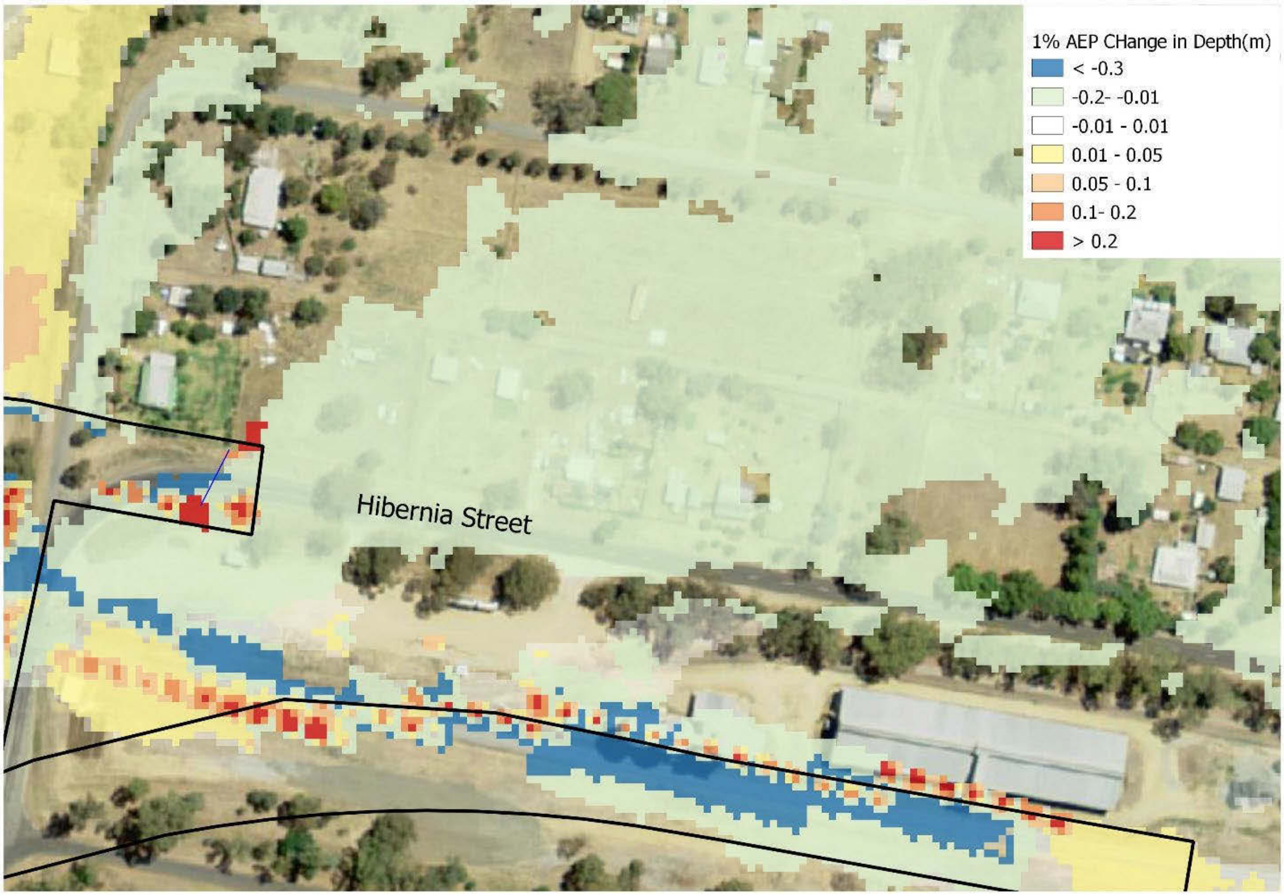

Figure 7.5 Change in 1% AEP flood depths for Hibernia Street

7.2.5 Scour and erosion impacts

All culvert inlets and outlets include scour protection to protect the structures from undermining due to scour during large flood events and reduce inlet and outlet velocities and prevent progressive erosion over time. The scour protection measures have been designed in accordance with industry standards, as described in section 4.4.2.2.

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 and dimensions of the culvert. The culvert rock aprons do not extend beyond the rail corridor but do extend along longitudinal drainage channels upstream and downstream of the culverts where necessary.

7.2.6 Culvert blockage factor sensitivity tests

As described in section 4.3.5, sensitivity tests were undertaken on culvert blockage to determine how flood impacts may vary with culvert blockage. Afflux maps for the 1% AEP event for blockage factors of 0% and 25% are provided in Appendix D. The results show the following:

- For the 0% blockage case the estimated 1% AEP peak flood levels are up to 200mm less across the entire proposal.
- For the 25% blockage case the estimated 1% AEP peak flood levels are ±10mm across the proposal. This is not unexpected as the estimated blockage from the ARR2019 approach resulted in blockages of 12.50% through to 25% across the proposal.

Given the influence of blockage factors on the predicted flood level, further testing at the detailed design stage is required to test the assumptions around the adopted blockage factors.

7.2.7 Emergency management

As discussed in section 6.8.8 the Cootamundra Local Flood Plan (SES June 2007) governs flood emergency management arrangements for the urban areas of Stockinbingal, but there are no specific flood emergency management procedures for the rural areas surrounding the proposal.

As discussed above, 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 will 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 will need to be prepared for the re-aligned Lake Cargelligo rail line and the Inland Rail line. It is noted that whilst the rail line will feature areas free of inundation in a flood event, the rail line does not provide a safe refuge area as train movements may continue during a flood event.

7.2.8 Impacts under extreme 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. For this event, the rail embankment, ballast and rail infrastructure was modelled as fully intact. This assumption will exaggerate the predicted flood level impacts of the proposal under this event as the ballast layers, and possibly some sections of the formation earthworks, may wash away under such conditions, which would act to equalise water levels across the rail corridor at the peak of the event. Extreme event flood mapping is included in the maps sets in Appendix C and Appendix D.

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.

At Stockinbingal, the existing Stockinbingal to Parks and Lake Cargelligo rail line are located downstream of the proposal in the Dudauman Creek floodplain. Neither of these lines will be removed as part of the proposal and they currently control the behaviour of flood heights and flows through the urban areas of Stockinbingal up to and including the PMF event. Washout of the proposed rail embankment has been assessed but it is noted that the existing Stockinbingal to Parkes line is assumed to remain in place.

The approach to understand the impact of washout has been to assume an embankment failure similar to a dam or reservoir. The Froehlich approach has been considered suitable to understand the potential breach width. It is noted the approach does not include any information on the proposed formation geotechnical design or materials used to build the formation. It also does not consider the geotechnical conditions of the existing Stockinbingal to Parkes rail formation. Using the Froelich equations several breach widths were estimated based on the design PMF flood model results and these widths were tested in the model to understand the changes to hydraulic hazard categories in the urban areas of Stockinbingal as a result of failure of the formation. Noting that the modelling assumed the existing Stockinbingal to Parkes rail formation remains in place and therefore breach flows would overtop the Stockinbingal to Parkes line or flow through the existing Dudauman Creek culverts. Refer to Appendix A for more details.

The results indicate that up to 11 properties in Stockinbingal will experience an increase in hydraulic hazard category as a result of a washout of the formation. Table 7.7 presents the existing and worst breach case results for the velocity depth product which informs the hydraulic hazard classification. It is noted that the estimated velocities following the breach are largely less than 1.0m/s. The increase is hydraulic hazard category is relatively small for most of the locations with only one location experiencing an increase of 22% which results in a hydraulic hazard category change to H3 which is considered unsafe for vehicles, children and the elderly. The four houses with an increase above 14% are located in the vicinity of Cambria Street. The increased risk to the community resulting from a washout is low but should be addressed through proper geotechnical design of the proposal formation and consideration of the geotechnical conditions of the existing Stockinbingal to Parkes rail formation.

Table 7.7 Washout Hydraulic Categories

Property type	Existing VxD (m^2/s)	Worst breach case vxd (m^2/s)	Percentage change (%)	Design velocity (m/s)	Existing hydraulic classification (m^2/s)	Estimated hydraulic classification (m^2/s)
House	0.55	0.61	11	0.68	<=0.6	<=1.0
House	0.27	0.33	22	0.72	<=0.3	<=0.6
House	0.56	0.64	14	0.98	<=0.6	<=1.0
House	0.53	0.63	19	0.76	<=0.6	<=1.0
House	0.90	1.03	14	0.83	<=1.0	<=4.0
House	0.58	0.61	5	0.80	<=0.6	<=1.0
House	0.58	0.61	5	0.92	<=0.6	<=1.0
House	0.60	0.62	3	0.80	<=0.6	<=1.0
House	0.29	0.31	7	0.61	<=0.3	<=0.6
House	0.58	0.60	3.5	1.06	<=0.6	<=1.0
House	0.59	0.61	3.4	1.41	<=0.6	<=1.0

For the remainder of the proposal a qualitative assessment of potential for overtopping of the rail has been undertaken based on the PMF results. This has identified the following locations at risk of overtopping and hence at risk of washout:

- Billabong Creek floodplain – during the 1% AEP, a section approximately 400m in length on the western side of the floodplain experiences overtopping with depths in the order of 0.2m. For the PMF event overtopping of the rail can occur over approximately 1.6km with depths the varying from 0.1m at the extents of the floodplain to depths of up to 2.5m in the immediate western overbank of Billabong Creek. It is further noted that there is a difference of about 2m in some locations in upstream and downstream water levels showing that the proposal, existing rail and Olympic Highway act as a significant barrier to flood flows during extreme events. Since there are no residential properties downstream of the proposal in the Billabong Creek floodplain no further assessment of the risk of washout was considered necessary at this stage.

- Powder Horn Creek – The PMF overtops the rail over approximately 230m on the eastern side of the main channel with overtopping depths in the order of a maximum of 0.1m. The rail provides a barrier to flood flow with water levels up to 2m higher on the upstream side of the rail as compared to the downstream side. The nearest residential house is 700m downstream and the urban area of Stockinbingal is over 1000m downstream of the proposal the risk was deemed minimal and no further assessment of washout was considered necessary at this stage for Powder Horn Creek.

While the risk of washout is confined to a small number of locations, the risk will need to be further investigated at the detailed design stage to determine the likelihood of embankment failure based on the geotechnical design and hydraulic parameters such as velocity and duration of overtopping.

7.2.9 Geomorphological impacts

The geomorphic impact assessment has focused on the changes to flood levels and velocities. Over time the ephemeral creeks and overland flow paths around the proposal have developed a channel form in equilibrium with historical flood levels and 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 will not change the contributing catchment areas to any of the creeks or overland flow paths (except for the localised diversion which is discussed in section 7.2.2.3) which means the magnitude and recurrence of flows and flood levels that have formed the channels and overland flows paths will not change.

The proposed culverts have been sized and located to minimise impacts on flood levels and velocities and for many of the culverts the change in flood levels and velocities is minor and local to immediately upstream and downstream of the culvert. Mitigation measures in the form of scour protection have been proposed to manage velocities around culvert inlets and outlets and within longitudinal drainage channels which will avoid high velocities at transitions from drainage infrastructure to the contributing and receiving channels and flow paths. It is predicted that there will be local impacts to overland flow path channels but no long-term changes to the geomorphic form of many of the overland flow paths intersected by the proposal.

The following sections provide the geomorphic impact assessments for creeks with bridges which also correspond to fish passage requirements. These named watercourses have also been classified under the NSW River Styles Framework.

7.2.9.1 Billabong Creek

As described in section 6.9.1, Billabong Creek has high fragility and is susceptible to change if the creek vegetation and contributing catchment are impacted, but it has moderate recovery potential. The proposal will not impact the contributing catchment, as there will be no change to the catchment area or the catchment land uses that currently influence runoff flows.

The proposal will include a bridge with round piers, the piers have been located out of the main low flow channel and the abutments have also been located out of the channel and provide the same width of flow as the downstream existing rail bridge.

The modelling results indicate that for the relatively more frequent events, the flood flows are confined to the channel and there is no increase in peak flood levels in the vicinity of the bridge or upstream of the bridge. Downstream of the bridge the peak water levels are reduced for the 0.2 EY event but not changed for the other events. For these events the maximum velocity in the channel is less than 1m/s and is not predicted to increase upstream or downstream in the channel with the proposal in place. For larger events the flood flows break out from the channel across the right overbank. The peak flood levels are expected to decrease slightly upstream for the 2% AEP and increase slightly for the 1% AEP. Velocities for these two higher events are generally less than 1m/s and are predicted to generally stay less than 1m/s or not change by more than 20%.

The proposal is expected to have negligible impact on geomorphology conditions downstream as the creek is already influenced by the existing rail and road bridges. Upstream of the proposal the expected impact to geomorphic conditions will be local as the low flow channel will not be obstructed by the proposal, there will be minimal removal of vegetation in the creek and there will be no changes to the flow regime as there will be no change to catchment conditions as a result of the proposal.

7.2.9.2 Ulandra Creek

Ulandra Creek has a high fragility which means this section of creek is susceptible to change if the creek vegetation and contributing catchment are impacted. But it has moderate recovery potential. Refer to section 6.9.2 for further information on the existing geomorphic conditions.

The proposal will include a bridge with round piers to cross the Ulandra Creek channel. The piers have been located out of the low flow channel to minimise impacts to flow and fish passage. The proposed bridge is 84m long with 56m clear of abutments which more than covers the 19m main channel width.

The topography indicates that the creek meanders both upstream of Ironbong Road and downstream of the alignment with the 0.2EY confined to the channel. The 10% AEP and greater events break out from the channel upstream of Ironbong Road and subsequently the proposal results in an increase in flood levels of up to 100mm across the floodplain both upstream and downstream of the proposal for up to 500m. Velocity changes across the range of flood events are minimal.

The inclusion of culverts under the proposal and new culverts under Ironbong Road result in minimal change to flood levels and velocity, however, given the fragility of the creek currently, it is possible that minor impacts on geomorphic conditions could occur downstream. It is noted that there will be no change to catchment conditions so the frequency and volume of channel forming flows will not change. Upstream of the proposal the expected impact to geomorphic conditions will be localised and only continue as far as Ironbong Road. Upstream of Ironbong Road the creek form is influenced by existing land use practices and the Ironbong Road culverts. The connection of the main channel to the floodplain will not be impacted due to the location of the bridge so changes to geomorphic conditions will be local and not propagate too far downstream.

7.2.9.3 Run Boundary Creek

Run Boundary Creek has an ill-defined channel with low fish passage potential and is considered to have high recovery potential.

The proposal will cross the creek with a bridge on round piers. The bridge piers will be well clear of the creek channel at the crossing point but the channel is not well defined so parts of the embankments may encroach into the floodplain for the creek.

The flood modelling results indicate no change to peak flood levels for the 0.2 EY and 10% AEP events. For the larger events there is a minor increase in peak flood levels upstream of the proposal which dissipates within 100m of the bridge and no change in peak flood levels predicted for downstream of the proposal. There are no predicted changes to velocities where velocities are above 1m/s.

The proposal is expected to have a minor impact on the geomorphic conditions in Run Boundary Creek. There will be no changes to the frequency or peak flood flow magnitudes that form the channel. Peak velocities are only predicted to change at the bridge opening where scour protection measures will be in place. 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 will be local as the key channel forming influences of flow, velocity and frequency will not change.

7.2.9.4 Isobel Creek and Tributary

Isobel Creek and its tributary are both well-defined channels with fish passage potential. It has moderate fragility which means its geomorphic conditions will only change locally but it has little potential to recover when impacted.

The proposal will cross both creeks with a bridge on blade piers with round ends. For both crossings the piers will be clear of the main creek channel as will the abutments.

With the proposal out of the main creek channel for both watercourses it is expected that the impact to geomorphic conditions will be minor. There are minor changes to peak flood levels or velocities in the vicinity of the proposal but no changes to catchment areas or the frequency of flooding. This indicates the impact to the geomorphic condition will be local. It is noted that downstream of the proposal Isobel Creek is crossed by an unformed road which would also impact geomorphic condition. It is therefore likely that if changes occur this road would be the limit of the changes. Upstream of the proposal the creeks become overland flow paths with no vegetation and several farm dams across the catchment. The upstream land uses will have the largest impact on geomorphic form for Isobel Creek and tributary.

7.2.9.5 Powder Horn Creek and Tributary

Powder Horn Creek and its tributary are both meandering creeks in poor condition and realigned in some reaches with minimal potential for fish passage due to being impacted by land uses and clearing of vegetation across its catchment both upstream and downstream of the proposal. The channels have moderate fragility and are susceptible to change with significant erosion already evident.

The proposal will include bridges with round piers across the main channel and floodplains for both the creek and tributary. The abutments have also been located out of the floodplain extents to minimise impacts.

Given the current eroded condition of the existing channels, it is predicted that geomorphic conditions will change as a result of the proposal. The modelling indicates localised changes to peak flood height for the 0.2 EY to 1% AEP flood event upstream of the proposal. These impacts are confined to within 50m of the proposal and along the proposal at the bridges and between them. There is no predicted change to peak flood levels downstream of the proposal. Peak velocity changes are also predicted to be local to the bridges with no changes modelled upstream or downstream of the proposal for the range of flood events.

The predicted changes to geomorphic conditions are likely to be increased erosion within the channels of the creek and tributary watercourse due to the increased velocities predicted at the bridge. These changes may propagate upstream but will 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 downstream are likely to be minimal and contained to the area immediately downstream of the proposal.

7.2.9.6 Dudauman Creek and Tributary

As presented in section 6.9.8 Dudauman Creek and tributary have been channelised and realigned and are in a poor condition with minimal potential for fish passage.

The proposal will cross the watercourse with a bridge with round piers and embankments out of the main flow channels as identified by the flood modelling. The proposal does not impact the main creek channel except for the bridge crossing immediately upstream of the Stockinbingal to Parkes rail culverts.

The flood modelling has predicted 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 will be no change to the overall contributing catchment but there will be a localised redistribution of flows between Burley Griffin Way and the existing Lake Cagelligo rail line. The extent of impact to geomorphic conditions will 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 will be confined to the Stockinbingal to Parkes rail line and potentially a small section of the channel downstream. 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.

7.2.10 Surface water availability and supply

The proposal has included sufficient waterway bridges and culverts to maintain existing flow paths and therefore not impact local surface water supplies. One diversion drain is proposed, and its impacts are discussed in section 7.2.2.3 in detail. The impacts of this diversion drain are localised and will not affect water supply.

There are also no expected impacts to environmental water availability as the proposal will not be capturing or storing water permanently. Refer to section 7.2.2.3 for the discussion on flow distribution. As described in section 6.7.1 it is unlikely that there are Water Access licences in the proposal vicinity and the operation of the proposal will not require permanent water supply. It is therefore determined that there will be no impacts to licences across the proposal study area.

7.2.11 Consistency with relevant policy and guidelines

The flood models developed for the proposal are described in section 4.3 and Appendix A and are consistent with the industry guideline 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).

As outlined in section 2.3.1, the Cootamundra Local Environmental Plan 2013 is the relevant local planning regulation, Part 6, Clause 6.2 Flood Planning. The proposal will not impact any planning provisions outlined in this plan. It is noted that the NSW Floodplain Development Manual (DIPNR, 2005) is the key flood planning tool for managing flood risk in Stockinbingal.

The Stockinbingal Floodplain Management Study and Plan (SMEC, 2002) proposed 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 millimetres 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 will therefore have no significant impact on the extent of the flood planning area and therefore the area of land to which the flood planning controls would apply.

The proposal works will largely be confined to upstream of the existing hydraulic control which is the existing Stockinbingal to Parkes rail line and would not limit or preclude the potential future levee bank works proposed for downstream of West Street.

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 Government, 2019 has been considered in this assessment and site specific data and recommended methods for regional flood frequency analysis (RFFE) have been adopted. This manual applies to all flood prone land where specific plans are not available such as in Stockinbingal. This manual indicates that development of flood prone land should be commensurate with the flood hazard and flood function of the land. As outlined in section 7.2.2.6 the design has considered the flood hazard and flood function of the land through the placement and size of hydraulic structures.

7.2.12 Social and economic impacts

During times of drought, rainfall and flood events are considered positive events for rural communities and landowners. Rainfall can be collected in farm dams and stored for later use and overland and flood flows provide direct moisture to paddocks and vegetation. Lack of rainfall and loss of overland and flood flows to fill dams and water storages is considered more detrimental to the economic use of the land and catchments surrounding the proposal. Consultation with landowners indicated that maintenance of flow to farm dams is considered essential.

A key outcome of the landowner meetings was the need to include individual farm surface water management systems in the form of farm dams and contour banks. Existing farm contour banks have been included in the assessment and the assessment indicates that only one contour bank will be impacted by the proposal.

The proposal has been designed to maintain all but one overland flow path (refer to diversions at Chainage 16.0km) which should therefore minimise the impact to farm dam flows.

Refer to Technical Paper 11 – Social and Technical Paper 12 – Economic for further discussion.

8 Mitigation and management measures

8.1 Approach to mitigation and management

Environmental management for the proposal would be carried out in accordance with the approach detailed in Chapter 27 (Approach to environmental management and mitigation) of the EIS. This would include a soil and water management sub-plan, prepared as part of the Construction Environmental Management Plan (CEMP) and an operational environmental management framework (EMF).

Design measures have been developed during the development of the reference design to manage the impacts of the proposal. Such measures are described in the following section.

8.1.1 Proposed design measures

The design of the drainage features including culverts and diversion channels have been included in the flood models and been provided to inform the overall reference design. The models are based on the available LIDAR and detailed survey as described in section 4.3. Further detailed survey of the proposal corridor should be collected to refine the reference design of the culverts, drainage channels and scour protection at the detailed design stage.

8.1.1.1 Afflux at buildings

As described in section 7.2.3 there is a predicted increase in peak flood level above the QDL criteria for two non-residential buildings. These properties occur downstream of the proposal. The nature of flooding downstream of the proposal is affected by Council and/or landowner levees along the main Dudauman Creek channel between the Stockinbingal to Parkes line through to Grogan Road.

Adjustments to culverts and longitudinal drainage channels at the Dudauman Creek crossing and local solutions to balance flows around the proposal are likely to reduce these impacts to below the QDL criteria.

8.1.1.2 Culverts

The culverts have been sized to provide sufficient capacity to convey the 1% AEP flood event, ensure the formation is above the 1% AEP peak flood level and ensure changes to flood behaviour are minimal and within the Qualitative Design Limits. The number of culverts at each flow path were iterated and results reviewed for the full range of events up to the 1% AEP event. It is anticipated that detailed survey of the proposal corridor will improve topographic definition around the proposed culvert locations and allow for refinement during detailed design.

8.1.1.3 Scour protection

Scour and erosion protection measures have been incorporated into the design in areas determined to be at risk, such as around culvert headwalls and drainage discharge pathways. All scour protection will be within the proposal corridor as the corridor has accounted for standard scour protection measures. Should additional scour protection be required beyond the proposal corridor then it is anticipated that this would be negotiated with the land owner and a suitable range of mitigation measures agreed.

At risk locations were identified as locations where the outlet culvert velocities are at a velocity of greater than 0.5m/s. The design of the scour protection at the outlet to culverts has been in accordance with Austroads Guide to Road Design Part 5: Drainage – General and Hydrology Considerations.

There are a number of locations beyond the proposal boundary where there is a predicted increase in velocity above the QDL. At these locations, soil testing will be undertaken to establish a site specific ETV which may be higher than the current adopted value of 0.5m/s. Soil testing will inform refinement of the design of the longitudinal channels, and scour design to suit the existing conditions and reduce this impact. Site specific scour design may need to include rock lined channels with check dams to slow the flows to below acceptable levels but it is anticipated that this would be negotiated with the landowner and a suitable range of mitigation measures agreed at the detailed design stage.

Scour protection has been included in the flood models as a rougher surface area and the following examples show that the proposed scour measures are effective at these locations at reducing the velocities at the proposal boundary. Figure 8.1 to Figure 8.3 show both flat and steep locations across the proposal.

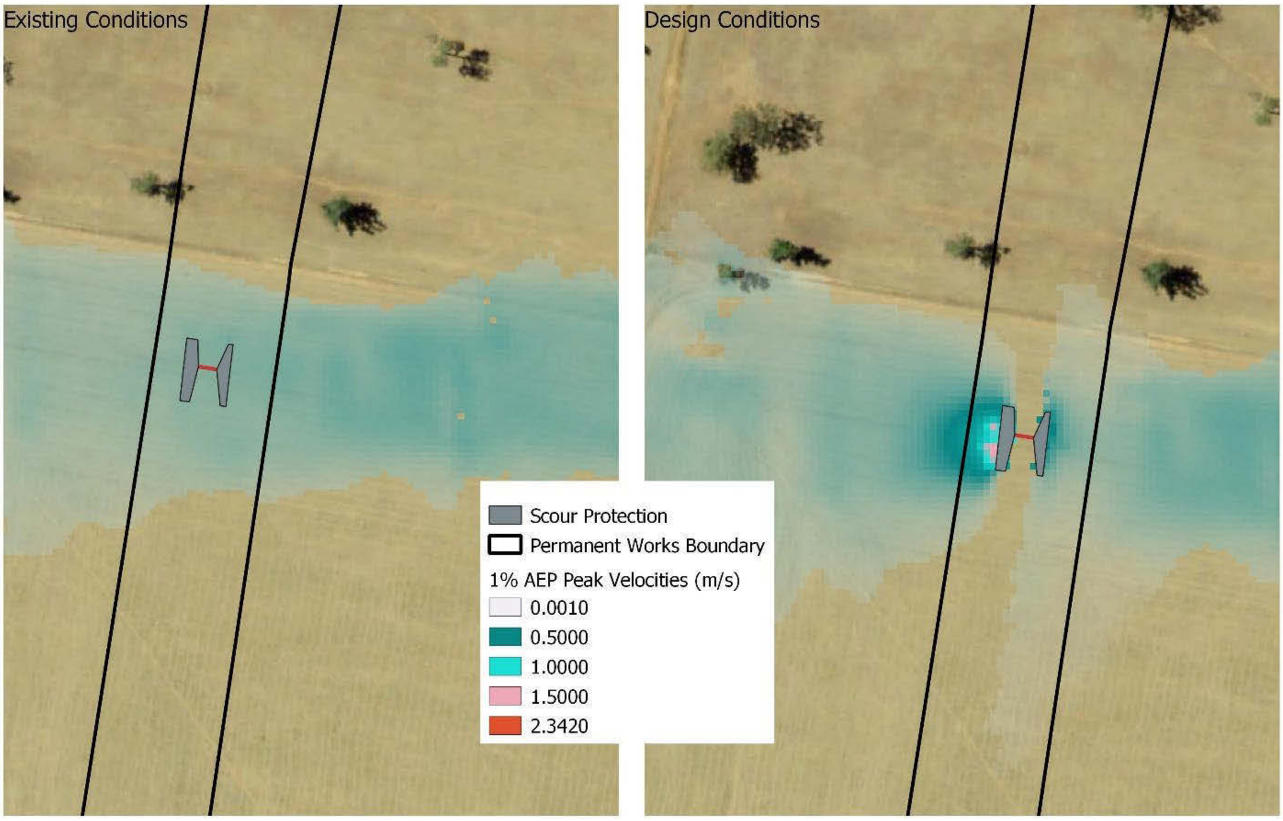

Figure 8.1 Peak 1% AEP velocities and scour protection at CH6.9km (flat) (Murrumbidgee)

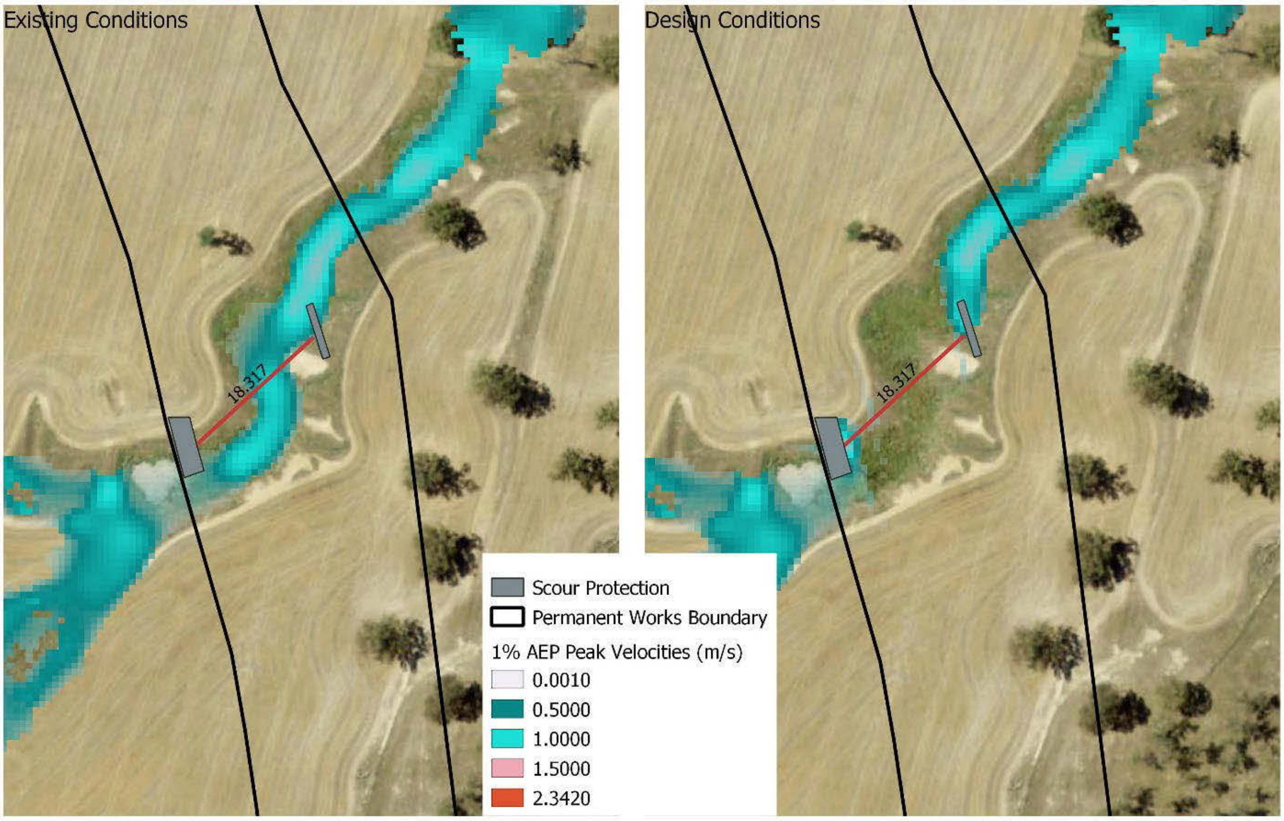

Figure 8.2 Peak 1% AEP velocities and scour protection at Chainage 18.3km (steep) (Murrumbidgee)

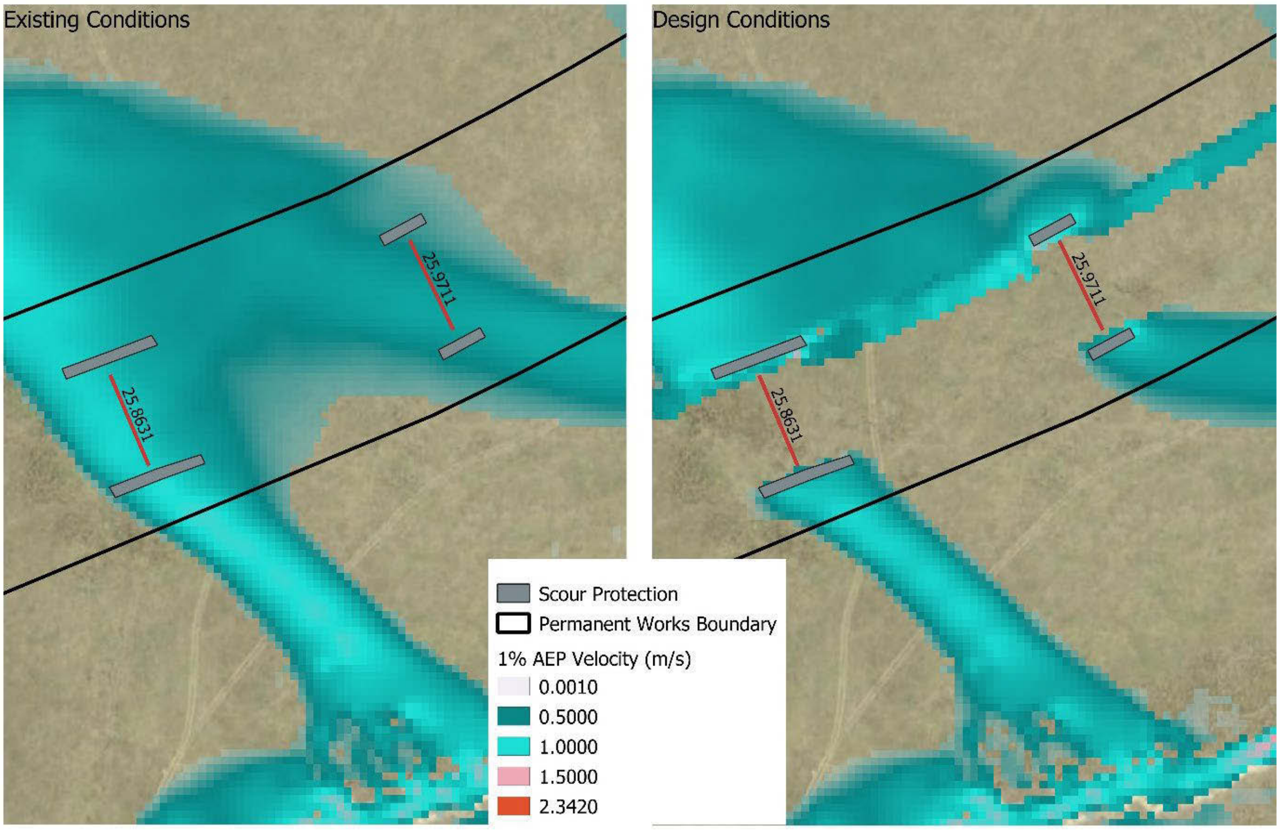

Figure 8.3 Peak 1% AEP velocities and scour protection at Chainage 25.8km (steep) (Lachlan)

8.1.1.4 Diversion drains

For the diversion channels in the Dudauman Creek floodplain options for managing these overland flows were considered and included storage and/or diversion channels. Storage has been proposed at the eastern end of the diversion channel to compensate for the loss of floodplain storage in the vicinity of the realigned Burley Griffin Way. The diversion channels and storage basin connect to a culverts under the realigned Burley Griffin Way that balance the flows and minimise the impacts of flooding to the urban areas of Stockinbingal. The alignment of the channels was located clear of the base of the Burley Griffin Way embankment and the proposal – Lake Cargelligo Line turnouts on either side of the Burley Griffin Way bridge. The channel location and preliminary sizing were undertaken to meet the QDLs for afflux through the urban areas.

8.1.1.5 Duration

The design has located culverts and bridges at all overland flow path locations and defined waterways to minimise impacts to the duration of inundation. There are minor localised areas where durations have increased above the QDL due to the proposal obstructing overland flow paths. These changes occur across land that is already subject to inundation and the increase will not impact grazing practices across the land.

Detailed survey of the dams and watercourses at the locations where increases occur could be used to inform the detailed design of drainage for the proposal. This would also assist with understanding the site specific water storage management for the property and how the additional duration could be managed on a site by site basis.

8.1.1.6 Hazard

The velocity depth product which defines the flood hazard is impacted by the proposal in a few locations and described in section 7.2.2.5. The impacts are largely due to increases in velocities and scour protection has been included to reduce velocities to within the QDL criteria. Detailed design could include a combination of scour protection measures to reduce velocities, depths and hazard to below the QDL criteria.

8.2 Summary of mitigation measures

The mitigation measures to manage impacts to flooding and surface water management from the proposal during detailed design/pre-construction, construction and operation are outlined in Table 8.1.

Table 8.1 Proposal-specific mitigation measures for flooding and surface water management

Issue/impact	Mitigation and management measure	Project phase
Flooding impacts	The design would continue to be refined where practicable to not worsen existing flooding characteristics at sensitive receptors, up to and including the 1% Annual Exceedance Probability (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, Industry and Environment, the NSW State Emergency Service and potentially impacted landholders.	Detailed design/ pre-construction

Issue/impact	Mitigation and management measure	Project phase
	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.	
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 utilize 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
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
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; and • 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.	Construction
Sedimentation and erosion management	A soil and water management plan would be prepared and implemented as part of the CEMP. 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
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
Management of flood emergency risks beyond the rail corridor	To mitigate flood risks to life or property beyond the rail corridor along 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

9 Conclusion

The Illabo to Stockinbingal portion of the Inland Rail proposal traverses the upper reaches of the Murrumbidgee and Lachlan catchments. The study area is characterised by small, short steep catchments with scattered farm dams that flatten out into agricultural land used for grazing and cropping. Fifty seven overland flow paths and upper catchment waterways have been identified as intersecting the proposal, but none contained permanent water. The named waterways include Billabong, Ulandra, Run Boundary and Isobel Creeks in the Murrumbidgee catchment and Powder Horn and Dudauman Creeks in the Lachlan catchment.

Hydrologic and hydraulic models have been built to understand flood behaviour across the proposal. The XP-RAFTS hydrologic and hydraulic TUFLOW models were verified with the use of the Regional Flood Frequency Estimation tool. The model also underwent a peer review that deemed the models suitable for the Reference design and primary approvals assessment and identified that a review of the timing and volume of flows and culvert blockage to be completed at detailed design.

The proposal includes bridges and box culverts at as many overland flows paths as possible, pipe culverts for deep fill embankments and one diversion of overland flows away from a cutting. The proposal has been designed to minimise impacts to within acceptable limits, to meet the proposal Basis of Design and proposed Quantitative Design Limits (QDLs). The QDLs for afflux, change in velocity, flood flow distribution, flood duration, flood hazard, surface water supply and geomorphologic changes have largely been met through the reference design except at a few isolated locations.

The flood modelling identified the complexity of flood behaviour in Dudauman Creek between Burley Griffin Way and the urban areas of Stockinbingal. The existing multiple culverts, bridges and flood levees guide flood flows in this area but detailed topographic survey is required to fully understand the flood behaviour and risks in the area. Flood modelling of the construction staging will be essential to understanding and managing the temporary changes in flood behaviour in the Dudauman Creek floodplain. The Reference Design has been developed so that it meets the proposed QDLs downstream of the proposal through Stockinbingal. There are also areas of non-compliance in the vicinity of the realigned Burley Griffin Way, Lake Cargelligo line and Inland Rail line. Further topographic survey and design development is required to minimise impacts and/or develop a strategy to deal with changes to flood behaviour of the land. The area impacted is in and around the Dudauman Creek channel and is predominantly used for agricultural purposes and impacts have the potential to affect the agricultural productivity of the land. Local flood emergency management measures will need to be updated to consider all changes to flood behaviour and manage flood events for the land near the proposal.

Mitigation of the impacts has been incorporated into the design through the preference for bridges across fish passage waterways and box culverts to convey overland flows. Scour protection measures have been proposed to reduce velocities and round and rounded blade piers for bridges to manage velocity impacts and associated impacts on geomorphology.

10 References

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