APPENDIX

E

Flood Study Report

IR_1432

Technical and Approvals Consultancy Services: Narrabri to North Star

Flood Study Report

Submissions and Preferred Infrastructure Report

August 2019

3-0001-260-IHY-00-RP-0005

Prepared for

Australian Rail Track Corporation

Prepared by

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Document Information

Document information	
Report Title	Flood Study Report
Subtitle	Submissions and Preferred Infrastructure Report
Document Number:	3-0001-260-IHY-00-RP-0005
Filename	3-0001-260-IHY-00-RP-0005_B Flood Study Report – Submissions and Preferred Infrastructure Report
Date	August 2018

Rev	Date	Details
A	29/01/2019	Initial draft for ARTC review based on 70% design (previously supplied as 3-0001-260-IHY-00-RP-0003)
B	16/08/2019	Updated draft for ARTC review based on IFC design

Revision details

Revision details				
Prepared by	Kate Stephens	Date: 16/08/2019	Signature:	
Reviewed by	Rob Leslie	Date: 16/08/2019	Signature:	
Approved by	Richard Bromilow	Date: 16/08/2019	Signature:	

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Glossary

1D	One dimensional
2D	Two dimensional
4SBC	4-Sided Box Culvert
AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARTC	Australian Rail Track Corporation
ARR2016	Australian Rainfall and Runoff 2016
BoD	Basis of Design
CoA	Conditions of Approval
DEM	Digital Elevation Model
EIS	Environmental Impact Statement
EY	Exceedances per Year
FFA	Flood Frequency Analysis
FMO	Flood Management Objectives
FLC	Form Loss Coefficient
GIS	Geographic Information System
HPC	Heavily Parallelised Computations
HQ	Flow Boundary
IL	Initial loss (rainfall) – a RAFTS model parameter
IR	Inland Rail
IRDJV	Inland Rail Design Joint Venture – A joint venture of WSP Australia and Mott MacDonald set up to deliver the design for the project
IFD	Intensity-Frequency-Duration
Kc	The flood routing parameter ‘kc’ is the principal parameter within RORB and is a function of catchment area, catchment non-linearity and discharge
LX	Level Crossing
LiDAR	Light Detection and Ranging
mAHD	Metres above Australian Height Datum

MCA	Multi-Criteria Analysis
N2NS	Narrabri to North Star
QT	Time Boundary
RFFE	Regional Flood Frequency Estimation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RAATM	Requirements Analysis, Allocation and Traceability Matrix
RMS	Roads and Maritime Services
RORB	An industry standard hydrologic modelling software program
SPIR	Submissions and Preferred Infrastructure Report
SRTM	Shuttle Radar Topography Mission
TIN	Triangular Irregular Network
TOF	Top of Formation
TUFLOW	Water Flow Modelling Software (www.tuflow.com)

1 Introduction

1.1 Background

The Australian Government has undertaken to deliver the Melbourne to Brisbane Inland Rail, as a vital piece of infrastructure to complete the National Freight Network and to provide for a significant modal shift of freight from road to rail. On behalf of the Department of Infrastructure, Transport, Cities and Regional Development, Australian Rail Track Corporation (ARTC) has been tasked with preparing a 10-year delivery strategy for Inland Rail.

The Narrabri to North Star (N2NS) section of Inland Rail is predominantly a brownfield upgrade project, extending from 575.000km to 760.460km on the existing line within the ARTC network between Narrabri and North Star. The rail line is a single bi-directional track, running a variety of freight, grain and passenger trains.

This report documents the flood modelling and cross drainage hydraulic design undertaken to support the Submissions and Preferred Infrastructure Report (SPIR) for the project. This document and the SPIR addresses Phase 1 of the project, which covers the project area outside the Gwydir-Mehi regional river and floodplain system. Phase 1 covers 169.46km of rail corridor and extends from 575 to 666km and from 682 to 760.46km.

Phase 2 covers the 16km of rail corridor that runs through or adjacent to the Gwydir-Mehi river and floodplain system and extends from south of the Mehi River at approximately 666km to beyond the Camurra Bypass at 682km. Phase 2 is subject to a separate environmental approvals process and is outside the scope of the SPIR and this report.

1.2 Scope

This report assesses flood behaviour within the local catchments crossed by Phase 1 of the project, within the Namoi, Gwydir and Macintyre River basins, including estimates of flood levels and velocities for existing and design conditions for the 39, 10, 1 and 0.05% Annual Exceedance Probability (AEP) events and the 1% AEP event with allowance for climate change.

The report documents the SPIR flood modelling analyses for Phase 1; the hydraulic design of cross drainage structures based on the flood modelling; and assessment of the compliance of the design with flood management objectives (or flood impact limits) currently assumed for the project.

1.3 Objectives

The objectives of this Flood Study were as follows:

- Establish a set of hydrological and hydraulic models for the project area that make best use of all available data and are sufficiently accurate to inform the SPIR;
- Define the baseline or existing flooding conditions within the catchments, adjacent to the project area and predict the impact of the project on these flood conditions;
- Inform the selection of the minimum required flood immunity of the upgraded rail formation, by providing input to ARTC's Flooding Multi-Criteria Analysis (MCA) process that informs ARTC's business decision on rail flood immunity; and
- Design the cross drainage systems for the upgraded rail corridor, to achieve the required minimum rail formation flood immunity and meet flood management objectives for land adjacent to the rail corridor.

2 Project Description and Study Area

2.1 Project Description

The project consists of approximately 186km of upgraded rail track, including a 3km greenfield re-alignment to remove the existing Camurra Hairpin and associated infrastructure. The project is located along the existing rail corridor between Narrabri and North Star and passes through Moree. The southern 15km of the project is located within part of the Namoi River Basin, the middle 119km crosses the Gwydir River Basin and the northern 51km is located within part of the Border Rivers Basin.

2.2 Study Area

2.2.1 Catchment Overview

While the corridor lies within these three major river basins, it only lies directly within one major river, the Gwydir River, north of Moree. The section of rail extending approximately 16km from Moree is subject to regional scale flooding from the Gwydir River. The remainder of the project corridor is subject to the local catchment flooding processes, of minor (and predominantly ephemeral) watercourses and their tributaries that feed into the larger regional scale rivers. These watercourses include:

- Namoi River Basin:
  - Spring Creek; and
  - Bobbiwaa Creek.
- Gwydir River Basin:
  - Galathera Creek;
  - Ten Mile Creek;
  - Boggy Creek;
  - Gehan Creek;
  - Tookey Creek;
  - Waterloo Creek;
  - Little Bumble Creek;
  - Gurley Creek;
  - Tycannah Creek;
  - Clarks Creek;
  - Halls Creek; and
  - Marshalls Ponds Creek and several tributaries.
- Border Rivers Basin (Macintyre River Catchment):
  - Gil Gil Creek; and
  - Croppa Creek.

Beyond the rail corridor, the project area and surrounding land is mostly cleared for agricultural purposes, particularly cotton, wheat and livestock. Small pockets of uncleared native vegetation have been retained in the form of National Park or State Forest, within the contributing catchments. Moree is the largest urban area within the project area and project and passes through other smaller developed areas such as Edgeroi, Bellata, Gurley, Croppa Creek and North Star. The project passes through intensively farmed areas within the Gwydir Basin north of Moree, which contains significant irrigation channels and levees. Further information on the study area can be found in the EIS Technical Report 6: Hydrology and Flooding Assessment (GHD, 2017).

2.2.2 Study Area Breakdown

For the purposes of this flood study, the project has been broken into six discrete sections within Phase 1:

- Namoi River Basin:
  - Covered by the hydraulic model NAMOI01 from 575km to 590km;
- Gwydir River Basin: Covered by the following three separate hydraulic models:
  - GWYDIR01 from 590km to 619km;
  - GWYDIR02 from 619km to 666km; and
  - GWYDIR03 from 682km to 709km.
- Border Rivers Basin (Macintyre River Catchment): Covered by the following two separate hydraulic models:
  - MACINTYRE01 from 709km to 727km; and
  - MACINTYRE02 from 727km to 760.460km.

Refer to Figure 2.1 and Figure 2.2 for an overview of the study area and model breakdown.

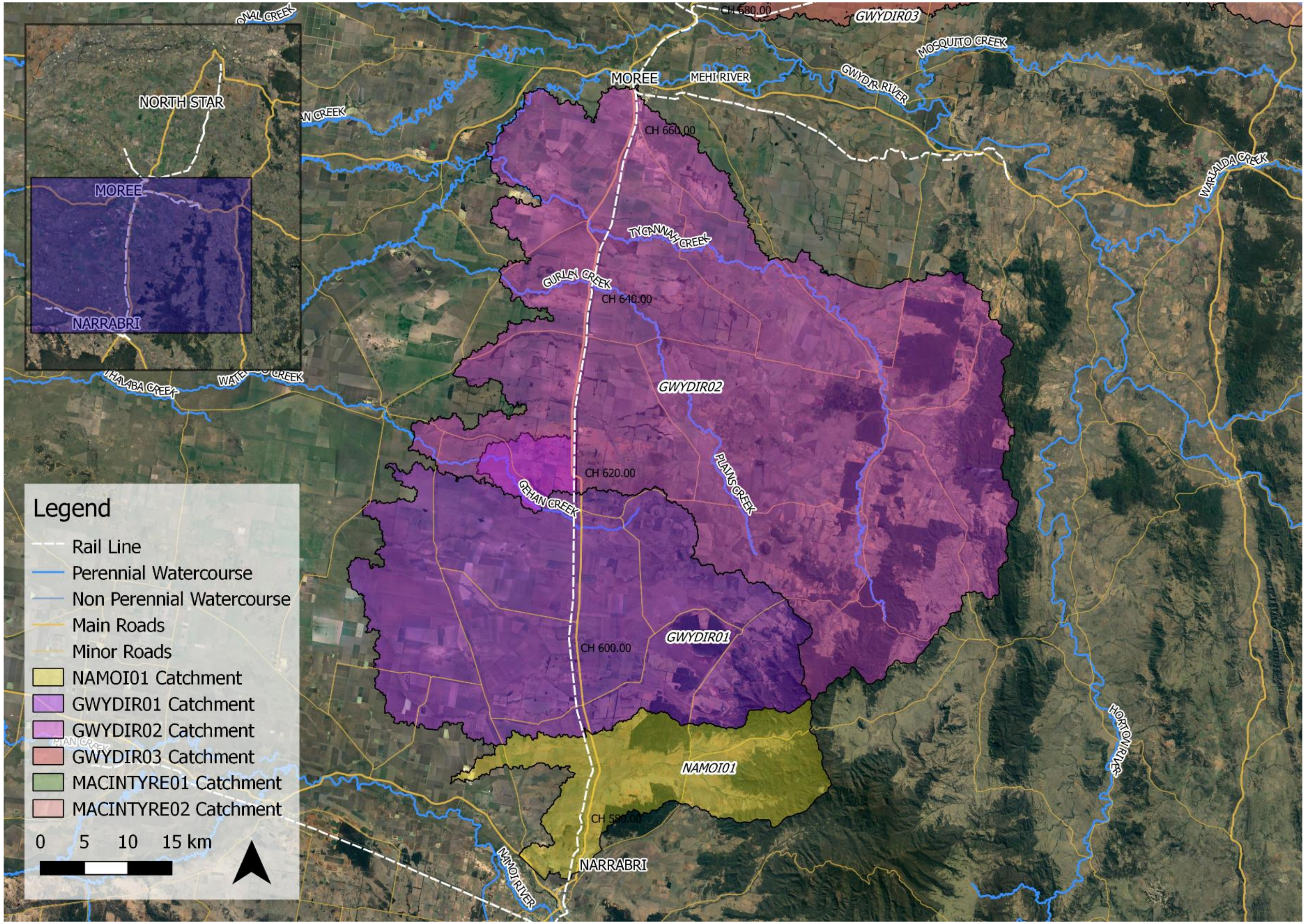

Figure 2.1 N2NS study area and extent of NAMOI01, GWYDIR01 and GWYDIR02 flood models

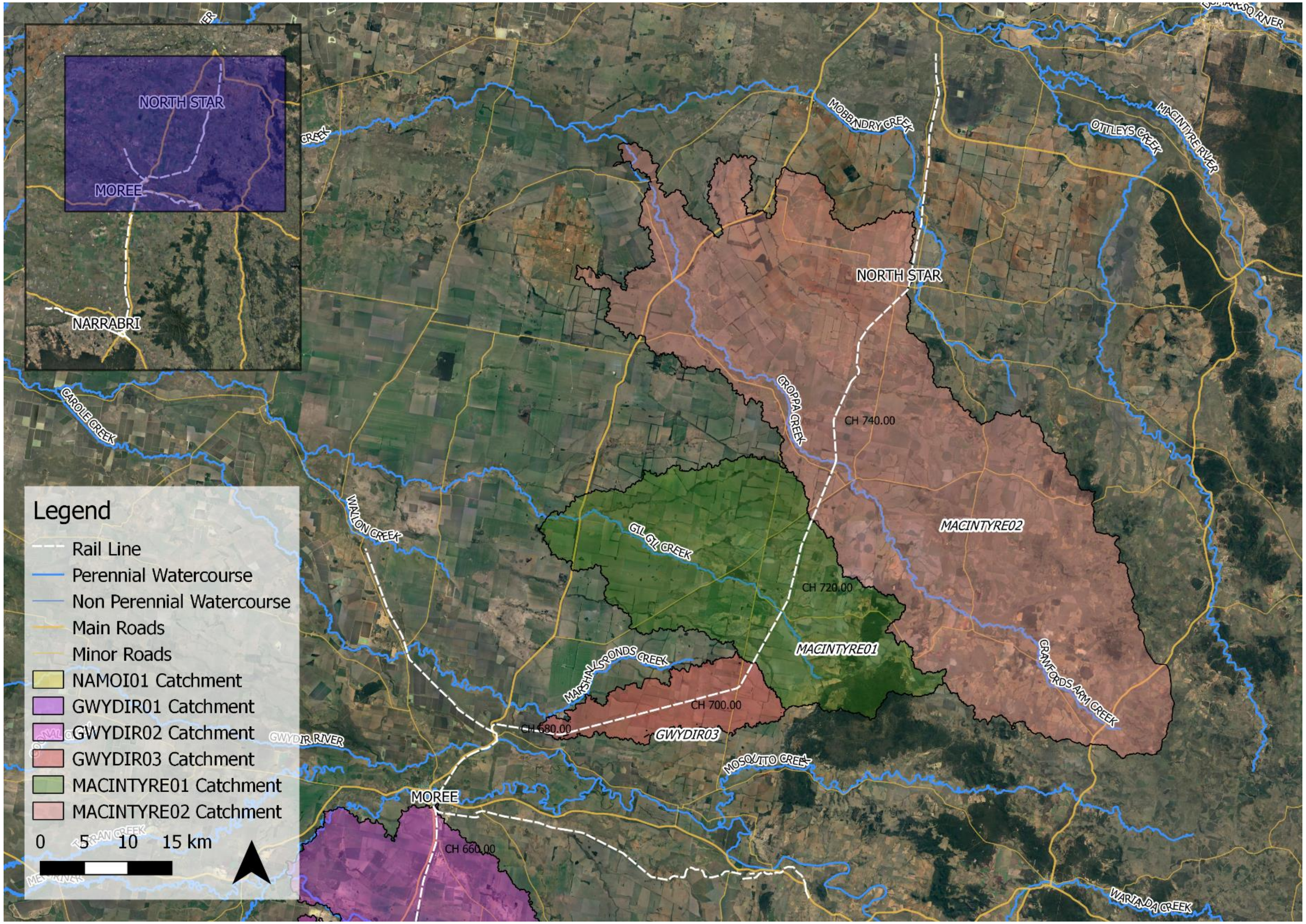

Figure 2.2 N2NS study area and extent of GWYDIR03, MACINTYRE01 and MACINTYRE02 flood models

2.2.3 Catchment Descriptions

The project area is bounded by the regional floodplains of the Namoi River at the southern end, the Border Rivers at the northern end and is located within the Namoi, Gwydir and Border River basins. While the project area is located outside of the regional floodplain of the Namoi and the Border Rivers, the middle section of the project, which constitutes Phase 2 and is not within the scope of this report, lies within the regional floodplain of the Gwydir River. Phase 1 is located within local upland catchments of the Namoi, Gwydir and Border River basins and does not interact with regional river systems.

2.2.3.1 Namoi River Local Catchments

At the southern end of the project, there is no direct interaction with the Namoi River regional floodplain and the project is not impacted by regional scale flooding. The rail alignment is located within the upper portion of the Namoi River catchment. Approximately 15km of the rail line lies within the Namoi River catchment and generally runs in a northern direction from Narrabri towards Edgeroi alongside the Newell Highway. The design rail alignment in this section is a brownfield upgrade of the existing corridor.

The flood behaviour in this area is predominantly local overland flow, with majority of the upstream catchments taken up by farmland. The flood immunity for the existing rail formation within the NAMOI01 hydraulic model area, is estimated to be less than the 10% AEP event in some localised low points, and greater than the 1% AEP event in other areas where shallow overland flow is the predominant flood behaviour.

2.2.3.2 Gwydir River Local and Regional Catchments

The rail alignment is located within the upper portions of the Gwydir River catchment and crosses upper tributaries / local catchments of the Gwydir system for approximately 100km of the alignment. The rail line crosses and runs adjacent to the regional floodplain of the Gwydir River over approximately 20km, crossing the main river channel just north of Moree. The rail generally runs in a north-south direction, passing through Moree and generally following close to the Newell Highway. North of Moree, the rail passes through the ‘Camurra Hairpin’, turning and continues to the north east. The design rail alignment within the Gwydir River Catchment is predominantly a brownfield upgrade, however, there is a 3km greenfield section to bypass the Camurra Hairpin.

The flood behaviour in the Gwydir local catchments is predominantly local overland flow, with majority of the upstream catchments taken up by farmland. The flood immunity of the existing rail formation within the Gwydir River catchment ranges from less than the 10% AEP event in some areas, and to greater than the 1% AEP event in other areas.

2.2.3.3 Macintyre River Local Catchments

The northern 50km of the existing rail alignment crosses through the Gil Gil and Croppa Creek local catchments, which feed into the Boomi River, in which forms part of the Macintyre River catchment within the Border Rivers Basin. The rail alignment in this location generally runs in a north-easterly direction, into North Star. This section lies outside of the Macintyre regional floodplain and is therefore not impacted by regional scale flooding in this basin.

The flood behaviour in this area is predominantly local overland flow, with majority of the upstream catchments taken up by farmland. As for the other sections of the project, the flood immunity of the existing rail formation ranges from less than the 10% AEP event to greater than the 1% AEP event.

2.3 Previous Studies and Data

Refer to the Hydrological Calibration Report in Appendix E for details of the previous studies and data that were used to inform this flood study.

3 Design Criteria, Assumptions and Inputs

3.1 Design Criteria

The flood study and cross drainage design have been undertaken in accordance with the ARTC Basis of Design (BoD), and Requirements Analysis, Allocation and Traceability Matrix (RAATM) for the Inland Rail Program. A summary of the key design requirements with respect to flooding are documented in this section.

3.1.1 Flood Management Objectives

Flood Management Objectives (FMOs), or impact criteria, have not yet been established for the project, however, it is expected that these will be provided as part of the Conditions of Approval (CoA) following determination of the EIS and the SPIR. In the interim, IRDJV have agreed a working set of FMOs with ARTC based on the adjacent land use, the commitments of the EIS and previous experience of similar projects. The adopted FMOs are provided in Table 3.1. The FMOs are considered to apply to all flood events up to and including the 1% AEP event.

Table 3.1 Flood Management Objectives

Afflux	**Location**	**Maximum allowable afflux**
	Residential and commercial buildings	50mm (10mm limit for above floor level flooding)
	Cropping paddocks	200mm
	Stock paddocks	200mm
	Newell Highway	50mm
	Other roads	100mm
	Public infrastructure (pump stations, sewage treatment plants, health services etc.)	50mm (10mm limit for above floor level flooding)
Flood velocity	**General criteria**	**Applicable land uses and other specific criteria**
	Beyond the boundaries of the rail corridor, velocities to remain below 1.0m/s where currently below this figure and an increase of no more than 20% where existing velocities are above 1.0m/s.	Residential and commercial buildings – no change to the flood hazard regime
		Cropping paddocks
		Stock paddocks
		Newell Highway – no change to the flood hazard regime
		Other roads – no change to the flood hazard regime
		Public infrastructure (pump stations, sewage treatment plants, health services etc.)
Flood hazard	**Land use**	**Design criteria**
	Residential and commercial buildings	No change in flow hazard regime for people (Table 6.7.1. Flow Hazard Regimes for People, Australian Rainfall & Runoff 2016 (ARR 2016)).
	Newell Highway	No change in flow hazard regime for cars (Table 6.7.2. Interim Flow Hazard Regimes for Vehicles (ARR 2016).

	Other roads	No change in flow hazard regime for cars (Table 6.7.2. Interim Flow Hazard Regimes for Vehicles (ARR 2016).
Flood duration	**Design criteria**	**Applicable land uses**
	Total flood duration to remain less than 6 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 6 hours	Residential and commercial buildings – No increase in above floor flooded duration.
		Newell Highway
		Public infrastructure (pump stations, sewage treatment plants, health services etc.)
	Total flood duration to remain less than 12 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 12 hours.	Cropping paddocks
		Stock paddocks
	No more than a 10% increase in flood duration	Other roads

The above FMOs for afflux and duration are general consistent with or a proposed improvement on the effects and commitments documented in the EIS, as demonstrated below in Table 3.2.

Table 3.2 Comparison of EIS effects and commitments with SPIR FMOs for afflux and duration

Land Use	EIS effects and commitments	SPIR FMOs
Residential and commercial buildings	No specific limit nominated Impacts of up to 920mm noted Minor increase in the number of affected properties	50mm if the building is not flooded above floor level; 10mm if the building is flooded above floor level No increase in above floor flooded duration
Cropping paddocks	No specific limit nominated General reduction in extent with level and flood footprint changes Extended duration in areas of upstream impact and in areas of increased footprint	200mm Total flood duration to remain less than 12 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 12 hours
Stock paddocks	No specific limit nominated General reduction in extent with level and flood footprint changes Extended duration in areas of upstream impact and in areas of increased footprint In areas of increased impact some locations have temporary loss of access	200mm Total flood duration to remain less than 12 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 12 hours
Newell Highway	No specific limit nominated Impacts in various locations, of up to 430mm overtopping at 1% AEP Increase at Moree of up to 70mm noted, but no greater loss of trafficability than existing	50mm Total flood duration to remain less than 6 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 6 hours
Other roads	No specific limit nominated Variable impacts noted, with some roads experiencing an increase while others a decrease in flood level	100mm No more than a 10% increase in flood duration

Land Use	EIS effects and commitments	SPIR FMOs
Public infrastructure	No specific limit nominated Where feasible, facilities and routes identified as being critical to emergency response operations would be protected from the PMF level	50mm if the building is not flooded above floor level; 10mm if the building is flooded above floor level Total flood duration to remain less than 6 hours where currently less than this figure; and an increase of no more than 10% in flood duration where existing flooded durations are above 6 hours

3.1.2 Additional Criteria and General Guidelines and Standards

Additional criteria for flooding impacts and cross drainage design have been extracted from the Requirements Analysis, Allocation and Traceability Matrix (RAATM), which incorporates the Basis of Design (BoD) developed for the project.

The RAATM provides the following key requirements for afflux:

- Where there are existing flood prone buildings (habitable and non-habitable), the afflux should be close to zero, with a maximum afflux threshold of 0.01m allowed above floor levels of existing buildings;
- The allowable afflux for neighbouring infrastructure such as roads, should generally also be no more than 0.01m unless specific permission is obtained; and
- In other land use areas, the allowable afflux should be determined based on specific assessments, with a higher afflux possible in particular situations.

The RAATM provides the following key requirements for flood velocity:

- In the absence of soil data, the outlet velocity for all culverts should be less than 2.5m/s;
- The design should attempt to maintain a safe flow velocity through the structures from local soil test and environmental assessments; and
- Where soil data is not available, and the flow velocity is higher than 2.5m/s at the culvert or bridge outlet velocities, appropriate scour protection must be designed.

The cross drainage design presented in this study has also been developed based on the following guidelines and standards:

- ARTC - Code of Practice Section 10 Flooding - Technical Note ETD-10-02;
- ARTC - Code of Practice Section 10 Flooding;
- ARTC - Engineering Specification - Flooding - ETG-10-01;
- ARTC - Technical Specification - Drainage - ETC-10-01;
- ARTC Technical Specification ETC-10-01: Drainage;
- AS7637:2014: Railway Infrastructure – Hydrology and Hydraulics;
- Australian Rainfall and Run-off 2016 (ARR2016);
- Austroads Guide to Road Design, Part 5: Drainage – General and Hydrology Considerations and Part 5B: Drainage – Open Channels, Culverts and Floodways, Austroads 2013;
- Austroads (2013), Guide to Bridge Technology, Part 4: Design Procurement and Concept Design;
- Austroads (1994), Waterway Design - A Guide to the Hydraulic Design of Bridges, Culverts and Floodways; and
- US Department of Transportation Federal Highway Administration, Hydraulic Engineering Circular No.18, Evaluating Scour at Bridges, Fifth Edition (2012).

It should be noted that these guidelines and standards do not contain specific flood impact criteria for land adjacent to the cross drainage infrastructure and the flood impact criteria are as proposed in Section 3.1.1.

3.1.3 ARTC Flooding Multi Criteria Analysis

ARTC have developed a Flooding Multi-Criteria Analysis (MCA) process that identifies a minimum flood immunity required for the Top of Formation (TOF) for rail upgrade projects. The process considers operational criticality, flood risk parameters, extent and magnitude of potential flood damage and time to return to operation. The process has been applied during this study and the outputs used to guide the design of the rail vertical alignment and cross drainage. It should be noted that regardless of the flood immunity selected for the TOF, the overarching requirement is for no overtopping of the rail to occur throughout the design for the 1% AEP event. Refer to Sections 4.5 and 5.2 for further discussion.

3.2 Assumptions

The following key assumptions were made in the flood modelling analysis and cross drainage design:

- Standard spans and pier widths for new / upgraded bridges are as follows:
  - 9m spans with single 1.2m wide piers; and
  - 23m spans with single 1.35m wide piers.
- Standard sizes for new / upgraded Reinforced Concrete Box Culverts (RCBCs) are as listed below in Table 3.3 (based on constructability, maintenance and value engineering discussions between ARTC and IRDJV).

Table 3.3 Standard sizes for RCBCs

No.	RCBC cell width (mm)	RCBC cell height (mm)
Rail Culverts – Crown Units		
1	450	300
2	600	450
3	600	600
4	900	450
5	900	900
6	1200	450
7	1200	600
8	1200	900
9	1200	1200
10	1500	600
11	1800	600
12	1800	800
13	1800	900
14	1800	1200
15	1800	1800
16	2100	750
17	2100	900

No.	RCBC cell width (mm)	RCBC cell height (mm)
18	2400	800
19	2400	900
20	2400	1200
21	2400	1500
22	2400	1800
23	2400	2400
24	3000	1100
25	3000	1200
26	3000	1500
27	3000	1800
28	3000	2100
29	3000	2400
30	3600	1800
Rail Culverts – 4-Sided Boxes		
1	600	600
2	900	900
3	1200	450
4	1200	900
5	1200	1200
6	1800	600
7	1800	900
8	1800	1200
9	2400	900
10	2400	1200
11	2400	1500
12	2400	2400
13	3000	1200
14	3000	1500
15	3000	2100
16	3000	2400
Road Culverts		
1	450	300
2	600	300
3	600	450

No.	RCBC cell width (mm)	RCBC cell height (mm)
4	900	600
5	1200	600
6	1500	600
7	1800	600
8	1800	900
9	2400	600
10	2400	900
11	2400	1200

- For level crossings, Reinforced Pipe Culverts (RCPs) are to be used with the following minimum cover requirements:
  - Private level crossing: 450mm; and
  - Public level crossing: 600mm.
- The formation is to have a minimum of 1% AEP flood immunity, except in areas where ARTC’s Flooding MCA process has identified that a lower minimum formation flood immunity is acceptable;
- The project works are to meet the flood impact assessment criteria nominated in the RAATM and the FMOs proposed in Table 3.1;
- In general, RCBCs have been used in preference to bridge structures for new waterway crossings and culvert upgrades;
- Specific blockage factors at each structure were estimated using the latest guidance in Chapter 6, Book 6 of ARR2016, and found to vary between 0 and 13%, with a single outlier at 25%. A standard factor of 15% was adopted in the design to provide a consistent factor across all drainage structures. Refer to Appendix D for details of the blockage assessment;
- There is no requirement to provide freeboard above the 1% AEP design flood level to bridge soffits and culvert obverts.
- The following structures are proposed to be retained as these assets have adequate condition and residual life:
  - Edgeroi Creek Culvert at kilometrage 603.850;
  - Culvert at kilometrage 616.170;
  - Tookey Creek Underbridge at kilometrage 620.610;
  - Culvert at kilometrage 627.490;
  - Tycannah Creek Culvert at kilometrage 649.520; and
  - Culvert at kilometrage 658.850

3.3 Inputs

The design has been based on the following site investigations and base information:

- LiDAR provided by ARTC supplemented by detailed ground surveys managed by IRDJV;
- Previous site investigation data provided by ARTC; and
- Site assessments completed for culverts and bridges.

4 Methodology

4.1 Hydrological Modelling

Hydrological models have been used to simulate rainfall generation and flow routing through the catchments upstream of the alignment. The hydrological modelling has provided critical runoff hydrographs for input into the six hydraulic models of local catchments covering the project area.

For Phase 1, a series of new hydrology models were developed using the RORB software. The following process was completed in the development and calibration of these models (further details are provided in the Hydrological Calibration Report provided in Appendix E):

- Develop a surface elevation model and identify broad hydrological catchment divides;
- Delineate the sub-catchments to an appropriate level of detail for hydrological estimation and hydraulic design;
- Use the catchment delineations and aerial photos to define the hydrological sub-catchment nodes in a hydrological model;
- Build and calibrate the hydrological model to available streamflow gauge data;
- Use the calibrated hydrological model to estimate design flows for a range of events at the rail cross drainage locations and compare these to Regional Flood Frequency Estimation (RFFE) method flow estimates to confirm that the model produces credible design peak flow estimates; and
- Run design rainfall events in the calibrated hydrological model to develop design flows at each cross drainage location.

4.1.1 Model Construction

The hydrological models were constructed in the RORB modelling software and calibrated where data allowed. The project area was divided into six sections, each of which were modelled separately in RORB.

Refer to Figures A1.1 to A1.4 in Appendix A for schematics of the RORB models.

4.1.2 Catchment and Climate Parameters and Characteristics

4.1.2.1 Topography and Survey Data

The following topographic datasets were used to generate a surface elevation model representing the study area:

- LiDAR survey (2015) – 0.2m resolution covering approximately a 10km wide strip along the project corridor;
- LiDAR survey (2017) – 0.2m resolution covering approximately a 1km wide strip along the project corridor;
- Site survey – survey of local features and structures; and
- Shuttle Radar Topographic Mission (SRTM) data – elevation grid data with 30m resolution – adopted to supplement the surface model outside of the LiDAR extent.

Catchment delineation and physical parameters such as slope were determined based on the combined surface elevation model generated from the above datasets.

4.1.2.2 Rainfall Depths and Temporal Patterns

The design rainfall was specified as per the ARR2016 design guidelines (Chapter 3, Book 2, ARR 2016). Rainfall depths for the range of design storms were generated from the Bureau of Meteorology 2016 Intensity-Frequency-Duration (IFD) dataset and applied to temporal patterns sourced from the ARR2016 datahub. The data was extracted for each of the six hydrological models separately, giving area specific rainfall parameters for each of the sections.

Pre-burst rainfall was generated from the ARR2016 datahub for each section and applied to the hydrological models.

4.1.2.3 Catchment Loss and Catchment Routing Parameter

Section specific rainfall losses were generated from the ARR2016 datahub website for the sections of the project area. The rainfall losses generated from the ARR2016 datahub were calibrated against historical rainfall and gauged flows in accordance with the ARR2016 guidelines (Chapter 3, Book 5, ARR2016). The loss values are provided in Table 4.1.

Table 4.1 Adopted initial and continuing loss values in design event RORB models

RORB Model	Initial Loss (mm)	Continuing Loss (mm)
NAMOI01	42	0.8
GWYDIR01	57	0.2
GWYDIR02	56	0.4
GWYDIR03	54	0.1
MACINTYRE01	52	0.3
MACINTYRE02	58	0.1

The flood routing parameter ‘k_c’ is the principal parameter within RORB and is a function of catchment area, catchment non-linearity and discharge. The k_c values adopted in the RORB models are provided in Table 4.2.

Table 4.2 Adopted k_c values in design event RORB models

RORB Model	Total catchment area (km²)	Adopted k_c value
NAMOI01	415.4	31.9
GWYDIR01	1,264.9	55.6
GWYDIR02	2,537.0	78.8
GWYDIR03	153.9	19.41
MACINTYRE01	703.1	41.4
MACINTYRE02	1,834.3	67.0

Note that the adopted k_c values are based on model calibration at Croppa Creek (within the MACINTYRE02 model area). For further details refer to the Hydrological Calibration Report in Appendix E.

4.1.2.4 Areal Reduction Factor

An Areal Reduction Factor (ARF) is a reduction factor applied to rainfall depth in larger catchments, to allow for the fact that larger catchments are less likely to experience the high intensity rainfall depth estimated at a point location simultaneously across the entire area, as per ARR2016 design guidelines (Chapter 4, Book 2, ARR2016).

The ARR2016 guideline estimates the ARF factor to the point of interest (e.g. to an individual cross drainage structure), with the factor varying based on AEP, storm duration and catchment area. ARR2016 also states that "*There has been limited research on ARF applicable to catchments that are less than 10 km^2. The recommended procedure is to adopt an ARF of unity for catchments that are less than 1 km^2, with an interpolation to the empirically derived equations for catchments that are between 1 and 10 km^2*".

Table 4.3 demonstrates the range of catchment areas in the N2NS project area, and a summary of where ARF have been applied.

Table 4.3 Summary of ARF methodology

Catchment Area	Estimated ARF range	ARF adopted
<1km^2	1	1
1km^2 - 10km^2	0.9-1	1
>10km^2	0.7-1	Assessed per catchment

4.1.3 Calibration and Validation

Calibration and validation of the hydrological parameters and models has been undertaken and this process is documented in detail in the Hydrological Model Calibration Report provided in Appendix E.

4.1.4 Design Event Modelling

Table 4.4 provides the list of design events required for simulation.

Table 4.4 Hydrological design events

Design event	Approximate equivalent Average Recurrence Interval (ARI)	Purpose of event analysis
39% AEP	2.5 year ARI	Flood impact assessment
18% AEP	5 year ARI	Flood impact assessment
10% AEP	10 year ARI	Flood impact assessment and potential lower standard adopted for TOF flood immunity as part of MCA process
5% AEP	20 year ARI	Flood impact assessment and potential lower standard adopted for TOF flood immunity as part of MCA process
2% AEP	50 year ARI	Flood impact assessment and potential lower standard adopted for TOF flood immunity as part of MCA process
1% AEP	100 year ARI	Flood impact assessment and typical standard adopted for TOF flood immunity as part of MCA process

Design event	Approximate equivalent Average Recurrence Interval (ARI)	Purpose of event analysis
1% AEP with climate change allowance	100 year ARI	Sensitivity test to assess impact of climate change on flood impacts and TOF flood immunity
0.05% AEP	2000 year ARI	Flood impact assessment and to inform loading for structural stability assessments for bridges

This report only includes flood maps for the 39%, 10%, 1% and 0.05% AEP events and the 1% AEP event with climate change allowance. Impacts were also checked for the 18, 5 and 2% AEP events and confirmed to be in the range of impacts predicted for the mapped events.

The hydrological modelling has been undertaken using the ensemble method of flow estimation, as detailed within the ARR2016 design guidelines (Chapter 3, Book 4, ARR 2016) and shown in Figure 4.1. Each flood event (AEP) was run for a range of standard durations and for an ensemble of 10 temporal patterns within each duration. Results were extracted for the critical flow at each culvert crossing separately, and the median of these flows was selected as the design flow for each AEP event.

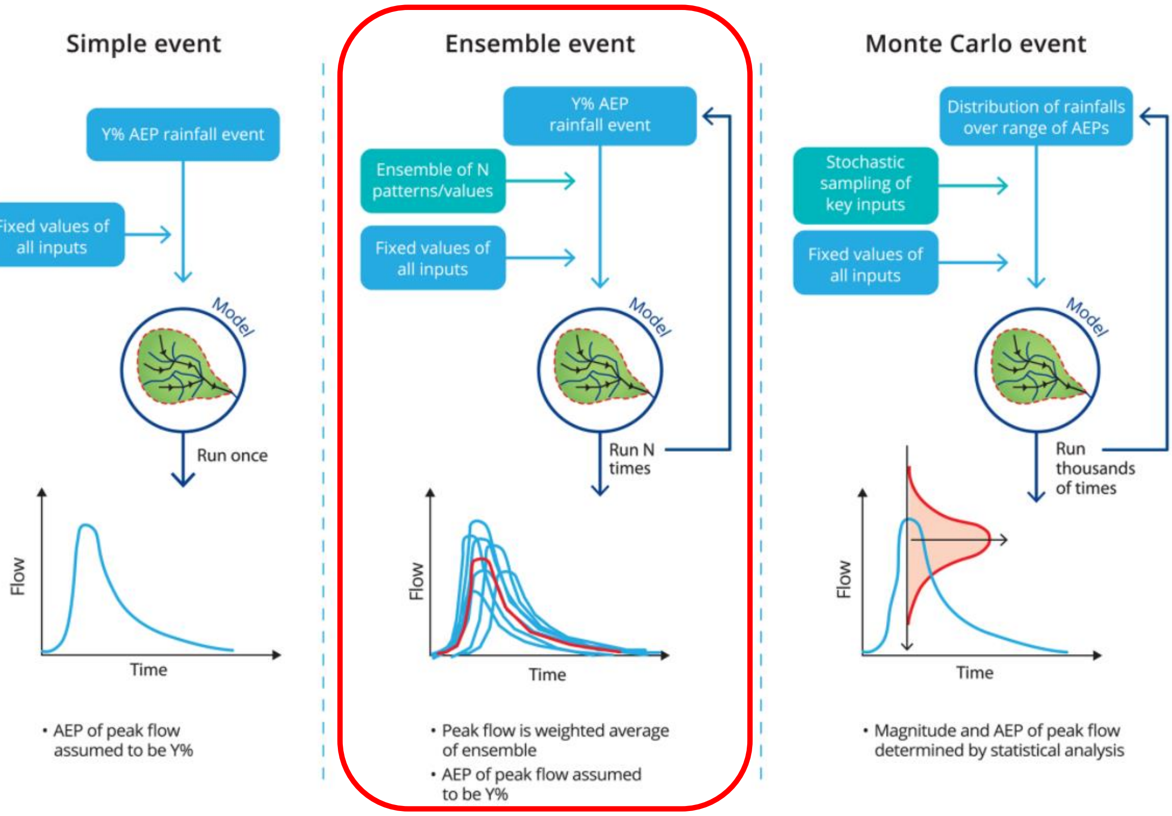

Figure 4.1 ARR2016 approaches to estimation of peak flow

Source: ARR design guidelines Book 4 Chapter 3 (ARR 2016) http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

The design modelling scenarios for RORB were set up using the software program Storm Injector (Catchment Simulation Solutions, 2018). Storm Injector sets up appropriate combinations of storm durations, Areal Reduction Factors (ARFs) and point and areal temporal patterns and for input to RORB. Table 4.5 provides the key inputs to the RORB model that were set up within Storm Injector based on the variable upstream catchment size to each rail cross drainage culvert. In addition to those given in Table 4.5, the following key inputs were also provided to RORB / Storm Injector:

- 2016 Intensity-Frequency-Duration design rainfalls: obtained from Bureau of Meteorology website;
- Initial and continuing losses and pre-burst depths: obtained from the ARR2016 data hub; and

- k_c parameter: as per Section 4.1.2.3.

Table 4.5 Key hydrological inputs to RORB / Storm Injector

Upstream catchment size	Storm duration	Areal Reduction Factor (ARF)	Temporal Pattern
<1 km^2	All durations	ARF = 1 (as per ARR2016 Book 2, Chapter 4, Table 2.4.1)	Point temporal patterns for all catchments < 75km^2 (as per ARR2016 Book 2, Chapter 5, Section 5.9.1)
1 to 10 km^2	All durations	ARF = 1 (based on calculations as per ARR2016 Book 2, Chapter 4, Table 2.4.1 which produced values very close to 1 in all cases)	Point temporal patterns for all catchments < 75km^2 (as per ARR2016 Book 2, Chapter 5, Section 5.9.1)
10 to 75 km^2	All durations	ARF varies (calculated by Storm Injector as per ARR2016 Book 2, Chapter 4, Table 2.4.1)	Point temporal patterns for all catchments < 75km^2 (as per ARR2016 Book 2, Chapter 5, Section 5.9.1)
>75 km^2	< 12 hours	ARF varies (calculated by Storm Injector as per ARR2016 Book 2, Chapter 4, Table 2.4.1)	Point temporal patterns were adopted for < 12 hour duration storms as ARR2016 has not produced areal temporal patterns for these durations. There is no guidance for this case in ARR2016.
	=/> 12 hours	ARF varies (calculated by Storm Injector as per ARR2016 Book 2, Chapter 4, Table 2.4.1)	As per ARR2016 Book 2, Chapter 5, Section 5.6.3 different areal temporal patterns were used between: - 75km^2 – 150km^2 - 150km^2 – 350km^2 - 350km^2 – 750km^2 - 750km^2 – 1750km^2 There were no catchments in the project >1750km^2.

The RORB models were set up and run separately for each culvert using the inputs in Table 4.5 for the ensemble suite of temporal patterns. At each culvert, the critical duration and temporal pattern for that culvert was determined as follows:

- The critical temporal pattern was selected as the 'first above median' from the set of temporal patterns for every duration separately; and
- The maximum in any duration was selected (from the set of 'first above medians' determined above) to find the critical duration (and corresponding critical temporal pattern).

The output from this process was the critical duration and temporal pattern for every individual culvert with the associated critical flow for a range of return periods (AEPs).

A summary of the critical duration and temporal pattern storm combinations generating the median flow at each cross drainage location is provided in Table 4.6.

Table 4.6 Cross drainage sub-catchment critical duration and temporal pattern combinations

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
576.03	2	2221	2	2252	6	2375	6	2370
576.185	2	2252	2	2252	6	2370	6	2370
577.445	2	2221	2	2252	6	2370	6	2370
578.725	1.5	2186	2	2221	2	2257	6	2370
579.585	0.75	2157	1.5	2186	1.5	2227	2	2257
581.18	4.5	2284	4.5	2284	6	2375	12	2434
581.8	2	2221	2	2252	6	2375	6	2370
582.605	12	3572	48	3928	48	3928	48	3928
582.837	2	2252	2	2252	6	2375	6	2370
583.43	2	2252	2	2006	6	2370	6	2368
586.2	12	3577	12	3577	12	3582	24	3755
587.09	2	2221	2	2252	6	2370	6	2370
587.7	2	2252	2	2252	6	2370	6	2372
587.835	2	2252	2	2252	6	2370	6	2370
588.815	2	2252	2	2252	6	2370	6	2372
589.3	2	2252	2	2252	6	2370	6	2375
590.02	4.5	2332	4.5	2321	6	2372	12	2429
590.225	1.5	2186	1.5	2186	2	2260	2	2257
591.685	4.5	2333	12	2391	12	2429	12	2429
591.766	12	2419	18	2285	48	2492	48	2449
591.925	2	2255	4.5	2284	12	2429	12	2429
592.075	4.5	2284	4.5	2333	12	2429	12	2429
593.06	2	2255	4.5	2284	12	2429	12	2429
593.82	4.5	2333	12	2391	12	2429	12	2429
595.52	4.5	2284	4.5	2207	12	2429	12	2429
596.43	12	2424	18	2285	48	2212	48	2212
597.23	4.5	2284	12	2391	12	2429	12	2429
599.445	4.5	2284	4.5	2207	12	2429	12	2429
600.5	24	3755	96	4123	48	3941	48	3935
600.8	4.5	2284	4.5	2333	12	2429	12	2429
601.865	4.5	2284	12	2391	12	2429	12	2429

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
602.45	12	2391	12	2391	12	2429	12	2429
603.85	72	4020	72	4022	72	4022	72	4022
607.83	18	2285	18	2285	144	2551	48	2212
608.07	4.5	2284	4.5	2333	12	2429	12	2429
609.55	12	2419	12	2424	12	2429	48	2492
613.19	12	2419	12	2419	12	2429	48	2492
613.99	12	2391	12	2419	12	2429	12	2429
614.445	2	2255	4.5	2284	12	2429	12	2429
614.65	12	3572	48	3928	48	3928	72	4020
614.93	12	2419	18	2462	48	2492	48	2449
616.17	4.5	2284	12	2391	12	2429	12	2429
617.075	4.5	2284	12	2391	12	2429	12	2429
618.025	2	2255	4.5	2284	6	2264	12	2429
620.61	6	2322	12	2391	12	2429	12	2429
621.855	4.5	2284	4.5	2333	12	2429	12	2429
623.03	4.5	2284	4.5	2284	12	2429	12	2429
627.34	12	3572	12	3572	24	3753	48	3932
631.085	12	2419	12	2419	12	2429	12	2429
631.525	4.5	2284	4.5	2284	12	2429	12	2429
633.72	12	2391	12	2391	12	2429	48	2492
635.09	4.5	2284	4.5	2284	12	2429	12	2429
636.65	2	2006	4.5	2284	12	2429	12	2429
637.23	4.5	2284	4.5	2333	12	2429	12	2429
638.08	12	2419	12	2419	12	2429	24	2501
638.46	4.5	2284	4.5	2333	12	2429	12	2429
639.69	4.5	2284	12	2391	12	2429	12	2429
641.54	24	3767	24	3771	48	3952	48	3954
642.315	4.5	2284	4.5	2333	12	2429	12	2429
643.16	4.5	2284	4.5	2284	12	2429	12	2429
643.91	12	2419	12	2419	12	2431	48	2449
644.91	4.5	2333	12	2391	12	2429	12	2429
645.415	4.5	2284	4.5	2333	12	2429	12	2429

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
645.85	4.5	2284	4.5	2284	12	2429	12	2429
646.09	4.5	2284	4.5	2333	12	2429	12	2429
647.095	12	2419	12	2419	12	2431	48	2492
647.605	48	3963	48	3961	48	3956	48	3956
647.836	4.5	2284	4.5	2333	12	2429	12	2429
648.32	12	2419	12	2419	12	2431	24	2501
648.565	4.5	2284	4.5	2333	12	2429	12	2429
649.115	2	2006	2	2255	6	2264	12	2429
649.52	4.5	2284	12	2391	12	2429	12	2429
650.26	4.5	2284	4.5	2284	12	2429	12	2429
650.61	4.5	2284	4.5	2333	12	2429	12	2429
652.44	4.5	2284	4.5	2333	12	2429	12	2429
652.636	12	2419	12	2419	12	2429	12	2429
653.07	2	2255	4.5	2284	12	2429	12	2429
653.62	4.5	2284	4.5	2333	12	2429	12	2429
654.445	4.5	2284	4.5	2333	12	2429	12	2429
655.895	4.5	2284	12	2391	12	2429	12	2429
658.85	4.5	2284	4.5	2333	12	2429	12	2429
660.61	12	2419	12	2424	12	2429	48	2492
663.35	2	2255	2	2255	6	2264	12	2429
664.905	2	2006	2	2255	6	2264	12	2429
684.897	2	2252	2	2255	6	2367	12	2429
686.404	2	2252	2	2255	6	2367	12	2429
686.44	2	2252	2	2255	6	2367	12	2429
686.495	2	2006	4.5	2284	6	2375	12	2429
690.82	12	2419	12	2419	12	2431	12	2429
691.025	2	2006	4.5	2284	6	2367	12	2429
695.21	4.5	2284	4.5	2333	12	2429	12	2429
696.99	4.5	2321	6	2322	12	2429	12	2429
699.88	12	2419	12	2419	12	2429	12	2429
702.38	2	2221	2	2006	6	2372	12	2429
703.065	2	2006	2	2006	6	2367	12	2429

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
704.79	4.5	2284	4.5	2284	12	2429	12	2429
706.25	12	2391	12	2419	12	2429	12	2429
706.675	2	2252	2	2255	6	2367	12	2429
707.4	2	2006	4.5	2284	6	2367	12	2429
707.565	2	2252	2	2255	6	2367	12	2429
708.435	12	2391	12	2419	12	2429	12	2429
709.74	2	2006	4.5	2284	12	2429	12	2429
711.5	12	2419	12	2419	12	2431	12	2431
711.627	4.5	2333	12	2419	12	2429	12	2429
711.775	2	2006	4.5	2284	6	2375	12	2429
712.54	2	2006	4.5	2284	6	2375	12	2429
713.35	2	2252	2	2006	6	2372	12	2429
714.61	4.5	2321	4.5	2333	12	2429	12	2429
714.82	2	2252	2	2006	6	2372	6	2264
716.85	12	3577	12	3582	24	3755	24	3755
718.044	2	2252	2	2006	6	2372	6	2264
718.2	2	2252	2	2006	6	2372	6	2367
718.39	2	2252	2	2006	6	2372	6	2367
718.9	2	2252	2	2006	6	2367	12	2429
719.905	2	2252	2	2006	6	2368	6	2264
720.175	2	2252	2	2006	6	2372	12	2429
720.74	2	2252	2	2006	6	2367	12	2429
721.03	12	2419	12	2419	12	2431	12	2429
721.17	2	2252	4.5	2284	6	2367	12	2429
721.645	2	2006	4.5	2284	6	2375	12	2429
722.82	2	2006	4.5	2284	6	2375	12	2429
723.005	4.5	2333	12	2391	12	2429	12	2429
723.225	2	2006	4.5	2284	6	2368	12	2429
723.6	2	2252	2	2006	6	2367	12	2429
723.875	2	2252	4.5	2284	6	2367	12	2429
724.62	2	2252	4.5	2284	6	2375	12	2429
725.275	4.5	2321	4.5	2333	12	2429	12	2429

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
725.59	2	2252	2	2006	6	2372	6	2367
726.115	2	2006	4.5	2284	6	2368	12	2429
726.54	2	2252	2	2006	6	2372	6	2264
726.96	2	2252	2	2006	6	2372	12	2429
727.695	2	2252	2	2006	6	2367	12	2429
728.4	4.5	2284	4.5	2284	12	2429	12	2429
728.91	2	2006	2	2255	6	2368	12	2429
729.7	2	2006	2	2255	6	2368	12	2429
729.96	4.5	2333	4.5	2333	12	2429	12	2429
730.39	2	2006	2	2255	6	2368	12	2429
730.57	2	2006	2	2255	6	2368	12	2429
732.01	2	2006	4.5	2284	6	2264	12	2429
734.945	12	2391	12	2391	12	2429	12	2429
735.115	48	3963	48	3961	48	3956	36	2557
736.21	4.5	2284	4.5	2284	12	2429	12	2429
737.555	12	2391	12	2419	12	2429	12	2429
740.665	24	3762	24	3758	48	3943	48	3944
740.945	2	2006	2	2255	6	2264	12	2429
741.345	4.5	2284	4.5	2284	12	2429	12	2429
742.24	4.5	2284	4.5	2284	12	2429	12	2429
742.69	2	2006	4.5	2284	6	2367	12	2429
744.555	12	2419	12	2419	12	2431	48	2492
745.41	4.5	2284	4.5	2333	12	2429	12	2429
746.025	2	2006	4.5	2284	12	2429	12	2429
746.6	2	2006	4.5	2284	6	2367	12	2429
747.905	2	2006	2	2255	6	2368	12	2429
748.425	2	2006	4.5	2284	6	2264	12	2429
749.45	2	2006	2	2255	6	2368	12	2429
750.965	12	2391	12	2391	12	2429	48	2492
751.113	2	2006	4.5	2284	12	2429	12	2429
752.49	2	2006	2	2255	6	2367	12	2429
753.1	2	2006	4.5	2284	12	2429	12	2429

Catchment ID	1% AEP		2% AEP		5% AEP		10% AEP	
	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern	Critical Duration (Hrs)	Temporal Pattern
755.225	4.5	2333	4.5	2333	12	2429	12	2429
755.49	2	2006	2	2255	6	2264	12	2429
755.975	2	2006	4.5	2284	6	2368	12	2429
757.003	4.5	2284	4.5	2333	12	2429	12	2429

4.1.5 Climate Change Scenario Modelling

The 1% AEP event was selected for a climate change scenario assessment. This scenario involved simulation of a 12% increase in rainfall intensity for the 1% AEP event, based on the ARR2016 recommendation to adopt the CSIRO Representative Concentration Pathway 4.5 as an appropriate climate change scenario. This scenario was used to determine the potential impacts on rail formation flood immunity and impacts on adjacent land under climate change.

4.1.6 Extreme Event Modelling

The 0.05% AEP event was also run to assess the impact of flooding on the rail corridor and the impacts of the project on adjacent land under an extreme flooding scenario, and to provide input to the hydraulic loading and scour calculations for the structural design of bridges.

4.2 Hydraulic Modelling

Hydraulic models have been used to simulate the interaction between runoff hydrographs generated by the hydrological models, site topography and hydraulic structures along the rail alignment. Two dimensional (2D) hydraulic models have been developed using the TUFLOW hydraulic modelling software program. The models have been build using the 2017 version of TUFLOW and adopt the HPC (Heavily Parallelised Computations) solver.

The TUFLOW models were used to simulate the events listed in Table 4.3 for both existing conditions and the design case.

4.2.1 Model Construction

Refer to Figures A2.1 to A2.7 in Appendix A for schematics of the TUFLOW models.

4.2.1.1 Topography and Survey Data

LiDAR datasets (refer to 4.1.2.1) were used to build surface elevation models of the rail corridor and adjacent land. This data was supplemented with detailed site survey of the existing structures and rail corridor.

4.2.1.2 Culverts

As the proposed rail alignment is generally raised and cutting off existing flow paths, culvert structures along the existing rail alignment have been replaced and upgraded in the design case, to provide adequate conveyance of the flood flows through the alignment, and to meet the design requirements for the project. The existing flood immunity of the rail formation is lower than 10% AEP in many locations. This has been upgraded generally to a minimum of 1% AEP flood immunity in the design case, except in areas where ARTC's MCA process has identified that a lower minimum formation flood immunity is acceptable.

Culvert structures have been represented in the hydraulic model using a one dimensional (1D) network type '*1d_nwk'* TUFLOW input. This representation of culvert provides a 1D representation of a culvert structure, transporting flows between two locations within a 2D mesh. 1D/2D connectivity has been represented with a '*2d_bc'* layer, defining connection between the culvert network and the 2D mesh.

Refer to Table 4.7 for Manning's 'n' values adopted for culverts.

Table 4.7 Manning's 'n' values adopted for culverts

Culvert type	Manning's 'n' value
Corrugated Iron	0.027
Reinforced Concrete	0.013

4.2.1.3 Newell Highway Representation

The Newell Highway is adjacent to the rail alignment between Narrabri and Moree. Representation of the highway was included within the NAMOI01, GWYDIR01 and GWYDIR02 models. The elevation of the Newell Highway has been represented based on ground levels identified within the LiDAR survey used for the flood modelling. The ridge of the road was set using a TULFOW '*2d_zline*', to ensure the high points on the highway are represented.

Road culverts and bridges were represented in the models based on survey data received from RMS. This data did not contain full details of the structures (e.g. no culvert invert data was available), and estimations of some details of the road culverts were made where necessary based on site and aerial photos.

4.2.1.4 Bridge Representations

Bridge structures have been represented in the hydraulic model using a 'layered flow constriction' type TUFLOW input. This representation of the bridge structure allows a depth varied form loss coefficient to be applied to represent the different elements of the bridge structure.

The representation of the existing rail embankment and bridge abutments are included in the 2D TUFLOW model grid, and this representation inherently simulates the contraction and expansion losses as flow passes through the bridge structure. The form losses are applied uniformly across the width of the bridge structure opening, to represent the additional losses due to piers, which are not represented in the TUFLOW model grid. At bridges, that surcharge (i.e. flows that exceed the soffit level), the layered flow constriction file allows the level of the soffit to be set with an additional loss factor and blockage induced when this level is exceeded to represent surcharging of the bridge. The Form Loss coefficient (FLC) values adopted for layer one represent hydraulic losses associated with the bridge piers, and are derived using the process outlined in Section 5.4 of Austroads (1994), based on the approach from Bradley (1978). The bridge structure is generally represented with layers representing the following:

- Layer 1 – FLC value representing the bridge piers with blockage factor where required to represent reduced waterway opening. FLC value varies depending on bridge design;
- Layer 2 – FLC value (1.56) representing the bridge deck and parapet with 100% blockage factor;
- Layer 3 – FLC value (0.50) representing bridge safety barriers/railings with 50% blockage factor; and
- Layer 4 – Flow over the top of railings – assumed to be unimpeded.

Bridge representations in the model have been derived from survey provided, or site images in lieu of detailed survey.

4.2.1.5 Boundary Conditions

Hydrographs for incoming flows were imported from the hydrological models. Incoming flows were applied on a sub-catchment scale using a *'2d_sa'* TUFLOW boundary for local catchment flows and using a *'2d_bc'* flow versus time (QT) boundary for concentrated upstream overland flow in rivers and creeks.

Water level versus flow (HQ) boundary conditions with slopes matching the outflowing channel beds were used as the downstream boundaries of the TUFLOW models.

4.2.1.6 Manning's 'n' Values for Floodplain Areas

The Manning's 'n' values used in the hydraulic models for floodplain areas are consistent with ARR2016 guidance and were estimated from land use mapping and aerial photography. The Manning's 'n' values adopted are unchanged between the existing conditions and design cases, except in locations within the project boundary, to allow representation of the future railway embankment and structures. The Manning's 'n' values adopted for the floodplain areas are provided in Table 4.8.

Table 4.8 Manning's 'n' values adopted for floodplain areas

Land use	Manning's 'n' value
Pasture	0.05
Roads/Rail	0.02
Buildings	3
Ponds and other water	0.03
Urbanised Areas	0.1
Industrial Areas	0.1
Low Density Urbanised Areas	0.08
Heavily Vegetated Creek	0.08
Maintained Grass	0.04

4.2.1.7 Grid Size and Timestep

A 10m grid size was adopted for the hydraulic models. The grid size was selected following initial testing of several model grid resolutions (5m, 10m and 20m grid). 10m grid resolution was adopted as it achieved a balance between sufficient resolution to model the catchment features and reduced model run times to allow for multiple design iterations within the project program.

The TUFLOW HPC modelling solution adopted for this project implemented an adaptive time step solution that allows the solution to vary the timestep and repeat timesteps as required to maintain stability when resolving the equation.

4.2.1.8 Blockage

Blockage of hydraulic structures in both existing and design scenarios has been assessed as per the recommendations of ARR 2016 (Chapter 6, Book 6, ARR2016). This assessment is a risk based analysis of the potential blockage risk and mechanism in the catchment at each cross drainage structure location. The assessment takes into consideration parameters such as:

- Debris Type and Dimensions - Whether floating, non-floating, urban or sediment debris present in the source area and its size;
- Debris Availability - The volume of debris available in the source area;
- Debris Mobility - The ease with which available debris can be moved into the stream;
- Debris Transportability - The ease with which the mobilised debris is transported once it enters the stream;
- Structure Interaction - The resulting interaction between the transported debris and the bridge or culvert structure; and

- Random Chance - An unquantifiable but significant factor.

The process and assumptions adopted for the assessment are documented in detail in Appendix D. A full list of results from the blockage assessment is provided in Appendix D, with the resultant blockage values ranging from 0% to 13%, with a single outlier at 25%. Based on these results, a single blockage factor of 15% has been adopted at all cross drainage locations. This uniform assumption has been adopted to allow for a consistent approach to blockage of structures across the project. The uniform blockage approach has been adopted as there is an element of subjectivity involved in the determination of the parameters used to assess the potential for blockage and this method provides consistency in the design approach at each cross drainage structure location.

4.2.2 Design Flood Level Selection

As detailed in Section 4.1.4, the hydrological modelling has been undertaken using the ensemble method of flow estimation from the ARR2016 design guidelines (Chapter 3, Book 4, ARR2016). For each individual catchment, a critical duration median storm design flow was selected for each AEP event. All selected storms were run through the hydraulic models across all catchments to capture hydraulic connectivity of sub-catchment during large flood events.

A result filtering method was developed to ensure results were only derived from appropriate combinations of temporal patterns and ARFs. Hydraulically independent catchments within a single model were isolated through filtering to minimise conservativeness within the results, while allowing hydraulically connected catchments to interact with neighbouring catchments and structures. The method is summarised below:

- An initial review of the RORB model runs was undertaken to filter out those that represent inappropriate or incorrect combinations of ARF, temporal patterns and catchment size, e.g.:
  - Results for small sub-catchments where areal temporal patterns were applied;
  - Results for large sub-catchments where point temporal patterns were applied; and
  - Results where inappropriate ARF values were applied.
- Following filtering out of these RORB model runs, the remaining RORB outputs were run through the TUFLOW models and the results of all runs were combined into a single grid result for each storm duration and AEP. The storm duration grid results were then further combined to produce a maximum grid result for each AEP for flood level and velocity, i.e.:
  - Flood level: maximum flood levels at each culvert were enveloped to generate the maximum flood level grid for each AEP; and
  - Flood velocity: maximum flood velocities at each culvert were enveloped to generate the maximum flood velocity grid for each AEP.

This process is slightly conservative as the maximum grid result may be slightly higher than the critical value for a particular culvert at some locations. The conservativeness was particularly apparent in smaller sub-catchments on the periphery of large catchments where areal temporal patterns are applied, but generally had a minor impact otherwise.

4.3 Flood Impact Assessment

The results of the hydraulic model outputs for the existing conditions and design case were compared using GIS software, to determine changes in the following flood parameters in land adjacent to the corridor:

- Flood level;
- Flood velocity; and
- Flood duration.

The changes in these parameters were then compared to the RAATM requirements and FMOs (see Sections 3.1.1 and 3.1.2), which propose different impact limits depending on the land use, with lower limits set for sensitive land uses (e.g. buildings, roads) than for less sensitive land uses (e.g. forested and agricultural land).

Impacts were assessed for the 39%, 10% and 1% AEP events and mitigated by modifying the design to minimise the impacts, and/or confine them to areas local to the rail corridor. Impacts were then checked for the 18%, 5% and 2% AEP events to confirm that the impacts under these events fell within the range of those predicted for the 39%, 10% and 1% AEP events.

4.4 Cross Drainage Hydraulic Design

4.4.1 Sizing

The cross drainage structures were sized using the hydraulic models. In general, the design has adopted a strategy to replace existing culverts with structures that provide an equivalent waterway opening and hydraulic performance. In some locations, a track lift is required to provide the required flood immunity to the top of rail formation. Additional cross drainage structures have been provided at these locations to replace the existing overtopping flow hydraulic behaviour.

The cross drainage has been designed in accordance with the Inland Rail BoD, and to meet the RAATM and FMOs set out in Section 3.1. The design approach to sizing the structures was broadly as follows:

- Where overtopping of the rail occurs for the 1% AEP event under existing conditions, the waterway area corresponding to the overtopping flow was calculated and used as a first pass to size the new cross drainage structures required at that location;
- This first pass cross drainage upgrade estimate was trialled in the model for the 1% AEP event and was typically found to be too conservative (allowing too much flow through the structure). The structure was then optimised by reducing size / number of cells until the following two criteria were met:
  - The required minimum formation flood immunity was achieved; and
  - The upstream afflux impact was at or close to the upper limit of compliance based on the adjacent land use;
- The next step was to test the structure performance under the 39% and 10% AEP events to determine if a similar afflux impact was achieved. Typically, the upstream afflux was low or negative for these lower events and increased flood levels occurred on the downstream side of the corridor. The structure was further optimised to balance the afflux compliance upstream and downstream across all three of the key events (39%, 10% and 1% AEP events);
- Once the afflux was balanced, the velocity was then checked through the structure and downstream. If the structure was found to generate high velocities (typically in excess of 3 m/s) then additional cells were added to increase the waterway area and reduce the velocity;
- The flood duration impacts were then checked and impacts across all parameters were checked for the intermediate design events (18%, 5% and 2% AEP events) to check if any anomalous impacts occurred that were not observed in the trends for the key events. If any anomalies were found, the structure was further investigated and optimised; and
- Overlaying the above process was the need to coordinate the cross drainage design with the other disciplines of rail, road, longitudinal drainage and utilities. In some areas, the other infrastructure posed constraints on the cross drainage design and optimising the structure following the procedure above was not possible. In these cases, a compromise was necessary in the cross drainage design that resulted in a non-compliant flood impact or a non-compliant rail formation flood immunity. Such non-compliances were then further assessed and justified as required.

4.4.2 Scour Protection Design

4.4.2.1 Culverts

The flood model predictions of culvert flood levels and velocities were used to design appropriate scour protection measures at the inlets and outlets of culverts, where necessary. The design is based on the procedure recommended in the Austroads Guide to Road Design, Part 5: Drainage – General and Hydrology Considerations (Austroads 2013), which identifies requirements for rip rap aprons, extended aprons and energy dissipaters depending on velocities, Froude Numbers and in-situ soil type. A velocity threshold of 1.6m/s was used to determine when scour protection is required, i.e. for velocities of 1.6m/s or less no scour protection is deemed necessary.

The design procedure also incorporates the following decision-making processes to minimise excavation and rock quantities and mitigate potential clashes with utilities and other adjacent infrastructure:

- Determine need for scour protection based on culvert inlet/outlet velocity:
  - Where velocity < 1.6 m/s, no scour protection is required;
  - Where 1.6 m/s < velocity < 4 m/s, scour protection is required; and
  - Where velocity > 4m/s, review the culvert design (add cells and / or flatten grade) to reduce velocity below 4 m/s and provide scour protection based on the reduced velocity;
- Identify appropriate options for scour protection treatment measures:
  - Reinforced turf mat / coir mat solutions that require vegetation to be established will not be used due to the risk of extended droughts and failure of vegetation to establish;
  - Rock protection to be used as the preferred measure to be placed to a depth of 2 x D_{50} of the rock size identified at each culvert from application of the Austroads procedure;
  - Where the 2 x D_{50} rock placement depth does not cause a clash with adjacent utilities or other infrastructure, adopt the required rock size and placement depth; and
  - Where the 2 x D_{50} rock placement depth causes a clash with adjacent infrastructure, use reno mattress to minimise excavation depth to approximately 300mm;
- Assess excavation depth requirements and treatment measures at each culvert requiring scour protection:
  - Assess excavation depth and extent required to construct culvert foundations (1);
  - Assess excavation depth and extent required to install rock protection to a depth of 2 x D_{50} of the rock required at that culvert (2);
  - If (1) > (2) adopt standard rock protection to a depth of 2 x D_{50};
  - If (2) > (1) and D_{50} < 200mm adopt standard rock protection to a depth of 2 x D_{50}; and
  - If (2) > (1) and D_{50} > 200mm adopt reno mattress.

4.4.2.2 Bridges

The flood model predictions of flood levels and velocities at bridges were used to estimate scour depths at bridge abutments and piers to inform the geotechnical and structural design calculations and to design appropriate scour protection measures around the bridges. The design is based on the Austroads Guide to Bridge Technology, Part 8: Hydraulic Design of Waterway Structures (Austroads 2018). As per industry standards, scour protection at abutments was designed for the 1% AEP flood event while no scour protection is provided at piers as the geotechnical and structural design allows for the predicted scour depths at the piers.

4.5 ARTC Flooding Multi-Criteria Analysis and Rail Flood Immunity

The flood immunity of the rail corridor is defined as the flood immunity of the TOF, with the overarching requirement that the track is not to be overtopped at the 1% AEP event regardless of the TOF flood immunity. The minimum required flood immunity for the TOF is determined by the ARTC Flood Risk Assessment Working Group through application of ARTC's *Flood Risk Assessment Procedure – Upgraded Sections of Inland Rail*. The procedure is summarised below:

1. Undertake initial existing conditions flood modelling and extract key parameters (flood levels, velocities, times of formation submergence and rail overtopping lengths) for a range of flood events (1% to 39% AEP) to populate the Flooding MCA Criteria Input reporting tables.
2. ARTC review the Flooding MCA Criteria Input reporting tables and identify where a TOF flood immunity of less than 1% AEP may be acceptable, and alternative TOF flood immunities for further investigation.
3. The identified options are then assessed in the design case flood models and further parameters extracted from the results (including cross drainage structure sizings, flood impact parameters and flood risk parameters) to populate Concept Drainage Sizing reporting tables.
4. ARTC review the Concept Drainage Sizing reporting tables and select the preferred option for design.

The procedure has been applied and used to inform the current design of the rail vertical alignment and cross drainage. Further refinement of the design and re-assessment of the flood immunity against the MCA process will be undertaken at the detailed design stage.

4.6 Independent Verification

The hydrological and hydraulic models have been subject to internal IRDJV independent verification which included the following:

- Model conceptualisation and assumptions;
- Model input parameters;
- Hydraulic representations of the existing and future rail infrastructure and other adjacent infrastructure that affects the flood behaviour;
- The methodology for combining multiple models results for the ensemble storm events; and
- Model results and numerical stability.

5 Results

5.1 Existing Conditions

Refer to the maps in Appendix B for existing conditions results for flood depth and extent, velocity and duration for the 39%, 10%, 1% and 0.05% AEP events.

5.1.1 NAMOI01 Model Area (575 to 590km)

Flooding in this section of the project is generally constrained to the creeks with some flows spilling over the floodplain near Spring Creek. Cross drainage sub-catchments tend to be hydraulically independent. In the 1% AEP event the existing rail alignment is overtopped in several locations. It is noted that the existing rail formation has a flood immunity of less than the 10% AEP event in some locations.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s and in-channel velocities are generally less than 2 m/s.

The existing rail line causes significant retention of floodwaters on the upstream (eastern side) of the rail line and consequent diversion of the natural flow paths, particularly in the following areas:

- 573 to 575km;
- 581 to 586km; and
- 586.5 to 590.5km.

5.1.2 GWYDIR01 Model Area (590 to 619km)

Flooding in the sections between chainages 590 to 619km is generally constrained local to the creeks and cross drainage sub-catchments tend to be hydraulically independent. In the 1% AEP event the existing rail alignment is overtopped for short distances in several locations. It is noted the existing rail formation has a flood immunity of less than the 10% AEP event in some locations.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s. Higher velocities occur local to existing structures and in-channel, but the velocities are generally less than 2 m/s.

The existing rail line causes significant retention of floodwaters on the upstream (eastern side) of the rail line and consequent diversion of the natural flow paths, particularly in the following areas:

- 612.5 to 614.5km.

5.1.3 GWYDIR02 Model Area (619 to 666km)

Flood flows in the section between chainages 619 and 657km is generally constrained local to the creeks. The Tycannah Creek has a large floodplain where flood flows are widespread. In the 1% AEP event the existing rail alignment is overtopped over large sections at the mid-section of this modelled area. It is noted the existing rail formation has a flood immunity of less than the 10% AEP event at some locations.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s and in-channel velocities are generally less than 2 m/s.

The existing rail line causes significant retention of floodwaters on the upstream (eastern side) of the rail line and consequent diversion of the natural flow paths, particularly in the following areas:

- 629.5 to 640.5km;
- 642 to 647km;
- 652.5 to 655km; and
- 657 to 658km.

5.1.4 GWYDIR03 Model Area (682 to 709km)

The flood extents in the 1% AEP event in this section are generally constrained local to the creeks and cross drainage sub-catchments tend to be hydraulically independent. In the 1% AEP event the existing rail alignment is overtopped for short distances in several locations. It is noted the existing rail formation has a flood immunity of less than the 10% AEP event in some locations.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s and in-channel velocities are generally less than 2 m/s.

The GWYDIR03 model area exhibits less floodwater retention and flow diversion around the existing rail corridor than other modelled areas in the Gwydir system.

5.1.5 MACINTYRE01 Model Area (709 to 727km)

The flood extents in the 1% AEP event within this section show flooding is generally constrained local to the creeks and cross drainage sub-catchments tend to be hydraulically independent. It is noted that the existing rail formation has a flood immunity of less than the 2% AEP event at some locations but flood immunity is greater than 5% AEP.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s and in-channel velocities are generally less than 2 m/s.

The MACINTYRE01 model area exhibits less floodwater retention and flow diversion around the existing rail corridor than other modelled areas in the Macintyre system.

5.1.6 MACINTYRE02 Model Area (727 to 760.46km)

The flood extents in the 1% AEP event within this section show flooding is generally constrained local to the creeks and cross drainage sub-catchments tend to be hydraulically independent. It is noted that the existing rail formation has a flood immunity of less than the 10% AEP event at some locations.

Floodplain flow velocities for the 1% AEP event are generally less than 1m/s and in-channel velocities are generally less than 2 m/s.

The existing rail line causes significant retention of floodwaters on the upstream (eastern side) of the rail line and consequent diversion of the natural flow paths, particularly in the following areas:

- 734 to 735km; and
- 750.5 to 751.5km.

5.2 Flooding MCA Procedure

The outcomes of the MCA Procedure were a list of locations where the flood risk was sufficiently low to justify ARTC accepting a minimum TOF flood immunity lower than the 1% AEP event. The results of this assessment are presented in Table 5.1 which identifies the alternative minimum flood immunity locations. At all other locations, the 1% AEP event was chosen as the minimum required TOF immunity. The outcomes in Table 5.1 were provided as an input to the first pass rail vertical alignment design, and the vertical alignment was set according to the existing conditions flood levels.

Table 5.1 Rail flood immunity requirements identified from the Flooding MCA procedure

No.	Model Area	Kilometrage	Minimum Top of Formation Flood Immunity
1	NAMOI01	576.185	Existing: >2% AEP
2	NAMOI01	579.585	Existing: >5% AEP
3	NAMOI01	582.605	2% AEP
4	NAMOI01	584.805	5% AEP
5	NAMOI01	590.020	10% AEP
6	NAMOI01	591.766	Existing: >10% AEP
7	GWYDIR01	593.820	Existing: >5% AEP
8	GWYDIR01	596.430	Existing: >5% AEP
9	GWYDIR01	600.500	Existing: >2% AEP
10	GWYDIR01	607.830	Existing: >5% AEP
11	GWYDIR01	609.550	Existing: >5% AEP
12	GWYDIR01	614.650	2% AEP
13	GWYDIR02	627.230	2% AEP
14	GWYDIR02	633.720	5% AEP
15	GWYDIR02	639.690	Existing: >5% AEP
16	GWYDIR02	643.910	5% AEP
17	GWYDIR02	647.095	5% AEP
18	GWYDIR02	647.605	5% AEP
19	GWYDIR02	660.610	2% AEP
20	GWYDIR03	690.820	5% AEP
21	GWYDIR03	695.310	Existing: >5% AEP
22	GWYDIR03	696.990	5% AEP
23	GWYDIR03	699.880	5% AEP
24	GWYDIR03	703.065	10% AEP
25	GWYDIR03	704.790	5% AEP
26	GWYDIR03	706.250	2% AEP
27	GWYDIR03	707.565	10% AEP

No.	Model Area	Kilometrage	Minimum Top of Formation Flood Immunity
28	GWYDIR03	708.435	2% AEP
29	GWYDIR03	709.740	Existing: >5% AEP
30	MACINTYRE01	711.627	2% AEP
31	MACINTYRE01	715.625	Existing: >5% AEP
32	MACINTYRE01	718.900	10% AEP
33	MACINTYRE01	720.740	2% AEP
34	MACINTYRE01	721.645	Existing: >5% AEP
35	MACINTYRE01	723.005	5% AEP
36	MACINTYRE01	725.275	2% AEP
37	MACINTYRE01	726.115	Existing: >10% AEP
38	MACINTYRE01	726.690	Existing: >5% AEP
39	MACINTYRE02	728.910	Existing: >2% AEP
40	MACINTYRE02	729.960	Existing: >5% AEP
41	MACINTYRE02	736.210	5% AEP
42	MACINTYRE02	737.555	2% AEP
43	MACINTYRE02	740.665	2% AEP
44	MACINTYRE02	742.240	Existing: >2% AEP
45	MACINTYRE02	744.555	2% AEP
46	MACINTYRE02	747.905	Existing: >10% AEP
47	MACINTYRE02	750.965	2% AEP
48	MACINTYRE02	753.100	5% AEP
49	MACINTYRE02	755.975	5% AEP

The rail flood immunity was checked at each design stage to determine whether the minimum requirements defined in Table 5.1 were met in the design case. Where the minimum flood immunity was not achieved, design modifications in the form of track lifts and/or cross drainage improvements were made to achieve the required flood immunity. The current design has achieved or exceeded the rail flood immunity requirements given in Table 5.1.

5.3 Design Case

Refer to the maps in Appendix C for design case results for: afflux, velocity change and duration change for the 39%, 10%, 1% and 0.05% AEP events and for the 1% AEP event with climate change. The design case represents the future upgraded rail corridor and new/upgraded/retained cross drainage structures listed in the following sections. Compliance of the design case is discussed in Section 5.4.

5.3.1 Culverts

5.3.1.1 New / Upgraded Culverts

The list of new / upgraded culverts for the design case is provided below.

Table 5.2 List of new and upgraded culverts

No.	Model Area	Kilometrage	Number of cells	Structure Type
1	NAMOI01	576.030	1	600x600 4SBC
2	NAMOI01	576.185	1	1800x900 4SBC
3	NAMOI01	577.445	1	1800x900 4SBC
4	NAMOI01	578.730	1	1800x1200 4SBC
5	NAMOI01	579.480	2	2400x1500 4SBC
6	NAMOI01	579.590	2	1800x1200 4SBC
7	NAMOI01	579.650	3	2400x1200 4SBC
8	NAMOI01	579.700	5	1800x600 4SBC
9	NAMOI01	579.965	8	1800x900 4SBC
10	NAMOI01	580.920	1	2400x900 4SBC
11	NAMOI01	581.030	1	2400x1200 4SBC
12	NAMOI01	581.070	3	3000x1200 4SBC
13	NAMOI01	581.180	16	3000x1500 4SBC
14	NAMOI01	581.400	16	2400x1200 4SBC
15	NAMOI01	581.550	18	2400x900 4SBC
16	NAMOI01	581.800	15	3000x1500 4SBC
17	NAMOI01	581.920	10	2400x900 4SBC
18	NAMOI01	582.390	8	2400x900 4SBC
19	NAMOI01	582.605	18	3000x2400 4SBC
20	NAMOI01	582.840	3	2400x1500 4SBC
21	NAMOI01	583.430	3	2400x1200 4SBC
22	NAMOI01	583.700	7	2400x1200 4SBC
23	NAMOI01	584.810	5	3000x2100 4SBC
24	NAMOI01	585.200	5	1800x900 4SBC
25	NAMOI01	585.350	7	2400x900 4SBC
26	NAMOI01	585.460	7	2400x1200 4SBC
27	NAMOI01	585.620	5	2400x900 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
28	NAMOI01	585.800	4	600x600 4SBC
29	NAMOI01	587.090	7	2400x900 4SBC
30	NAMOI01	587.710	7	3000x1500 4SBC
31	NAMOI01	587.840	4	3000x1500 4SBC
32	NAMOI01	587.920	2	2400x1500 4SBC
33	NAMOI01	588.550	7	2400x900 4SBC
34	NAMOI01	588.830	6	3000x1500 4SBC
35	NAMOI01	589.065	2	1800x600 4SBC
36	NAMOI01	589.310	3	3000x1200 4SBC
37	NAMOI01	590.020	1	3000x1200 4SBC
38	NAMOI01	590.240	5	2400x1200 4SBC
39	NAMOI01	591.700	7	2400x1200 4SBC
40	NAMOI01	591.790	11	2400x1200 4SBC
41	NAMOI01	591.950	4	2400x1200 4SBC
42	GWYDIR01	593.080	2	1800x600 4SBC
43	GWYDIR01	593.860	4	3000x1200 4SBC
44	GWYDIR01	595.540	4	3000x1200 4SBC
45	GWYDIR01	596.450	8	3000x1500 4SBC
46	GWYDIR01	597.250	3	3000x1500 4SBC
47	GWYDIR01	599.470	2	3000x1200 4SBC
48	GWYDIR01	600.870	6	2400x900 4SBC
49	GWYDIR01	601.880	3	1800x600 4SBC
50	GWYDIR01	602.470	6	3000x1200 4SBC
51	GWYDIR01	607.870	40	3000x1500 4SBC
52	GWYDIR01	608.090	3	1800x600 4SBC
53	GWYDIR01	609.590	8	3000x1500 4SBC
54	GWYDIR01	613.230	1	600x600 4SBC
55	GWYDIR01	614.020	4	1800x1200 4SBC
56	GWYDIR01	614.480	14	3000x1500 4SBC
57	GWYDIR01	614.690	40	3000x1500 4SBC
58	GWYDIR01	614.990	8	3000x2100 4SBC
59	GWYDIR01	616.100	2	3000x1500 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
60	GWYDIR01	617.110	1	1800x600 4SBC
61	GWYDIR02	618.065	2	3000x1500 4SBC
62	GWYDIR02	619.070	2	3000x2100 4SBC
63	GWYDIR02	619.300	1	2400x1500 4SBC
64	GWYDIR02	621.895	3	3000x2400 4SBC
65	GWYDIR02	623.075	4	3000x2400 4SBC
66	GWYDIR02	624.805	1	1800x900 4SBC
67	GWYDIR02	625.570	2	1200x450 4SBC
68	GWYDIR02	627.280	50	3000x2400 4SBC
69	GWYDIR02	627.430	30	3000x2100 4SBC
70	GWYDIR02	627.760	10	2400x1200 4SBC
71	GWYDIR02	630.925	2	600x600 4SBC
72	GWYDIR02	631.140	3	1800x900 4SBC
73	GWYDIR02	631.580	1	600x600 4SBC
74	GWYDIR02	633.780	35	3000x2400 4SBC
75	GWYDIR02	635.145	6	1800x600 4SBC
76	GWYDIR02	635.410	2	2400x900 4SBC
77	GWYDIR02	636.705	4	600x600 4SBC
78	GWYDIR02	637.170	1	1800x600 4SBC
79	GWYDIR02	637.290	1	1800x900 4SBC
80	GWYDIR02	638.140	5	2400x1200 4SBC
81	GWYDIR02	638.525	13	2400x900 4SBC
82	GWYDIR02	639.740	60	2400x900 4SBC
83	GWYDIR02	640.380	20	1800x900 4SBC
84	GWYDIR02	640.650	15	1800x1200 4SBC
85	GWYDIR02	641.950	35	3000x2400 4SBC
86	GWYDIR02	642.380	75	3000x2400 4SBC
87	GWYDIR02	643.000	45	1800x1200 4SBC
88	GWYDIR02	643.230	45	3000x1500 4SBC
89	GWYDIR02	643.980	72	3000x1200 4SBC
90	GWYDIR02	644.980	55	3000x1200 4SBC
91	GWYDIR02	645.490	20	3000x1200 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
92	GWYDIR02	645.920	2	2400x900 4SBC
93	GWYDIR02	646.065	2	2400x900 4SBC
94	GWYDIR02	646.160	10	3000x1200 4SBC
95	GWYDIR02	646.850	25	2400x1200 4SBC
96	GWYDIR02	647.155	40	3000x2400 4SBC
97	GWYDIR02	647.315	10	3000x1200 4SBC
98	GWYDIR02	647.670	10	3000x1500 4SBC
99	GWYDIR02	647.925	4	2400x1200 4SBC
100	GWYDIR02	648.240	6	2400x900 4SBC
101	GWYDIR02	648.395	10	3000x2400 4SBC
102	GWYDIR02	648.635	6	2400x900 4SBC
103	GWYDIR02	649.185	2	1800x600 4SBC
104	GWYDIR02	650.330	1	2400x900 4SBC
105	GWYDIR02	650.690	2	2400x900 4SBC
106	GWYDIR02	652.530	2	1800x600 4SBC
107	GWYDIR02	652.715	1	1800x600 4SBC
108	GWYDIR02	653.150	1	600x600 4SBC
109	GWYDIR02	653.620	6	2400x900 4SBC
110	GWYDIR02	653.700	1	2400x900 4SBC
111	GWYDIR02	654.525	1	1800x900 4SBC
112	GWYDIR02	655.270	6	3000x1200 4SBC
113	GWYDIR02	655.980	5	3000x1200 4SBC
114	GWYDIR02	660.705	35	3000x2400 4SBC
115	GWYDIR02	660.705	10	3000x2400 4SBC
116	GWYDIR02	663.135	1	600x600 4SBC
117	GWYDIR02	663.460	4	1800x600 4SBC
118	GWYDIR02	664.870	3	1800x600 4SBC
119	GWYDIR02	664.982	1	1800x600 4SBC
120	GWYDIR03	686.410	2	1800x900 RCBC
121	GWYDIR03	686.490	2	1800x1200 RCBC
122	GWYDIR03	690.820	8	2400x1500 RCBC
123	GWYDIR03	691.020	4	1800x600 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
124	GWYDIR03	695.210	1	1200x1200 RCBC
125	GWYDIR03	695.285	1	2100x900 RCBC
126	GWYDIR03	696.985	5	2400x1500 RCBC
127	GWYDIR03	699.790	8	3000x1200 RCBC
128	GWYDIR03	699.875	12	3000x1800 RCBC
129	GWYDIR03	702.370	1	1200x600 RCBC
130	GWYDIR03	702.380	1	1200x600 RCBC
131	GWYDIR03	703.065	2	1800x600 RCBC
132	GWYDIR03	704.810	14	3000x1800 RCBC
133	GWYDIR03	706.100	6	1200x600 RCBC
134	GWYDIR03	706.250	3	2400x1800 RCBC
135	GWYDIR03	706.505	1	3000x1100 RCBC
136	GWYDIR03	706.695	3	1200x600 RCBC
137	GWYDIR03	707.405	2	1800x600 RCBC
138	GWYDIR03	707.575	8	1800x600 RCBC
139	GWYDIR03	708.445	13	3000x1200 RCBC
140	GWYDIR03	709.740	5	2400x900 RCBC
141	MACINTYRE01	711.410	10	2400x900 RCBC
142	MACINTYRE01	711.510	6	3000x1200 RCBC
143	MACINTYRE01	711.640	15	3000x1500 RCBC
144	MACINTYRE01	711.770	11	3000x1200 RCBC
145	MACINTYRE01	712.070	7	1800x600 RCBC
146	MACINTYRE01	712.540	12	2400x900 RCBC
147	MACINTYRE01	712.610	10	1800x600 RCBC
148	MACINTYRE01	712.820	1	1800x600 RCBC
149	MACINTYRE01	713.350	11	1800x600 RCBC
150	MACINTYRE01	713.500	1	1800x600 RCBC
151	MACINTYRE01	714.620	13	2400x900 RCBC
152	MACINTYRE01	714.830	1	1800x600 RCBC
153	MACINTYRE01	716.280	17	1800x600 RCBC
154	MACINTYRE01	716.410	14	2400x900 RCBC
155	MACINTYRE01	716.640	32	3000x1800 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
156	MACINTYRE01	716.730	7	3000x2100 RCBC
157	MACINTYRE01	718.050	1	1800x600 RCBC
158	MACINTYRE01	718.200	1	1200x450 RCBC
159	MACINTYRE01	718.390	1	1800x600 RCBC
160	MACINTYRE01	718.910	2	2400x900 RCBC
161	MACINTYRE01	719.080	3	1800x600 RCBC
162	MACINTYRE01	719.130	2	1800x600 RCBC
163	MACINTYRE01	719.180	3	1800x600 RCBC
164	MACINTYRE01	719.910	1	1800x900 RCBC
165	MACINTYRE01	720.180	3	3000x1800 RCBC
166	MACINTYRE01	720.370	3	3000x1800 RCBC
167	MACINTYRE01	720.740	3	3000x1800 RCBC
168	MACINTYRE01	721.040	6	3000x2100 RCBC
169	MACINTYRE01	721.650	2	2400x1800 RCBC
170	MACINTYRE01	722.820	1	2400x1500 RCBC
171	MACINTYRE01	723.010	2	2400x1500 RCBC
172	MACINTYRE01	723.230	3	2400x1500 RCBC
173	MACINTYRE01	723.610	2	2400x1800 RCBC
174	MACINTYRE01	723.880	2	2400x1500 RCBC
175	MACINTYRE01	724.630	2	2400x1500 RCBC
176	MACINTYRE01	725.280	4	3000x1800 RCBC
177	MACINTYRE01	725.560	1	2400x1200 RCBC
178	MACINTYRE01	725.600	1	1800x1800 RCBC
179	MACINTYRE01	726.120	2	3000x1200 RCBC
180	MACINTYRE01	726.210	1	1800x600 RCBC
181	MACINTYRE01	726.550	2	3000x1200 RCBC
182	MACINTYRE01	726.970	2	3000x1500 RCBC
183	MACINTYRE01	727.130	3	1800x600 RCBC
184	MACINTYRE01	727.710	1	3000x1200 RCBC
185	MACINTYRE02	728.360	1	1200x600 RCBC
186	MACINTYRE02	728.440	4	3000x1500 RCBC
187	MACINTYRE02	728.920	1	2400x1500 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
188	MACINTYRE02	729.710	1	2400x900 RCBC
189	MACINTYRE02	729.890	1	1800x1200 RCBC
190	MACINTYRE02	729.970	4	3000x1500 RCBC
191	MACINTYRE02	730.400	1	900x900 RCBC
192	MACINTYRE02	730.580	1	2400x1500 RCBC
193	MACINTYRE02	732.020	1	3000x1200 RCBC
194	MACINTYRE02	734.270	1	3000x1500 RCBC
195	MACINTYRE02	734.495	1	3000x1500 RCBC
196	MACINTYRE02	736.220	3	2400x900 RCBC
197	MACINTYRE02	736.310	2	2400x900 RCBC
198	MACINTYRE02	737.570	4	3000x2100 RCBC
199	MACINTYRE02	740.960	24	3000x2400 RCBC
200	MACINTYRE02	741.460	2	1800x1200 RCBC
201	MACINTYRE02	742.140	3	2400x900 RCBC
202	MACINTYRE02	742.260	1	1800x600 RCBC
203	MACINTYRE02	742.710	1	1800x1800 RCBC
204	MACINTYRE02	744.570	10	3000x2400 RCBC
205	MACINTYRE02	745.430	1	1800x1200 RCBC
206	MACINTYRE02	746.040	1	1800x900 RCBC
207	MACINTYRE02	746.600	2	1800x900 RCBC
208	MACINTYRE02	747.910	2	1800x900 RCBC
209	MACINTYRE02	748.430	2	2400x2400 RCBC
210	MACINTYRE02	749.460	1	2400x1500 RCBC
211	MACINTYRE02	750.970	8	3000x2100 RCBC
212	MACINTYRE02	751.140	1	3000x2100 RCBC
213	MACINTYRE02	752.500	1	1500x600 RCBC
214	MACINTYRE02	753.120	7	3000x1500 RCBC
215	MACINTYRE02	755.250	1	3000x1200 RCBC
216	MACINTYRE02	755.440	1	2400x1200 RCBC
217	MACINTYRE02	755.490	3	3000x1500 RCBC
218	MACINTYRE02	755.980	2	1800x1200 RCBC
219	MACINTYRE02	757.040	16	2400x900 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
220	MACINTYRE02	758.230	2	1200x450 RCBC
221	MACINTYRE02	758.270	2	900x450 RCBC

5.3.1.2 Retained Culverts

A number of existing culverts will be retained with some modifications required to the headwalls. The retained culverts are listed below.

Table 5.3 List of retained culverts

No.	Model Area	Kilometrage	Number of cells	Structure Type
1	GWYDIR01	603.850	7	3500x2400 RCBC
2	GWYDIR01	616.170	9	3700x2000 RCBC
3	GWYDIR02	627.490	8	4800x1700 RCBC
4	GWYDIR02	649.520	4 4	3500x1500 RCBC 3500x2200 RCBC
5	GWYDIR02	658.850	4	3100x1100 RCBC

5.3.1.3 Culvert Scour Protection

Scour protection has been specified at culvert inlets and outlets where required in accordance with the methodology described in Section 4.4.2.1. Scour protection has also been specified at retained culverts as required based on the hydraulic parameters extracted from the flood models at these locations. The scour protection at culverts consists of rock aprons, however, the option to use reno mattresses (refer to Section 4.4.2.1) is proposed to minimise excavation depths if required during construction.

5.3.2 Bridges

5.3.2.1 New / Upgraded Bridges

The list of new / upgraded bridges for the design case is provided below.

Table 5.4 List of new and upgraded bridges

No.	Model Area	Kilometrage	Structure Type	Waterway
1	NAMOI01	586.200	5x9m span PSC slab	Bobbiwaa Creek
2	GWYDIR01	600.500	8x9m span PSC slab	Ten Mile Creek
3	GWYDIR02	641.540	13x9m span PSC slab	Gurley Creek
4	MACINTYRE01	716.850	4x9m span PSC slab	Gil Gil Creek
5	MACINTYRE02	734.945	9x9m span PSC slab	Croppa Creek overbank
6	MACINTYRE02	735.115	3x23m span Super-T girder	Croppa Creek main channel
7	MACINTYRE02	760.665	6x9m span PSC slab	Yallaroi Creek

5.3.2.2 Retained Bridges

The retained bridges are listed below.

Table 5.5 List of retained bridges

No.	Model Area	Kilometrage	Structure Type	Waterway
1	GWYDIR02	620.610	2x13m span PSC girder	Tookey Creek

5.3.2.3 Bridge Scour Protection

Bridge scour protection has been designed at the abutments in accordance with the methodology described in Section 4.4.2.2. A table of key outputs from the bridge scour assessments is provided below.

Table 5.6 Key outputs from bridge scour assessments

Waterway	Kilometrage	1% AEP flood event velocity (m/s)	Abutment scour protection D_{50} (mm)	Abutment scour protection thickness (mm)	Scour extent from toe of abutment (m)	Height of rock protection extension (mAHD)
Bobbiwaa Creek	586.200	1.2	250	500	2.0	247.90
Ten Mile Creek	600.500	3.0	550	1000	2.0	238.00
Tookey Creek	620.610	2.0	250	500	3.0	226.30
Gurley Creek	641.540	1.5	250	500	6.0	219.40
Gil Gil Creek	716.850	2.7	300	500	5.0	280.60
Croppa Creek overbank	734.945	2.9	550	1000	4.5	275.80
Croppa Creek main channel	735.115	2.4	250	500	4.5	275.90
Yallaroi Creek	740.665	2.1	300	500	6.0	269.70

5.4 Design Compliance

5.4.1 RAATM and BoD

5.4.1.1 Afflux

Refer to Section 3.1.2 for the afflux design criteria. The non-compliances with the afflux criteria in the RAATM for the 39, 10 and 1% AEP events are as listed in the tables below.

Table 5.7 Locations of non-compliance with afflux criteria in RAATM for 39% AEP event

Model / Land Use	39% AEP Event Non-Compliant Impacts
NAMOI01 (575 to 590 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR01 (590 to 619 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR02 (619 to 666 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Impact of >50mm adjacent to but not on highway at 633.6 to 634.5, 635.25, 637.95 to 638.8, 646.5 to 647 and 660.3 to 660.85
Local Roads*	None
GWYDIR03 (682 to 709 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE01 (709 to 727 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE02 (727 to 760.46 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
****Note: Afflux limits of 50mm at the Newell Highway and 100mm at local roads have been proposed in the Hydrological and Hydraulic Investigation Plan which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

Table 5.8 Locations of non-compliance with afflux criteria in RAATM for 10% AEP event

Model / Land Use	10% AEP Event Non-Compliant Impacts
NAMOI01 (575 to 590 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR01 (590 to 619 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR02 (619 to 666 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Impact of >50mm adjacent to but not on highway at 627.75 to 627.9, 633.55 to 635.85 and 643.75 to 647.0
Local Roads*	Localised impact of >100mm on local road at 659.1km
GWYDIR03 (682 to 709 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE01 (709 to 727 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE02 (727 to 760.46 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
****Note: Afflux limits of 50mm at the Newell Highway and 100mm at local roads have been proposed in the Hydrological and Hydraulic Investigation Plan which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

Table 5.9 Locations of non-compliance with afflux criteria in RAATM for 1% AEP event

Model / Land Use	1% AEP Event Non-Compliant Impacts
NAMOI01 (575 to 590 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Marginal non-compliances (just over 50mm) at: 582.44 to 582.57km (52mm), 582.885 to 582.945km (57mm) and 583.78 to 584.095km (57mm)
Local Roads*	None
GWYDIR01 (590 to 619 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR02 (619 to 666 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	Localised impact of >100mm on local road at 636.3km
GWYDIR03 (682 to 709 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE01 (709 to 727 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	None
MACINTYRE02 (727 to 760.46 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	N/A (highway is remote from rail corridor)
Local Roads*	Impact of >100mm at Croppa Moree Road at 733.94km
****Note: Afflux limits of 50mm at the Newell Highway and 100mm at local roads have been proposed in the Hydrological and Hydraulic Investigation Plan which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

5.4.1.2 Velocity

Refer to Section 3.1.2 for the velocity design criteria. The design of the culverts has not maintained all flow velocities below 2.5 m/s. Instead, culverts have been designed to meet the afflux criteria as far as possible and scour protection measures have been designed based on the resulting design velocities and the design procedure described in Section 4.4.2. For the 1% AEP event 35% of culverts have velocities greater than 2.5m/s, 18% have velocities greater than 3m/s and 1% have velocities greater than 4m/s. The highest culvert velocity is 4.45m/s which occurs at 647.925km. These velocity values occur inside the culvert structure and quickly dissipate to less than 2m/s as the flow spreads out across the outlet concrete apron and rock scour protection, where provided.

5.4.1.3 TOF Flood Immunity

The design complies with the minimum TOF flood immunity requirements identified through the Flooding MCA process (refer to Section 5.2).

5.4.2 Flood Management Objectives

The adopted FMOs are provided in Table 3.1.

5.4.2.1 Afflux

Agricultural Land

The afflux non-compliances with the RAATM identified in Tables 5.7 to 5.9 also constitute non-compliances with the afflux FMOs. In addition to those identified in Tables 5.7 to 5.9, the additional areas identified below in Table 5.10 are also non-compliant with the afflux FMOs.

Table 5.10 Locations of non-compliance with afflux criteria for general rural land (excluding buildings and local roads)

Model	39% AEP Event Non-Compliant Impacts	10% AEP Event Non-Compliant Impacts	1% AEP Event Non-Compliant Impacts
NAMOI01	583.7km 585.35km 585.46km 585.62km 588.83km	582.23km 582.39km 582.605km 584.81km 585.2km 585.62km 588.83km	581.8km 582.39km 58.605km 584.81km 585.2km 587.71km
GWYDIR01	607.82km	607.82km	607.82km
GWYDIR02	664.95km	664.95km 659.1km	664.95km 659.55 to 660.05km
GWYDIR03)	None	None	None
MACINTYRE01	711.4km 723.61km	711.41km 720.4km 720.74km	712.82km 716.5 to 716.73km 719.8km
MACINTYRE02	740.96km	733.94km 742.2km	741.5km 755.4 to 755.49km

Where these impacts affect non-sensitive land use (such as general agricultural land rather than property accesses) they may be accepted as minor low risk impacts subject to agreement from ARTC and consultation with the affected landowners.

Buildings

An assessment of afflux at individual buildings has been undertaken and buildings experiencing afflux greater than 10mm in the 1% AEP event have been identified. These are listed in the table below.

Table 5.11 Locations where 1% AEP event afflux exceeds 10mm at buildings

Model	Property ID	Existing conditions 1% AEP flood depth (mm)	1% AEP afflux (mm)	10% AEP afflux (mm)	39% AEP afflux (mm)
GWYDIR02	Lot 1 DP633825 (approx chainage 643km east of rail)	823	+44	-281	-62
	Lot 142 DP751785 (approx chainage 644km east of rail)	881	+48	-343	Not flooded
MACINTYRE01	Lot 3 DP751087 (approx chainage 733km east of rail)	236	+32	Not flooded	Not flooded
MACINTYRE02	Lot 23 DP751087 (approx chainage 734km east of rail)	152	+148	Not flooded	Not flooded

For the buildings affected in the GWYDIR02 model, the table shows that the 1% AEP event afflux causes a minor increase in flood depth at the buildings of approximately 5%. In both cases the buildings experience negative afflux (reduced flood level) for the 10% and 39% AEP events. On balance, the impact at these buildings is considered to be positive due to the significant reductions in flood level experienced for the more frequent events.

For the building affected in the MACINTYRE01 model, the table shows that the 1% AEP event afflux causes a minor increase in flood depth at the building of approximately 14%, with the building remaining flood free for the 10 and 39% AEP events. Given that the impact is minor and only occurs for the infrequent event, this impact may be acceptable to the landowner but would need to be confirmed through the consultation process.

For the building affected in the MACINTYRE02 model, the table shows that the 1% AEP event afflux causes a 69% increase in flood depth at the building, with the building remaining flood free for the 10 and 39% AEP events. This impact does not comply with the FMOs and affects a school building and access / driveway to the school. The impact is caused by the raised level crossing at this location and further refinement of the level crossing and road cross drainage is ongoing to resolve this non-compliant impact.

5.4.2.2 Velocity

Velocity impacts were assessed against the FMOs and found to be generally compliant. A number of non-compliances occur around the inlets and outlets of some culverts; however, these impacts are very localised to the structures and generally do not extend more than approximately 20 metres from the structure. These increases in velocity are managed through scour protection measures at the inlets and outlets that are placed within the zones where velocities are high enough to erode the existing soils. Designing out these non-compliances would only be possible by including additional numbers of culvert cells at additional cost, which may not be justified given the localised nature of the non-compliances and the scour protection measures provided in the design. These localised velocity non-compliances are therefore considered to be low risk as the scour risk is mitigated in the design and the non-compliances will not affect the use of the land.

There are some exceptions where the velocity impact occurs some distance away from the rail corridor but these are very localised and confined to existing channels, and on that basis also considered to be low risk impacts that do not affect the existing land use.

5.4.2.3 Duration

Duration impacts were assessed against the FMOs and found to be generally compliant. Some areas of non-compliance occur but these are confined to the rail corridor or localised within well defined channels and/or overland flow areas within rural land. These areas are listed in the table below.

Table 5.12 Locations of non-compliance with duration criteria

Model	39% AEP Event Non-Compliant Impacts	10% AEP Event Non-Compliant Impacts	1% AEP Event Non-Compliant Impacts
NAMOI01	582.5km	581km 582.5km 585.5km	581 to 583.5km 585.5km 588.5 to 589km
GWYDIR01	None	None	601km 608km 614.5km
GWYDIR02	631 to 633km (confined to rail corridor) 633.5km 642.5km 644km 647km 660.5km	627 to 628km 631 to 633km (confined to rail corridor) 633.5km 638km (confined to rail corridor) 642.5km 644km 647km 660.5km	627 to 628km 631 to 633km (confined to rail corridor) 633.5km 635km 644km 646.5 to 647km 660.5km
GWYDIR03	708.5km	708.5km	708.5km
MACINTYRE01	711.5km 716.5km	711.5km 716.5km	711.5km 716.5km 720.5km 723.5km
MACINTYRE02	755km (confined to rail corridor)	744.5km 753km (confined to rail corridor) 755km (confined to rail corridor)	734.5km 741km 744.5km 751km 753km (confined to rail corridor) 755km (confined to rail corridor)

Changes in flood duration occur primarily because of the elimination of the rail overtopping mechanism and replacement of the mechanism with flow under the rail via the new/upgraded cross drainage structures. Increases in flood duration can occur both upstream and downstream of the corridor depending on the capacity of the new/upgraded structures relative to the overtopping capacity of the existing rail at each location. Some changes in flood duration also occur due to the new under-rail flow mechanism causing changes in distribution of flow and timing of peak flood flows occurring within the drainage sub-catchments.

To assess the impact of the duration increases in detail, flood depth hydrographs have been extracted at a selection of locations where non-compliances occur for the 1% AEP event. These locations and the extracted hydrographs are shown below in Figures 5.1 and 5.2.

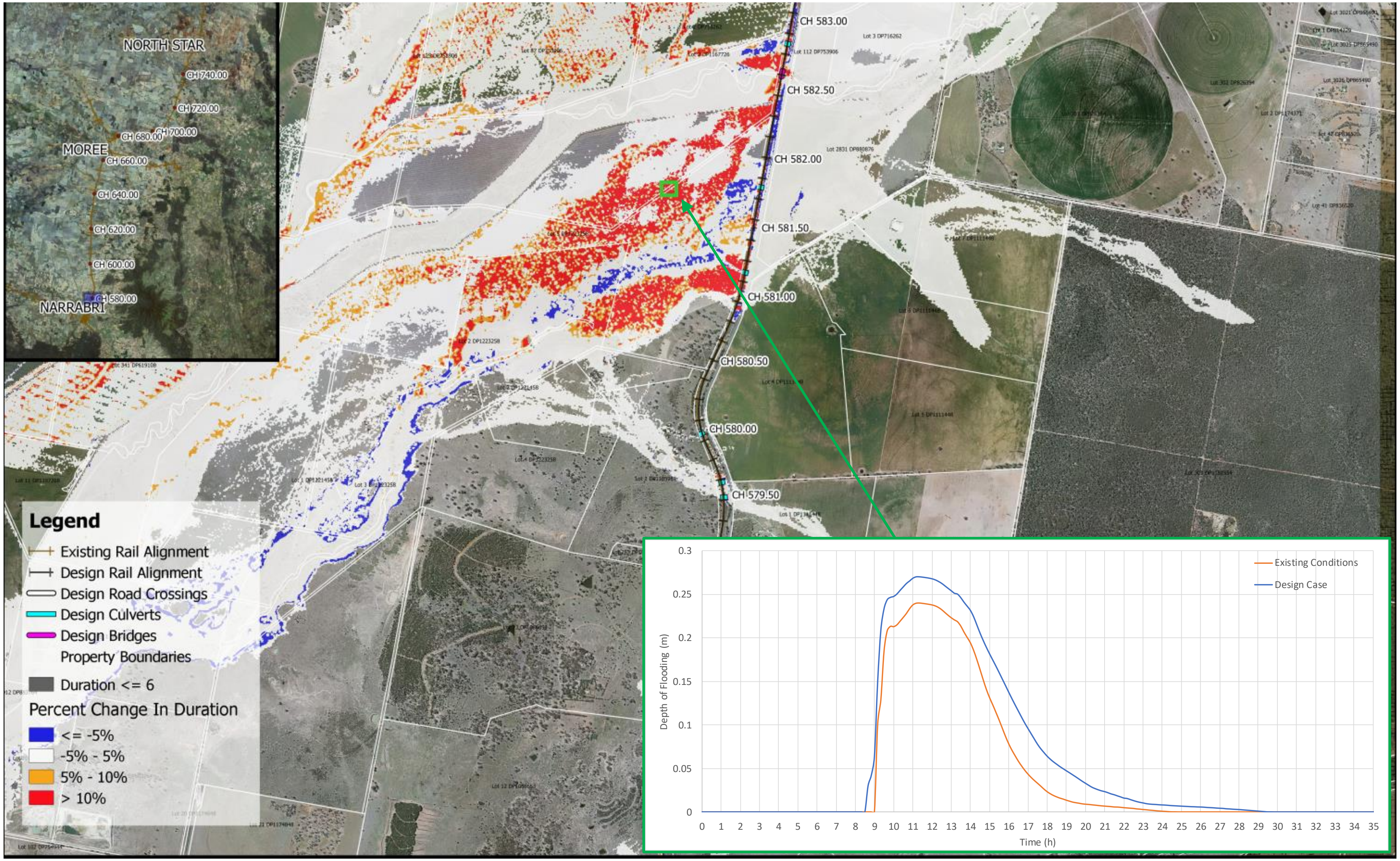

Figure 5.1 Example of 1% AEP duration impact mapping with extracted hydrograph at 582km

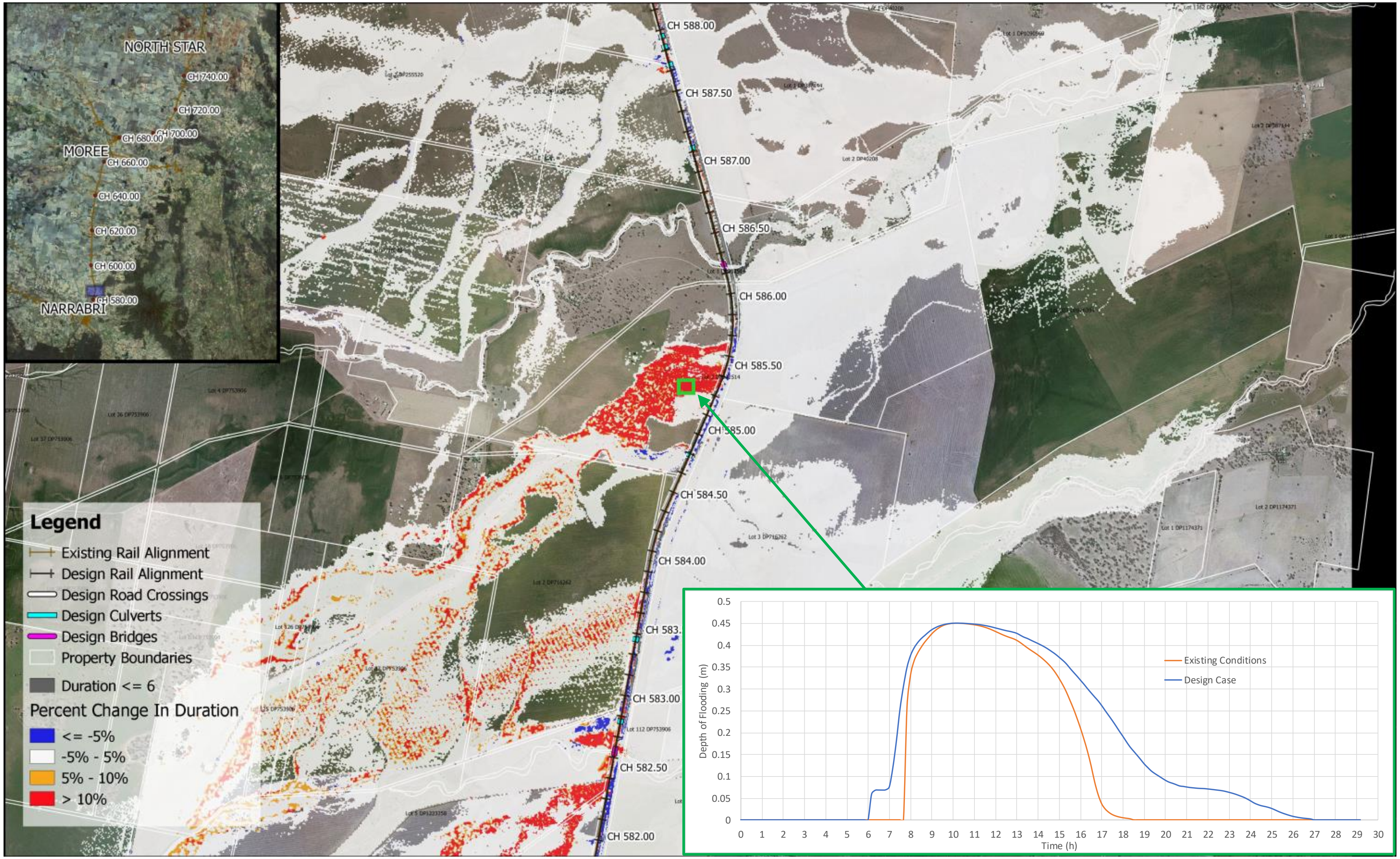

Figure 5.2 Example of 1% AEP duration impact mapping with extracted hydrograph at 585km

The following is observed from the results shown in the above figures:

- The specific duration increases at these locations are as follows:
  - 582km: 5.3 hours, 34%; and
  - 585km: 10.2 hours, 97%;
- The non-compliances occur in shallow depth areas, with peak depths less than 450mm; and
- The most significant extension of flood durations occur when flood depths reduce below 100 to 200mm.

Based on these results, the duration impacts that do not comply with the FMOs are considered to be low risk due to the following:

- The impacts are confined to agricultural / rural land and do not extend to urban or commercial areas;
- The impacts are confined to shallow depth areas on the floodplain;
- The non-compliant impacts are considerably more extensive for the 1% AEP than for the 10% and 39% AEP events, with the lower order event non-compliances distributed over less catchments and highly scattered and isolated in nature; and
- The extended durations are limited to less than 20 hours for the 1% AEP event. This relatively short and infrequent occurrence should not significantly affect agricultural activity and the productivity of the land.

Notwithstanding the above, these impacts should be subject to consultation with the affected landowners to assess the sensitivity of their land and activities to the impacts.

5.4.2.4 Newell Highway Flood Hazard

Flood hazard is the product of flood depth and flood velocity and is used to define safe uses of land based on the flood risk. Figure 5.3 is taken from ARR2016 Chapter 7 Section 7.2.7 and provides flood hazard curves and definitions.

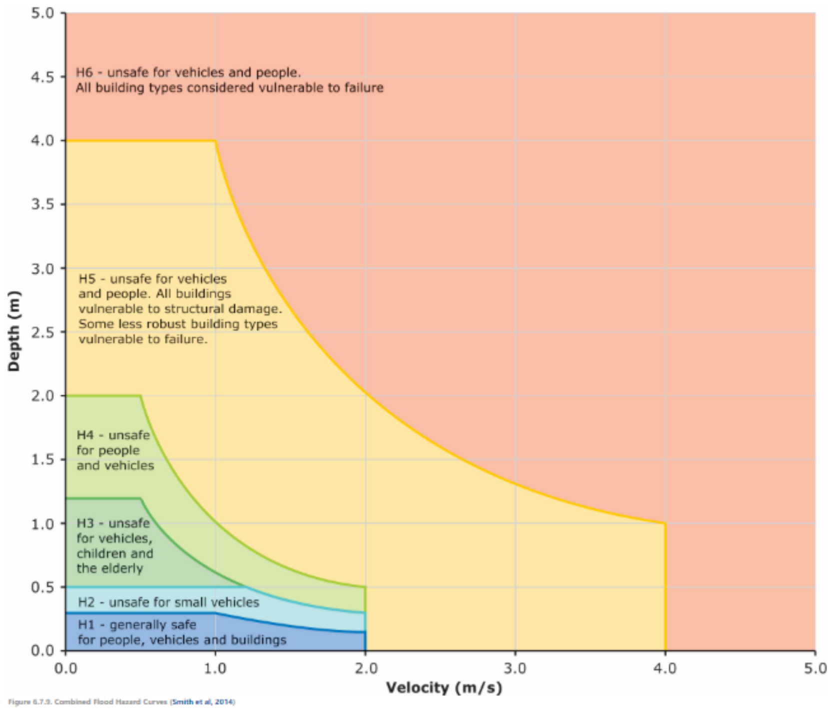

Figure 5.3 Flood hazard curves and definitions (ARR2016, Chapter 7, Section 7.2.7)

The rail corridor is located close the Newell Highway for approximately 79km of the corridor within Phase 1, with the highway located immediately upstream of the corridor between 575 and 619km and immediately downstream of the corridor between 619 and 646km and between 658 and 666km. Parts of the highway and land immediately adjacent to the highway experience both afflux and velocity impacts from the project, which could also increase the hazard categorisation. The highway is therefore critical infrastructure that is sensitive to changes in flood risk and hazard caused by the project.

An assessment of the hazard under both existing conditions and the design case has been undertaken for the flood prone sections of the Newell Highway and the results are presented in Tables 5.13 to 5.15.

Table 5.13 Flood hazard assessment for Newell Highway for 39% AEP event

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
577350	0.06	0.26	0.01	H1	0.06	0.26	0.01	H1	No change
580950	0.16	0.65	0.11	H1	0.12	0.62	0.08	H1	No change
585950	0.00	0.05	0.00	H1	0.00	0.05	0.00	H1	No change
607800	0.14	0.19	0.03	H1	0.18	0.17	0.03	H1	No change
621900	0.12	0.36	0.04	H1	0.12	0.36	0.04	H1	No change
633800	0.19	0.61	0.12	H1	0.20	0.62	0.12	H1	No change
641650	1.22	0.81	0.98	H4	1.22	0.81	0.99	H4	No change
649300	0.71	1.62	1.16	H5	0.72	1.62	1.16	H5	No change
659250	0.40	0.29	0.12	H1	0.40	0.30	0.12	H1	No change

Table 5.14 Flood hazard assessment for Newell Highway for 10% AEP event

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
577400	0.01	0.93	0.01	H1	0.01	0.93	0.01	H1	No change
581150	0.14	0.91	0.13	H1	0.14	0.90	0.12	H1	No change
581650	0.11	0.59	0.06	H1	0.08	0.40	0.03	H1	No change
582650	0.68	1.30	0.88	H4	0.42	1.54	0.65	H4	No change
584650	0.42	0.83	0.35	H2	0.30	1.11	0.33	H2	No change
585350	0.19	1.04	0.20	H1	0.14	1.17	0.16	H1	No change
587700	0.07	1.08	0.07	H1	0.07	1.16	0.08	H1	No change

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
588550	0.02	0.30	0.01	H1	0.02	0.18	0.00	H1	No change
588800	0.20	0.65	0.13	H1	0.14	0.66	0.09	H1	No change
590400	0.09	0.58	0.05	H1	0.05	0.58	0.03	H1	No change
591750	0.20	0.76	0.15	H1	0.19	0.72	0.13	H1	No change
596450	0.07	0.97	0.07	H1	0.07	0.97	0.07	H1	No change
607500	0.08	0.53	0.04	H1	0.08	0.54	0.05	H1	No change
607850	1.39	1.26	1.76	H5	1.37	1.27	1.74	H5	No change
609500	0.34	0.29	0.10	H2	0.34	0.29	0.10	H2	No change
614650	0.26	1.10	0.28	H1	0.22	0.96	0.21	H1	No change
614950	0.28	0.09	0.03	H1	0.30	0.07	0.02	H1	No change
616250	0.09	1.88	0.17	H1	0.09	1.88	0.18	H1	No change
618050	0.36	0.41	0.15	H2	0.36	0.41	0.15	H2	No change
620650	0.15	0.82	0.12	H1	0.15	0.82	0.12	H1	No change
620700	0.14	1.14	0.16	H1	0.14	1.14	0.16	H1	No change
620750	0.10	1.12	0.11	H1	0.10	1.12	0.11	H1	No change
621900	0.24	1.05	0.26	H1	0.24	0.46	0.11	H1	No change
633800	0.30	0.78	0.24	H2	0.30	0.77	0.23	H2	No change
641650	1.61	0.87	1.40	H5	1.61	0.87	1.39	H5	No change
647800	0.09	1.09	0.10	H1	0.12	1.22	0.15	H1	No change
648600	0.24	1.28	0.31	H2	0.27	1.38	0.37	H2	No change
648800	0.11	0.33	0.04	H1	0.12	0.34	0.04	H1	No change
649300	0.89	1.51	1.35	H5	0.91	1.51	1.37	H5	No change
659250	0.42	0.34	0.14	H2	0.41	0.34	0.14	H2	No change

Table 5.15 Flood hazard assessment for Newell Highway for 1% AEP event

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m²/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m²/s)	Hazard Category	
577400	0.06	0.66	0.04	H1	0.04	0.61	0.03	H1	No change
579400	0.03	0.57	0.02	H1	0.02	0.57	0.01	H1	No change
579450	0.20	1.36	0.27	H1	0.22	1.33	0.29	H1	No change
579500	0.21	1.01	0.21	H1	0.21	1.01	0.21	H1	No change
580950	0.27	0.81	0.22	H1	0.23	0.81	0.18	H1	No change
581050	0.17	1.12	0.19	H1	0.15	1.14	0.17	H1	No change
581150	0.19	0.81	0.15	H1	0.19	0.83	0.16	H1	No change
581300	0.18	0.66	0.12	H1	0.11	0.69	0.08	H1	No change
581500	0.24	1.10	0.27	H1	0.16	1.17	0.18	H1	No change
581650	0.20	0.84	0.17	H1	0.15	0.85	0.13	H1	No change
581800	0.09	1.01	0.09	H1	0.09	0.96	0.09	H1	No change
581900	0.12	0.95	0.11	H1	0.00	0.92	0.00	H1	No change
582000	0.07	0.65	0.05	H1	0.08	0.67	0.05	H1	No change
582100	0.19	0.86	0.17	H1	0.20	0.87	0.17	H1	No change
582200	0.33	1.04	0.34	H2	0.33	1.07	0.35	H2	No change
582300	0.35	0.98	0.34	H2	0.30	0.88	0.27	H2	No change
582450	0.35	0.75	0.26	H2	0.35	0.74	0.26	H2	No change
582500	0.34	0.80	0.27	H2	0.36	0.68	0.25	H2	No change
582600	0.80	1.39	1.11	H5	0.45	1.48	0.67	H4	Reduced hazard
582650	0.85	1.43	1.22	H5	0.44	1.68	0.74	H4	Reduced hazard
582750	0.29	1.13	0.32	H2	0.26	1.22	0.32	H2	No change
582800	0.13	0.96	0.13	H1	0.07	1.03	0.07	H1	No change
583700	0.03	0.51	0.02	H1	0.01	0.55	0.01	H1	No change
583850	0.06	0.91	0.05	H1	0.05	0.75	0.04	H1	No change

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
583950	0.06	0.65	0.04	H1	0.06	0.53	0.03	H1	No change
584400	0.11	0.76	0.08	H1	0.12	0.76	0.10	H1	No change
584550	0.25	1.04	0.26	H1	0.28	1.04	0.29	H1	No change
584650	0.47	0.89	0.42	H2	0.49	1.12	0.55	H2	No change
584700	0.22	0.97	0.21	H1	0.16	0.99	0.16	H1	No change
584950	0.17	0.87	0.15	H1	0.09	0.78	0.07	H1	No change
585050	0.23	1.04	0.24	H1	0.14	0.94	0.13	H1	No change
585100	0.32	0.98	0.32	H2	0.21	0.84	0.18	H1	Reduced hazard
585200	0.30	0.91	0.27	H2	0.17	0.95	0.16	H1	Reduced hazard
585350	0.28	1.29	0.36	H2	0.25	1.31	0.33	H2	No change
585450	0.27	1.27	0.34	H2	0.24	1.27	0.30	H2	No change
585500	0.24	1.65	0.39	H2	0.23	1.66	0.38	H2	No change
585550	0.18	1.00	0.18	H1	0.22	1.01	0.22	H1	No change
587500	0.24	0.85	0.20	H1	0.14	0.88	0.12	H1	No change
587700	0.23	0.99	0.23	H1	0.21	1.05	0.22	H1	No change
588350	0.13	0.73	0.09	H1	0.08	0.76	0.06	H1	No change
588350	0.13	0.73	0.09	H1	0.08	0.76	0.06	H1	No change
588450	0.14	0.60	0.08	H1	0.07	0.78	0.06	H1	No change
588450	0.14	0.60	0.08	H1	0.07	0.78	0.06	H1	No change
588550	0.23	0.56	0.13	H1	0.13	0.80	0.10	H1	No change
588550	0.23	0.56	0.13	H1	0.13	0.80	0.10	H1	No change
588700	0.22	0.48	0.11	H1	0.16	0.65	0.10	H1	No change
588700	0.22	0.48	0.11	H1	0.16	0.65	0.10	H1	No change
588800	0.34	0.76	0.26	H2	0.27	0.93	0.25	H1	Reduced hazard
588800	0.34	0.76	0.26	H2	0.27	0.93	0.25	H1	Reduced hazard

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
588900	0.25	0.74	0.19	H1	0.16	0.75	0.12	H1	No change
588900	0.25	0.74	0.19	H1	0.16	0.75	0.12	H1	No change
589950	0.10	0.84	0.08	H1	0.06	0.86	0.05	H1	No change
589950	0.10	0.84	0.08	H1	0.06	0.86	0.05	H1	No change
590200	0.03	0.61	0.02	H1	0.01	0.66	0.01	H1	No change
590200	0.03	0.61	0.02	H1	0.01	0.66	0.01	H1	No change
590300	0.11	0.77	0.09	H1	0.05	0.71	0.04	H1	No change
590300	0.11	0.77	0.09	H1	0.05	0.71	0.04	H1	No change
590400	0.14	0.75	0.10	H1	0.07	0.80	0.05	H1	No change
590400	0.14	0.75	0.10	H1	0.07	0.80	0.05	H1	No change
591600	0.47	0.79	0.37	H2	0.00	0.82	0.00	H1	Reduced hazard
591600	0.47	0.79	0.37	H2	0.00	0.82	0.00	H1	Reduced hazard
591750	0.46	1.00	0.46	H2	0.11	1.01	0.11	H1	Reduced hazard
591750	0.46	1.00	0.46	H2	0.11	1.01	0.11	H1	Reduced hazard
591850	0.23	0.94	0.22	H1	0.01	0.93	0.01	H1	No change
591850	0.23	0.94	0.22	H1	0.01	0.93	0.01	H1	No change
596300	Not flooded	Not flooded	Not flooded	N/A	0.01	0.44	0.01	H1	New flooding (extension of existing H1 area)
596450	0.21	1.13	0.24	H1	0.21	1.13	0.24	H1	No change
596500	0.13	1.00	0.13	H1	0.10	0.91	0.09	H1	No change
607500	0.17	0.98	0.17	H1	0.14	1.00	0.14	H1	No change
607650	0.44	1.72	0.76	H4	0.43	1.73	0.74	H4	No change
607700	0.58	0.39	0.23	H3	0.58	0.38	0.22	H3	No change
607800	0.50	0.37	0.18	H2	0.50	0.34	0.17	H2	No change

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
607850	0.43	1.06	0.45	H2	0.26	1.05	0.28	H1	Reduced hazard
607900	0.36	1.27	0.46	H2	0.17	1.10	0.19	H1	Reduced hazard
607950	0.48	0.25	0.12	H2	0.48	0.24	0.12	H2	No change
608050	0.30	0.23	0.07	H1	0.29	0.23	0.07	H1	No change
609450	0.43	0.50	0.22	H2	0.43	0.50	0.21	H2	No change
609500	0.48	0.32	0.15	H2	0.59	0.33	0.19	H3	Increased hazard
609650	0.21	0.32	0.07	H1	0.07	0.33	0.02	H1	No change
614300	0.14	0.66	0.10	H1	0.03	0.84	0.02	H1	No change
614450	0.32	1.09	0.35	H2	0.24	1.04	0.24	H1	Reduced hazard
614650	0.37	1.76	0.65	H4	0.34	1.80	0.62	H4	No change
614800	0.18	0.80	0.14	H1	0.15	0.90	0.13	H1	No change
614950	0.51	0.10	0.05	H3	0.59	0.08	0.05	H3	No change
615000	0.47	0.03	0.01	H2	0.52	0.03	0.01	H3	Increased hazard
616250	0.26	1.81	0.47	H2	0.24	1.80	0.44	H2	No change
616300	0.28	1.41	0.40	H2	0.12	0.62	0.07	H1	Reduced hazard
618050	0.48	0.47	0.22	H2	0.22	0.48	0.11	H1	Reduced hazard
620650	0.27	1.19	0.33	H2	0.33	0.27	0.09	H2	No change
620700	0.24	1.52	0.37	H2	0.37	0.24	0.09	H2	No change
620750	0.17	1.62	0.28	H1	0.28	0.17	0.05	H1	No change
621900	0.28	1.58	0.45	H2	0.45	0.28	0.13	H2	No change
633800	0.39	0.89	0.34	H2	0.34	0.36	0.12	H2	No change
639200	0.13	1.29	0.17	H1	0.17	0.09	0.02	H1	No change
639250	0.11	1.46	0.15	H1	0.15	0.07	0.01	H1	No change
641000	0.13	1.05	0.14	H1	0.14	0.10	0.01	H1	No change
641100	0.25	1.64	0.40	H2	0.40	0.21	0.09	H2	No change

Location (km)	Existing Conditions				Design Case				Hazard Category Impact
	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	Depth (m)	Velocity (m/s)	Hazard (m^2/s)	Hazard Category	
641200	0.19	1.18	0.22	H1	0.22	0.17	0.04	H1	No change
641350	0.15	2.07	0.32	H5	0.32	0.15	0.05	H2	Reduced hazard
641400	0.24	1.80	0.44	H2	0.44	0.24	0.10	H2	No change
641450	0.16	2.45	0.40	H5	0.40	0.14	0.06	H2	Reduced hazard
641500	0.09	2.10	0.18	H5	0.18	0.08	0.01	H1	Reduced hazard
641550	0.14	1.97	0.28	H1	0.28	0.15	0.04	H1	No change
641650	1.78	0.95	1.69	H5	1.69	1.77	2.99	H5	No change
641700	0.10	1.69	0.17	H1	0.17	0.13	0.02	H1	No change
641750	0.21	2.23	0.48	H5	0.48	0.23	0.11	H2	Reduced hazard
641800	0.11	2.35	0.25	H5	0.25	0.12	0.03	H1	Reduced hazard
641900	0.11	1.85	0.20	H1	0.20	0.10	0.02	H1	No change
642200	0.13	1.91	0.25	H1	0.25	0.09	0.02	H1	No change
642300	0.42	1.61	0.67	H4	0.67	0.39	0.26	H3	Reduced hazard
642400	0.25	2.27	0.56	H5	0.56	0.24	0.13	H3	Reduced hazard
642500	0.20	1.82	0.37	H2	0.37	0.20	0.07	H2	No change
642600	0.12	1.75	0.21	H1	0.21	0.11	0.02	H1	No change
643450	0.10	1.60	0.16	H1	0.16	0.10	0.02	H1	No change
643800	0.10	0.87	0.08	H1	0.08	0.11	0.01	H1	No change
647800	0.22	1.78	0.39	H2	0.39	0.21	0.08	H2	No change
648600	0.44	1.73	0.75	H4	0.75	0.43	0.32	H3	Reduced hazard
648800	0.14	0.43	0.06	H1	0.06	0.14	0.01	H1	No change
649300	1.03	1.37	1.40	H5	1.40	1.03	1.44	H5	No change
649500	0.18	2.61	0.47	H5	0.47	0.18	0.08	H2	Reduced hazard
649600	0.29	1.40	0.41	H2	0.41	0.29	0.12	H2	No change
659250	0.43	0.41	0.18	H2	0.18	0.43	0.08	H1	Reduced hazard

The tables show that the project causes no changes to the hazard categories for the 39 and 10% AEP events. For the 1% AEP event there are 25 locations where the hazard is reduced and 3 locations where the hazard is increased. While some increases in flood depths occur, in general the project does not increase the flood hazard on the highway and in the 1% AEP event causes an overall reduction in hazard on the highway as a result of removal of the rail overtopping mechanism and passage of flow under the rail via new and upgraded culverts in a more controlled manner.

5.4.3 Focus for Additional Compliance Investigations

The following area of non-compliance will continue to be investigated with the intent of removing or significantly reducing the non-compliance:

- Non-compliant afflux at building on Lot 23 DP751087 and afflux generally around the level crossing at 734km in the MACINTYRE02 model area.

5.5 Impacts of Climate Change

The 1% AEP climate change scenario was used to assess the potential impacts of climate change on the rail formation flood immunity and the flooding impacts of the project on adjacent land to determine if the design has capacity to deal with future climate changes. The results are discussed in the following sections.

5.5.1 Impact on Rail Formation Flood Immunity

The increase in flood level for the 1% AEP event under the climate change scenario was checked to determine the impact on the rail formation flood immunity. The climate change scenario results in variable increases in flood level at the rail corridor as summarised in Table 5.16 below, with an average increase of 109mm and a maximum increase of 638mm.

Table 5.16 Impact of climate change on 1% AEP flood levels at rail corridor

Flood level increase	Extent of rail corridor affected
0 to 100mm	57.4%
100 to 200mm	31.2%
200 to 300mm	7.4%
300 to 400mm	2.8%
400 to 500mm	1.0%
500 to 600mm	0.1%
600 to 700mm	0.1%
>700mm	N/A

The increased flood levels under the climate change scenario reduce the TOF flood immunity and result in the 1% AEP flood level getting to within 100mm of the top of rail level at several locations, but do not cause overtopping of the rail at any location.

The results are considered to demonstrate resilience in the design and capacity to accommodate climate change for the following reasons:

- The 1% AEP flood levels are increased by less than 200mm for 89% of the project corridor; and
- No overtopping of the rail occurs for the 1% AEP event with climate change.

5.5.2 Impacts on Adjacent Land

The 1% AEP with climate change flood impact maps are provided in Appendix C. The maps demonstrate the following:

- Afflux is increased in most areas when compared to the 1% AEP impacts without climate change, with the occurrence of some new areas of non-compliant impacts. However, the general pattern of flood level impact remains similar to the 1% AEP event without climate change and any new non-compliances are mostly confined to rural or agricultural land areas. The impacts on more sensitive urban / settlement areas are as follows:
  - Bellata (chainage 615km): no significant change in afflux (refer to Figures DE1A9 and DE1CCA9 in Appendix C);
  - Gurley (chainage 636km): no significant change in afflux to key sensitive area west of the rail line (refer to Figures DE1A13 and DE1CCA13 in Appendix C);
  - South of Halls Creek (chainage 659km): approximately 100mm increase in afflux around some commercial properties south of the Halls Creek crossing, noting that these properties are prone to flooding at the 10% AEP event and above under existing conditions. These impacts under climate change would constitute new non-compliant impacts at the affected commercial properties (refer to Figures DE1A18 and DE1CCA18 in Appendix C);
  - Croppa Creek: approximately 100mm increase in afflux around some properties (including the school) north and south of the level crossing on the east side of the rail line, noting that these properties are prone to flooding at the 39% AEP event and above under existing conditions. As noted in Section 5.4.3, impacts in this area are subject to further investigation post-IFC (refer to Figures DE1A33 and DE1CCA33 in Appendix C);
- Velocity impacts remain very similar to the 1% AEP event impacts without climate change (compare Figures DE1VC1 to DE1VC37 with Figures DE1CCVC1 to DE1CCVC37 in Appendix C); and
- Duration impacts also remain very similar to the 1% AEP event impacts without climate change (compare Figures DE1D1 to DE1D37 with Figures DE1CCD1 to DE1CCD37 in Appendix C).

For impacts on adjacent land, the most affected parameter is afflux. However, the majority of the increased afflux areas occur within agricultural land, with increases around urban areas and buildings confined to localised areas that are already flood prone.

5.6 Extreme Event Impacts

The 0.05% AEP event was simulated to determine structural loading parameters for bridges and to assess the potential impacts of the project under an extreme flood event. For this event, the rail line was modelled as fully intact. This assumption will exaggerate the predicted flood level impacts of the project under this event as the ballast layers, and possibly the full embankment, are likely to wash away at many locations under such conditions, which would equalise water levels across the rail corridor at the peak of the event.

The 0.05% AEP event flood maps for existing conditions and the flood impact maps for the design case are provided in Appendices B and C. This section summarises the 0.05% AEP event impacts of the project at key sensitive locations.

Figures 5.3 and 5.4 show the 0.05% AEP afflux and velocity impacts at Bellata. The figures show that the developed areas remain flood free for this event, with afflux of less than 100mm occurring in some lots in the southern area of the settlement and no velocity change occurring within the developed areas. The flood impacts to the settlement under extreme event conditions are therefore considered to be low.

Figures 5.5 and 5.6 show the 0.05% AEP afflux and velocity impacts at Gurley. The figures show that the developed areas on the western side of the rail line do not experience afflux or velocity impacts; while the agricultural land on the eastern side of the rail line experiences extensive areas of afflux in excess of 200mm. Therefore, flood impacts to Gurley under extreme events are considered to be low provided the land east of the rail line remains under agricultural use.

Figures 5.7 and 5.8 show the 0.05% AEP afflux and velocity impacts south of Halls Creek. The figures show that the developed areas on the eastern side of the rail line will experience afflux of less than 200mm with no change in velocity. The flood impacts to this area under extreme event conditions are therefore considered to be low.

Figures 5.9 and 5.10 show the 0.05% AEP afflux and velocity impacts at Croppa Creek. The figures show that the developed areas on the eastern side of the rail line will experience afflux in excess of 200mm with no significant change in velocity. The flood impacts to this area under extreme event conditions are therefore considered to be medium due to the increased flood depths around the local roads and buildings east of the rail line.

In general, it is considered that the impacts under the extreme event are acceptable given the low impacts on velocity and the likelihood that localised failure of the rail embankment, or at least the ballast layers, would occur under such events which would reduce the afflux upstream of the rail line. In cases where high affluxes are predicted, the flood depths are significant under existing conditions and the afflux caused by the rail line would generally add 300 to 400mm to flood depths that are in excess of 1m under existing conditions.

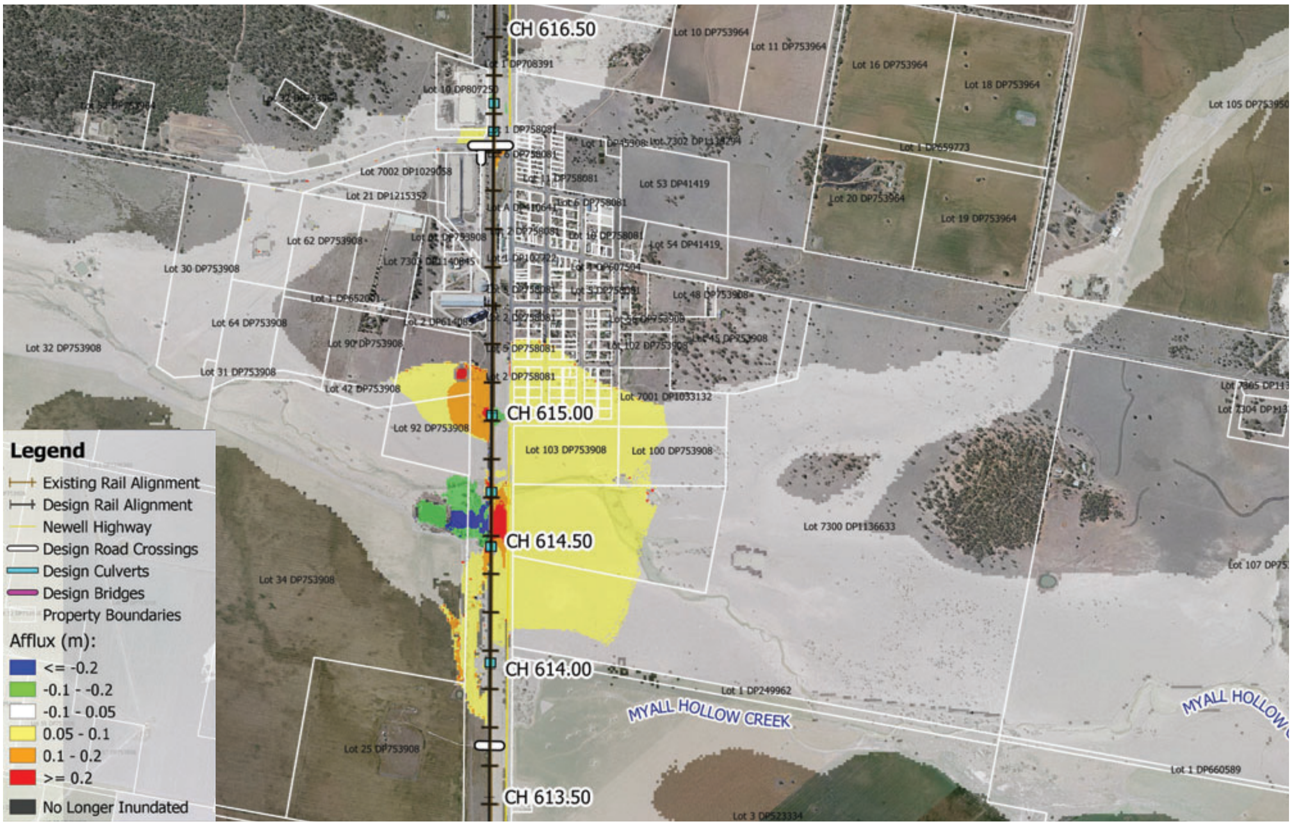

Figure 5.4 0.05% AEP afflux at Bellata

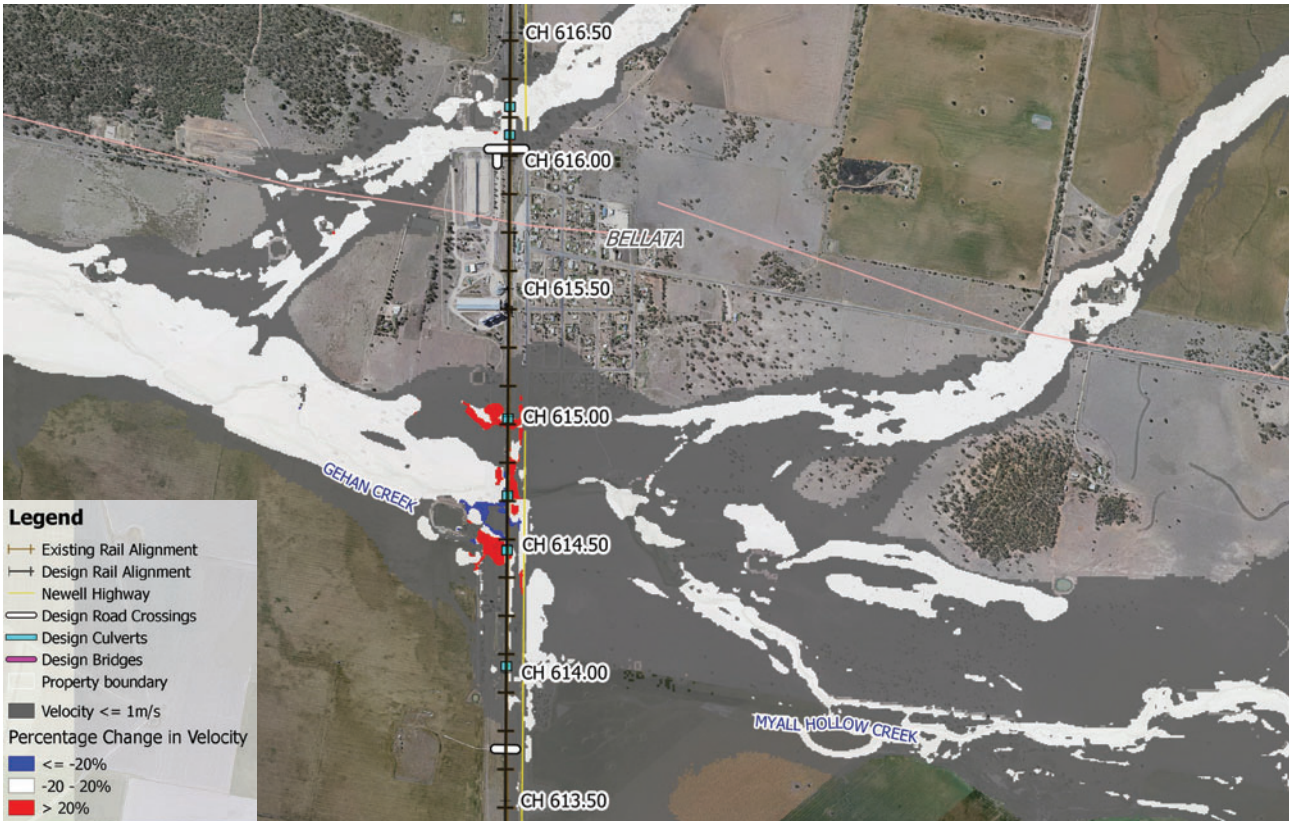

Figure 5.5 0.05% AEP velocity impact at Bellata

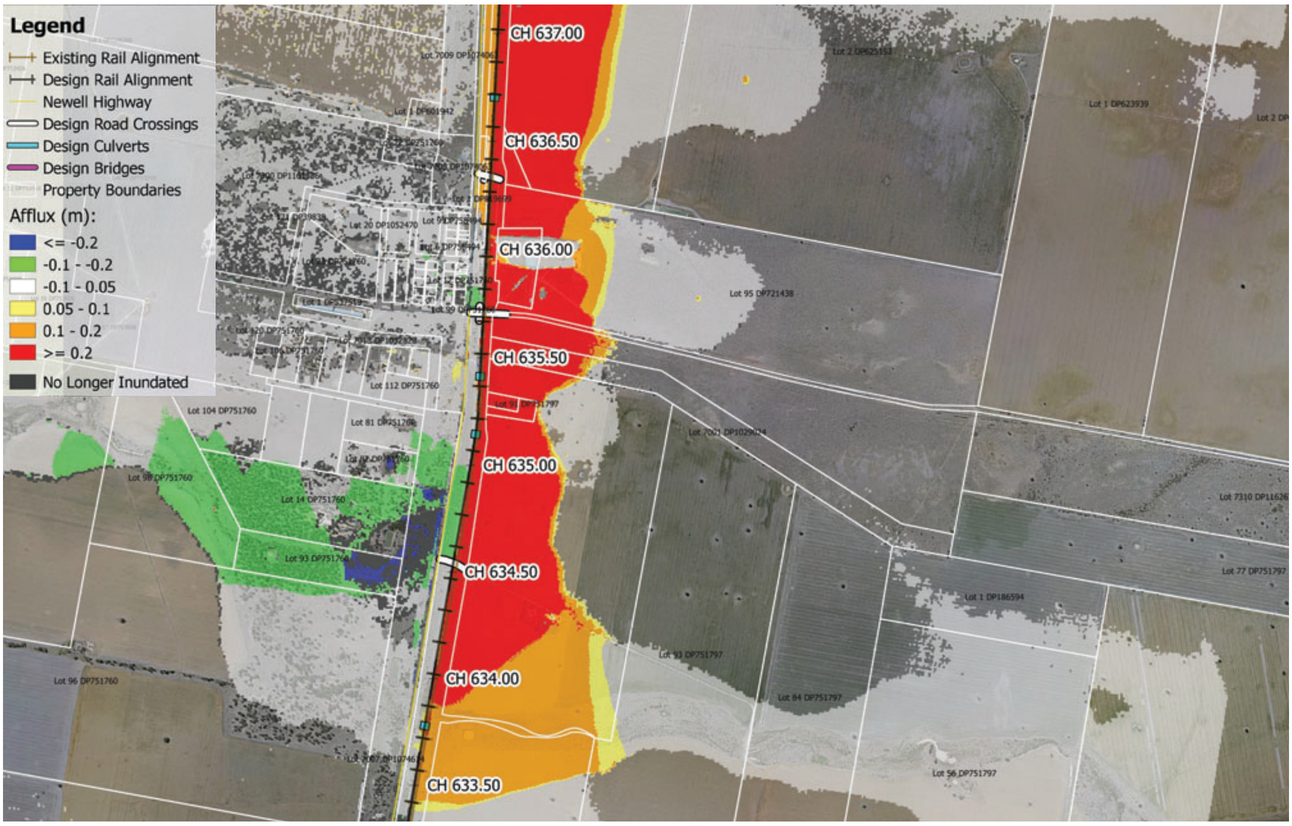

Figure 5.6 0.05% AEP afflux at Gurley

Figure 5.7 0.05% AEP velocity impact at Gurley

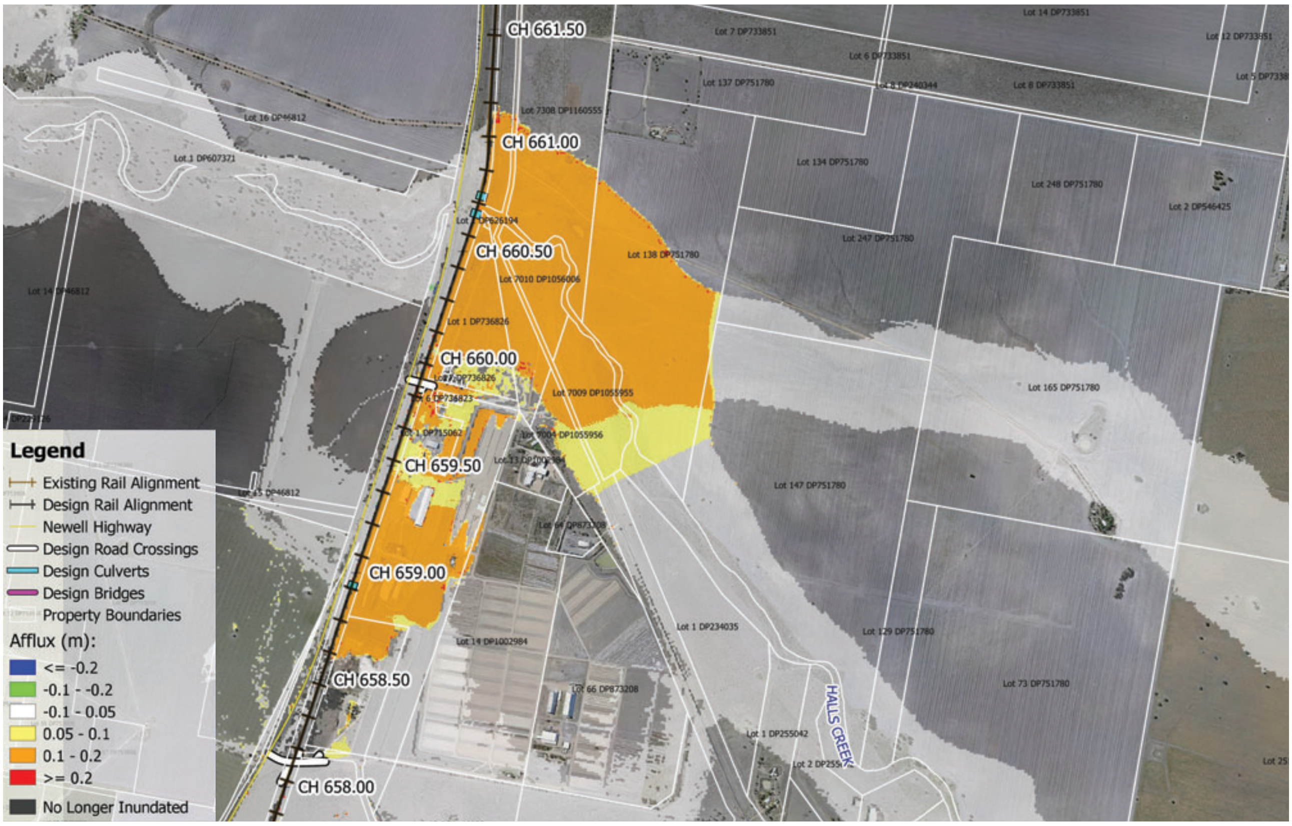

Figure 5.8 0.05% AEP afflux south of Halls Creek

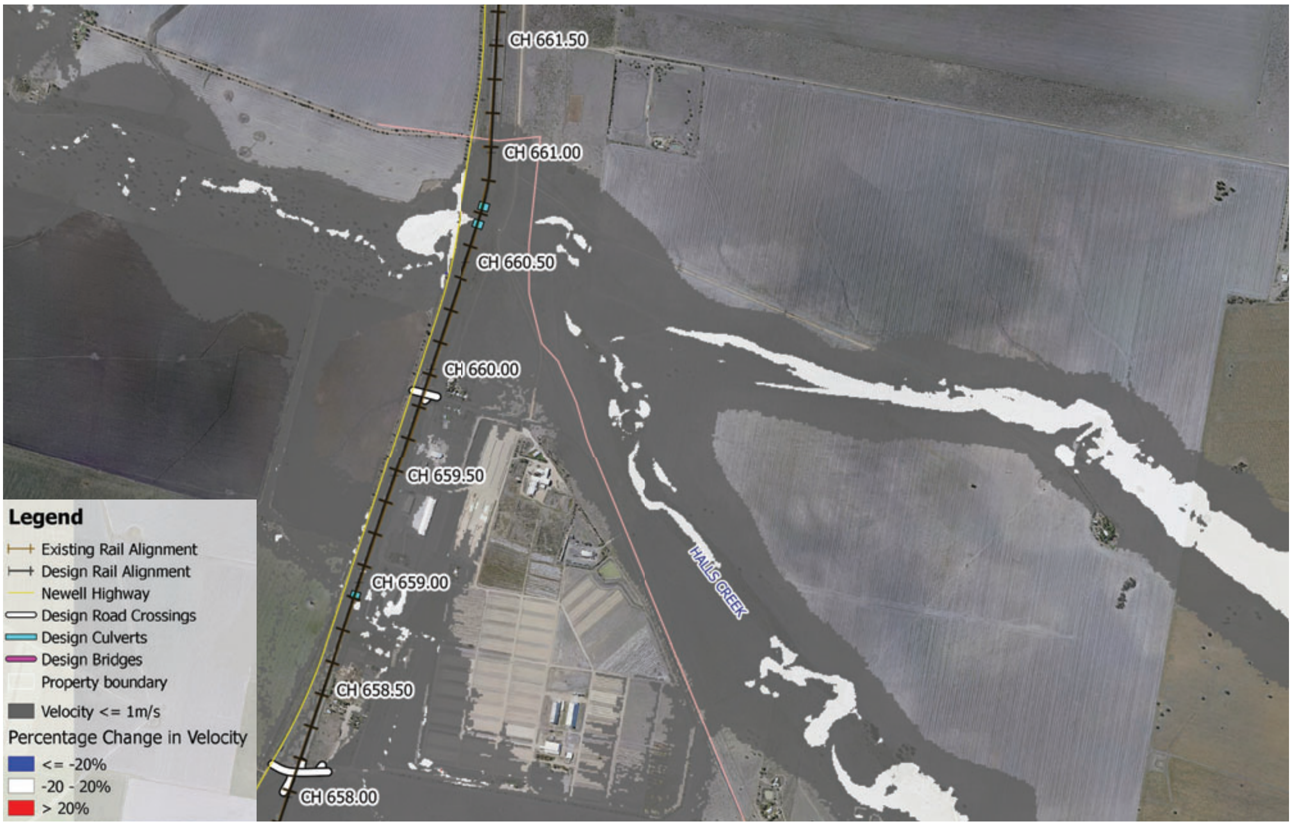

Figure 5.9 0.05% AEP velocity impact south of Halls Creek

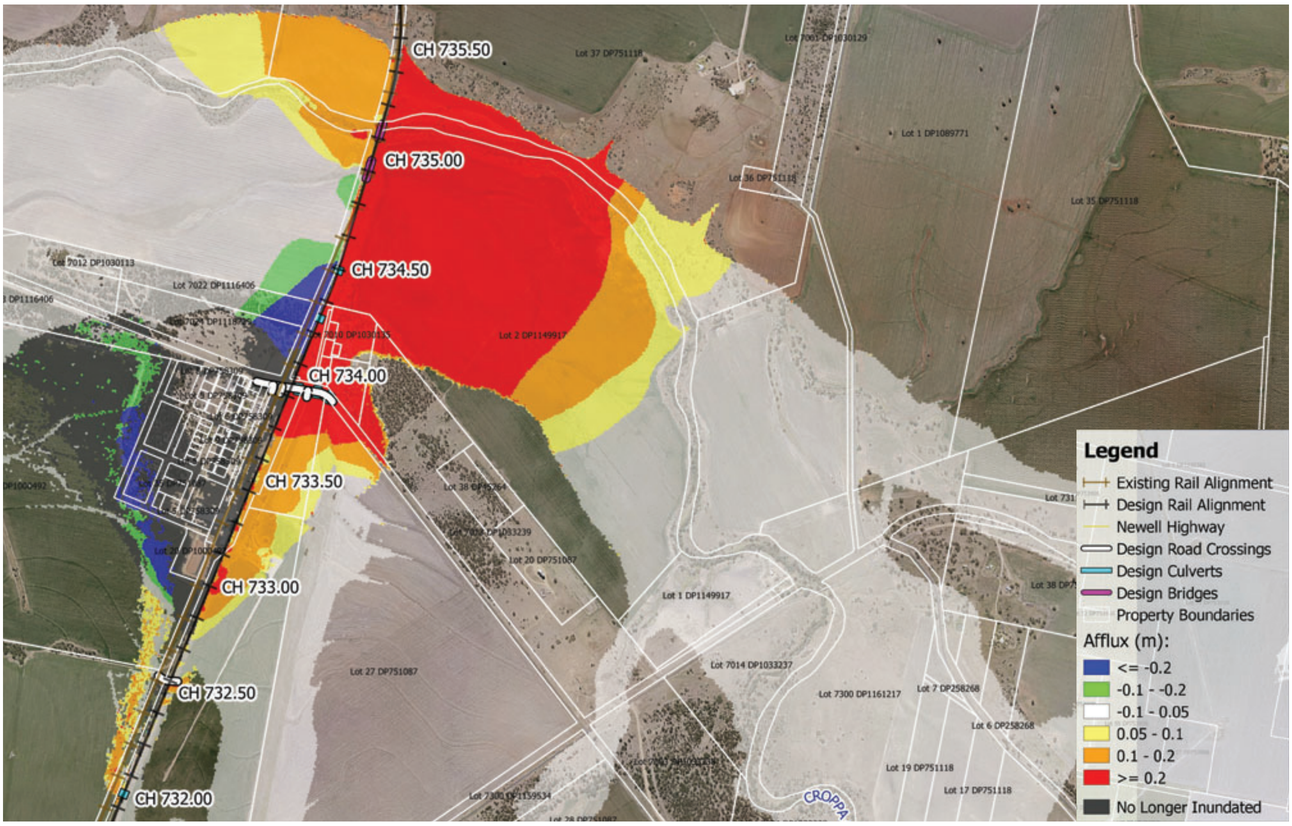

Figure 5.10 0.05% AEP afflux at Croppa Creek

Figure 5.11 0.05% AEP velocity impact at Croppa Creek

6 Conclusions and Further Work

6.1 Conclusions

This report has described the methodology and results of the flood modelling undertaken for the SPIR. This report includes an assessment of flood impact compliance for the 39, 10 and 1% AEP events, with the ARTC RAATM and BoD and the FMOs.

At this stage, several non-compliances with the flood design criteria have been identified which are proposed as acceptable impacts on the basis that they do not affect the ongoing use of the land or introduce new hazardous flooding conditions, and can therefore be classified as low risk impacts. All impacts presented in this report are subject to acceptance by affected landowners through the consultation process.

6.2 Further Work

Further work relating to the flooding and cross drainage design includes the following:

- Improvement of the non-compliant afflux at building on Lot 23 DP751087 and afflux generally around the level crossing at 734km in the MACINTYRE02 model area.

7 References

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