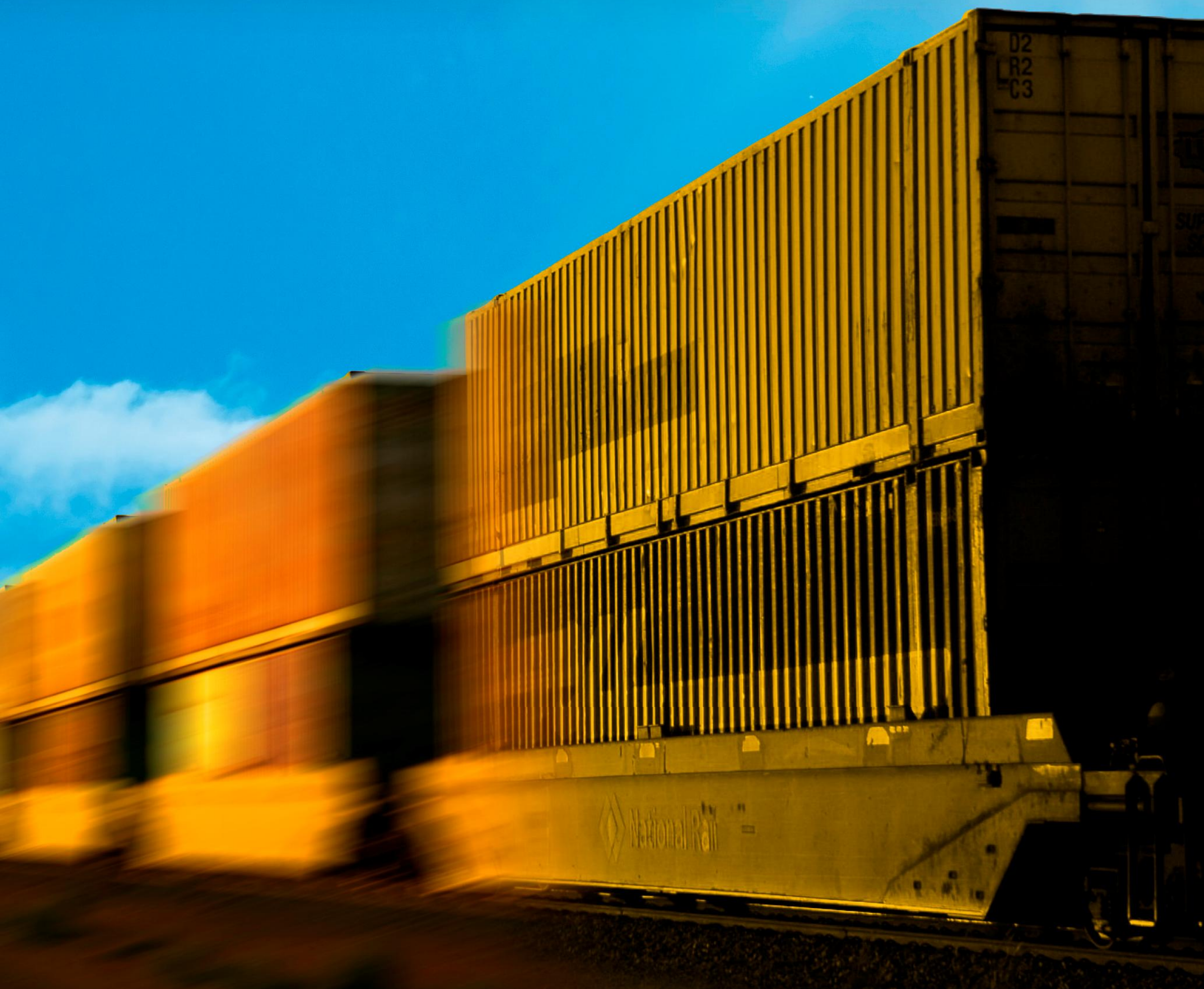
Technical and Approvals Consultancy Services: Narrabri to North Star

Flood Design Verification Report for Phase 1

Issued For Construction

August 2021

3-0001-260-IHY-00-RP-0006



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Glossary

1D	One dimensional
2D	Two dimensional
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
DD	Detailed Design
DEM	Digital Elevation Model
DIRD	Department of Infrastructure and Regional Development
DPIE	NSW Department of Planning, Industry and Environment
EIS	Environmental Impact Statement
EY	Exceedances per Year
FFA	Flood Frequency Analysis
FLC	Form Loss Coefficient
GIS	Geographic Information System
HPC	Heavily Parallelised Computations
HQ	Flow Boundary
IFC	Issued For Construction
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 detailed design for the project
IFC	Issued for Construction
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
QDL	Quantitative Design Limit
QT	Time Boundary
RFFE	Regional Flood Frequency Estimation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RFI	Request for Information
RAATM	Requirements Analysis, Allocation and Traceability Matrix
RAFTS	Water Resource Engineering Software (www.wateronline.com)
R&O	Risk & Opportunity
RORB	An industry standard hydrologic modelling software program
SRTM	Shuttle Radar Topography Mission
TA	Technical Advisor
TfNSW	Transport for NSW
TIN	Triangular Irregular Network
TOF	Top of Formation
TUFLOW	Flood Modelling Software (www.tuflow.com)
VE	Value Engineering

1 Introduction

1.1 Background

The Australian Government has undertaken to deliver the Melbourne to Brisbane Inland Rail (IR), 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 and Regional Development (DIRD), 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.

Delivery of the N2NS Project is being undertaken in two phases. Phase 1 covers the majority of the project area, other than the area of the Gwydir-Mehi regional river system and associated floodplain. Phase 2 covers the rail corridor that crosses the two rivers and extends across the floodplain.

Phase 1 addresses 169.46km of rail corridor, from 575 to 666km and from 682 to 760.46km. This report documents the outcomes of the flood modelling and cross drainage hydraulic design for this portion of the project.

Phase 2 addresses 16km of rail corridor, from 666 to 682km. Phase 2 is subject to a separate environmental approval process and associated documentation.

1.2 Scope

This report has been prepared in response to the Conditions of Approval (CoA) issued by the NSW Department of Planning, Industry and Environment (DPIE) for N2NS Phase 1.

The report assesses flood behaviour within the local catchments crossed by 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, 18, 5, 2, 1 and 0.05% Annual Exceedance Probability (AEP) events. The results of a sensitivity assessment of the effects of climate change applied to the 1% AEP event are also documented.

The report documents the Issued For Construction (IFC) detailed design 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 Quantitative Design Limits (QDLs), or flood impact criteria, set out in the CoA. The report also addresses the CoA requirements for a Flood Emergency Response Plan and Independent Peer Review; and documents the outcomes of the stakeholder consultation on flooding and drainage matters.

1.3 Objectives

The objectives of the flooding analyses undertaken for the project are 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 detailed design of the project;
- 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 process for and selection of flood planning levels for the rail infrastructure consistent with ARTC's business decisions; and

Design the cross drainage systems for the upgraded rail corridor, to achieve the required minimum rail formation flood immunity and satisfy the flood performance conditions, including QDLs relating to flooding impacts in land adjacent to the rail corridor.

1.4 Related documents

This report should be read in conjunction with the following additional documents produced for the project:

Detailed Design Flood Study Report Volume 1 (3-0001-260-IHY-00-RP-0002) and Volume 2 (3-0001-260-IHY-00-RP-0003): This report summarised the flooding and drainage analysis undertaken for the detailed design of the project and describes the methodologies used for the design flood modelling and results of the rail formation flood immunity assessment, the flood impact assessment and the compliance of the cross drainage design and flood modelling with the Requirements Analysis, Allocation and Traceability Matrix (RAATM), ARTC's Flooding Multi-Criteria Analysis outcomes and flood impact criteria adopted in advance of the QDLs issued with the CoA. Volume 1 contains existing conditions and design conditions flood mapping for the 39%, 10% and 1% AEP events and the 1% AEP event with climate change allowance. Volume 2 contains existing conditions and design conditions flood mapping for the 18%, 5%, 2% and 0.05% AEP events.

Submissions and Preferred Infrastructure Report – Flood Study Report (3-0001-260-IHY-00-RP-0005): This report presented similar content to the Detailed Design Flood Study Report (see above) but with a summary of key findings for the purposes of the Submissions and Preferred Infrastructure Report.

Hydrological Model Calibration Report (3-0001-260-IHY-00-RP-0001): This report describes the hydrological modelling methodology; provides a summary of the review of hydrological data used to build and calibrate the hydrological models, a description of the hydrological model calibration process and the results achieved; and provides a description of additional sensitivity tests and validation checks on the hydrological models of the existing flooding conditions within the project area. This is a key document that is required to give ARTC and the Technical Advisor (TA) confidence in the hydrological modelling and design flow estimates before proceeding to adopt the hydrological model for the detailed design. This report is included as Appendix E to the Submissions and Preferred Infrastructure Report – Flood Study Report (3-0001-260-IHY-00-RP-0005) described above.

This report reproduces most of the technical content of the above reports with results and flood impact mapping updated to assess the impacts of the project against the QDLs and document design changes since the Submissions and Preferred Infrastructure Report was published.

1.5 Status of report

The report is currently at the Issued For Construction (IFC) design stage draft status, and is subject to review by ARTC, the TA and the Independent Peer Reviewer.

1.6 Design developments since Submissions and Preferred Infrastructure Report

Since the Submissions and Preferred Infrastructure Report was published, a number of changes to the design have been made and a number of flood impact mitigation measures have been designed following consultation with landowners. These design developments are summarised below, with further details of the consultation process provided in Section 6:

Updates to GWYDIR02 model and associated rail cross drainage infrastructure: Following consultation with a landowner that farms a significant area of land on the east of the rail corridor within and around the Tycannah Creek catchment, it was identified that the model did not extend sufficiently far east to capture key breakouts from Tycannah Creek that divert flows to the north towards the Halls Creek catchment. The existing conditions model was subsequently extended approximately 15km to the east to capture the Tycannah Creek breakout. The revised existing conditions flood maps were presented to the landowner who confirmed that the updated model predictions matched the observed flood behaviour in previous events. This change to the modelled flood behaviour required significant changes to the cross drainage design in the section from chainage 619 to 666km, which involved redistribution of culverts to match the changes in the predicted floodplain flow distribution. The overall number of culverts remained similar to the previous design iteration, with relocation of culverts from the south to the north of this section to match the updated modelled flow distribution.

Flood impact mitigation measures within the NAMOI01 model: In the section from chainage 575 to 592.5km the Newell Highway is located immediately upstream of the rail corridor and the cross drainage was designed to minimise impacts on the highway. This results in more flow directed to land downstream of the rail corridor affecting some areas of agricultural land and property accesses. Following consultation with these landowners a number of diversion channels within the rail corridor were designed to capture and direct additional flows to main watercourses and flow paths preferred by the landowners. Other mitigation measures included works outside the corridor, such as design of new property accesses or design of raised accesses and improvements to cross drainage under the access roads / tracks, and raising existing levee banks that are used to control and direct flood flows and protect cropping land from flood damage.

Flood impact mitigation measures within the Gurley area: At Gurley the project has downstream flood impacts around a number of properties located west of the rail corridor. These impacts affect property accesses and driveways. Following consultation with landowners on these impacts a number of mitigation measures were investigated to reduce / remove the impacts, including a diversion channel within the rail corridor and modifications to the minor drainage structures around a level crossing. These mitigation measures are still under investigation and yet to be confirmed. No changes to the main rail cross drainage structures are proposed.

Other flood impact mitigation measures: Flood impact mitigation measures are also required at several other locations throughout the project area. These involve relatively minor works within or outside the rail corridor, such as flow diversion channels / contour banks / levee raising to direct flow within properties as preferred by landowners, raising of levees to protect buildings and earthworks and rock protection around culvert outlets to improve flow transitions and mitigate potential future erosion issues. No changes to the main rail cross drainage structures are proposed.

In some cases the flood impact mitigation measures are subject to ongoing consultation and agreement with landowners and this process is expected to continue through the early part of the construction phase. These mitigation measures may involve works within or outside the rail corridor (such as flow diversion channels, levee / contour bank raising, access track raising, etc.) rather than any changes to the cross drainage infrastructure within the rail corridor. The final outcomes of these negotiations will be documented in future revisions of this report.

1.7 Cumulative impact assessment with Newell Highway Upgrade

Transport for NSW (TfNSW) is planning to upgrade the Newell Highway between Narrabri and Moree as part of the Newell Highway Upgrade Program. The objectives of the Upgrade Program are to improve safety for motorists, reduce future maintenance requirements, reduce travel time, improve flood immunity and reduce vehicle operating costs.

Between Narrabri and Moree where the Newell Highway runs close to N2NS Phase 1, upgrades of four sections of the Newell Highway are planned over a distance of approximately 34.3 km, at the following locations:

- 6.9 km north of Narrabri from rail chainage 574.9 to 581.8 km (highway is upstream of rail corridor);
- 8.1 km south of Edgeroi from rail chainage 586.1 to 594.2 km (highway is upstream of rail corridor);
- 11.6 km north of Belatta from rail chainage 614.7 to 626.3 km (highway is upstream of rail corridor to chainage 619km and downstream of rail corridor from chainage 619km); and
- 7.8 km south of Moree from rail chainage 655.2 to 663.0 km (highway is downstream of rail corridor).

Within these sections the upgrade works will consist of new road surface, widening of shoulders, intersection improvements, wide centreline treatment, improved flood immunity (raised road level) and overtaking lanes.

While the detailed design for these upgrade sections has been completed, a construction date has not yet been announced, and construction of the N2NS Phase 1 works will proceed in advance of construction of the Newell Highway upgrades.

This report presents two sets of results for the N2NS Phase 1 flood impact assessment:

- Results showing the flooding impacts of the N2NS Phase 1 works only (presented in main report Section 5); and
- Results showing the cumulative or combined flooding impacts of both the N2NS Phase 1 works and the Newell Highway Upgrade works (presented in Appendix D).

1.8 Conditions of Approval

The CoA relevant to flooding and where they are addressed in this report are provided in the table below.

Table 1.1 Conditions of Approval relating to flooding

Condition		Where addressed in report
Quantitative Design Limits (QDLs)		
E27	The CSSI must meet the QDLs in Appendix A – FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS. Unless otherwise noted, these QDLs apply outside the rail corridor except for level crossings. These QDLs apply in any flood event up to and including the 1% AEP, and in any duration. In circumstances where the CSSI does not meet the QDL at a specific location, the Proponent must achieve compliance through modified design of the CSSI. If this is not possible or practical the Proponent must: (a) document the extent of the non-compliance with the QDL and justify why it is not possible or practical to achieve compliance through CSSI design changes; (b) in every instance of non-compliance with the QDLs, consult with and obtain agreement from the affected land or property owners to either: i) the non-compliance; or ii) establish an alternative level of mitigation of impacts for that location through alternative design measures; (c) where an alternative level of mitigation of impacts is required for a location, achieve a level of mitigation through design measures beyond the rail corridor; and (d) describe and detail the mitigation measures in the Flood Design Verification Report required by Condition E28;	Section 5.4.2 Section 6 – consultation process and mitigation measures
Flood Design Verification Report		
E28	Compliance with the QDLs as required by Condition E27 must be demonstrated in a Flood Design Verification Report that details flood behaviour under existing conditions and with the final detailed design of the approved CSSI. The flood modelling informing the report must be developed in consultation with EES, relevant councils and Transport for NSW, and completed to the specifications in Appendix A – FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS. The Flood Design Verification Report must include: (a) details of the flood modelling that informs the report; (b) details of how the project's flood planning level (FPL) was decided, with reference to relevant considerations of the NSW Floodplain Development Manual; (c) an assessment of the infrastructure's compliance with the Quantitative Design Limits (QDLs) for flooding, hydrology and geomorphology listed in Appendix A –	Section 4 – flood modelling methodology Section 5 – flood impact assessment Section 4.6.2 and Appendix I – independent peer review

Condition		Where addressed in report
	FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS; (d) floor level surveys of potentially affected buildings to accurately confirm compliance with afflux limits. Where a floor level has not been surveyed, the Report shall adopt the existing ground level as the floor level, with appropriate annotation; (e) an assessment of the impacts of the CSSI on erosion, scouring, bank stability, stream stability and geomorphology; (f) mitigation and management measures that will be undertaken if the QDLs are exceeded, as specified in Condition E27; (g) mitigation measures to minimise potential adverse impacts and responses to actual impacts with regard to the NRAR's Guidelines for Controlled Activities on Waterfront Land; (h) an assessment of risk to life caused by formation failure in extreme flood events, including management measures to mitigate this risk; and (i) an assessment of aquaplaning risks where the CSSI produces additional inundation of highways or sealed roads with a speed limit of 80km/h or greater. Where an aquaplaning risk is attributable to the CSSI, undertake infrastructure changes to remove the additional inundation or to introduce risk mitigation measures to manage this risk. The flood model and results must be independently peer-reviewed in accordance with Condition E29 and be submitted to the Planning Secretary for information at least one month prior to the commencement of construction of permanent works that may impact on flooding. *Note: Components of the SPIR hydrology technical report that are still relevant to the final design of the CSSI may be reused to prepare the Flood Design Verification Report where they meet the requirements of Condition E28 and Appendix A.*	
Independent Peer Review		
E29	The Flood Design Verification Report (including the flood model upon which it is based) must be reviewed and endorsed by a suitably qualified and experienced hydrologist who has extensive experience in flood modelling including with the hydrological and hydraulic software used for the model. This hydrologist must be independent of the Proponent and the organisation(s) who prepared the flood model, having regard to the Department's Post Approval Guidance for Infrastructure Projects: Seeking Approval from the Department for the Appointment of Independent Experts (DPIE, 2020). The review must: (a) review the flood model files and the description of the model provided within SPIR and any adjustments to this as per the Flood Design Verification Report; (b) assess the establishment, calibration, validation and operation of the flood model items as per (a); (c) identify and document existing and future purposes for which the model can and cannot be used, including adaptation of this model by others, and any limitations on this; (d) (d) document the review findings including specifically responding to Condition E28(a) to E28(i) and, after any recommended model and/or reporting improvements have been undertaken to the peer reviewer's satisfaction, provide written certification within the review report that the Flood Design Verification Report, modelling and mitigation measures: i) have been prepared consistent with current and appropriate methodologies and standards; and ii) accurately depict and resolve design impacts of the CSSI. The peer reviewer's endorsement must be appended to the Flood Design Verification Report. *Note: The independent reviewer must have extensive experience with the software packages applied in the modelling for the SPIR and the Flood Design Verification Report,*	Section 4.6.2 and Appendix I

Condition		Where addressed in report
	although this may not necessarily include the specific software version(s) used in the SPIR and Flood Design Verification Report, provided the software version updates are not relevant to the peer review.	
Flood Emergency Response Plan (FERP) for Flood Risks within the Rail Corridor		
E30	The Proponent must prepare a Flood Emergency Response Plan (FERP) which documents how the risks to life and property within the rail corridor are to be safely managed during a flood. The FERP must detail activities before, during and after a flood, including for staff training and maintenance and updating of the FERP. (a) The FERP must be prepared by an experienced flood emergency response specialist who has extensive experience in preparation of these plans. (b) This specialist must confirm that residual flood risks are acceptable and the procedures within the FERP are consistent with best practice and the requirements of the NSW Floodplain Development Manual. (c) The FERP must be appended to the Flood Design Verification Report. *Note: Nothing in this condition prevents the adaptation of an existing flood management or emergency plan to satisfy this condition.*	Appendix H
Information to Facilitate Management of Flood Emergency Risks beyond the Rail Corridor		
E31	Where the CSSI has the potential to adversely impact flood risks to life or property beyond the rail corridor, the Proponent must document the flood risk information in sufficient detail so that relevant emergency services personnel and affected third parties can prepare, respond and recover from future flood emergencies. This shall include but not be limited to: (a) documentation of the changes to flood behaviour including levels, depths, velocities, etc, that may result in adverse impacts to life and property beyond the rail corridor, in any future flood events including events up to the PMF; (b) consideration of changes to flood behaviour that may result from CSSI infrastructure failures or embankment collapses where these may occur during floods; (c) provision of sufficient detail and scope to enable the relevant personnel or agency (including the NSW SES, the local council, affected property or infrastructure owners) to prepare for management of flood emergencies; (d) respond to requests for information about the CSSI from those personnel or agencies in (c) to assist them in preparing their own flood emergency response plans. This documentation shall be appended to the Flood Design Verification Report and be certified as consistent with the requirements of this condition by the same specialist preparing and certifying the FERP (required by Condition E30).	Section 5 – flood impact assessment Appendix C – design case flood impact mapping
Flood Review after Construction		
E32	For the first 15 years of operation, the Proponent must prepare Flood Review Report(s) within three months after the first defined flood event for any of the following flood magnitude ranges that occur – the 1-5% AEP, 5-10% AEP and 10-20% AEP events. The Flood Review Report(s) must be prepared by a suitably qualified and experienced hydrologist(s) and include: (a) a comparison of the observed extent, level, and duration of the flooding event against those predicted in (or inferred from) the SPIR and the Flood Design Verification Report required by Condition E28; (b) identification of the properties and infrastructure affected by flooding during the reportable event; and (c) where the observed extent and level of flooding or other flooding or erosion impacts exceed those predicted due to the CSSI with the consequent effect of adversely impacting on property(ies), structures, infrastructure or the environment, and/or exceed the requirements specified in Conditions E27 and E28:	To be addressed in a separate report

Condition		Where addressed in report
	i) determine if the exceedance is attributable to the CSSI, and ii) where the cause is attributable to the CSSI, identification of the rectification measures that would be implemented to reduce future adverse impacts of flooding from similar events related to the CSSI works, including the timing and responsibilities for implementation. A copy of the Flood Review Report(s) must be submitted for information to the Secretary and EES and relevant council(s) within three (3) months of finalising the report. Any rectification measures identified within the Flood Review Report(s) must be developed in consultation with the affected third parties (e.g. land and property owners, infrastructure owners, EES, the relevant council(s), state and local government agencies, etc) and implemented within the timeframes specified in the Flood Review Report(s) or as agreed with the affected parties.	
E33	To analyse the lengths of rail corridor impacted by rainfall and consequential flood events for the purposes of Condition E32, the Proponent must develop spatially defined monitoring zones and associated monitoring methodologies for the flood catchments modelled in the SPIR. The monitoring methodologies shall provide an approach to inter rainfall intensities utilising the available Bureau of Meteorology rainfall monitoring stations suitable for each catchment. The methodology must be developed in consultation with DPIE and submitted to the Planning Secretary for information within six (6) months prior to the commencement of operation of the CSSI.	To be addressed in a separate report
Information Sharing		
E34	Flood information resulting from the requirements of this approval, including flood reports, models and geographic information system outputs, and work as executed information from a registered surveyor certifying finished ground levels and the dimensions and finished levels of all structures within flood prone land, must be made available to the relevant council(s), TfNSW, EES and the SES upon request. The relevant councils, TfNSW, EES and the SES must be notified in writing that the information is available no later than one (1) month following the completion of construction. Information requested by a relevant council, TfNSW, EES or the SES must be provided within six (6) months.	Not addressed in this report. Arrangements for data sharing and handover to be agreed between ARTC and relevant agencies.
Water Quality and Drainage		
E36	The Proponent must consult with TfNSW in relation to stormwater and drainage management to coordinate drainage infrastructure with the Newell Highway Upgrade.	Section 6.5
E37	Prior to the installation of a new culvert, the Proponent must consult with the landowner that is located immediately downstream of the new culvert to determine the potential for impacts on agricultural productivity, farm operations and farm dams (including changes in water supply yield, reliability of supply, flood flows and embankment stability) due to the introduction or alteration of flows. Where potential adverse impacts are identified, the Proponent must consult with the affected landowner on the management measures that will be implemented to mitigate the impacts.	Sections 6.3 and 6.4
Traffic, Transport and Access		
E42	The Proponent must consult with TfNSW prior to, and at regular intervals during, construction to co-ordinate and implement mitigation measures to reducing any potential concurrent impacts arising from the construction of the CSSI and Newell Highway upgrade works.	Section 6.5

2 Project description and study area

2.1 Project description

The project consists of 169.46km of upgraded rail track and associated infrastructure. The project is located along the existing rail corridor between Narrabri and North Star south of Moree and east / north of the Camurra hairpin. The southern 15km of the project is located within part of the Namoi River Basin, the central 103.46km is located within the Gwydir River Basin (excluding the Gwydir regional river and floodplain north of Moree, which is crossed by Phase 2 of the project) and the northern 51km is located within part of the Border Rivers Basin.

2.2 Study area

2.2.1 Catchment overview

While the Phase 1 corridor lies within three major river basins, it does not cross or interact with the main regional rivers but crosses 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; and
- 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.

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 592.5km;
- Gwydir River Basin: Covered by the following three separate hydraulic models:
  - GWYDIR01 from 592.5km to 619km;
  - GWYDIR02 from 619km to 666km; and
  - GWYDIR03 from 682km to 709km; and
- 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.

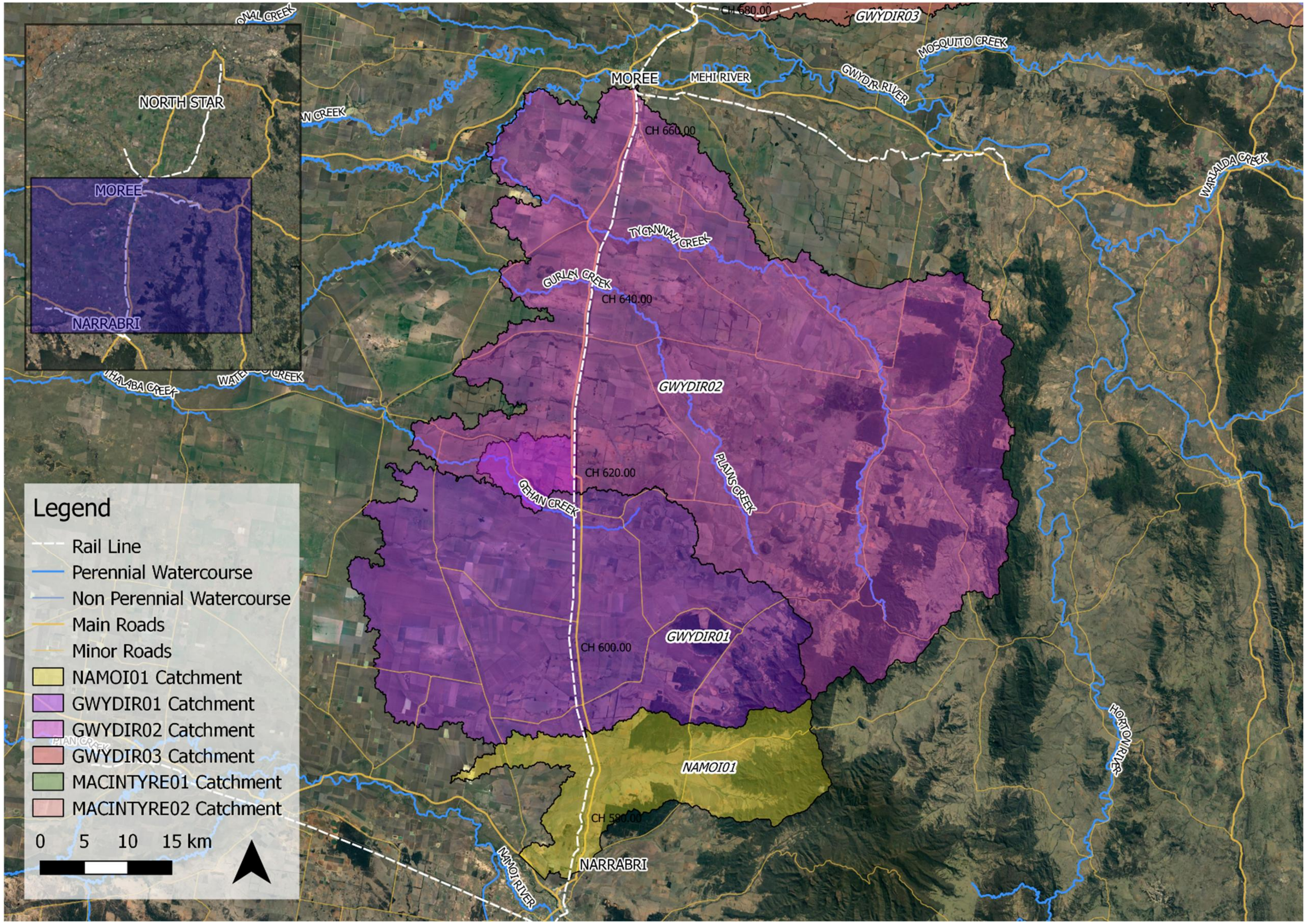

Figure 2.1 N2NS Phase 1 study area and extent of NAMOI01, GWYDIR01 and GWYDIR02 flood models

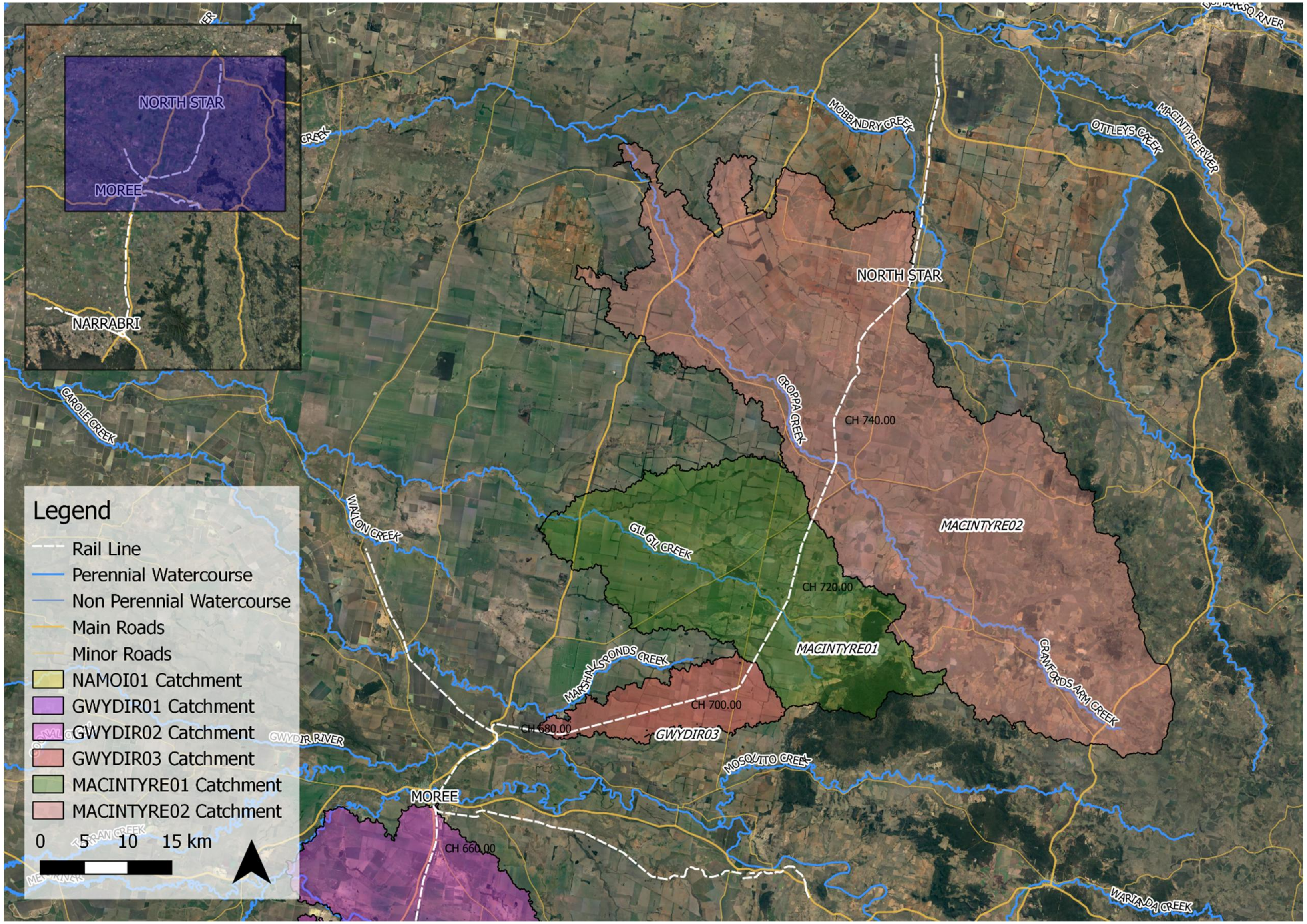

Figure 2.2 N2NS Phase 1 study area and extent of GWYDIR03, MACINTYRE01 and MACINTYRE02 flood models

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. The project area is located outside of the regional floodplain of the Namoi, Gwydir and the Border Rivers, and is located within local upland catchments of the Namoi, Gwydir and Border River basins with no interaction with the regional river channels and floodplains.

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 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 generally runs in a north-south direction to Moree. After Phase 2, Phase 1 commences again several kilometres east of the Camurra hairpin and extends to the north east. The design rail alignment within the Gwydir River Catchment is a brownfield upgrade of the existing corridor.

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. The design rail alignment within the Macintyre River Catchment is a brownfield upgrade of the existing corridor. 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 Model Calibration Report (3-0001-260-IHY-00-RP-0001) 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 Planning Approval sets performance criteria for the rail infrastructure on the external environment. This is applied through the CoA, and specifically, through the QDLs established under Condition E27.

Design criteria for the rail infrastructure are set by ARTC's Basis of Design (BoD) and Requirements Analysis, Allocation and Traceability Matrix (RAATM) for the Inland Rail Program. Where the RAATM includes design or impact criteria for the environment outside the rail corridor, those requirements are applied in light of the CoA and the QDLs.

The key design criteria and requirements with respect to flooding are documented in this section.

3.1.1 Flood impact criteria

The flood impact criteria adopted for the project are the QDLs provided in Appendix A of the CoA. These are reproduced in the table below.

Table 3.1 Flood impact criteria – QDLs set by the CoA

Parameter	Location or Land Use	Limit
Afflux i.e. increase in flood level resulting from implementation of CSSI	Habitable floors[4]	10mm increase[5]
	Non-habitable floors	20mm increase
	Other urban and recreational	100mm increase
	Agricultural	200mm increase
	Forest and unimproved grazing land	300mm increase
	Highways and sealed roads >80km/hr6	No increase in depth where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase
	Unsealed roads and sealed roads <80km/hr[6]	100mm increase
Scour/Erosion Potential i.e. increase in flood velocity resulting from implementation of CSSI	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads and most urban, commercial, industrial, recreational and forested land	20% increase in velocity where existing velocity already exceeds 1m/s
	Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is to be limited to 20% where the existing velocity already exceeds 0.5m/s
Flood Hazard i.e. increase in velocity~depth product (vd) and/or flood hazard category resulting from implementation of CSSI. (Does not apply where vd>0.1m^2/s)	Urban, commercial, industrial, highways[6] and sealed roadways[6]	10% increase in vd where H1 or H2 category. 0% increase in vd where H3 or greater hazard category.
	Elsewhere	20% increase in vd
Flood Duration	Habitable floors[4]	No increase in inundation duration above floor level.

Parameter	Location or Land Use	Limit
i.e. increase in duration of inundation resulting from implementation of CSSI (Does not apply to inundated areas less than 100m^2)		10% increase in inundation duration where below floor level and when existing inundation duration exceeds one hour. Otherwise inundation duration not to exceed one hour.
	Highways and sealed roads >80km/hr[6]	10% increase in inundation duration.
	Elsewhere	10% increase in inundation duration when existing inundation duration exceeds one hour. Otherwise inundation duration not to exceed one hour.

Notes:

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

[5] 10 mm has been set to provide a margin for modelling uncertainties/tolerances. The intent of this requirement is that existing flood levels above floor level do not increase.

[6] Including where located within CSSI corridor.

3.1.2 Project specific criteria and general guidelines and standards

The BoD and RAATM contain the primary design criteria and objectives for the flooding analysis and cross drainage design.

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 design 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), with consideration given to ARR2019 as appropriate;

- 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).

3.1.3 Flood Planning Level and ARTC Flooding Multi Criteria Analysis

The Flood Planning Level (FPL) for the project is the required flood immunity of the upgraded rail corridor set by ARTC. The flood immunity of the rail corridor is defined as the flood immunity of the Top of Formation (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. For N2NS Phase 1 the minimum TOF flood immunity varies throughout the corridor, with the majority of the corridor achieving a 2% AEP or great flood immunity but lower immunities of between 10% and 2% AEP accepted in some areas based on application of the MCA process.

The ARTC Flooding MCA process was applied at the primary cross drainage locations where most flow is concentrated, to provide a continuous assessment of the Top of Formation (TOF) flood immunity for existing rail line. The results were provided to ARTC at the 50% design stage in the MCA Stage 1 Reporting Tables spreadsheets, and ARTC advised where a TOF flood immunity option of less than the 1% AEP event may be accepted in the design case.

A final detailed review of the TOF flood immunity was undertaken at the IFC stage to ensure all MCA requirements were met. Refer to Sections 4.5 and 5.2.1 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 follows (based on constructability, maintenance and value engineering discussions between ARTC and IRDJV):
  - Rail culverts ranging in width from 0.45m to 3m and in height from 0.3m to 2.4m; and
  - Road culverts ranging in width from 0.45m to 2.4m and in height from 0.3m to 1.2m;
- For level crossings where Reinforced Pipe Culverts (RCPs) can be utilised, RCPs are to be Class 4 pipes 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 SDLs provided in Table 3.1;
- In general, RCBCs have been used in preference to bridge structures for new waterway crossings and culvert upgrades;

For culvert scour protection, a velocity threshold of 1.6m/s will be used to determine where scour protection is likely to be required, based on previous experience in applying the Austroads design procedure (Austroads Guide to Road Design, Part 5: Drainage – General and Hydrology Considerations and Part 5B: Drainage – Open Channels, Culverts and Floodways, Austroads 2013). This is a more conservative assumption than the 2.5m/s suggested in the ARTC Basis of Design document and the value of 1.6 m/s was taken from Table 2.6 of the Austroads Guide and corresponds to a permissible velocity value for channel gradients up to 1% with 50% stable surface cover in an erosion resistant soil. This value is used solely to determine the need for scour at culvert inlets and outlets based on the flow velocity in the culvert. Separate to this process, the impact assessment considers changes in flood velocities in the adjacent land around the culvert and a more stringent limit of 0.5 m/s for velocity change was used to determine potential impacts in the adjacent land – refer to Section 3.1.1 for further details;

Bridge scour analysis and design of scour protection measures is based on the following guidelines:

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, U.S Department of Transportation-Federal Highway Administration – Evaluating Scour at Bridges (Fifth Edition);

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 Section 4.2.1.8 for further 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, with bridges designed to withstand hydraulic loading from surcharging; and

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:

Light Detection and Ranging (LiDAR) provided by ARTC supplemented by detailed ground surveys (in progress) 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 Model Calibration Report 3-0001-260-IHY-00-RP-0001):

- 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 Appendix A for the following information on the RORB models:

- Appendix A1 Figures A1.1 to A1.4 provide overviews of the RORB model layouts and sub-catchments;
- Appendix A3 provides print-outs of the RORB model '.catg' files giving information such as model node and reach linkages, sub-catchment areas, reach lengths and reach slope; and
- Appendix A4 Figures A4.1 to A4.37 provide the RORB model sub-catchment delineations around the rail corridor along with sub-catchment node names and areas.

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 (note that the LiDAR data has been validated against ground survey – refer to LiDAR Validation Report 3-0001-260-ISV-00-RP-0001);
- 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	19.4
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 Model Calibration Report (3-0001-260-IHY-00-RP-0001).

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 (3-0001-260-IHY-00-RP-0001). The model validation included a comparison of the design flow estimates produced by the RORB models at each cross drainage location to those estimated by RFFE and the EIS analysis.

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 (if required)

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.

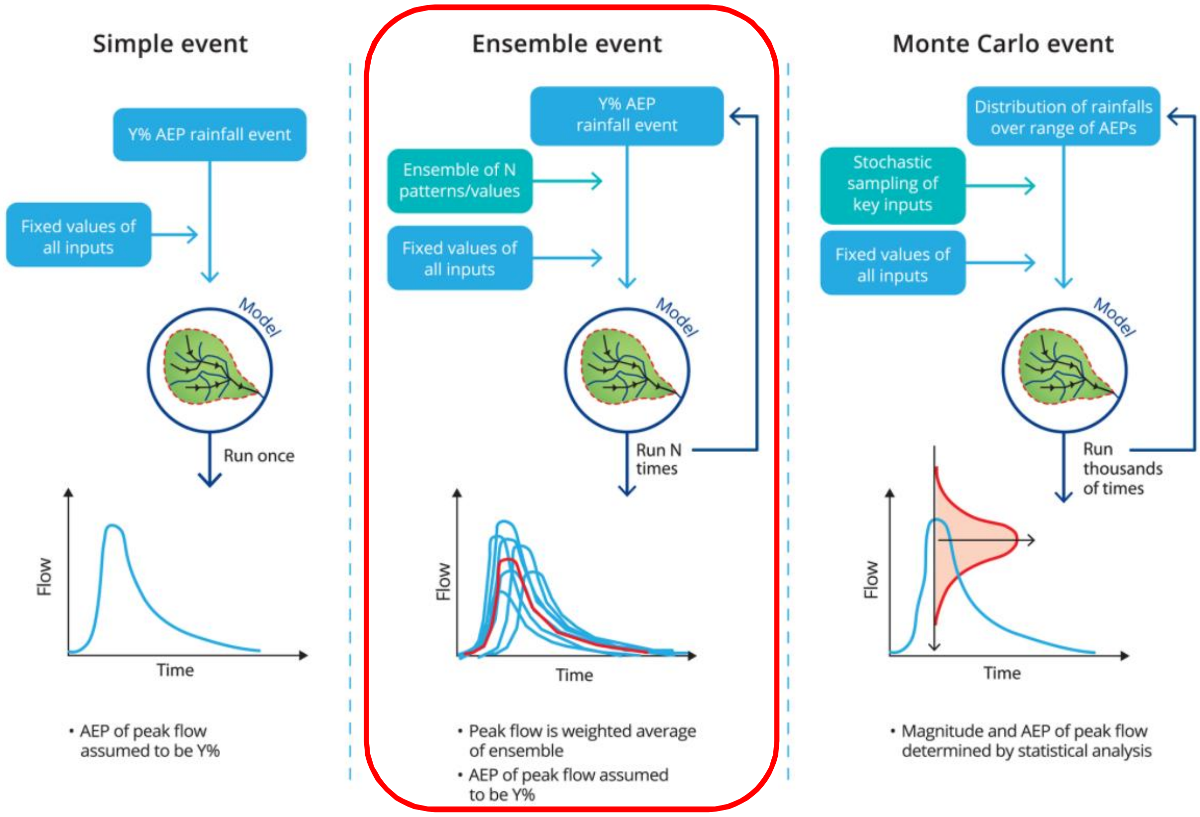

Figure 4.1 ARR2016 approaches to estimation of peak flow

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 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 Appendix A2 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 Transport for NSW (TfNSW). 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.

As noted in Section 1.7, four sections of the Newell Highway adjacent to N2NS Phase 1 will be upgraded in the near future. The planned upgrades are as follows:

Upgrade section 1: 6.9km of highway adjacent to and upstream (east) of the rail corridor between 574.9 and 581.8km – this upgrade section is located within the NAMOI01 hydraulic model area.

Upgrade section 2: 8.1km of highway adjacent to and upstream (east) of the rail corridor between 586.1 and 594.2km – this upgrade section is located within the NAMOI01 and GWYDIR01 hydraulic model areas.

Upgrade section 3: 11.6km of highway adjacent to the rail corridor between 614.7 and 626.4km, with the section up to 619km located upstream (east) and the section after 619km located downstream (west) of the rail corridor – this upgrade section is located within the GWYDIR02 hydraulic model area.

Upgrade section 4: 7.8km of highway adjacent to and downstream (west) of the rail corridor between 655.2 and 663.0km – this upgrade section is located within the GWYDIR02 hydraulic model area.

IFC design information for the upgrades has been provided by TfNSW and included in the design case hydraulic models for the cumulative impact assessment (Appendix D). The existing pre-upgrade condition of the highway is represented in the existing conditions hydraulic models.

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 simulate the hydraulic effects of 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 and for this project the range was from 0.08 to 0.3 depending on the length of the bridge;

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.

Representations of existing bridges in the model have been derived from survey provided, or site images in lieu of detailed survey. Representations of design case bridges were based on the structural design drawings for the bridges.

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 E. A full list of results from the blockage assessment is provided in Appendix E, 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 culvert locations. This uniform assumption has been adopted to allow for a consistent approach to blockage of culverts 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 culvert location.

The 15% blockage assumption is supported by information provided by ARTC operations and maintenance staff on the typical level of blockage of structures that is observed prior to routine inspection and cleaning. Main types of debris / blockage are wheat stubble, sticks, branches (of various sizes), long grass and silt/ top soil from adjacent farms. Photos of all existing cross drainage structures were reviewed and showed the following:

- South of Moree: The majority of culverts have no or minimal blockage. For some of the smaller culverts there is some level of blockage due to sediment build-up and vegetation but the level of blockage is generally less than 15%.
- North of Moree: As above the majority of culverts have minimal blockage, however, there are a number of small culverts that have a high level of blockage due to sediment. The number of culverts displaying the higher level of blockage is low.

Figures 4.2 to 4.5 provide photos of a sample of the existing culverts displaying the typical level of blockage.

The new/upgraded culverts will be taller and wider structures with 4m long inlet and outlet concrete aprons and will therefore be less susceptible to blockage than the existing culverts which are smaller and, in the case of the circular pipe culverts, generally lack formal aprons or other treatments to control vegetation and siltation.

The consultation process (see Section 6) identified that landowners downstream of the rail corridor are more sensitive to changes in flood behaviour, particularly the potential for erosion of cropping paddocks as a result of increased flows through the rail corridor, or new flow paths that develop as a result of new culverts installed where none currently exist. Therefore, highly conservative blockage assumptions have not been made so that the culverts are not overdesigned with potential for increased downstream impacts if high blockage values are not realised in practice.

Figure 4.2 Photos of example culverts showing typical level of blockage – 577.445km

Figure 4.3 Photos of example culverts showing typical level of blockage – 589.3km

Figure 4.4 Photos of example culverts showing typical level of blockage – 621.848km

Figure 4.5 Photos of example culverts showing typical level of blockage – 745.41km

While the majority of the project cross drainage structures are culverts, the project also includes a total of 8 waterway bridges. All bridges have a minimum span of 9m. In accordance with standard industry practice, no blockage has been assumed at bridges on the basis that debris mobilised from the upstream rural catchments is unlikely to be of sufficient dimension to significantly block 9m wide bridge openings.

4.2.1.9 Farm dam representation

Numerous farm dams are present throughout the modelled areas. These are represented in the TUFLOW models as topographic features, with invert levels based on the LiDAR data that is likely to have recorded the water level occurring in the dams at the time of the survey. Inflows are generally applied upstream of the dams and flow is therefore hydraulically routed through the dams, which means that the flow attenuating effects of the dams is taken into account in the models. The majority of the dams are very small features that have a weak attenuating effect and therefore little or no influence on the magnitude of the flow arriving at the rail corridor.

Some larger dams exist within the MACINTYRE01 and MACINTYRE02 modelled areas. For these, a sensitivity analysis was undertaken to simulate the effect of a flood occurring when the dams are completely full and the potential change in flood impacts under this scenario. The results of the sensitivity analysis are discussed in the Flood Study Report Volume 1 (3-0001-260-IHY-00-RP-0002).

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; and
- 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 (in the order of 200mm or less) 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;
- Flood duration; and
- Flood hazard.

The changes in these parameters were then compared to the QDLs and RAATM requirements (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).

As noted in Section 1.7, the flood impact assessment has been undertaken for two design case scenarios: (1) the N2NS Phase 1 works only and (2) the N2NS Phase 1 and Newell Highway Upgrade works.

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 QDLs 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 culvert barrel 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 value of 1.6 m/s was taken from Table 2.6 of the Austroads Guide and corresponds to a permissible velocity value for channel gradients up to 1% with 50% stable surface cover in an erosion resistant soil. This value is used solely to determine the need for scour at culvert inlets and outlets based on the flow velocity in the culvert. Separate to this process, the impact assessment considers changes in flood velocities in the adjacent land around the culvert and a more stringent limit of 0.5 m/s for velocity change was used to determine potential impacts in the adjacent land – refer to Section 3.1.1 for further details.

It should be noted that the culvert design includes relatively short barrels (<5 metres long) with 4 metre long inlet and outlet concrete aprons, beyond which the additional rock scour protection is placed where required. The concrete aprons provide additional safeguard against scour at the inlets and outlets of the culverts and protect the underlying soil from erosion due to velocity transitions at the inlets and outlets.

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 barrel 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. Full details of the bridge scour design methodology are provided in Appendix F.

4.5 Flood Planning Level and ARTC Flooding Multi-Criteria Analysis

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 was determined by the ARTC Flood Risk Assessment Work 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.

Steps 1 and 2 of the procedure have been completed and the outcomes were used to inform the 50% design. Step 3 was trialled during the 70% design stage and the size of the cross drainage structures was found to be governed by achieving the flood impact criteria, with limited opportunity for alternative sizing. Application of the procedure is discussed further in Section 5.2.1. The design was checked against the flood immunity requirements at the 100% design and IFC stages and confirmed predominantly compliant with some localised minor non-compliances that were accepted in the basis of low risk – refer to Section 5.2.1.

4.6 Independent verification and peer review

4.6.1 Internal independent verification

The hydrological and hydraulic models have been subject to internal IRDJV independent verification which included but was not limited to 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;
- Model results and numerical stability; and
- The bridge scour assessment methodology and results.

The technical review comments from the IRDJV Internal Independent Verifier were addressed and closed out at the 100% detailed design stage.

4.6.2 External independent peer review

To meet the requirements of the CoA, ARTC has appointed BMT as an External Independent Peer Reviewer. The Independent Peer Review has focussed on the following elements:

- Adequacy of the adopted flood modelling methodology;
- Basis for design flow estimation;
- Sensitivity of flood impacts to variation in flow estimates; and
- Sensitivity of flood impacts to variation in cross drainage blockage assumptions.

The draft Independent Peer Review Report is provided in Appendix I. IRDJV are currently processing results of the sensitivity tests recommended by the Peer Reviewers and a document providing a full response to the review comments is in preparation. This document and the final Peer Review Report will be provided in Appendix I of further revisions of this report.

5 Results

5.1 Existing conditions

Refer to the maps in Appendix B for existing conditions results for flood depth and extent, velocity, duration and hazard for the 39, 18, 10, 5, 2, 1 and 0.05% AEP events.

5.1.1 NAMOI01 model area (575 to 592.5km)

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.

The existing Newell Highway is located immediately to the east of the rail corridor and on the upstream side of the rail with respect to the predominant east to west nature of the flow paths crossing the road and rail corridors. The highway therefore has a significant effect on flow patterns upstream of the rail up to the point at which it is overtopped, which is typically at the 10% AEP flood event.

5.1.2 GWYDIR01 model area (592.5 to 619km)

Flooding in the sections between chainages 592.5 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.

As for the NAMOI01 model area, the existing Newell Highway is located immediately to the east (upstream side) of the rail corridor and the highway has a significant effect on flow patterns upstream of the rail up to the point at which it is overtopped, which is typically at the 10% AEP flood event.

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.

The Newell Highway crosses over the rail corridor at the southern end of the GWYDIR02 model area and runs alongside the rail corridor on the western side of the corridor, and downstream of the rail with respect to the predominant east to west nature of the flow paths crossing the road and rail corridors. At chainage 646km the highway deviates away from the rail corridor to the west and then returns to run alongside the rail corridor at 658km. In this model area the rail corridor has an effect on flow patterns around the Newell Highway as the flow is conveyed through the rail corridor first before reaching the highway.

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 Design case

Refer to the maps in Appendix C for design case results for: afflux, velocity change, duration change and hazard change for the 39, 18, 10, 5, 2, 1 and 0.05% AEP events, as well as the 1% AEP with allowance for climate change. The design case represents the future upgraded rail corridor and new/upgraded/retained cross drainage structures listed in the following sections. Flood impact compliance of the design case is discussed in Section 5.3.

The design case does not include representations of the proposed Newell Highway upgrades described in Section 4.2.1.3 – results of the design case including the proposed Newell Highway upgrades are provided in Appendix D.

5.2.1 Rail flood immunity and flooding MCA procedure

5.2.1.1 Stage 1 of the MCA procedure (50% design stage)

During the 50% design stage ARTC implemented Stage 1 of the Flooding MCA Procedure and identified the minimum required TOF flood immunity for the entire project corridor. To inform the process, IRDJV provided Flooding Reporting Table spreadsheets that summarise key flood risk parameters at cross drainage locations (grouped together where the structures are hydraulically connected).

Application of the Flooding MCA process was found to be complex for the N2NS local catchment models due to the high degree of hydraulic connectivity between the cross drainage sub-catchments in some of the modelled areas, particularly for large events. This meant that the individual sub-catchments that combine under large events could be grouped to produce a smaller set of Flooding Reporting Tables which provided a more reliable basis for the MCA decision-making process.

The outcomes of Stage 1 of the 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 rail vertical alignment design, and the vertical alignment was set according to the existing conditions flood levels.

Table 5.1 Results of Stage 1 of the MCA process

No.	Model Area	Kilometrage	Minimum Top of Formation Flood Immunity	Notes
1	NAMOI01	576.185	Existing: >2% AEP	
2	NAMOI01	579.585	Existing: >5% AEP	Adopt 1% AEP if possible to achieve by increasing culvert size only
3	NAMOI01	582.605	2% AEP	Adopt 1% AEP if hydraulically linked to structure at 581.180
4	NAMOI01	584.805	5% AEP	
5	NAMOI01	590.020	10% AEP	
6	NAMOI01	591.766	Existing: >10% AEP	

No.	Model Area	Kilometrage	Minimum Top of Formation Flood Immunity	Notes
7	GWYDIR01	593.820	Existing: >5% AEP	
8	GWYDIR01	596.430	Existing: >5% AEP	Consider designing long drainage to contain spill from 597.500 during a 1% AEP event
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	Limit impact of lift to Gurley siding Ensure long drainage design considers significant flow along the alignment
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	
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	

No.	Model Area	Kilometrage	Minimum Top of Formation Flood Immunity	Notes
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	

5.2.1.2 Stage 2 of the MCA procedure and final design outcomes

Trial of concept drainage sizing stage of Flooding MCA Procedure

The concept drainage sizing stage of the Flooding MCA Procedure was trialled during the 70% design stage. This stage involves testing of a number of cross drainage sizing options in the flood models to determine the most cost effective option that meets the design criteria. The trial concluded the following:

- The key drivers of cross drainage design are: (1) ensuring no overtopping of the rail occurs for all events up to and including the 1% AEP; (2) achieving upstream impact criteria for all events up to and including the 1% AEP; and (3) achieving the required minimum formation flood immunity;
- The cross drainage sizing is primarily governed by the need to meet upstream afflux criteria for the 1% AEP event; and
- If the initial size has been determined as above by achieving afflux that approaches the compliance limit for the 1% AEP event, then reducing the cross drainage capacity to optimise the impact to approach the compliance limit for lower order events will result in the following:
  - Non-compliant impacts for the 1% AEP event; and
  - Increases in 1% AEP flood depth above the formation and velocities in and around the cross drainage structures, increasing the risk of flood damage to the rail corridor.

On that basis, the concept drainage sizing stage of the Flooding MCA Procedure was not adopted for N2NS.

Rail flood immunity

At the IFC design stage the flood immunity of the rail corridor was checked and determined that the TOF has 1% AEP or better flood immunity for over 91% of the rail corridor. In the remaining 9% of the corridor the TOF flood immunity varies from just under 10% AEP to 2% AEP immunity. A summary of the TOF flood immunity results for each of the flood model sections is provided in the table below.

Table 5.2 Breakdown of IFC design TOF flood immunity

Flood model	TOF flood immunity					
	= or > 1% AEP	2% AEP	5% AEP	10%AEP	18% AEP	< 18% AEP
NAMOI01 575 to 592.5km	16.73km, 96.7%	0.53km, 3.1%	-	0.04km, 0.2%	-	-
GWYDIR01 592.5 to 619km	25.67km, 96.8%	0.51km, 1.9%	0.28km, 1%	0.06km, 0.2%	-	-
GWYDIR02 619 to 666km	37.34km, 81.3%	4.78km, 10.4%	3.1km, 6.8%	0.52km, 1.1%	0.37km, 0.8%	-
GWYDIR03 682 to 709km	25.02km, 98.2%	0.35km, 1.4%	0.12km, 0.5%	-	-	-
MACINTYRE01 709 to 727km	17.96km, 98.2%	0.24km, 1.3%	0.06km, 0.3%	0.04km, 0.2%	-	-
MACINTYRE02 727 to 760.46km	32.00km,99.5%	0.13km, 0.40%	0.03km, 0.1%	-	-	-

Rail corridor flood damage risk

The risk of damage to the rail is a combination of the depth, velocity and duration of flooding. ARTC's flood risk assessment procedure provides a framework to assess the flood risk to the rail using a holistic approach that considers the depth, velocity and duration parameters. The procedure can be used to assign a risk rating or score for each parameter for the 1% AEP flood event, as follows:

- 1% AEP depth above TOF:
  - <0.3m: score = 0;
  - 0.3 to 0.74m: score = 5; and
  - >0.74m: score = 10;
- 1% AEP velocity at TOF:
  - <1m/s: score = 0;
  - 1.0 to 1.5m/s: score = 5; and
  - >1.5m/s: score = 10; and
- 1% AEP time of submergence of TOF:
  - <6 hours: score = 0;
  - 6 to 120 hours: score = 5; and
  - >120 hours: score = 10.

To holistically assess flood risk to the corridor considering all three parameters, a total risk score of all three parameters can be calculated and the results grouped into the following categories:

- Low risk: total 1% AEP risk score is equal to or less than 10;
- Medium risk: total 1% AEP risk score is 11 to 20; and
- High risk: total 1% AEP risk score is greater than 20.

This approach was applied using the 1% AEP design case flood model results and the above categories were calculated for the entire alignment. The results are summarised in Table 5.3 below and demonstrate that the residual flood risk to the rail corridor after the upgrade is acceptable, with no occurrences of high risk and only six occurrences of medium risk. The information in Table 5.3 can be used to identify areas most likely to experience damage during a flood event to inform the flood emergency response activities.

Table 5.3 Rail corridor flood damage risk for 1% AEP event

Flood model	Extent of flood damage risk	Locations of medium flood damage risk	Locations of high flood damage risk
NAMOI01 575 to 592.5km	Low risk: 0.25 km (1.5%) Medium risk: None High risk: None	None	None
GWYDIR01 592.5 to 619km	Low risk: 0.5 km (1.9%) Medium risk: 0.15 km (0.6%) High risk: None	607.650 to 607.750 km	None
GWYDIR02 619 to 666km	Low risk: 8.8 km (18.7%) Medium risk: 0.25 km (0.5 %) High risk: None	648.300 km 650.100 km 650.700 km 653.100 km 653.400 km	None
GWYDIR03 682 to 709km	Low risk: 0.3 km (1.1%) Medium risk: None High risk: None	None	None
MACINTYRE01 709 to 727km	Low risk: 0.35 km (1.9%) Medium risk: None High risk: None	None	None
MACINTYRE02	Low risk: 0.1 km (0.3%) Medium risk: None High risk: None	None	None

5.2.2 Culverts

5.2.2.1 New / upgraded culverts

The list of new / upgraded culverts for the design case is provided below. Key hydraulic parameters for the structures are provided in Appendix G.

Table 5.4 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	5	2400x1500 4SBC
6	NAMOI01	579.590	6	1800x1200 4SBC
7	NAMOI01	579.965	8	1800x900 4SBC
8	NAMOI01	580.920	1	2400x900 4SBC
9	NAMOI01	581.030	1	2400x1200 4SBC
10	NAMOI01	581.070	3	3000x1200 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
11	NAMOI01	581.180	16	3000x1500 4SBC
12	NAMOI01	581.400	16	2400x1200 4SBC
13	NAMOI01	581.550	18	2400x900 4SBC
14	NAMOI01	581.800	15	3000x1500 4SBC
	NAMOI01	581.920	10	2400x900 4SBC
16	NAMOI01	582.390	8	2400x900 4SBC
17	NAMOI01	582.605	18	3000x2400 4SBC
18	NAMOI01	582.840	3	2400x1500 4SBC
19	NAMOI01	583.430	3	2400x1200 4SBC
	NAMOI01	583.700	7	2400x1200 4SBC
21	NAMOI01	584.810	5	3000x2100 4SBC
22	NAMOI01	585.100	5	1800x900 4SBC
23	NAMOI01	585.200	5	1800x900 4SBC
24	NAMOI01	585.350	7	2400x900 4SBC
	NAMOI01	585.460	7	2400x1200 4SBC
26	NAMOI01	585.620	5	2400x900 4SBC
27	NAMOI01	585.800	4	600x600 4SBC
28	NAMOI01	587.090	7	2400x900 4SBC
29	NAMOI01	587.710	7	3000x1500 4SBC
	NAMOI01	587.840	4	3000x1500 4SBC
31	NAMOI01	587.920	2	2400x1500 4SBC
32	NAMOI01	588.550	7	2400x900 4SBC
33	NAMOI01	588.830	6	3000x1500 4SBC
34	NAMOI01	589.065	2	1800x600 4SBC
	NAMOI01	589.310	3	3000x1200 4SBC
36	NAMOI01	590.020	1	3000x1200 4SBC
37	NAMOI01	590.240	5	2400x1200 4SBC
38	NAMOI01	591.700	7	2400x1200 4SBC
39	NAMOI01	591.790	11	2400x1200 4SBC
	NAMOI01	591.950	4	2400x1200 4SBC
41	GWYDIR01	593.080	2	1800x600 4SBC
42	GWYDIR01	593.860	12	3000x1200 4SBC (see table footnote)
43	GWYDIR01	595.540	4	3000x1200 4SBC
44	GWYDIR01	596.450	8	3000x1500 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
	GWYDIR01	597.250	3	3000x1500 4SBC
46	GWYDIR01	599.470	2	3000x1200 4SBC
47	GWYDIR01	600.870	6	2400x900 4SBC
48	GWYDIR01	601.880	3	1800x600 4SBC
49	GWYDIR01	602.470	6	3000x1200 4SBC
	GWYDIR01	607.870	40	3000x1500 4SBC
51	GWYDIR01	608.090	1	1800x600 4SBC
52	GWYDIR01	609.590	8	3000x1500 4SBC
53	GWYDIR01	613.230	1	600x600 4SBC
54	GWYDIR01	614.020	4	1800x1200 4SBC
	GWYDIR01	614.480	14	3000x1500 4SBC
56	GWYDIR01	614.690	40	3000x1500 4SBC
57	GWYDIR01	614.990	8	3000x2100 4SBC
58	GWYDIR01	616.100	2	3000x1500 4SBC
59	GWYDIR01	617.110	1	1800x600 4SBC
	GWYDIR02	618.065	2	3000x1500 4SBC
61	GWYDIR02	619.070	2	3000x2100 4SBC
62	GWYDIR02	619.300	1	1200x600 4SBC
63	GWYDIR02	621.895	3	3000x2400 4SBC
64	GWYDIR02	623.075	4	3000x2400 4SBC
	GWYDIR02	624.805	1	1800x900 4SBC
66	GWYDIR02	625.570	2	1200x450 4SBC
67	GWYDIR02	627.280	50	3000x2400 4SBC
68	GWYDIR02	627.430	30	3000x2100 4SBC
69	GWYDIR02	627.760	10	2400x1200 4SBC
	GWYDIR02	630.925	2	600x600 4SBC
71	GWYDIR02	631.140	3	1800x900 4SBC
72	GWYDIR02	631.580	1	600x600 4SBC
73	GWYDIR02	633.780	46	3000x2400 4SBC
74	GWYDIR02	635.145	6	1800x600 4SBC
	GWYDIR02	635.410	1	2400x900 4SBC
76	GWYDIR02	636.705	1	600x600 4SBC
77	GWYDIR02	637.170	1	600x600 4SBC
78	GWYDIR02	637.290	1	1800x900 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
79	GWYDIR02	638.140	2	2400x1200 4SBC
	GWYDIR02	638.525	15	2400x900 4SBC
81	GWYDIR02	638.920	14	1800x600 4SBC
82	GWYDIR02	639.160	14	1800x600 4SBC
83	GWYDIR02	639.740	60	2400x900 4SBC
84	GWYDIR02	640.080	5	2400x900 4SBC
	GWYDIR02	640.380	20	1800x900 4SBC
86	GWYDIR02	640.650	15	1800x1200 4SBC
87	GWYDIR02	641.950	35	3000x2400 4SBC
88	GWYDIR02	642.380	63	3000x2400 4SBC
89	GWYDIR02	642.380	12	3000x2400 4SBC
	GWYDIR02	643.000	6	1800x1200 4SBC
91	GWYDIR02	643.230	2	3000x1500 4SBC
92	GWYDIR02	643.980	6	3000x1200 4SBC
93	GWYDIR02	644.980	5	3000x1200 4SBC
94	GWYDIR02	645.490	2	3000x1200 4SBC
	GWYDIR02	645.920	1	1800x900 4SBC
96	GWYDIR02	646.065	1	2400x900 4SBC
97	GWYDIR02	646.160	2	3000x1200 4SBC
98	GWYDIR02	646.850	12	2400x1200 4SBC
99	GWYDIR02	647.155	20	3000x2400 4SBC
	GWYDIR02	647.315	5	3000x1200 4SBC
101	GWYDIR02	647.670	5	3000x1500 4SBC
102	GWYDIR02	647.925	4	2400x1200 4SBC
103	GWYDIR02	648.240	6	2400x900 4SBC
104	GWYDIR02	648.395	8	3000x2400 4SBC
	GWYDIR02	648.635	6	2400x900 4SBC
106	GWYDIR02	649.185	4	1800x600 4SBC
107	GWYDIR02	649.700	30	2400x900 4SBC
108	GWYDIR02	650.040	36	1800x600 4SBC
109	GWYDIR02	650.330	2	2400x900 4SBC
	GWYDIR02	650.690	2	2400x900 4SBC
111	GWYDIR02	652.530	2	1800x600 4SBC
112	GWYDIR02	652.715	2	1800x600 4SBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
113	GWYDIR02	653.150	24	1800x600 4SBC
114	GWYDIR02	653.620	24	2400x900 4SBC
	GWYDIR02	653.700	10	2400x900 4SBC
116	GWYDIR02	654.525	1	1800x900 4SBC
117	GWYDIR02	655.270	18	3000x1200 4SBC
118	GWYDIR02	655.980	6	3000x1200 4SBC
119	GWYDIR02	656.240	5	2400x900 4SBC
	GWYDIR02	658.820	3	1800 x 600 4SBC
121	GWYDIR02	659.095	3	1800x600 4SBC
122	GWYDIR02	659.400	5	1800x600 4SBC
123	GWYDIR02	659.780	2	1800x600 4SBC
124	GWYDIR02	660.705	45	3000x2400 4SBC
	GWYDIR02	663.135	1	600x600 4SBC
126	GWYDIR02	663.460	4	1800x600 4SBC
127	GWYDIR02	664.870	3	1800x600 4SBC
128	GWYDIR02	664.982	1	1800x600 4SBC
129	GWYDIR03	686.410	2	1800x900 RCBC
	GWYDIR03	686.490	2	1800x1200 RCBC
131	GWYDIR03	690.820	8	2400x1500 RCBC
132	GWYDIR03	691.020	4	1800x600 RCBC
133	GWYDIR03	695.210	1	1200x1200 RCBC
134	GWYDIR03	695.285	1	2100x900 RCBC
	GWYDIR03	696.985	5	2400x1500 RCBC
136	GWYDIR03	699.790	8	3000x1200 RCBC
137	GWYDIR03	699.875	12	3000x1800 RCBC
138	GWYDIR03	702.370	1	1200x600 RCBC
139	GWYDIR03	702.380	1	1200x600 RCBC
	GWYDIR03	703.065	2	1800x600 RCBC
141	GWYDIR03	704.810	14	3000x1800 RCBC
142	GWYDIR03	706.100	6	1200x600 RCBC
143	GWYDIR03	706.250	3	2400x1800 RCBC
144	GWYDIR03	706.505	1	3000x1100 RCBC
	GWYDIR03	706.695	3	1200x600 RCBC
146	GWYDIR03	707.405	2	1800x600 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
147	GWYDIR03	707.575	8	1800x600 RCBC
148	GWYDIR03	708.445	13	3000x1200 RCBC
149	GWYDIR03	709.740	5	2400x900 RCBC
	MACINTYRE01	711.410	10	2400x900 RCBC
151	MACINTYRE01	711.510	6	3000x1200 RCBC
152	MACINTYRE01	711.640	15	3000x1500 RCBC
153	MACINTYRE01	711.770	11	3000x1200 RCBC
154	MACINTYRE01	712.070	7	1800x600 RCBC
	MACINTYRE01	712.540	12	2400x900 RCBC
156	MACINTYRE01	712.610	10	1800x600 RCBC
157	MACINTYRE01	712.820	1	1800x600 RCBC
158	MACINTYRE01	713.350	11	1800x600 RCBC
159	MACINTYRE01	713.500	1	1800x600 RCBC
	MACINTYRE01	714.620	13	2400x900 RCBC
161	MACINTYRE01	714.830	1	1800x600 RCBC
162	MACINTYRE01	716.280	17	1800x600 RCBC
163	MACINTYRE01	716.410	14	2400x900 RCBC
164	MACINTYRE01	716.640	32	3000x1800 RCBC
	MACINTYRE01	716.730	7	3000x2100 RCBC
166	MACINTYRE01	718.050	1	1800x600 RCBC
167	MACINTYRE01	718.200	1	1200x450 RCBC
168	MACINTYRE01	718.390	1	1800x600 RCBC
169	MACINTYRE01	718.910	2	2400x900 RCBC
	MACINTYRE01	719.080	3	1800x600 RCBC
171	MACINTYRE01	719.130	2	1800x600 RCBC
172	MACINTYRE01	719.180	3	1800x600 RCBC
173	MACINTYRE01	719.910	1	1800x900 RCBC
174	MACINTYRE01	720.180	1	3000x1800 RCBC
	MACINTYRE01	720.370	3	3000x1800 RCBC
176	MACINTYRE01	720.740	3	3000x1800 RCBC
177	MACINTYRE01	721.040	6	3000x2100 RCBC
178	MACINTYRE01	721.650	2	2400x1800 RCBC
179	MACINTYRE01	722.820	1	2400x1500 RCBC
	MACINTYRE01	723.010	2	2400x1500 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
181	MACINTYRE01	723.230	3	2400x1500 RCBC
182	MACINTYRE01	723.610	3	2400x1800 RCBC
183	MACINTYRE01	723.880	2	2400x1500 RCBC
184	MACINTYRE01	724.630	2	2400x1500 RCBC
	MACINTYRE01	725.280	4	3000x1800 RCBC
186	MACINTYRE01	725.560	1	2400x1200 RCBC
187	MACINTYRE01	725.600	1	1800x1800 RCBC
188	MACINTYRE01	726.120	2	3000x1200 RCBC
189	MACINTYRE01	726.210	1	1800x600 RCBC
	MACINTYRE01	726.550	2	3000x1200 RCBC
191	MACINTYRE01	726.970	2	3000x1500 RCBC
192	MACINTYRE01	727.130	3	1800x600 RCBC
193	MACINTYRE01	727.710	1	3000x1200 RCBC
194	MACINTYRE02	728.360	1	1200x600 RCBC
	MACINTYRE02	728.440	4	3000x1500 RCBC
196	MACINTYRE02	728.920	1	2400x1500 RCBC
197	MACINTYRE02	729.710	1	2400x900 RCBC
198	MACINTYRE02	729.890	1	1800x1200 RCBC
199	MACINTYRE02	729.970	4	3000x1500 RCBC
	MACINTYRE02	730.400	1	900x900 RCBC
201	MACINTYRE02	730.580	1	2400x1500 RCBC
202	MACINTYRE02	732.020	1	3000x1200 RCBC
203	MACINTYRE02	736.220	3	2400x900 RCBC
204	MACINTYRE02	736.310	2	2400x900 RCBC
	MACINTYRE02	737.570	4	3000x2100 RCBC
206	MACINTYRE02	740.960	24	3000x2400 RCBC
207	MACINTYRE02	741.460	2	1800x1200 RCBC
208	MACINTYRE02	742.140	3	2400x900 RCBC
209	MACINTYRE02	742.260	1	1800x600 RCBC
	MACINTYRE02	742.710	1	1800x1800 RCBC
211	MACINTYRE02	744.570	10	3000x2400 RCBC
212	MACINTYRE02	745.430	1	1800x1200 RCBC
213	MACINTYRE02	745.880	1	2400x2400 RCBC
214	MACINTYRE02	746.040	1	1800x900 RCBC

No.	Model Area	Kilometrage	Number of cells	Structure Type
215	MACINTYRE02	746.600	2	1800x900 RCBC
216	MACINTYRE02	747.910	2	1800x900 RCBC
217	MACINTYRE02	748.430	2	2400x2400 RCBC
218	MACINTYRE02	749.460	1	2400x1500 RCBC
219	MACINTYRE02	750.970	8	3000x2100 RCBC
220	MACINTYRE02	751.140	1	3000x2100 RCBC
221	MACINTYRE02	752.500	1	1500x600 RCBC
222	MACINTYRE02	753.120	7	3000x1500 RCBC
223	MACINTYRE02	755.250	1	3000x1200 RCBC
224	MACINTYRE02	755.440	1	2400x1200 RCBC
225	MACINTYRE02	755.490	3	3000x1500 RCBC
226	MACINTYRE02	755.980	2	1800x1200 RCBC
227	MACINTYRE02	757.040	16	2400x900 RCBC
228	MACINTYRE02	758.230	2	1200x450 RCBC
229	MACINTYRE02	758.270	2	900x450 RCBC
Note: This structure differs for the cumulative impact assessment design case which considered the combined effects of N2NS Phase 1 and the Newell Highway upgrades – refer to Appendix D for further details.				

5.2.2.2 Retained culverts

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

Table 5.5 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

5.2.2.3 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) should be retained to minimise excavation depths if required during construction. Scour protection arrangements are shown on the scour schedule and culvert general arrangement drawings. Key scour parameters for each culvert are provided in Appendix G.

5.2.3 Bridges

5.2.3.1 New / upgraded bridges

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

Table 5.6 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	740.665	6x9m span PSC slab	Yallaroi Creek

5.2.3.2 Retained bridges

The retained bridges are listed below.

Table 5.7 List of retained bridges

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

5.2.3.3 Bridge scour protection

Bridge scour protection has been designed at the abutments in accordance with the methodology described in Section 4.4.2.1, with further details provided in Appendix F. A table of key outputs from the bridge scour assessments is provided below. Scour protection arrangements are shown on the bridge drawings.

Table 5.8 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

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)
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

5.3 Flood impact compliance of design case

5.3.1 RAATM and BoD

5.3.1.1 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 (selected to represent the range of events assessed) are as listed in the tables below. Impacts for the other intermediate events (18, 5 and 2% AEP) fall within the range of impacts presented for the 39, 10 and 1% AEP events.

Table 5.9 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 592.5 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	None
Local Roads*	None
GWYDIR01 (592.5 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	Parts of commercial property at 658.5km
Other Residential/Commercial Buildings and Public Infrastructure	>100mm in land within commercial property at 658.5km
Newell Highway*	Some impacts of >50mm adjacent to the highway at 5 locations but no afflux on highway
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 QDLs which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

Table 5.10 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 592.5 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Impact of >50mm adjacent to highway at 1 location but no afflux on highway
Local Roads*	None
GWYDIR01 (592.5 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 highway at 5 locations but no afflux on highway
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 QDLs which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

Table 5.11 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 592.5 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Impacts of >50mm on the highway at 583.8 to 584.0km and 585.0km Impacts of >50mm adjacent to highway at other locations but no afflux on highway at these other locations
Local Roads*	None
GWYDIR01 (592.5 to 619 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	None
Newell Highway*	Impact of >50mm adjacent to highway at 2 locations but no afflux on highway
Local Roads*	None
GWYDIR02 (619 to 666 km)	
Newly inundated properties	None
Other Residential/Commercial Buildings and Public Infrastructure	Afflux limit of 10mm exceeded at 9 buildings
Newell Highway*	Impact of >50mm adjacent to highway at 2 locations but no afflux on highway
Local Roads*	Impact of >100mm over 450m of 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	Afflux limit of 10mm exceeded at 4 buildings
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 QDLs which exceed the 10mm afflux limit for roads nominated in the RAATM.***	

5.3.1.2 Velocity

Refer to Section 3.1.2 for the velocity design criteria. The design of the culverts has not been modified to maintain 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. 1% AEP event culvert velocities are provided in Appendix G. For the 1% AEP event 35% of culverts have velocities greater than 2.5m/s, 21% have velocities greater than 3m/s and 7% have velocities greater than 4m/s. The highest culvert velocity is 5m/s which occurs at 596.45km.

5.3.2 Quantitative Design Limits

The QDLs are provided in Table 3.1.

5.3.2.1 Afflux

Afflux impacts are presented in detail in the mapping contained in Appendix C. The following sections summarise the non-compliances that occur on specific land uses.

Agricultural land

The afflux non-compliances with the RAATM identified in Table 5.9 to Table 5.11 also constitute non-compliances with the afflux QDLs. In addition to these, the areas identified below in Table 5.12 are also non-compliant with the afflux QDLs.

Table 5.12 Locations of non-compliance with afflux criteria for agricultural 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	582.5km 584.7km 588.8km	582.5km 584.7km 584.8km 585.0km 588.5km 588.8km	579.5km 580.0km 584.7km 584.8km 585.1km 585.8km
GWYDIR01	607.87km	607.87km	None
GWYDIR02	649.5km 650.0km 653.15km 658.5km	None	None
GWYDIR03	709.5km	None	None
MACINTYRE01	716.75km 719.15km	711.4 to 711.5km 712.61km 716.75km 720.3 to 720.8km 722.8 to 723km	716.7km 716.55 to 716.75km
MACINTYRE02	740.96km	None	733.94km 741.5km 755.4 to 755.49km

Buildings

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

Table 5.13 Locations where afflux exceeds 10mm at buildings

Model	Property ID	39% AEP afflux (mm)	10% AEP afflux (mm)	1% AEP afflux (mm)
GWYDIR02	Lot92DP751797(SensitiveR35)	Not flooded	Not flooded	49
GWYDIR02	Lot1DP633825 (NNS_Rx0872)	Not flooded	0	46
GWYDIR02	Lot1DP633825 (SensitiveR40)	Not flooded	Not flooded	43
GWYDIR02	Lot142DP751785 (NNS_Rx0875)	Not flooded	0	21
GWYDIR02	Lot1DP222186 (NNS_Rx0878)	Not flooded	Not flooded	20
GWYDIR02	Lot3DP222186 (NNS_Rx0879)	Not flooded	Not flooded	12
GWYDIR02	(SensitiveR44)	Not flooded	No longer flooded	22
GWYDIR02	Lot1DP736823 (NNS_Rx0892)	Not flooded	No longer flooded	37
GWYDIR02	Lot2DP736823 (NNS_Rx0891)	Not flooded	Not flooded	35
MACINTYRE02	Lot3DP751087 (NNS_Rx2300)	Not flooded	Not flooded	33
MACINTYRE02	Lot7010DP1030135 (NNS_REPx0002)	Not flooded	Not flooded	38
MACINTYRE02	Lot 7009 DP1030135 (NNS_REAx0019)	Not flooded	Not flooded	39
MACINTYRE02	Lot7010DP1030135 (NNS_Rx2320)	Not flooded	3	39

For these buildings significant afflux only occurs for the 1% AEP event and does not exceed 50mm at any location. The afflux values provided in the table above are the highest afflux values occurring on the land around the buildings. The buildings are likely to be elevated above the general ground level and these impacts may be acceptable subject to consultation with the property owners and assessment of the floor levels of the buildings in relation to the ground levels around the buildings.

5.3.2.2 Velocity

Velocity impacts (refer to Appendix C for detailed impact maps) were assessed against the QDLs and found to be generally compliant across the project. 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. These localised velocity non-compliances are considered to be low impact 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.

5.3.2.3 Scour and erosion impacts

All bridge abutments and culvert inlets and outlets include scour protection to protect the structures from undermining due to scour during large flood events and progressive erosion over time. The scour protection measures have been designed in accordance with industry standards, as described in Section 4.4.2.

The culvert design includes relatively short barrels (<5 metres long) with 4 metre long inlet and outlet concrete aprons. Additional rock scour protection is provided beyond the concrete aprons, with the rock size and extent determined by the velocity regime and dimensions of the culvert. In most cases, the culvert rock aprons do not extend beyond the rail corridor but in some cases it is necessary to extend the rock apron beyond the rail corridor to achieve the required level of scour protection.

The scour protection prevents scour and erosion of the landscape immediately upstream and downstream of the culverts. The purpose of the extended rock aprons is to provide scour resistant material to the point at which velocities are reduced below erosive levels.

The potential for scour and erosion impacts on the landscape beyond the limits of the scour protection are assessed by examining the change in peak velocity around the rail corridor and within the wider floodplain. Section 5.3.2.2 provides an overview of the changes in the velocity regime within the floodplain surrounding the proposal and demonstrates that changes are predominantly localised around the culverts and within the rail corridor. Therefore, the project is not expected to cause widespread or frequent occurrences of soil erosion during flood events beyond the rail corridor.

5.3.2.4 Impacts on flow paths and geomorphology

In addition to the assessment of changes in the key flood parameters described in the previous sections, the potential for the proposal to divert or change flow paths and change flow and geomorphological conditions in waterways was assessed.

The existing rail line intercepts and diverts overland and floodplain flow on the upstream side of the rail corridor and directs flow to the existing cross drainage structures. The existing rail is overtopped in some localised areas at the 10% AEP event. The design replicates this existing influence of the rail line on flooding by replacing the overtopping regime with controlled flow under the rail line via the large number of new flood relief culverts. The design culverts have been carefully located and use different culvert floor levels to match as closely as possibly the combination of underflow through culverts and overtopping flow that occurs in the existing situation. This cross drainage design approach maintains the existing flow paths across the rail corridor.

The project does not cause any flow diversions or significantly changed flow conditions within the main waterways and overland flow paths crossing the project, as demonstrated by the flood impact maps that show no other significant areas of newly flooded or no longer flooded land for all events. As described in the previous sections, the velocity impacts of the proposal within the main waterways and overland flow paths are insignificant, with velocity regimes generally remaining unaltered apart from some localised changes around the culverts. The project is therefore considered to have no impact on the geomorphological regime of the main waterways and floodplain flow paths around the project.

5.3.2.5 Duration

Duration impacts (refer to Appendix C for detailed impact maps) were assessed against the QDLs 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 5.14 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	581.0km 582.5km 584.5km 590 to 590.5km	581.0 to 582.5km 584.6km 588.5km 590.0km 591.8km (minor area)	581.0 to 582.5km 584.0km 584.6 to 585.0km 585.5km 587.5 to 588.0km 588.5 to 589.0km 590.0km 591.8km (minor area)
GWYDIR01	593.8km 614.5km (minor area)	593.8km 614.65km (minor area)	593.8km 600.8km (minor area) 607.8km 614.45km

Model	39% AEP Event Non-Compliant Impacts	10% AEP Event Non-Compliant Impacts	1% AEP Event Non Compliant Impacts
GWYDIR02	633.5 to 634.0km 642.3km 643.5 to 644.5km 658.5 to 660.5km	627.0 to 627.8km 633.5 to 634km 634.5km 641.5km 642.3km (minor area) 643.5 to 644.5km 645.8km 647.0km 653.4km 656.0km 658.5 to 660.5km	627.0 to 628.0km 632.5km (minor area) 633.5 to 634.0km 634.5km 635.0km 638.0km 639.0km 641.5km 642.3km (minor area) 643.5 to 644.5km 645.8km 646.5 to 647.5km 648.5 to 650.0km 653.0 to 654.0km 656.0km 657.0 to 660.0km
GWYDIR03	708.5km	708.5km	690.5km 708.5km
MACINTYRE01	711.5km 716.5km 723.5km (minor area)	711.5km 714.5km 716.5km 720.5km 723.5km (minor area)	711.5km 714.5km 716.5km 720.5km 723.0km (minor area) 723.5km (minor area)
MACINTYRE02	737.5km (minor area) 752.5km 755.0km	730.0km 730.5km 733.0km 737.5km 741.0km 744.5km 751.0km 752.5km 755.0km	730.0km 730.5km 733.0km 737.5km 741.0km 744.5km (minor area) 751.0km 752.5km (minor area) 755.0km

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 Figure 5.1 and Figure 5.2.

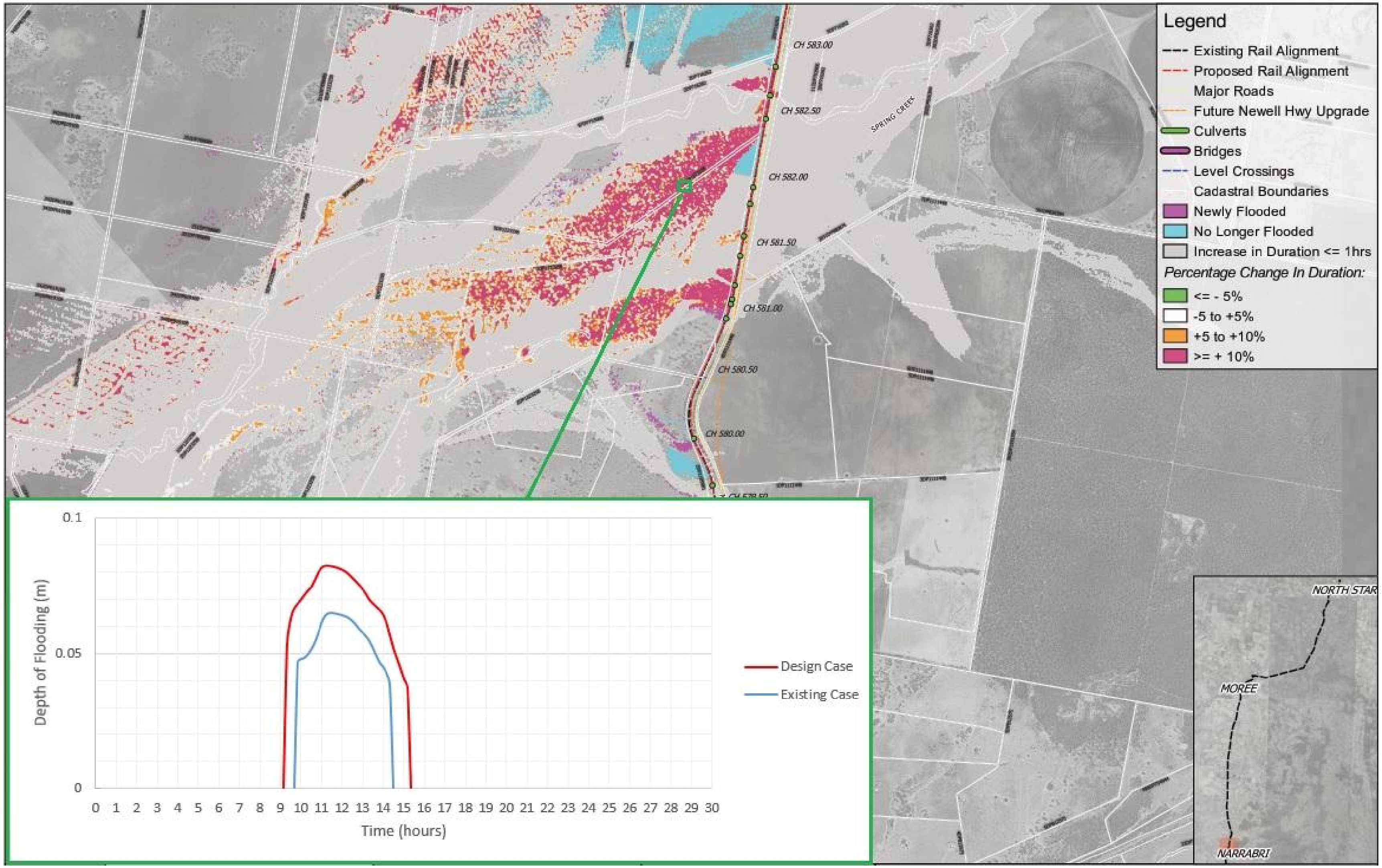

Figure 5.1 Example of 1% AEP duration impact mapping with extracted hydrograph at 582km

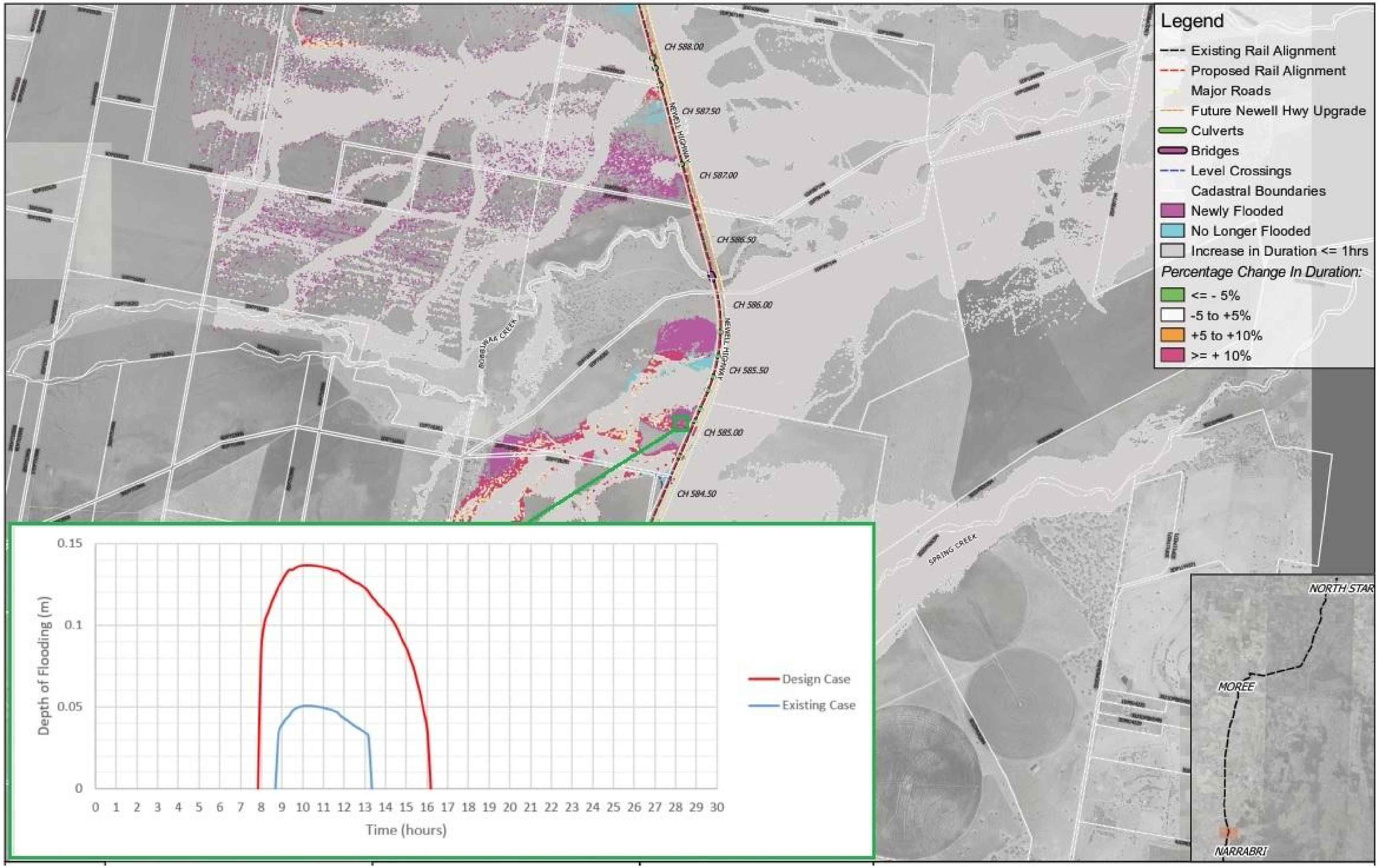

Figure 5.2 Example of 1% AEP duration impact mapping with extracted hydrograph at 585km

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

- The specific duration increases at these locations are as follows:
  - 582km: 1.3 hours, 30%; and
  - 585km: 3.7 hours, 85%.
- The non-compliances occur in shallow depth areas, with peak depths less than 150mm.

Based on these results, the duration impacts that do not comply with the QDLs 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.

5.3.2.6 Newell Highway flood impacts

The flooding impacts presented in this section relate to the Newell Highway in its current condition, prior to the upgrades planned by TfNSW discussed in Section 1.7. A separate flood risk impact of the future upgraded sections of the highway is presented in Appendix D.

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.

The QDLs in Table 3.1 identify the key flood risk parameters for the highway as afflux, hazard and duration. Parts of the highway and land immediately adjacent to the highway experience afflux, velocity and duration impacts from the project, which could also increase the flood hazard categorisation of the highway. The following sections present the results of the flood impact assessment for the existing highway with a focus on hazard categorisation and flood duration.

Overview of impacts

The flood model results for the existing conditions and design case were sampled at 10 metre intervals for the section of the Newell Highway adjacent to the rail corridor. Table 5.15 below provides a summary of impacts assessed against the QDLs at each sampled location.

Table 5.15 Summary of impacts along the existing Newell Highway

Parameter	10% AEP	5% AEP	2% AEP	1% AEP
Total points assessed (10m intervals)	9472	9472	9472	9472
Points flooded in existing conditions	909	1052	1452	1923
Points flooded in design case	868	1010	1395	1870
Points newly flooded	37	34	38	45
Points no longer flooded	78	76	95	98
Points with flood level increase > 50mm	5	11	0	9
Points with flow velocity increase > 20%	70	91	101	128

Parameter	10% AEP	5% AEP	2% AEP	1% AEP
Points with duration of flooding increase > 10%	8	15	42	115
Points with flood hazard (V*D) increase > 10%	44	53	55	118

The results demonstrate that N2NS Phase 1 causes localised increases in flood depth, duration and velocity along the highway. These impacts occur as a result of the rail upgrade causing changes to the flood behaviour local to the rail corridor in both upstream and downstream directions. However, the results also demonstrate there is a net decrease in the number of flooded locations at for all events, as follows:

net decrease of 41 flooded locations for the 10% AEP;

net decrease of 42 flooded locations for the 5% AEP;

net decrease of 57 flooded locations for the 2% AEP; and

net decrease of 53 flooded locations for the 1% AEP.

Flood hazard impacts

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.

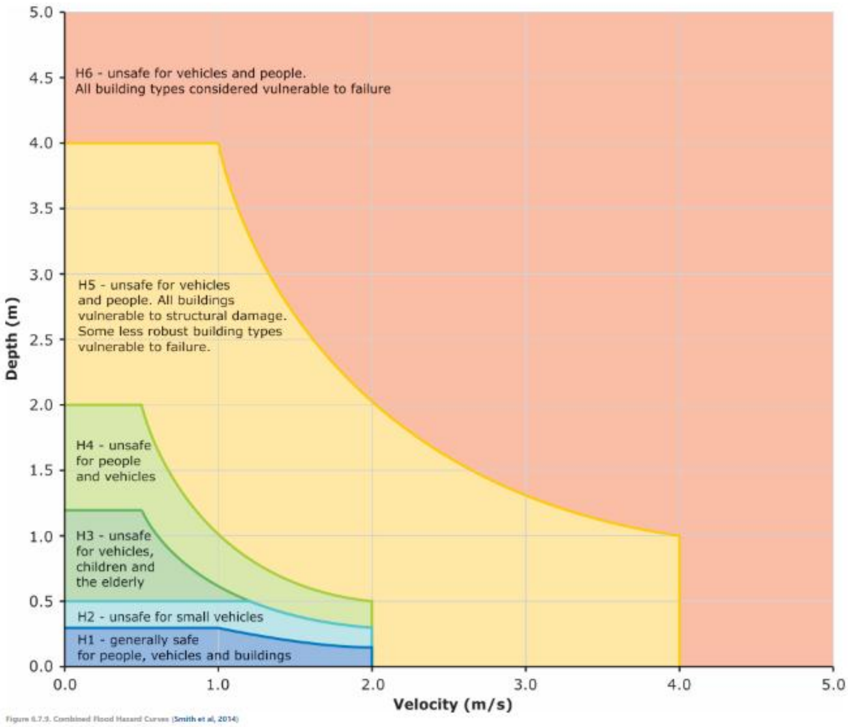

Figure 5.3 Flood hazard curves and definitions (ARR2016, Chapter 7, Section 7.2.7)

An assessment of the hazard under both existing conditions and the design case has been undertaken for the sections of the Newell Highway adjacent to N2NS Phase 1. The impacts on hazard are presented in Table 5.16.

Table 5.16 Flood hazard categorisation assessment for the existing Newell Highway

Design event and scenario		H1	H2	H3	H4	H5	H6
10% AEP	Existing Conditions	792	65	15	11	19	7
	Design Case	756	61	16	9	20	6
	Hazard Category Change	-4.55%	-6.15%	6.67%	-18.18%	5.26%	-14.29%
5% AEP	Existing Conditions	879	116	14	13	20	10
	Design Case	875	81	16	10	18	10
	Hazard Category Change	-0.46%	-30.17%	14.29%	-23.08%	-10.00%	0.00%
2% AEP	Existing Conditions	1164	214	17	22	24	11
	Design Case	1149	177	19	19	21	10
	Hazard Category Change	-1.29%	-17.29%	11.76%	-13.64%	-12.50%	-9.09%
1% AEP	Existing Conditions	1469	349	20	38	34	13
	Design Case	1466	297	20	35	39	13
	Hazard Category Change	-0.20%	-14.90%	0.00%	-7.89%	14.71%	0.00%

Table 5.16 demonstrates the overall change in hazard categorisation across the 4 events presented. The results show the following:

- An overall net decrease in hazard category at 193 locations, made up as follows:
  - net decrease in H1 category at 58 locations
  - net decrease in H2 category at 128 locations
  - net increase in H3 category at 5 locations
  - net decrease in H4 category at 11 locations
  - net increase in H5 category at 1 location; and
  - net decrease in H6 category at 2 locations.
- The overall net decrease in hazard category is distributed across the flood events as follows:
  - net decrease for the 10% AEP event at 41 locations
  - net decrease for the 5% AEP event at 42 locations
  - net decrease for the 2% AEP event at 57 locations; and
  - net decrease for the 1% AEP event at 53 locations.

Overall, the impact on the flood hazard of the existing Newell Highway is considered to be positive due to the net decrease in number of locations flooded and net decrease in hazard categories. The hazard category is increased at 6 locations but decreased at 199 locations.

Flood duration impacts

Increases in flood duration have the potential to increase saturation times of the highway embankment and associated damage. Figure 5.4 below shows a typical result in the non-compliant areas where the duration impact criteria are exceeded at the edge of the highway embankment (refer to second last row of Table 5.15 for total numbers of non-compliant locations for each event). The flood duration increases from 14.8 hours in the existing conditions to 21.3 hours in the design case. The increase in flood duration is therefore 6.5 hours, or 44%.

While the increase in duration is significant at this location, the overall flood duration and saturation time in the design case should not cause increased flood damage to the embankment as the flood level increase is limited to 35mm and the submergence time is a similar order of magnitude to the existing conditions (i.e. less than 24 hours). This is a typical worst case result for duration impacts along the Newell Highway where the QDL duration increase limit of 10% is exceeded.

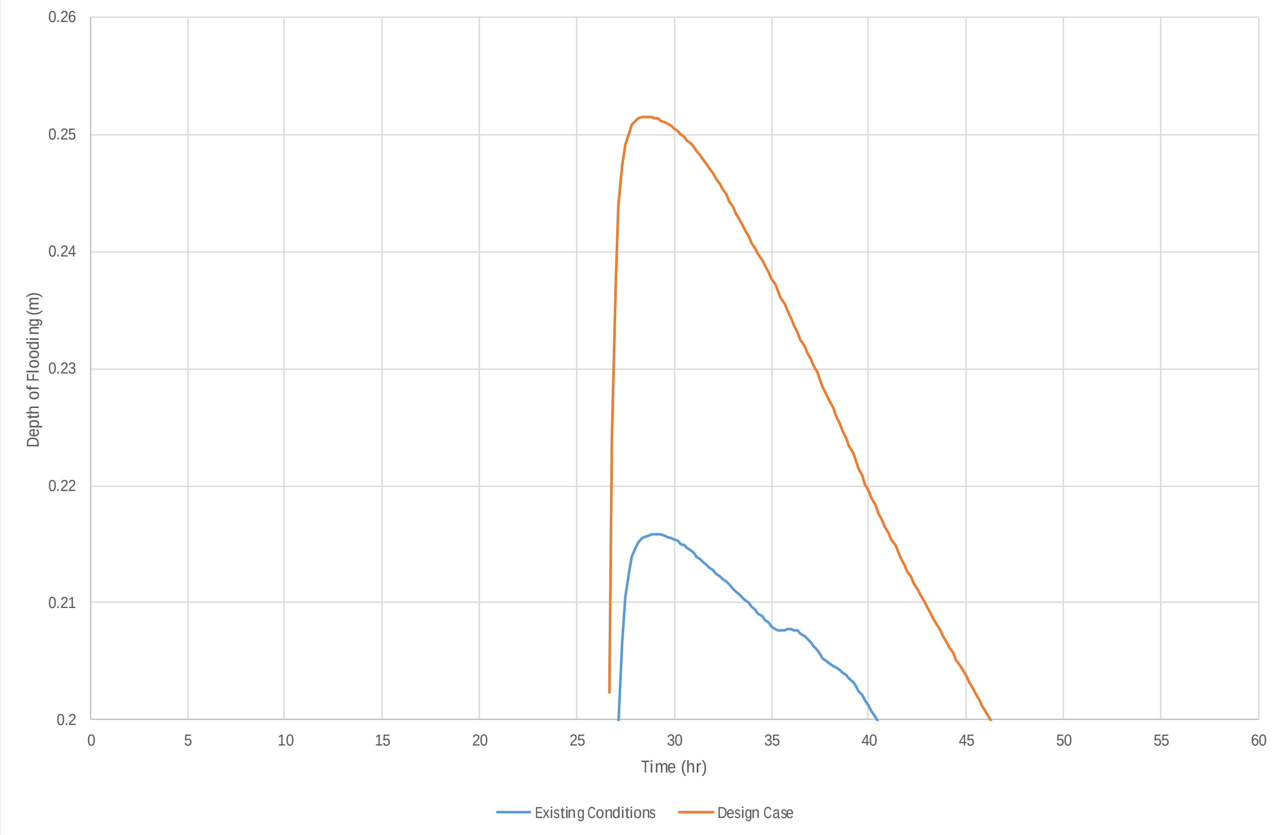

Figure 5.4 Example of typical duration impact around edge of existing Newell Highway embankment at rail chainage 658.040km

Conclusions

Impacts on the existing highway are considered acceptable given that the low number of non-compliances against the QDLs is offset by a net reduction in the extent of flooded areas of the highway and a net decrease in the hazard categories along the highway.

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

Figures 5.5 and 5.6 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 5.7 and 5.8 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 based on the existing agricultural land use of the land east of the rail line.

Figures 5.9 and 5.10 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 300mm and higher, with some areas experiencing increased velocities. The flood impacts to this area under extreme event conditions are therefore considered to be moderate.

Figures 5.11 and 5.12 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 widespread change in velocity. The flood impacts to this area under extreme event conditions are therefore considered to be moderate 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 or localised 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.

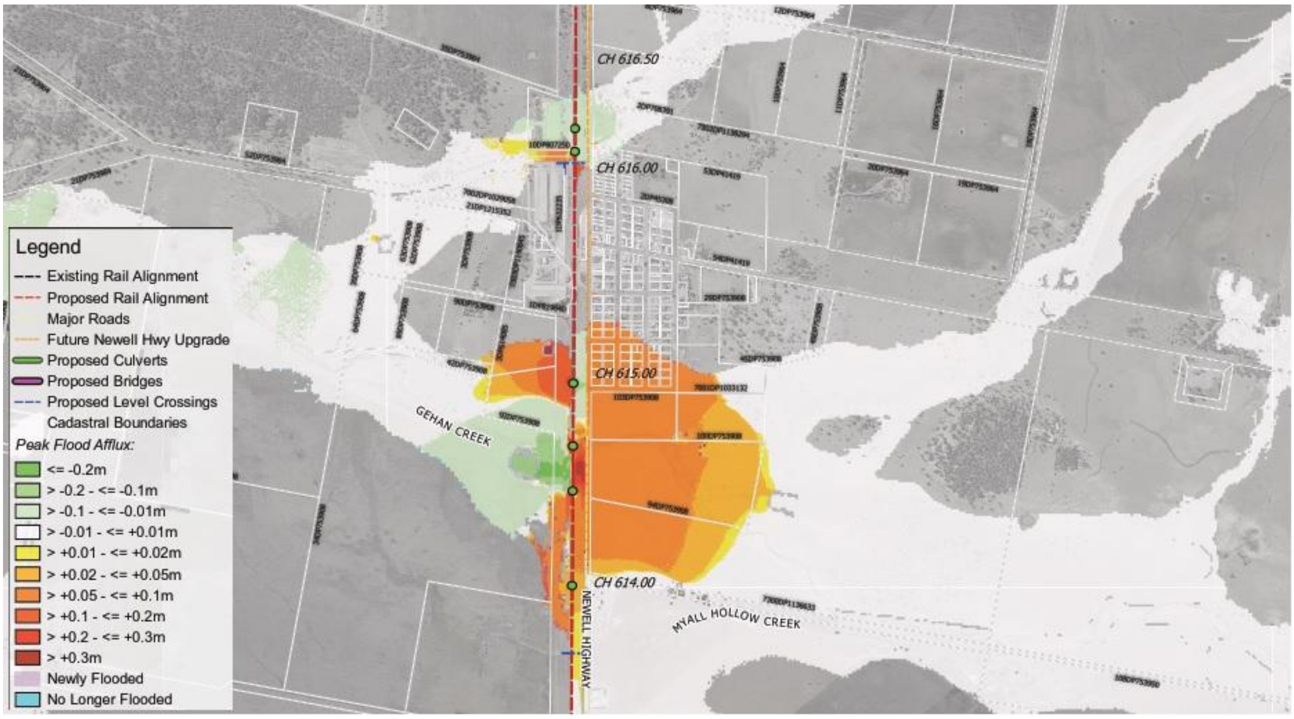

Figure 5.5 0.05% AEP afflux at Bellata

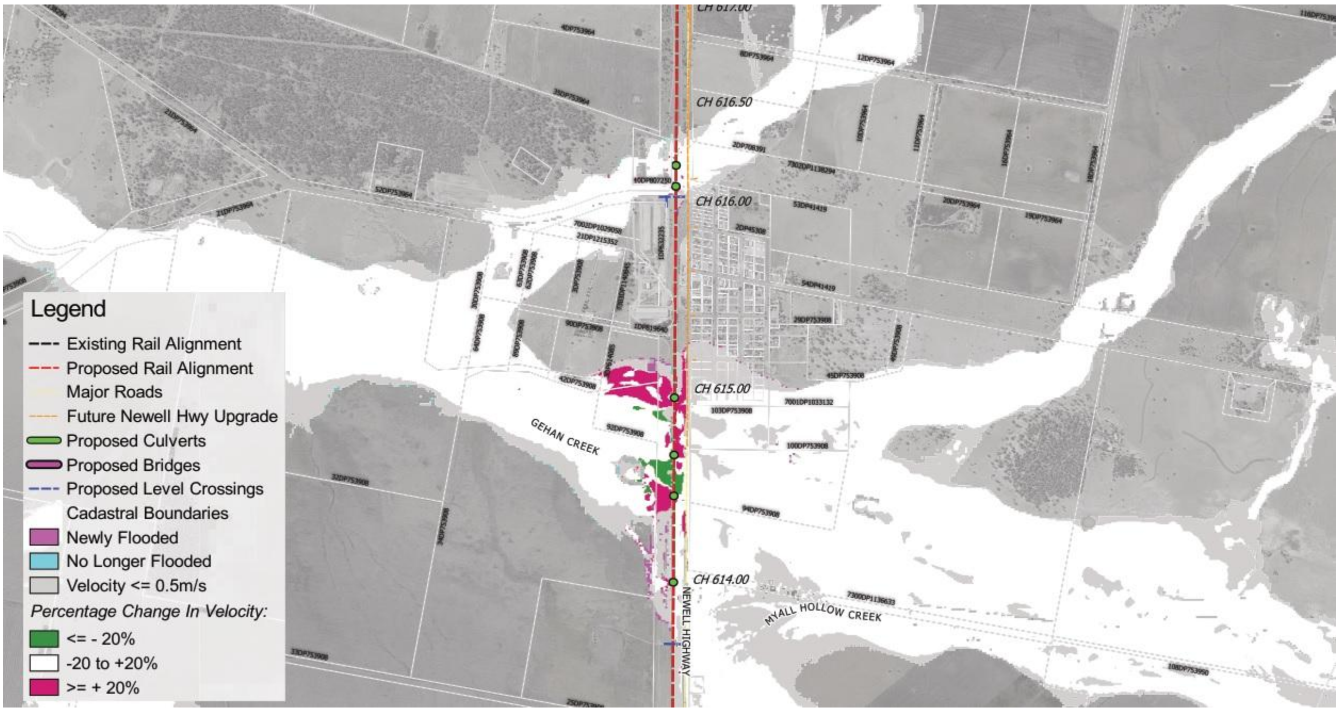

Figure 5.6 0.05% AEP velocity impact at Bellata

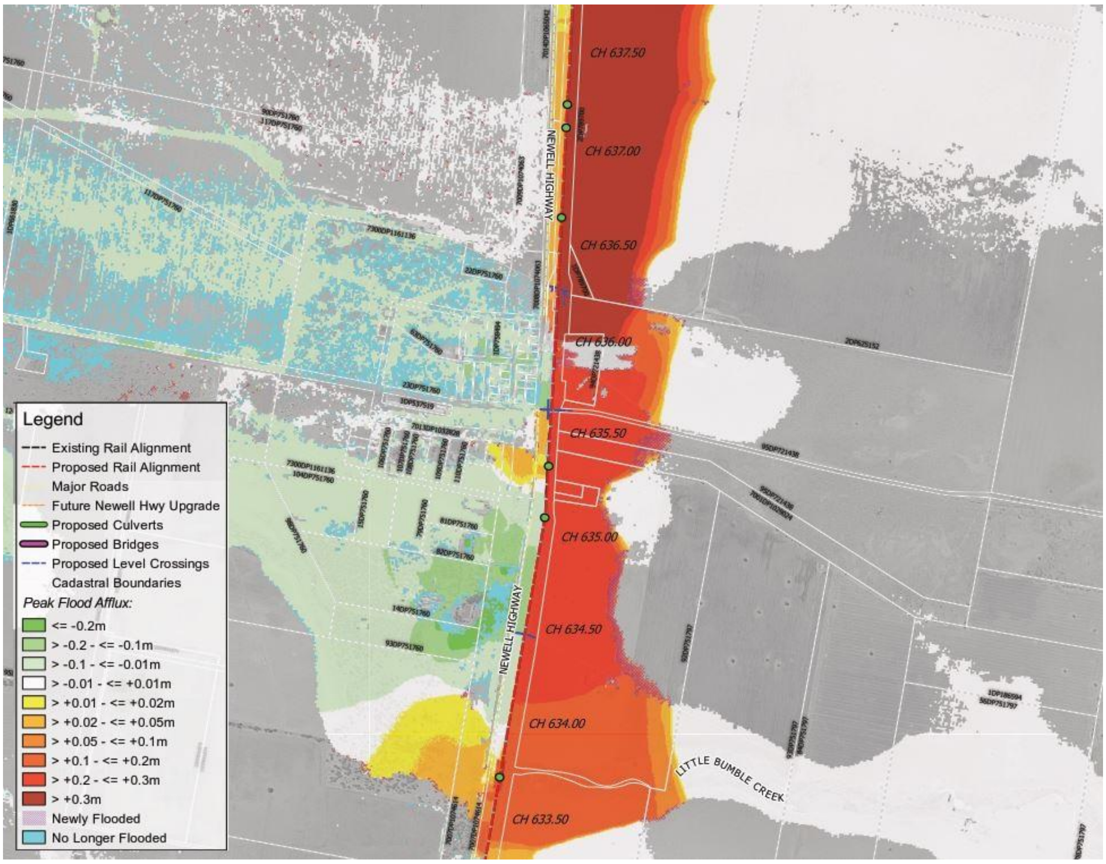

Figure 5.7 0.05% AEP afflux at Gurley

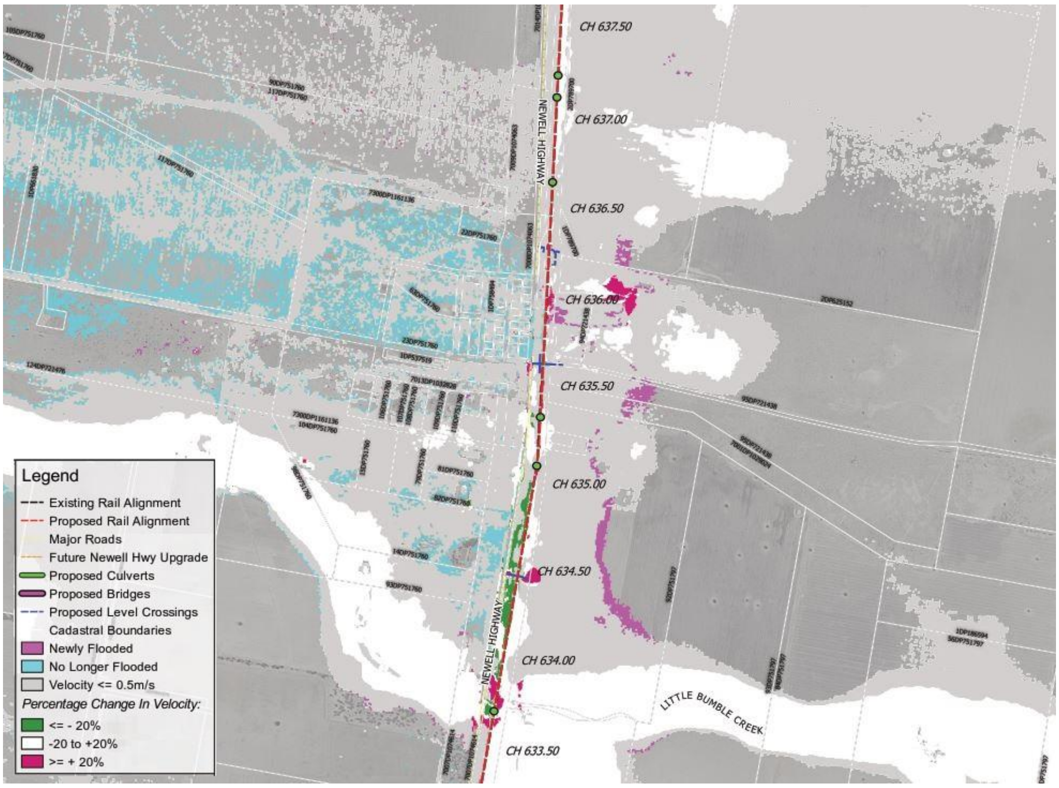

Figure 5.8 0.05% AEP velocity impact at Gurley

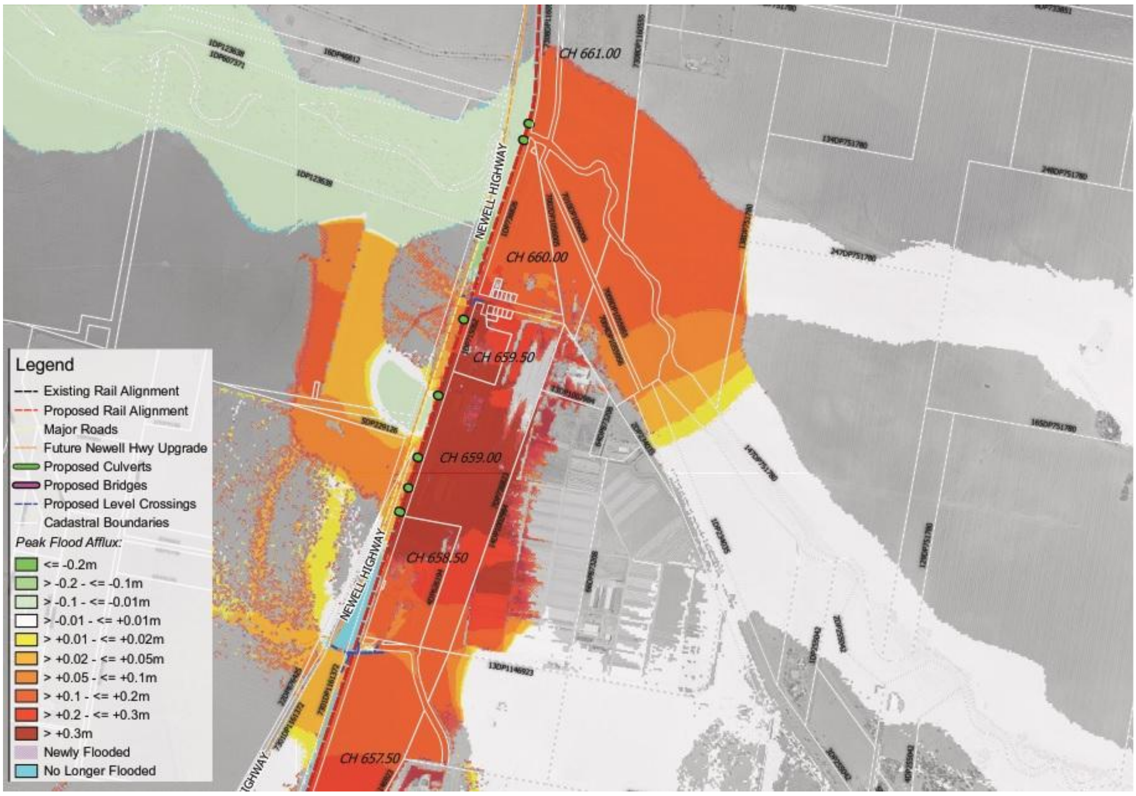

Figure 5.9 0.05% AEP afflux south of Halls Creek

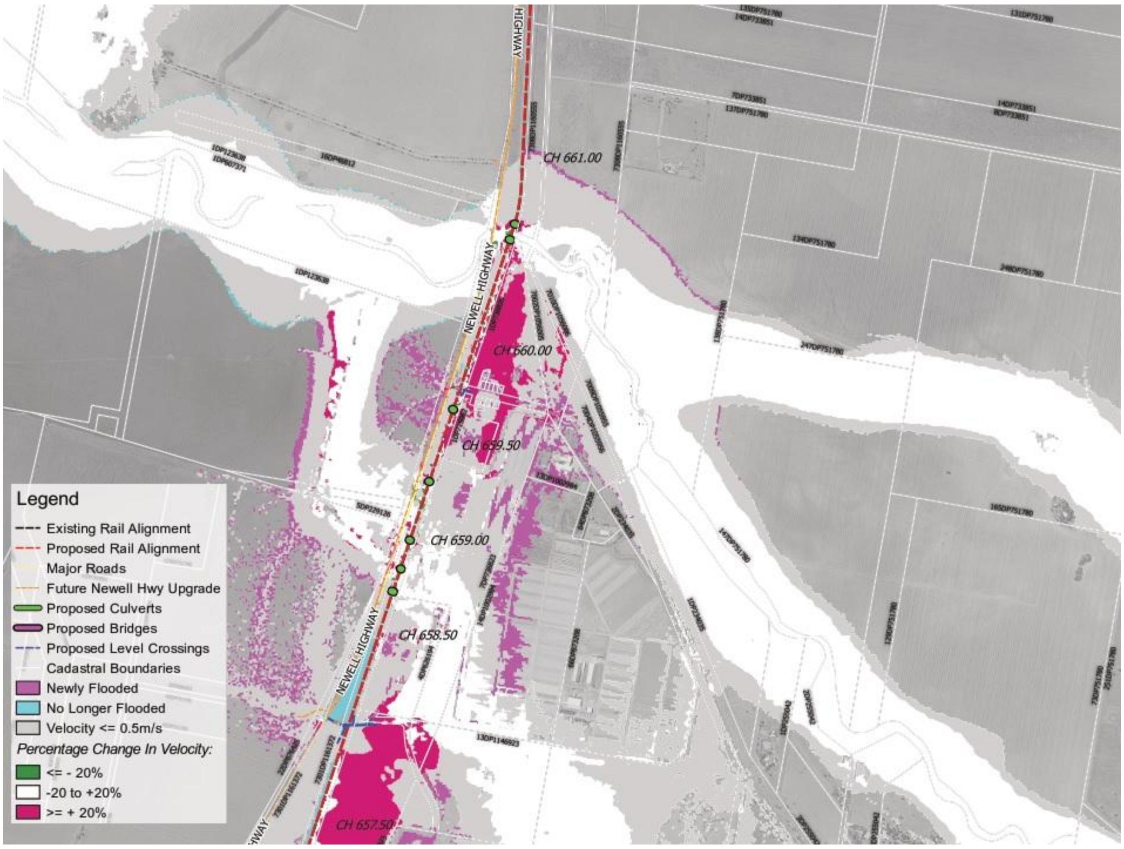

Figure 5.10 0.05% AEP velocity impact south of Halls Creek

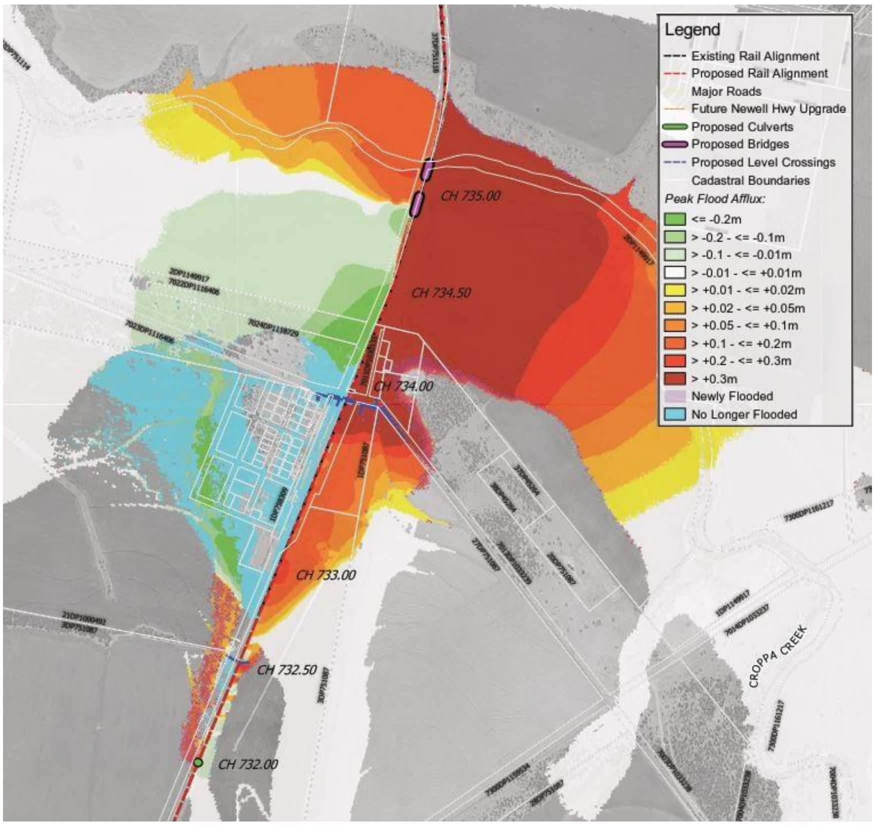

Figure 5.11 0.05% AEP afflux at Croppa Creek

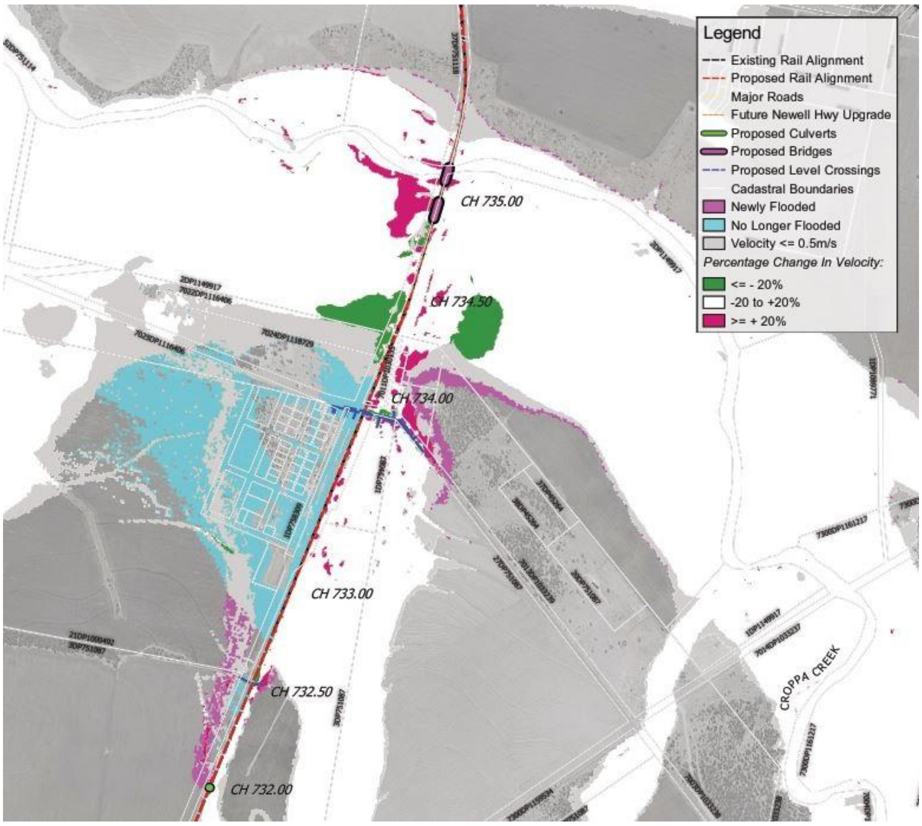

Figure 5.12 0.05% AEP velocity impact at Croppa Creek

6 Consultation

6.1 Introduction

The project will change the flood behaviour and drainage patterns around the rail corridor and the adjacent land to some extent, as described in Section 5. While these changes and associated impacts have been demonstrated to generally meet the requirements of the RAATM, BoD and CoA for the project, consultation with affected stakeholders on the flooding and drainage changes and impacts is required by the CoA. This section describes the consultation requirements and outcomes of the various stages of consultation undertaken during the detailed design phase of the project.

6.2 Consultation requirements

The CoA set out the stakeholder consultation requirements for flooding and drainage. Table 6.1 below summarises the requirements and how these have been met.

Table 6.1 Conditions of Approval requirements for consultation on flooding and drainage

Condition	Key extracts from Condition	Consultation requirements	Consultation undertaken to meet Condition
E27	The CSSI must meet the QDLs in Appendix A – FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS. Unless otherwise noted, these QDLs apply outside the rail corridor except for level crossings. These QDLs apply in any flood event up to and including the 1% AEP, and in any duration.	In circumstances where the CSSI does not meet the QDL at a specific location, the Proponent must achieve compliance through modified design of the CSSI. If this is not possible or practical the Proponent must: a) document the extent of the non-compliance with the QDL and justify why it is not possible or practical to achieve compliance through CSSI design changes; b) in every instance of non-compliance with the QDLs, consult with and obtain agreement from the affected land or property owners to either: I. the non-compliance; or II. establish an alternative level of mitigation of impacts for that location through alternative design measures; c) where an alternative level of mitigation of impacts is required for a location, achieve a level of mitigation through design measures beyond the rail corridor; and d) describe and detail the mitigation measures in the Flood Design Verification Report required by Condition **E28**	Consultation on drainage and flooding issues has been undertaken in two stages: Stage 1: Undertaken during the Reference design stage, 50%, 70% and 100% in Phase 1. - Consultation began in November 2019 and ended in January 2020. Stage 2: undertaken after the CoA were received in 2021 - Consultation began and was completed in July 2021

Condition	Key extracts from Condition	Consultation requirements	Consultation undertaken to meet Condition
E36	The Proponent must consult with TfNSW in relation to stormwater and drainage management to coordinate drainage infrastructure with the Newell Highway Upgrade.	The FDVR must be developed in consultation with TfNSW and EES (BCD). IR to provide further details of the impact of the Phase 1 N2NS project on flood risk to the Newell Highway. The information is intended to supplement the flood impact assessment contained in the N2NS Phase 1 Flood Design Verification Report (document reference 3-0001-260-IHY-00-RP-0006)	Consultation with TfNSW is ongoing. ARTC presented flooding impacts to Newell Highway in the same format as that developed for the N2NS SP2 Project – 14th July 2021 Technical memo issued on Wednesday 21 July 2021 ARTC and TfNSW to consider areas whereby cumulative impacts (i.e. caused by development of the IR and Newell Hwy), may necessitate combine consultation between IR and TfNSW – ongoing ARTC to provide final independent verification report to TfNSW and EES for information - TBC
E37	Prior to the installation of a new culvert, the Proponent must consult with the landowner that is located immediately downstream of the new culvert to determine the potential for impacts on agricultural productivity, farm operations and farm dams (including changes in water supply yield, reliability of supply, flood flows and embankment stability) due to the introduction or alteration of flows. Where potential adverse impacts are identified, the Proponent must consult with the affected landowner on the management measures that will be implemented to mitigate the impacts.	The FDVR must be developed in consultation with MSC, NSC and GSC. The FDVR must show evidence of consultation with landholders that are identified as being impacted beyond relevant criteria, referred to as QDL's. Impacted stakeholders may seek that the Project implement mitigation measures manage non-compliant impacts to their assets/properties. Similarly, the agencies and councils may supply technical commentary and queries on the FDVR.	Consultation on drainage and flooding issues has been undertaken in two stages: Stage 1: Undertaken during the Reference design stage, 50%, 70% and 100% in Phase 1. - Consultation began in November 2019 and ended in January 2020. Stage 2: undertaken after the CoA were received in 2021 - Consultation began and was completed in July 2021
E42	The Proponent must consult with TfNSW prior to, and at regular intervals during, construction to co-ordinate and implement mitigation measures to reducing any potential concurrent impacts arising from the construction of the CSSI and Newell Highway upgrade works.	Through this FDVR and ongoing consultation, collaboration with TfNSW is required to manage potential flooding impacts and risks as a result of the combined effects of N2NS Phase 1 and the planned upgrades of the Newell Highway	Refer to E36 above

6.3 Consultation strategy

Inland Rail's values commit the organisation to active engagement with stakeholders and the community.

The primary purpose of the stakeholder engagement activities was to inform the community, landowners and key stakeholders of current hydrology and flood modelling findings and consult on proposed mitigation measures.

Inland Rail's overarching strategy to communication and engagement is designed to:

Build Trust*: through quality engagement and interactions with our primary stakeholders, including landowners and communities, providing them with meaningful avenues for input and accurate honest information that allows them to get some certainty about what is happening and what they can expect so that they can make appropriate plans and decisions.*

Build Credibility*: through strong, timely engagement with key Government and organisational stakeholders and communications to the wider community, including an increased focus on the positive events and milestones and development of an ongoing program of support for Inland Rail by key community and business leaders.*

Build Visibility*: through persistence of broader communications and marketing including active participation in, and/or support for, local and regional community events as well as broader industry conferences.*

Inland Rail is also committed to active engagement in accordance with the 'best practice' measures implemented by the International Association for Public Participation (IAP2).

6.3.1 Consultation timing

Consultation on drainage and flooding issues has been undertaken in two stages:

Stage 1: Undertaken during the Reference design stage, 50%, 70% and 100% in Phase 1.

Consultation began in November 2019 and ended in January 2020.

Stage 2: undertaken after the CoA were received in 2021

Consultation began and was completed in July 2021

6.3.2 Key messages

The following key messages were used in the consultation process:

Flooding is a key consideration on the N2NS project.

Inland Rail will be designed in accordance with ARTC's guidelines, which specify that it is to provide flood immunity to the rail formation level for a flood event that has 1% annual exceedance probability (AEP). The rail formation level is the top of the embankment or structure on which the ballast and tracks sit.

A flood event with a 1% AEP has a one in 100 chance of being exceeded in any given year. It does not indicate the flood could only occur once in 100 years.

In Australia, the 1% AEP event is typically regarded as an acceptable level of flood immunity for planning purposes for projects of this nature.

In order to meet freight rail requirements, we will be raising and upgrading the existing track and foundation. In doing this, our objective is to maintain current water flow patterns to the greatest extent possible.

Our engineering designs have sought to minimise the changes in flood behaviour, though this is not fully achievable in all instances.

Our design modernises the drainage through the railway line to better control the movement of potential flood water. These culvert designs aim to balance potential flooding impacts upstream and downstream of the rail line.

As part of our work, we will be introducing culverts in new locations, as well as replacing most existing culverts or underbridges with upgraded sizes and materials.

Extensive flood modelling has been completed for a range of flood events. To build this modelling, a variety of information – including historical rainfall records, topographical data and the current and future infrastructure designs – have been combined to predict how different flood events will move throughout the wider project area.

Our methods have been reviewed by the Office of Environment and Heritage and the Department of Planning, Industry and Environment. Where applicable, local feedback has also been fed into models to support the accuracy of our findings.

6.3.2.1 Stage 1 key messages

Specific key messages used in Stage 1 were as follows:

Negligible impact

Our modelling has indicated that potential flooding impacts to lot X within your ownership exceed our flood management objectives.

However, we have confirmed that this exceedance is very small and therefore will create a negligible change.

Any other lots within your ownership are consistent within our flood management objectives, and no new flood impacts to buildings are anticipated on your property.

If you would like to talk through these changes, please get in touch. If you are happy with above impacts, no action is required.

Non-compliant impact

Based on our current modelling, we have determined there may be some changes to surface water movement and flood durations over the following lots within your ownership.

We will be in touch shortly to schedule a face-to-face meeting. Our technical staff will look to explain the potential changes and mitigation measures, as well as answer any questions you may have.

6.3.2.2 Stage 2 key messages

Key messages from Stage 1 were used as well as the below:

In response to earlier engagement we have further modified the design to limit impact on farmland and buildings. These designs better balance the impact across the upstream and downstream sides and across different events.

Based on our current modelling, we have determined there may be some changes to surface water movement and flood durations over the following lots within your ownership

We will be in touch shortly to schedule a face-to-face meeting. Our technical staff will look to explain the potential changes and mitigation measures, as well as answer any questions you may have.

6.3.3 Identifying stakeholders

A targeted engagement approach was undertaken in the delivery of hydrology and flooding methodology and mapping:

- Engaging with the broader community.
- Targeted engagement with N2NS landowners/stakeholders
- Engagement with Local Government and State Agencies

For Stage 2 engagement with the broader community was not deemed to be necessary as the recent changes were not considered to have a broad impact.

6.3.3.1 Stage 1 (2019/2020)

Inland Rail assessed all N2NS landowners against rigorous duration, velocity and afflux metrics, which were outlined in the project Environmental Impact Statement and based on work undertaken on similar projects – such as Parkes to Narromine. This consisted of GIS data queries/interrogation. We identified the following key stakeholder categories:

- Stakeholders receiving impacts that didn't comply with the assumed flood criteria
- Stakeholders whose land will have a new cross drainage structure where none currently exists
- Stakeholders whose land will have drainage infrastructure located on it (for example - scour protection, channel works extending beyond the ARTC land boundary into the adjacent private land)

We collated hard and soft copies of design / modelling outputs, which we used to facilitate consultation activities including:

- Flood level impact maps for 39%, 10% and 1% AEP events
- Flood velocity impact maps for 39%, 10% and 1% AEP events
- Flood duration impact maps for 39%, 10% and 1% AEP events
- Culvert plans showing landownership boundaries, proposed culvert configurations and extent of scour protection, channel works etc.

6.3.3.2 Stage 2 (2021)

Inland Rail assessed all N2NS landowners against the CoA and the IFC design assessing changes in afflux, duration, velocity and sensitive receivers and whether there were changes in cross drainage structures since landowners were previously consulted. The following key stakeholder categories were identified:

- Stakeholders whose land contained a building that was identified to be newly flooded
- Stakeholders receiving change in afflux to greater than 2% of their lot size
- Stakeholders receiving change in afflux to less than 2% of their lot size
- Stakeholders receiving a change in duration to all flood events

Stakeholders who have a new drainage structure and were not consulted in Stage 1 consultation round

Stakeholders whose land will have drainage infrastructure located on it (e.g. scour protection or channel works extending beyond the ARTC rail boundary) and whom had not been consulted in Stage 1.

Stakeholders who have non-compliant flood impacts were consulted on the following parameters:

Buildings where afflux exceeds the QDL limit of 10mm for the 1% AEP event only (there are no exceedances for the lower events i.e. 10% and 39%). Established building type and floor level to confirm if these are significant impacts.

Properties where **new culverts** have been added post IFC and therefore require consultation.

Properties where modifications have occurred to **scour protection** drainage infrastructure since the last consultation period. The changes in the new design were caused by changes to culverts south of Moree, level crossings and sidings.

As per Stage 1 Inland Rail collated hard and soft copies of design / modelling outputs to stakeholders to facilitate the consultation, including all documents provided for Stage 1 consultation:

Flood level impact maps for 39%, 10% and 1% AEP events

Flood velocity impact maps for 39%, 10% and 1% AEP events

Flood duration impact maps for 39%, 10% and 1% AEP events

Culvert plans showing landownership boundaries, proposed culvert configurations and extent of scour protection, channel works etc.

6.4 Consultation outcomes

The N2NS Stakeholder Engagement team contacted stakeholders who would be impacted by altered hydrology patterns or additional flood mitigation infrastructure, and those who would likely experience negligible changes. Initial contact was made via phone, email and/or written correspondence.

At these meetings, landowners were presented with an in-depth overview of hydrology modelling; water flow implications (existing, 1%, 10% and 39% AEP events) for duration, velocity and afflux; and proposed mitigation measures (including new culvert structures and scour protection).

6.4.1 Stage 1 outcomes

The key outcomes of the Stage 1 consultation are provided in Table 6.2.

Table 6.2 Key information obtained and outcomes from Stage 1 consultation

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
Broader Community	Seven (7) Community Information Sessions were held (Moree, Croppa Creek, North Star, Narrabri and Bellata) - approximately 90 attendees	The sessions targeted interested community members situated either outside the rail corridor and those landowners who had a broad interest in flood modelling activities and were not significantly impacted by ongoing work. In order to ensure accessibility to all interested parties, sessions were held at alternate times – both during the day and	The Community Information Sessions were attended by the N2NS Stakeholder Engagement and Project teams, including environmental specialists and design engineer. Importantly, the sessions also included the N2NS hydrologist, who was able to facilitate conversations and explain current modelling work.

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
		in the evening – and in major and minor townships throughout the local area.	
Individual Stakeholders	**Negligible** - 60 (sixty) landowners identified as receiving a negligible impact were sent written communication. Additionally, landowners who had negligible impacts were offered a meeting to provide further information.	This communication explained the existing infrastructure and flood behaviour. Explanations were also provided on how infrastructure and flood behaviour will change after the project is constructed. The meetings helped gain the landowner's in-principle acceptance of the new infrastructure and impacts.	In April 2020 one additional meeting with a landowner who had negligible impacts occurred after the landowner requested further information around hydrology. In June 2020, a further landowner identified some concerns around hydrology – face to face meeting was held.
	Non-compliance - 32 (thirty-two) individual landowner one-on-one meetings occurred. Meetings also occurred with a landowner's who had negligible impacts but requested further information.	Landowners who were deemed as moderately impacted were offered a face-to-face meeting with engagement and technical staff, including a hydrologist. From 26 November to 11 December 2019, the N2NS Stakeholder Engagement team issued 32 meeting request letters resulting in twenty-nine (29) face-to-face meetings with directly impacted landowners. In February 2020, landowners were issued with additional information. They were also provided with a further opportunity to meet face-to-face with the project team to discuss any concerns they might have. Four (4) meetings were subsequently booked and completed. Additional meetings were held in May 2020 with landowners who had been unable to meet in 2019.	18 (eighteen) landowners had further investigations required. Stakeholder meetings were held resulting in further design refinements - acceptance was received from 12 landowners. 6 landowner mitigation options were under review prior to stage 2 consultation.
Local Government and State Agencies	Local Government and State Agencies meetings: Narrabri Shire council Moree Plains Shire Council Gwydir Shire Council Narrabri Flood Plain Committee Moree Flood Plain Committee TfNSW SES LALC representatives.	Summary presentation of the flood modelling and cross drainage for the project. Analysis of previous key studies which were referred to during the flood modelling methodology. Stream gauge data for each basin within the project area. SP1 model build process and source of the SP2 model and its hydrological and hydraulic extent. SP2 model calibration process. Validation of design models process used broad-brush method to check hydrological models.	Moree Plains Shire Council requested LIDAR modelling (Digital Elevation Model) which would assist with their future LGA planning assessments.

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
		RORB model overlapped with Moree AFTS model. Validation that the kc parameter adopted agreed with the OEH independent models, developed independent to the project. Overview of the design procedure in relation to culvert infrastructure. Project design update including SPIR process and SP2 update.	

6.4.2 Stage 1 key issues

Table 6.3 Stage 1 consultation key issues

Forum	Key issue	Outcomes / Mitigations
Landowner meeting	Complex landowner issue related to flood modelling and operations. Landowner expressed concern with the validity of flood modelling and demonstrated historic flooding via photographs and markers.	N2NS team organised subsequent meetings. The N2NS Project team provided the landowner with detailed information about the flood modelling process. Landowner was reassured that the methods used had been reviewed by the Office of Environment and Heritage and the Department of Planning, Industry and Environment. Inland Rail noted a change in current design to reflect new water flow.
Landowner meeting	Feedback received on culverts in landowner meetings after hydrology meetings.	N2NS Stakeholder Engagement team provided feedback to N2NS Project Team; response provided to landowners as appropriate. Landowner acknowledged understanding of culvert placement and design change.
Local Government and State Agencies	Council requested LIDAR modelling (Digital Elevation Model) which would assist with their future LGA planning assessments.	The N2NS Project team provided Council's with relevant data to assist with their LGA planning assessments,
Broader Community	Attendee queried the extent/status of hydrology investigations between Moree and Camurra.	The N2NS Project team noted that this section of the project was part of SP2, was subject to an independent Environmental Impact Statement, and that new hydrology investigations would therefore be completed.

6.4.3 Stage 1 mitigation measures agreed with stakeholders

Some impacts do require complex mitigation and regular consultation. The key outputs from consultation are landowner accepting the model and mapping, and what mitigations measures (if any) are required to minimize unacceptable impacts. See below for a summary of these proposed measures.

Table 6.4 Summary of proposed mitigation measures after Stage 1

Property	Key issue	Outcomes / Mitigations
1//DP255520	Drainage Channel	Mitigation accepted - Drainage channel
125//DP753906	Drainage Channel	Mitigation accepted - Drainage channel agreed
125//DP753906	Request for earthworks due to increase in afflux	Mitigation accepted - Earthworks agreed Details to be discussed during construction
32//751747	Questioned culvert, and water-flow and requested minor earthworks.	Mitigation accepted - Earthworks agreed Details to be discussed during construction
5//1223258	likely requires mitigation, requires more information	Mitigation accepted - Earthworks agreed in principle
3//7555984	Feedback on culvert placement	Design accepted IFC design updated – landowner acceptance received

6.4.4 Stage 2 outcomes

Key information obtained from consultees during the Stage 2 consultation (no broader community consultation required) is as follows. Note that small number of engagements remain outstanding, details of which are presented in Table 6.6.

Table 6.5 Key information obtained and outcomes from Stage 2 consultation

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
Individual stakeholders	**Non-compliance** -24 landowners were contacted resulting in one-on-one meetings, either in person or via Microsoft Teams. These meetings comprised of engagement and specialist technical staff.	Impacted stakeholders were presented with an overview of the revised Hydrology modelling, along with the projects proposed implementation of mitigation measures to manage non-compliant impacts to their assets/properties.	14 (fourteen) landowners accepted the change in flood behaviour. 10 (ten) landowners have continued investigations where mitigation consultation is ongoing.
	Negligible Impact – 5 (five) landowners identified as receiving a negligible impact were sent an email or letter outlining the above key messages.	Written communication was sent to landowners who would be impacted by exceedances of flood management objectives, noting this exceedance is very small and will not create a noticeable change.	Meetings were offered to these landowners with impacts. This communication included key messages, relevant flood mapping and a description of their impact. 0 (zero) landowners requested a one-on-one meeting
Local Government and State Agencies	Local Government and State Agencies meetings: Narrabri Shire Council	Councils were presented with an initial draft version of the FDVR and an overview of relevant Conditions of Approval (CoA) that are driving	FDVR shared via DPIE Portal on 17.05.21. Portal allows 1 month for consultation/response from stakeholders.

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
	Narrabri Flood Plain Committee Moree Plains Shire Council Moree Flood Plain Committee Gwydir Shire Council	development of the FDVR, accompanied by historical project context related to the FDVR being mandated by the CoA. This included mention of the preceding Flood Design Report (FDR) provided as part of the Submission Preferred Infrastructure Report (SPIR) and DPIE's subsequent request to evaluate flooding impacts against quantitative design limits (QDL's) prescribed in the CoA (versus those used/applied in the FDR). Engagement with NSC has also facilitated the provision of minuting meetings, as prepared by ARTC and supply of a draft version of the independent peer review report.	Appendices zip file for N2NS SP1 Project Flood Design Verification Report (FDVR) issued 1.6.2021 Narrabri Shire Council – response received 21.6.2021 subsequently requested links to the FDVR appendices and model calibration report and independent peer review report. The appendices and calibration report were provided on 6.07.2021 and the draft peer review report on 9.08.2021. Further feedback from NSC received on 19.08.2021, which queried various matters, key amongst which the technical adequacy of the FDVR. Feedback under consideration by ARTC and engagement with NSC will therefore remain ongoing. Moree Plains Shire Council – no further requests for data Acceptance received. Gwydir Plains Shire Council – no further requests for data Acceptance pending.
	TfNSW EES (BCD)	TfNSW and BCD were presented with an initial draft version of the FDVR and an overview of relevant Conditions of Approval (CoA) that are driving development of the FDVR, accompanied by historical project context related to the FDVR being mandated by the CoA. This included mention of the preceding Flood Design Report (FDR) provided as part of the Submission Preferred Infrastructure Report (SPIR) and DPIE's subsequent request to evaluate flooding impacts against quantitative design limits (QDL's) prescribed in the CoA (versus those used/applied in the FDR). Engagement with TfNSW and BCD has also facilitated provision of a memo by ARTC to both agencies that addressed flooding impacts on the Newell Highway, letters from ARTC to both agencies addressing concerns upon the FDVR (as raised by both agencies) and supply of an updated draft of the FDVR to both agencies.	FDVR shared via DPIE Portal on 17.05.21. Portal allows 1 month for consultation/response from stakeholders. Both TfNSW and EES (BCD) had issues in downloading the appendices of the FDVR. This impacted review timeframes Appendices zip file for N2NS SP1 Project Flood Design Verification Report (FDVR) issued 1.6.2021 TfNSW – feedback received as of 25.06.21 and provided to IRDJV for consideration. Key concerns related to justifying and consulting with TfNSW upon non-compliances with QDL's and explaining risks related aquaplaning. BCD – Feedback received 28.06.213 and provided to IRDJV for consideration. Key concerns related to ensuring consultation was closed out as necessary, aspects of the FDVR (provided on 17.05.2021) still needed to be developed and justification concerning some technical aspects of the modelling was necessary.

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
			ARTC held a joint meeting with BCD and TfNSW on the 1.07.2021 to discuss feedback provided both agencies. ARTC recorded and distributed actions from the meeting on 6.07.2021. Actions included need for ARTC to provide a memo addressing some of TfNSW's concerns around impacts to the Newell Highway (memo provided to TfNSW and BCD on the 21.07.2021 by ARTC). Additional feedback (minor comments) following meeting provided by BCD on 16.07.2021 and TfNSW on 28.07.2021. ARTC responded to both BCD's and TfNSW's initial feedback (from June 2021) on 05.08.2021. ARTC provided both BCD and TfNSW with an update draft of the FDVR on 9.08.2021. Follow up meeting held with BCD on 17.08.2021 whereby BCD mentioned further feedback would be provided and therefore engagement with BCD remains ongoing. TfNSW are in the process of collating a response for ARTC and therefore engagement with TfNSW remains ongoing.

Table 6.6 Outstanding Consultation

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
Broader Community	An online Community Information Session for Gurley Creek	The sessions have targeted interested community members situated either outside the rail corridor and those landowners who had a broad interest in flood modelling activities and were not significantly impacted by ongoing work	Scheduled for Thursday 26th August 2021
Individual Stakeholders	3 Landowners have requested meetings after the Gurley Information Session.	Confirmation that the land affected is not of sensitive use; landowners accept modelling and do not require mitigation. Landowners will be presented with an in-depth overview of hydrology modelling; waterflow implications (existing, 1%, 10% and 39%) for duration, velocity and afflux; and proposed mitigation measures (including	Meetings postponed due to Covid.

Stakeholder	Consultee	Information obtained	Outcomes / Mitigations
		new culvert structures and scour protection).	
Local Government and State Agencies	CROWN/Local Land Services	Confirmation that the land affected is not of sensitive use; landowners accept modelling and do not require mitigation.	Meeting is scheduled for 24th August 2021 (online)

6.4.5 Stage 2 mitigation measures agreed with stakeholders

The key outputs from our consultation activities were focused on landowners accepting the model and mapping and identifying what mitigations measures (if any) were required to minimize unacceptable impacts. See below for a summary of these proposed measures.

Table 6.7 Summary of proposed mitigation measures after Stage 2

Property	Key issue	Outcomes / Mitigations
7//DP736823	3 cross drainage features added at 658.820.1,659.090.1, 659.400.1) Afflux area <2% total lot area in 39AEP)	Landowner accepted the modelling
136//DP751785	Afflux duration, Afflux area <2% total lot area in 10AEP	Mitigation - levee required to protect building
42//DP753908	Afflux area change <2% total lot area at 10AEP	Landowner accepted modelling
2//DP1223258	Duration change at 1AEP, 10AEP and 39AEP	Mitigation is dependent on further velocity/erosion forecast
2//DP1106981	Non-compliant afflux on <2% of total land in 1AEP	Landowner accepted modelling
1//DP633825	38 and 39mm Afflux height change affecting two buildings and afflux duration change	Landowner accepted modelling
1//DP1080910	non-compliant afflux area on <2% of total land in 1 and 10 and 39AEP	Landowner accepted modelling
101//DP1138114	Non-compliant afflux on <2% of total land in 1AEP	Landowner accepted modelling
1//DP577012	3 cross drainage features added to IFC at 638.920.1, 639.160.1, 640.080.1	Landowner accepted modelling
2//DP789700	Afflux flood area change <2% total lot area in 1AEP)	Landowner accepted modelling
109//DP751760	Afflux area <2% total lot area in 1AEP	Mitigation - levee required to protect building
91//DP751797	Non-compliant afflux on <2% of total land in 1AEP	Landowner accepted modelling
92//DP751797	Building Afflux	Mitigation - levee required to protect building
15//DP753961	Duration change	Mitigation - Investigate possible dam to reduce duration impacts
22//DP876425	Cross drainage at 659.090.1 and duration	Landowner accepted modelling

Property	Key issue	Outcomes / Mitigations
50//DP753919	Afflux area <2% I 10 AEP and boggy creek	Mitigation – flow over banks required to protect building
20//DP751129	Channel works added to IFC	Mitigation – flow over drainage channel required
12//DP751791	Duration impact at 1%, and afflux area <2%	Landowner accepted modelling
109//DP751760	Change in Afflux area <2% total lot area 1%AEP)	Landowner accepted modelling
1//DP1155508	Duration change at 1AEP	Mitigation – flow over banks or channels
2//DP1155508	Non-compliant afflux on <2% of total land in 1AEP	Landowner accepted modelling
21//DP1000492	duration change on lot and building afflux	Mitigation – possible bund (IR to also consider noise mitigation and fencing solutions)
5//DP1223258	Rock apron and new channel works added to IFC and duration changes and Afflux area change <2% total lot area in 10AEP	Mitigation – possible bund or drainage channel near rock apron
11//DP1197268	Afflux Area >2% total lot area in 1 and 10 AEP - 42cm on 0.02ha in 1AEP and 1.1m on 0.26ha on a 10AEP)	Landowner accepted modelling

6.5 Specific consultation with TfNSW

Details concerning the design implications of any associated flooding impacts have been shared with and discussed with TfNSW on an ongoing basis since as early as 2018. Engagement between ARTC and TfNSW has been achieved via meetings, both in person and via teleconference, delivery of presentations by ARTC to TfNSW to outline the scope of the N2NS Phase 1 Project and via the provision of electronic information such as reports, infrastructure design models and flood models. Key examples of the provision of such data are provided below.

Table 6.8 Details of consultation with TfNSW

Date	Subject	Context
28/11/2018	Native Models from N2NS 70% Deliverable	Provision of preliminary flood modelling data from ARTC to TfNSW
12/12/2018	N2NS Digital Survey	Provision of topographic survey data collected by ARTC to TfNSW
10/05/2019	N2NS - Digital Information	Provision of preliminary rail infrastructure design for N2NS from ARTC to TfNSW
23/07/2019	IFC Culvert and Bridge Models for N2NS for Information	Provision of final designs for culvert and bridge models from ARTC to RMS
05/11/2019	N2NS Digital Files Issued For Information to RMS	Provision of updated rail infrastructure design for N2NS from ARTC to RMS
31/12/2019	Submissions and Preferred Infrastructure Report (SPIR)	Provision of SPIR by ARTC to TfNSW, which included matters relating to hydrology

Date	Subject	Context
(Exact date not defined. SPIR made available to agencies in December 2019)		
28/01/2020	TfNSW Submission - SPIR SSI 7474	Comments supplied by TfNSW to ARTC regarding the SPIR
26/05/2020	Response to the SPIR/Amendment Report	Response to TfNSW by ARTC, regarding TfNSW's comments on the SPIR
09/02/2020	N2NS redesign and revised rail slew design	Provision of updated rail infrastructure design for N2NS from ARTC to TfNSW
01/09/2020	Phase 1 Models and Report Full IFC Package	Provision of final rail infrastructure design for N2NS from ARTC to TfNSW
17/05/2021	Provision of FDVR for review	Provision of flood modelling information from ARTC to TfNSW
01/06/2021	N2NS SP1 | Flood Design Verification Report for Separable Portion 1 - Appendices - For Information	Provision of draft FDVR appendices by ARTC to TfNSW
25/06/2021	Narrabri to North Star Phase 1 Flood Design Verification Report - Response from ROADS AND MARITIME SERVICES DIVISION	Comments supplied by TfNSW to ARTC regarding the FDVR
06/07/2021	Outcomes from FDVR Meeting with NSW Agencies	List of actions supplied by ARTC to TfNSW, following engagement regarding TfNSW's feedback on the FDVR
21/07/2021	Outcomes from FDVR Meeting with NSW Agencies	Memo supplied by ARTC to TfNSW regarding discussion of impacts to Newell Highway following above mentioned engagement with TfNSW
28/07/2021	FVDR comments from meeting	Further feedback provided by TfNSW to ARTC following correspondence on 27/01/2021
05/08/2021	Response to TfNSW Queries Regarding FDVR	Response (letter) to TfNSW by ARTC, regarding TfNSW's comments on the FDVR
09/08/2021	N2NS SP1 | Project Flood Design Verification Report - Final Draft	Provision of final draft version of the N2NS SP1 Project Flood Design Verification Report to TfNSW.

Sections 5.3.2.6 and Appendix D of this report provide additional details of impacts on the existing Newell Highway and future Newell Highway upgrades in response to feedback received from TfNSW during consultation meetings in June and July 2021.

ARTC acknowledges that upgrades of the Newell Highway proximal to N2NS Phase 1 have the potential to alter flooding impacts experienced in the region. Details of these potential cumulative impacts, i.e. generated as result of the both N2NS Phase 1 and the Newell Highway Upgrades, are presented in Appendix H. Construction of upgrades to the Newell Highway are planned to commence in the second quarter of 2022.

Condition of Approval E42 stipulates that ARTC must consult with TfNSW prior to and at regular intervals during construction to co-ordinate and implement mitigation measures to reduce any potential concurrent impacts arising from the construction of the N2NS Phase 1 and the Newell Highway Upgrade works. This engagement platform has and will continue to be used to address matters such identifying relevant cumulative flooding impacts and subsequently implement any necessary stakeholder engagement. Such engagement(s) would be a collaborative effort between ARTC and TfNSW. Input towards any subsequent mitigation measures would also likely be proportionate to each proponent's contribution to the associated cumulative flooding impacts.

7 Conclusions and further work

7.1 Conclusions

This report has described the methodology and results of the flood modelling undertaken for the IFC design stage of the project. This report includes an assessment of flood impact compliance with the ARTC RAATM and BoD and the CoA QDLs.

The report documents a number of non-compliances with the flood design criteria. The non-compliances have been subject to consultation with the affected stakeholders and fall into the following categories:

- Consultation has been undertaken on the impact with the affected landowner and the impact has been accepted – this typically applies where the impact is marginal, i.e. a minor exceedance of the QDLs, or only occurs for rare events and is offset by reduced flood risk on the property for more frequent events.
- Where the original impacts were found to be unacceptable to the affected landowners, mitigation measures have been designed to reduce or manage the residual impact to a level that the landowner deemed acceptable.

7.2 Further work

Further work relating to the flooding and cross drainage design to be completed post-IFC includes the following:

- Further negotiation with landowners to confirm the required mitigation measures identified from the first two stages of consultation.
- Further consultation with TfNSW on the flood risk to the existing Newell Highway and future sections to be upgraded, and potential requirements for mitigation of the risk where required.
- Further consultation with TfNSW and their designers on the effects of the Newell Highway upgrades and the combined effects of both projects.
- Agreement with TfNSW on combined consultation process with landowners affected by flood impacts caused by the combined effects of both projects.

8 References

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