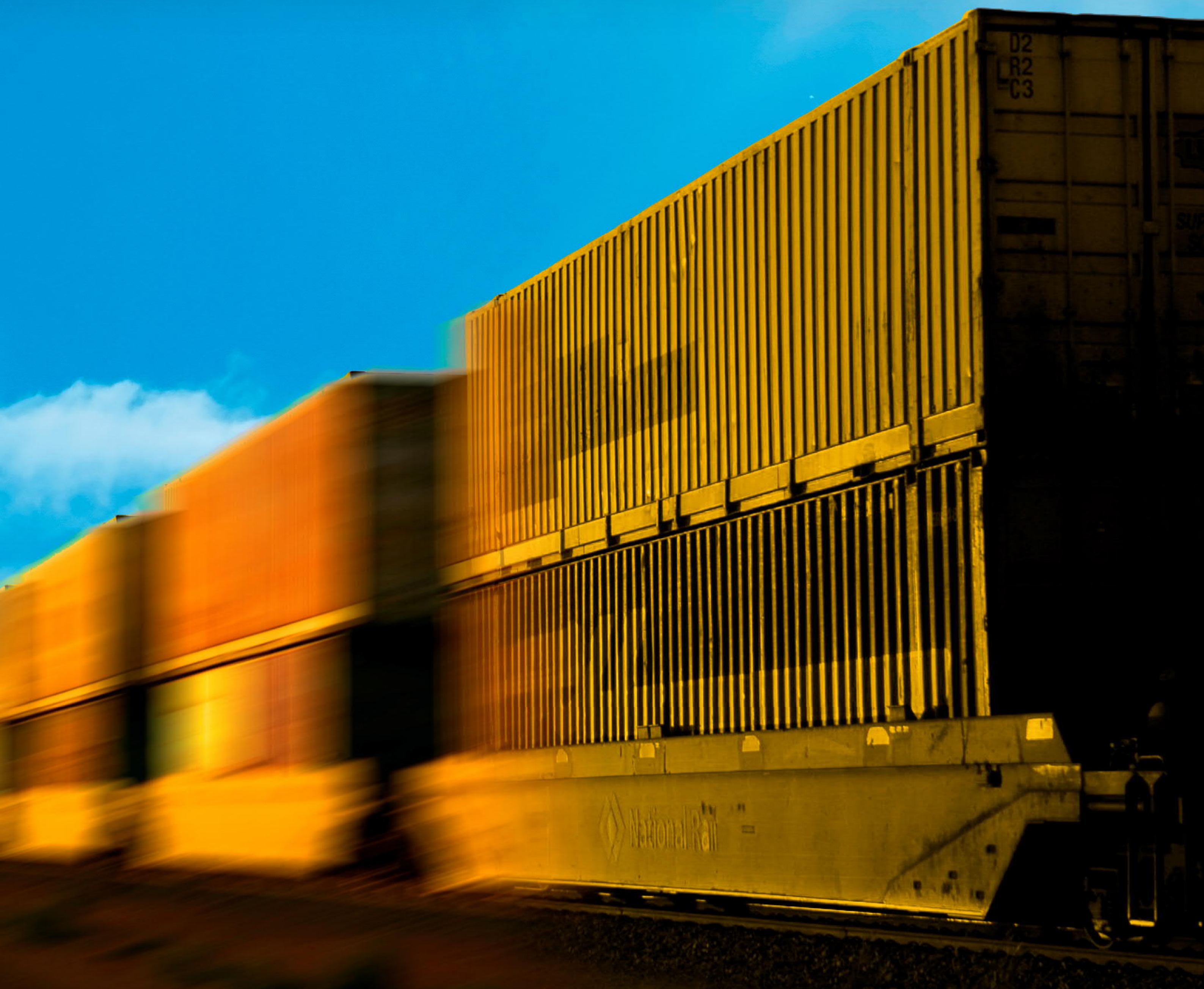
# Technical and Approvals Consultancy Services: Narrabri to North Star

# Flood Design Verification Report for Phase 1

## Issued For Construction

July 2022

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



## Prepared for

Australian Rail Track Corporation

## Prepared by

**IRDJV**

World Square
Level 27,
680 George Street, Sydney
New South Wales, 2000
Tel: +61 7 3854 6200

## Document Information

| Document information | |
|---|---|
| **Report Title** | Flood Design Verification Report for Phase 1 |
| **Subtitle** | Issued For Construction |
| **Document Number:** | 3-0001-260-IHY-00-RP-0006 |
| **Filename** | 3-0001-260-IHY-00-RP-0006_0.docx |
| **Date** | July 2022 |

| Rev | Date | Details |
|---|---|---|
| 0 | 05/07/2022 | Final submission |

## Revision details

| Revision details | | | | |
|---|---|---|---|---|
| **Prepared by** | Kate Stephens, Taher Karimian | Date: 05/07/2022 | Signature: | Kate Stephens. |
| **Reviewed by** | Rob Leslie | Date: 05/07/2022 | Signature: | Rob Leslie |
| **Approved by** | Denis Manassero | Date: 05/07/2022 | Signature: | DManassero |

# Table of Contents

## LIST OF TABLES



## LIST OF FIGURES

## LIST OF APPENDICES

# 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 has been reviewed 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. Changes to the cross drainage design have been limited to culverts, with the bridge designs remaining unchanged since the Submissions and Preferred Infrastructure Report. 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. These culvert design changes are listed in the table below, with red text denoting changes in the IFC design when compared against the SPIR design.

Table 1.1 Culvert design changes in GWYDIR02 model since SPIR stage

| No. | SPIR Design | | | IFC Design | | |
|---|---|---|---|---|---|---|
| | Kilometrage | Number of cells | Structure Type | Kilometrage | Number of cells | Structure Type |
| 1 | 618.065 | 2 | 3000x1500 4SBC | 618.065 | 2 | 3000x1500 4SBC |
| 2 | 619.070 | 2 | 3000x2100 4SBC | 619.070 | 2 | 3000x2100 4SBC |
| 3 | 619.300 | 1 | 2400x1500 4SBC | 619.300 | 1 | 1200x600 4SBC |
| 4 | 621.895 | 3 | 3000x2400 4SBC | 621.895 | 3 | 3000x2400 4SBC |
| 5 | 623.075 | 4 | 3000x2400 4SBC | 623.075 | 4 | 3000x2400 4SBC |
| 6 | 624.805 | 1 | 1800x900 4SBC | 624.805 | 1 | 1800x900 4SBC |
| 7 | 625.570 | 2 | 1200x450 4SBC | 625.570 | 2 | 1200x450 4SBC |
| 8 | 627.280 | 50 | 3000x2400 4SBC | 627.280 | 50 | 3000x2400 4SBC |
| 9 | 627.430 | 30 | 3000x2100 4SBC | 627.430 | 30 | 3000x2100 4SBC |
| 10 | 627.760 | 10 | 2400x1200 4SBC | 627.760 | 10 | 2400x1200 4SBC |
| 11 | 630.925 | 2 | 600x600 4SBC | 630.925 | 2 | 600x600 4SBC |
| 12 | 631.140 | 3 | 1800x900 4SBC | 631.140 | 3 | 1800x900 4SBC |
| 13 | 631.580 | 1 | 600x600 4SBC | 631.580 | 1 | 600x600 4SBC |
| 14 | 633.780 | 35 | 3000x2400 4SBC | 633.780 | 46 | 3000x2400 4SBC |
| 15 | 635.145 | 6 | 1800x600 4SBC | 635.145 | 6 | 1800x600 4SBC |
| 16 | 635.410 | 2 | 2400x900 4SBC | 635.410 | 1 | 2400x900 4SBC |
| 17 | 636.705 | 4 | 600x600 4SBC | 636.705 | 1 | 600x600 4SBC |
| 18 | 637.170 | 1 | 1800x600 4SBC | 637.170 | 1 | 600x600 4SBC |
| 19 | 637.290 | 1 | 1800x900 4SBC | 637.290 | 1 | 1800x900 4SBC |
| 20 | 638.140 | 5 | 2400x1200 4SBC | 638.140 | 2 | 2400x1200 4SBC |
| 21 | 638.525 | 13 | 2400x900 4SBC | 638.525 | 15 | 2400x900 4SBC |
| 21a | Not included at SPIR stage | | | 638.920 | 14 | 1800x600 4SBC |
| 21b | Not included at SPIR stage | | | 639.160 | 14 | 1800x600 4SBC |
| 22 | 639.740 | 60 | 2400x900 4SBC | 639.740 | 60 | 2400x900 4SBC |
| 22a | Not included at SPIR stage | | | 640.080 | 5 | 2400x900 4SBC |
| 23 | 640.380 | 20 | 1800x900 4SBC | 640.380 | 20 | 1800x900 4SBC |
| 24 | 640.650 | 15 | 1800x1200 4SBC | 640.650 | 15 | 1800x1200 4SBC |

| No. | SPIR Design | | | IFC Design | | |
|---|---|---|---|---|---|---|
| | Kilometrage | Number of cells | Structure Type | Kilometrage | Number of cells | Structure Type |
| | 641.950 | 35 | 3000x2400 4SBC | 641.950 | 35 | 3000x2400 4SBC |
| 26 | 642.380 | 75 | 3000x2400 4SBC | 642.380 | 63 | 3000x2400 4SBC |
| 26a | Not included at SPIR stage | | | 642.380 | 12 | 3000x2400 4SBC |
| 27 | 643.000 | 45 | 1800x1200 4SBC | 643.000 | 6 | 1800x1200 4SBC |
| 28 | 643.230 | 45 | 3000x1500 4SBC | 643.230 | 2 | 3000x1500 4SBC |
| 29 | 643.980 | 72 | 3000x1200 4SBC | 643.980 | 6 | 3000x1200 4SBC |
| | 644.980 | 55 | 3000x1200 4SBC | 644.980 | 5 | 3000x1200 4SBC |
| 31 | 645.490 | 20 | 3000x1200 4SBC | 645.490 | 2 | 3000x1200 4SBC |
| 32 | 645.920 | 2 | 2400x900 4SBC | 645.920 | 1 | 1800x900 4SBC |
| 33 | 646.065 | 2 | 2400x900 4SBC | 646.065 | 1 | 2400x900 4SBC |
| 34 | 646.160 | 10 | 3000x1200 4SBC | 646.160 | 2 | 3000x1200 4SBC |
| | 646.850 | 25 | 2400x1200 4SBC | 646.850 | 12 | 2400x1200 4SBC |
| 36 | 647.155 | 40 | 3000x2400 4SBC | 647.155 | 20 | 3000x2400 4SBC |
| 37 | 647.315 | 10 | 3000x1200 4SBC | 647.315 | 5 | 3000x1200 4SBC |
| 38 | 647.670 | 10 | 3000x1500 4SBC | 647.670 | 5 | 3000x1500 4SBC |
| 39 | 647.925 | 4 | 2400x1200 4SBC | 647.925 | 4 | 2400x1200 4SBC |
| | 648.240 | 6 | 2400x900 4SBC | 648.240 | 6 | 2400x900 4SBC |
| 41 | 648.395 | 10 | 3000x2400 4SBC | 648.395 | 8 | 3000x2400 4SBC |
| 42 | 648.635 | 6 | 2400x900 4SBC | 648.635 | 6 | 2400x900 4SBC |
| 43 | 649.185 | 2 | 1800x600 4SBC | 649.185 | 4 | 1800x600 4SBC |
| 43a | Not included at SPIR stage | | | 649.700 | 30 | 2400x900 4SBC |
| 43b | Not included at SPIR stage | | | 650.040 | 36 | 1800x600 4SBC |
| 44 | 650.330 | 1 | 2400x900 4SBC | 650.330 | 2 | 2400x900 4SBC |
| | 650.690 | 2 | 2400x900 4SBC | 650.690 | 2 | 2400x900 4SBC |
| 46 | 652.530 | 2 | 1800x600 4SBC | 652.530 | 2 | 1800x600 4SBC |
| 47 | 652.715 | 1 | 1800x600 4SBC | 652.715 | 2 | 1800x600 4SBC |
| 48 | 653.150 | 1 | 600x600 4SBC | 653.150 | 24 | 1800x600 4SBC |
| 49 | 653.620 | 6 | 2400x900 4SBC | 653.620 | 24 | 2400x900 4SBC |
| | 653.700 | 1 | 2400x900 4SBC | 653.700 | 10 | 2400x900 4SBC |
| 51 | 654.525 | 1 | 1800x900 4SBC | 654.525 | 1 | 1800x900 4SBC |
| 52 | 655.270 | 6 | 3000x1200 4SBC | 655.270 | 18 | 3000x1200 4SBC |
| 53 | 655.980 | 5 | 3000x1200 4SBC | 655.980 | 6 | 3000x1200 4SBC |
| 53a | Not included at SPIR stage | | | 656.240 | 5 | 2400x900 4SBC |

| No. | SPIR Design | | | IFC Design | | |
|---|---|---|---|---|---|---|
| | Kilometrage | Number of cells | Structure Type | Kilometrage | Number of cells | Structure Type |
| 53b | Not included at SPIR stage | | | 658.820 | 3 | 1800 x 600 4SBC |
| 53c | Not included at SPIR stage | | | 659.095 | 3 | 1800x600 4SBC |
| 53d | Not included at SPIR stage | | | 659.400 | 5 | 1800x600 4SBC |
| 53e | Not included at SPIR stage | | | 659.780 | 2 | 1800x600 4SBC |
| 54 | 660.705 | 45 | 3000x2400 4SBC | 660.705 | 45 | 3000x2400 4SBC |
| 55 | 663.135 | 1 | 600x600 4SBC | 663.135 | 1 | 600x600 4SBC |
| 56 | 663.460 | 4 | 1800x600 4SBC | 663.460 | 4 | 1800x600 4SBC |
| 57 | 664.870 | 3 | 1800x600 4SBC | 664.870 | 3 | 1800x600 4SBC |
| 58 | 664.982 | 1 | 1800x600 4SBC | 664.982 | 1 | 1800x600 4SBC |

- **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 were tested in the flood model and found to be ineffective. Further consultation was undertaken to determine any landowner sensitivities to the impacts which found that all impacted properties have raised floor levels and the afflux impacts will only affect some portions of driveways and access roads in large events but will not adversely affect trafficability or access in the events.
- **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.

## 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 1.2 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.<br>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:<br>(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;<br>(b) in every instance of non-compliance with the QDLs, consult with and obtain agreement from the affected land or property owners to either:<br>i) the non-compliance; or<br>ii) establish an alternative level of mitigation of impacts for that location through alternative design measures; | Section 5.3.2.1 provides a justification of why the design does not fully meet the QDLs.<br>Sections 5.3.2.2 to 5.3.2.7 document all of the QDL non-compliances with case studies justifying some of the key non-compliances.<br>Section 6 documents the consultation process and mitigation measures agreed with landowners on the non-compliances |

| Condition | | Where addressed in report |
|---|---|---|
| | (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<br>(d) describe and detail the mitigation measures in the Flood Design Verification Report required by Condition E28; | |
| **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.<br>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.<br>The Flood Design Verification Report must include:<br>(a) details of the flood modelling that informs the report;<br>(b) details of how the project's flood planning level (FPL) was decided, with reference to relevant considerations of the NSW Floodplain Development Manual;<br>(c) an assessment of the infrastructure's compliance with the Quantitative Design Limits (QDLs) for flooding, hydrology and geomorphology listed in Appendix A – FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS;<br>(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;<br>(e) an assessment of the impacts of the CSSI on erosion, scouring, bank stability, stream stability and geomorphology;<br>(f) mitigation and management measures that will be undertaken if the QDLs are exceeded, as specified in Condition E27;<br>(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;<br>(h) an assessment of risk to life caused by formation failure in extreme flood events, including management measures to mitigate this risk; and<br>(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.<br>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.<br>*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.* | Section 4 – flood modelling methodology<br>Section 5 – flood impact assessment<br>Section 4.6.2 and Appendix I – independent peer review |
| **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 | Section 4.6.2 and Appendix I |

| Condition | | Where addressed in report |
|---|---|---|
| | Infrastructure Projects: Seeking Approval from the Department for the Appointment of Independent Experts (DPIE, 2020).<br>The review must:<br>(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;<br>(b) assess the establishment, calibration, validation and operation of the flood model items as per (a);<br>(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;<br>(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:<br>i) have been prepared consistent with current and appropriate methodologies and standards; and<br>ii) accurately depict and resolve design impacts of the CSSI.<br>The peer reviewer's endorsement must be appended to the Flood Design Verification Report.<br>*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, 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.<br>(a) The FERP must be prepared by an experienced flood emergency response specialist who has extensive experience in preparation of these plans.<br>(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.<br>(c) The FERP must be appended to the Flood Design Verification Report.<br>*Note: Nothing in this condition prevents the adaptation of an existing flood management or emergency plan to satisfy this condition.* | The FERP is provided in Appendix H.<br>Section 5.5 provides an overview of the FERP and how it and ARTC's commitments to informing the emergency management planning process are consistent with the NSW Floodplain Development Manual. |
| **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:<br>(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;<br>(b) consideration of changes to flood behaviour that may result from CSSI infrastructure failures or embankment collapses where these may occur during floods; | Section 5.3.2 documents the changes to all flood parameters beyond the rail corridor and compliance against the QDLs.<br>Section 5.4 and Appendix L document the impact of the CSSI under extreme events, including an assessment of where rail embankment failure could occur and implications for downstream land uses. |

| Condition | | Where addressed in report |
|---|---|---|
| | (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;<br>(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.<br>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 5.4 provides an overview of the consultation process with agencies involved in flood emergency management and Section 6 provides details of the consultation undertaken and ARTC's commitments to providing outputs from this study to facilitate updates to existing agency management plans. |
| **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:<br>(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;<br>(b) identification of the properties and infrastructure affected by flooding during the reportable event; and<br>(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:<br>i) determine if the exceedance is attributable to the CSSI, and<br>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.<br>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.<br>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. | To be addressed in a separate report after commencement of operation |
| 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 after commencement of operation |
| **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 | Not addressed in this report. Arrangements for data sharing and handover to be agreed between ARTC and relevant agencies. |

| Condition | | Where addressed in report |
|---|---|---|
| | 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. | |
| **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.

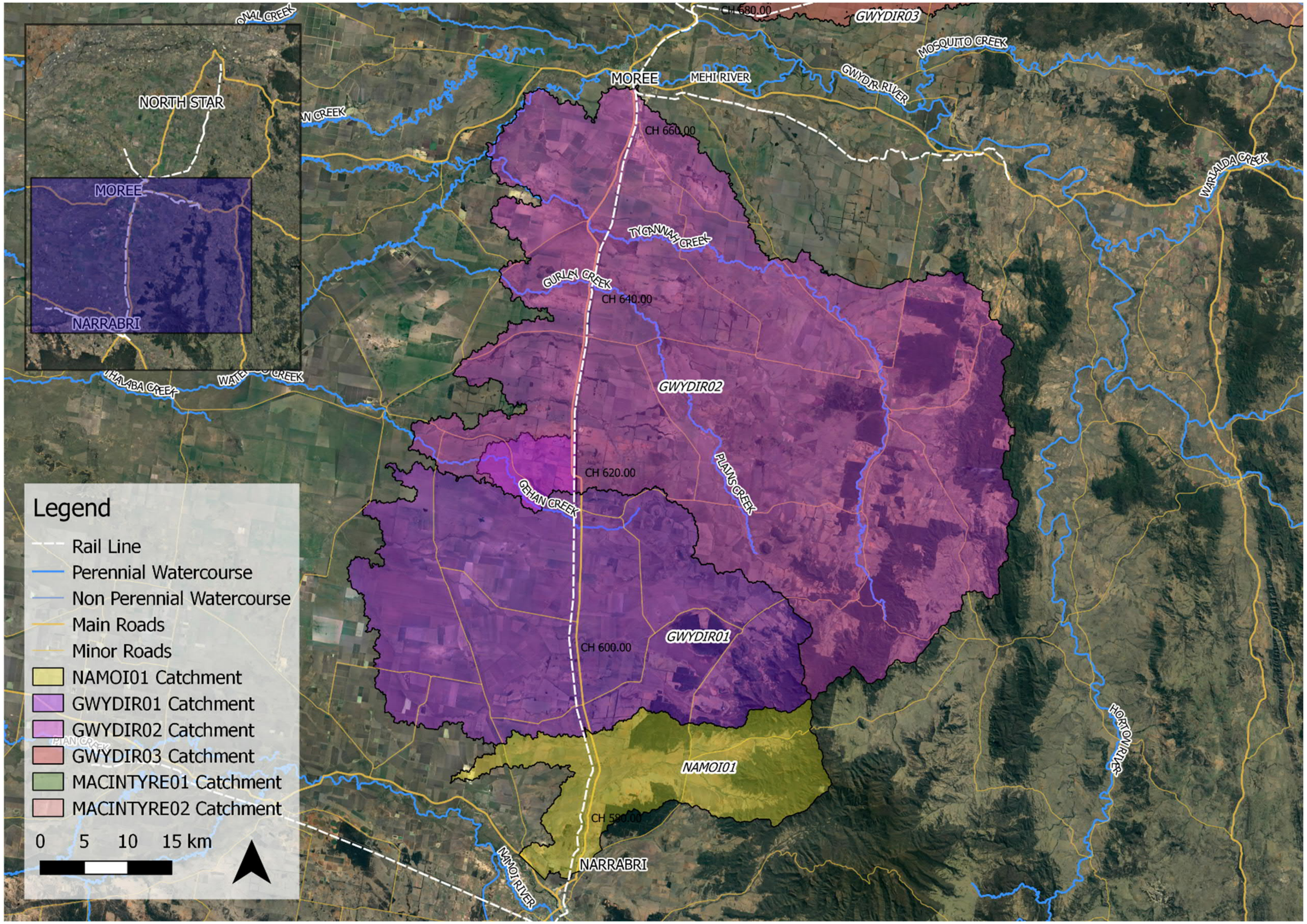



Figure 2.1 N2NS Phase 1 study area and extent of NAMOI01, GWYDIR01 and GWYDIR02 flood models

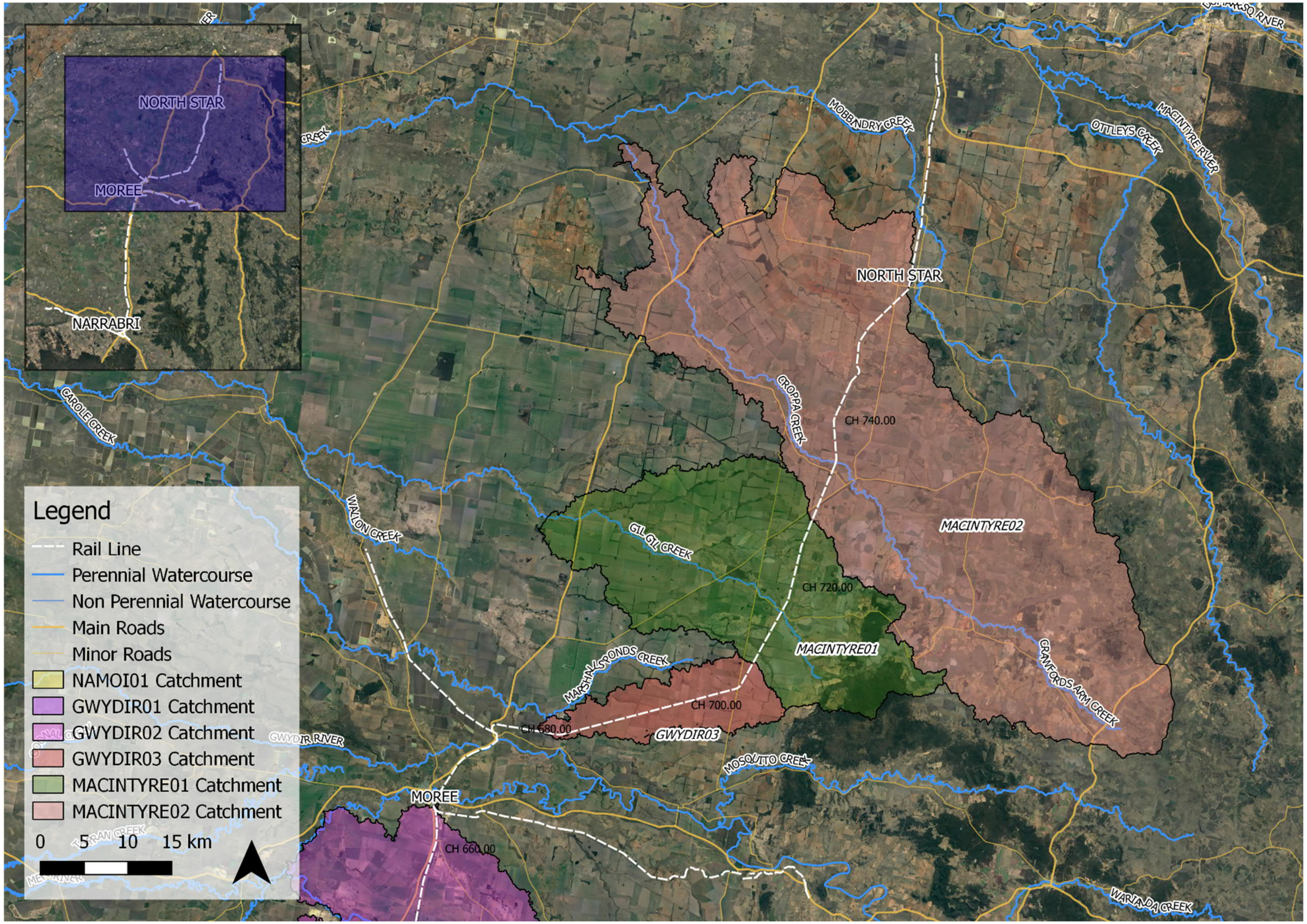



Figure 2.2 N2NS Phase 1 study area and extent of GWYDIR03, MACINTYRE01 and MACINTYRE02 flood models

### 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<br>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<br>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<br>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.<br>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 100m²) | | 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:

- ARTC LiDAR survey (2015) – 0.2m resolution covering approximately a 10km wide strip along the project corridor;
- ARTC 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);
- ARTC site survey – survey of local features and structures;

- Other publicly available LiDAR datasets sourced from the Elevation and Depth – Foundation Spatial Data resource (https://elevation.fsdf.org.au/) and
- Shuttle Radar Topographic Mission (SRTM) data – elevation grid data with 30m resolution – adopted to supplement the catchment terrain datasets beyond the extents of the above datasets.

Catchment delineation and physical parameters such as slope were determined based on the combined surface elevation model generated from the above datasets. The digital terrain models used in the hydraulic model domains were developed from the LiDAR and site survey datasets only and did not utilise the coarser resolution SRTM data. This includes the GWYDIR02 model which extends approximately 15km upstream of the rail corridor to capture breakouts from the Tycannah Creek system.

#### 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 and ARR2019 recommended losses

| RORB Model | Adopted Initial Loss (mm) | Adopted Continuing Loss (mm) | ARR2019 Initial Loss (mm) | ARR2019 Continuing Loss (mm) |
|---|---|---|---|---|
| NAMOI01 | 42 | 0.8 | 35 | 0.7 |
| GWYDIR01 | 57 | 0.2 | 41 | 0.6 |
| GWYDIR02 | 56 | 0.4 | 58 | 0 |
| GWYDIR03 | 54 | 0.1 | 59 | 0 |
| MACINTYRE01 | 52 | 0.3 | 59 | 0 |
| MACINTYRE02 | 58 | 0.1 | 73 | 0 |

It is noted that the ARR2019 update and associated NSW specific guidance modified the loss values set by ARR2016. The table above shows the ARR2019 recommended losses for the model areas which demonstrates that the adopted values are reasonably consistent with ARR2019.

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 |
| 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.

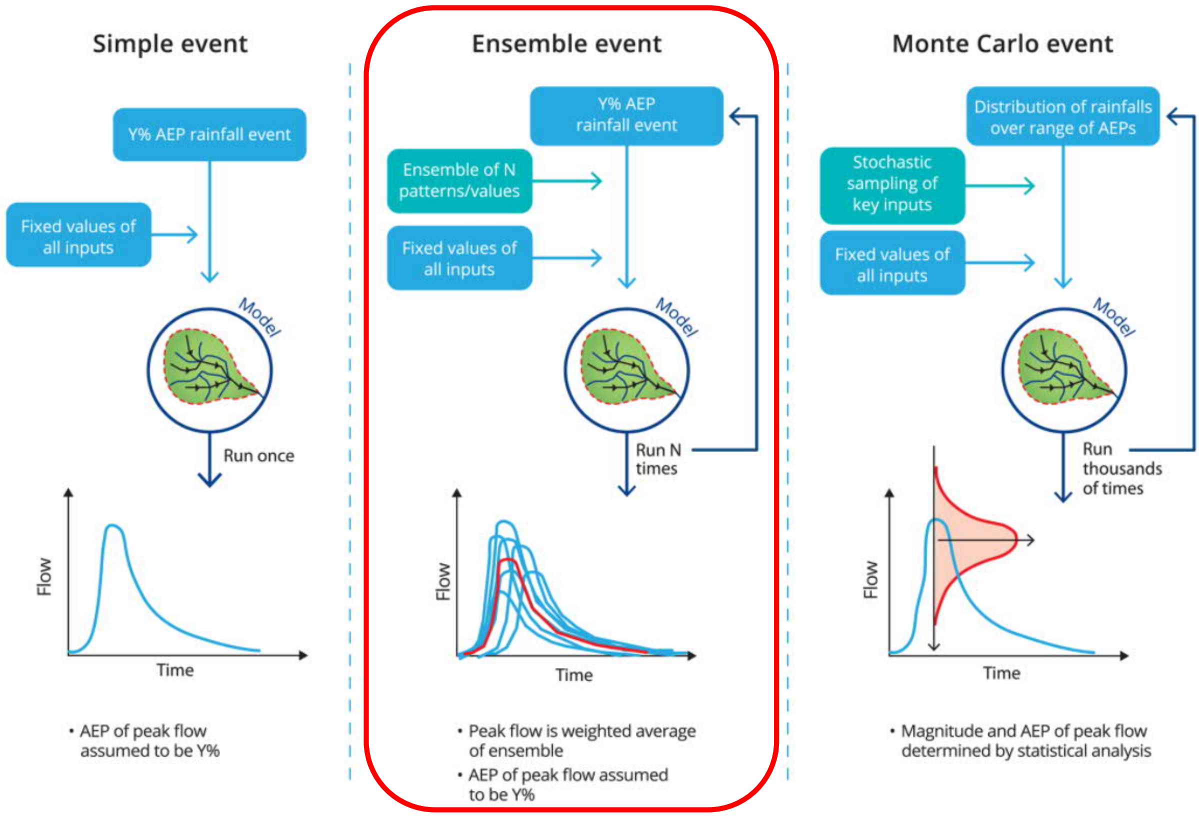



Figure 4.1 ARR2016 approaches to estimation of peak flow

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<br>(as per ARR2016 Book 2, Chapter 4, Table 2.4.1) | Point temporal patterns for all catchments < 75km$^2$<br>(as per ARR2016 Book 2, Chapter 5, Section 5.9.1) |
| 1 to 10 km$^2$ | All durations | ARF = 1<br>(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$^2$<br>(as per ARR2016 Book 2, Chapter 5, Section 5.9.1) |
| 10 to 75 km$^2$ | All durations | ARF varies<br>(calculated by Storm Injector as per ARR2016 Book 2, Chapter 4, Table 2.4.1) | Point temporal patterns for all catchments < 75km$^2$<br>(as per ARR2016 Book 2, Chapter 5, Section 5.9.1) |
| >75 km$^2$ | < 12 hours | ARF varies<br>(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<br>(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:<br>- 75km$^2$ – 150km$^2$<br>- 150km$^2$ – 350km$^2$<br>- 350km$^2$ – 750km$^2$<br>- 750km$^2$ – 1750km$^2$<br>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 |

| 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 |
| 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 |
| 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 |

| 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 |
| 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 |
| 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 |

| 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 |
| 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 |
| 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 |

| 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 |
| 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 |
| 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 |

| 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 |
| 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 |
| 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. Floor levels of buildings in areas affected by flooding were estimated using the LiDAR ground level data in the absence of floor level survey data.

#### 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;
- Sensitivity of flood impacts to variation in cross drainage blockage assumptions (with 0% and 50% blockage scenarios tested as compared to the 15% blockage factors adopted for the design);
- Sensitivity of flood impacts to variation in hydraulic model roughness (with 20% decrease and 20% increase in model domain surface roughness tested); and
- Sensitivity of flood impacts to use of the new sub-grid sampling feature within TUFLOW which allows the use of the resolution of the underlying topographic dataset to determine the water surface elevation versus width (or wetted perimeter) relationships for each model grid cell rather than the coarser resolution of the adopted model grid spacing. This approach will estimate the conveyance of channels and overland flow paths in more detail than the original model grid.

The Independent Peer Review Report is provided in Appendix I. IRDJV have completed all sensitivity tests recommended by the Peer Reviewers and a document providing the results of the sensitivity tests and a full response to the review comments is also included in Appendix I. The results show that the design performs as intended and within reasonable tolerances when key parameters such as structure blockage and hydraulic roughness are varied.

Due to the lack of streamflow gauging data in the subject catchments there is uncertainty in the flow estimates used in the flood modelling. BMT undertook a comprehensive verification exercise of the hydrology which concluded that the flows used in design were within +/-20% of flow estimates derived using alternative rainfall-runoff parameters and modelling methods. The flow and blockage sensitivity tests showed that there is increased risk to some properties in the GWYDIR02 and MACINTYRE02 models but this increased risk is offset by the following:

- GWYDIR02: The properties most at risk are located around 659.7km on the upstream side (east) of the rail corridor. The culverts at this location are relatively low (600mm high) which would imply a high blockage risk, however, the area upstream of these culverts is cleared land that has been developed for commercial purposes and unlikely to generate large debris in the overland flow paths that drain to the culverts. If precautionary mitigation measures to manage the potential for high blockage are deemed necessary at this location, provision of debris collection poles along the fence line on the upstream side of the rail corridor is recommended given that sensitive assets occur downstream (Newell Highway and other residential buildings) which would be adversely affected if additional culverts were provided and high blockage did not occur in practice. In addition, the design flows in this area were consistently higher than the flow estimates derived by BMT's verification and therefore the design flows are conservatively high at this location, indicating that the design is conservative and can accommodate higher flows than may occur in practice.
- MACINTYRE02: The increased risk to properties occurs as a result of increased flow rather than blockage. The properties affected are recreation / sports facilities in Croppa Creek rather than residential properties. Safeguarding these properties against this risk is not recommended given that other more sensitive properties such as residences and a school are located close by and could be

affected by flood mitigation works at the recreation / sport facilities. If this risk was realised then retrospective flood-proofing of the affected buildings would be a more appropriate mitigation measure.

As part of Narrabri Shire Council's review of this report, Council's flood consultant also undertook a review of the flood models. This review raised similar queries to BMT's review and suggested the same suite of sensitivity tests. The work document in Appendix I to address BMT's review comments therefore also address queries and suggestions raised by Council's flood consultant. Details of the consultation with Council are provided in Section 6.

### 4.6.3 Uncertainty in flow estimates and associated risk

The uncertainty in flow estimation for the subject catchments is discussed in detail in the BMT report (see Appendix I). It is not possible to resolve this uncertainty due to the lack of streamflow gauging data, however, extensive consultation with landowners on the flood model predictions of the existing conditions flood behaviour found that the model predictions correlated well with landowner observations of flooding patterns on their properties in the last 10 to 20 years.

Condition E32 (refer to Table 1.2 in Section 1.8) sets out a comprehensive flood review process for the first 15 years of operation of the project which requires ARTC to investigate all significant flood events and compare observations of flood behaviour during the events to the flood model predictions for the design case presented in this report. Where unforeseen flooding or erosion impacts are observed on neighbouring properties, and where the cause is attributable to N2NS, ARTC is required to implement rectification measures in consultation with the affected landowner to address these impacts. This process is also required to be documented and reported to the relevant state and local government agencies. This condition ensures that the risk associated with uncertainty in flow estimation and flood model predictions can be managed through further flood investigations following construction of the project.

# 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<br>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<br>575 to 592.5km | 16.73km, 96.7% | 0.53km, 3.1% | - | 0.04km, 0.2% | - | - |
| GWYDIR01<br>592.5 to 619km | 25.67km, 96.8% | 0.51km, 1.9% | 0.28km, 1% | 0.06km, 0.2% | - | - |
| GWYDIR02<br>619 to 666km | 37.34km, 81.3% | 4.78km, 10.4% | 3.1km, 6.8% | 0.52km, 1.1% | 0.37km, 0.8% | - |
| GWYDIR03<br>682 to 709km | 25.02km, 98.2% | 0.35km, 1.4% | 0.12km, 0.5% | - | - | - |
| MACINTYRE01<br>709 to 727km | 17.96km, 98.2% | 0.24km, 1.3% | 0.06km, 0.3% | 0.04km, 0.2% | - | - |
| MACINTYRE02<br>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<br>575 to 592.5km | Low risk: 0.25 km (1.5%)<br>Medium risk: None<br>High risk: None | None | None |
| GWYDIR01<br>592.5 to 619km | Low risk: 0.5 km (1.9%)<br>Medium risk: 0.15 km (0.6%)<br>High risk: None | 607.650 to 607.750 km | None |
| GWYDIR02<br>619 to 666km | Low risk: 8.8 km (18.7%)<br>Medium risk: 0.25 km (0.5 %)<br>High risk: None | 648.300 km<br>650.100 km<br>650.700 km<br>653.100 km<br>653.400 km | None |
| GWYDIR03<br>682 to 709km | Low risk: 0.3 km (1.1%)<br>Medium risk: None<br>High risk: None | None | None |
| MACINTYRE01<br>709 to 727km | Low risk: 0.35 km (1.9%)<br>Medium risk: None<br>High risk: None | None | None |
| MACINTYRE02 | Low risk: 0.1 km (0.3%)<br>Medium risk: None<br>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<br>4 | 3500x1500 RCBC<br>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<br>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

#### 5.3.2.1 Compliance status

The QDLs are provided in Table 3.1. The design of the N2NS Phase 1 vertical alignment and cross drainage has sought to remove the damaging rail overtopping mechanism in large flood events and replace it with controlled flow through the rail corridor using new and upgraded cross drainage structures. This alters the flood behaviour local to the rail corridor to some extent and the design has sought to address this alteration of the flood behaviour by balancing impacts upstream and downstream of the corridor and from low to high flood events. The balancing of impacts is a complex process outlined in Section 4.4.1 and the resulting impacts are the outcome of numerous iterations of the flood model to achieve the best balance of impact based on the adjacent land use and the most critical flood parameters for those land uses.

For example, where the Newell Highway is located just upstream of the rail corridor, the design has sought to avoid or minimise impacts on the highway as far as possible for all events up to and including the 1% AEP event to protect the critical infrastructure functions of the highway. This approach typically results in higher impacts on the less sensitive agricultural or undeveloped land downstream in events less than the 1% AEP as a result of the new and upgraded cross drainage passing flow downstream more efficiently. In other locations where residential development is located downstream of the rail corridor, the new drainage infrastructure has been strategically sized to meet the low afflux QDL for residences downstream while meeting the higher afflux QDL for agricultural or undeveloped land upstream.

This impact balancing process results in QDL exceedances that are the result of numerous attempts to remove or reduce exceedances as far as practical. It has therefore not been possible to achieve the QDLs in all areas nor remove the remaining QDL exceedances through design changes or further iterations of the design.

#### 5.3.2.2 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<br>584.7km<br>588.8km | 582.5km<br>584.7km<br>584.8km<br>585.0km<br>588.5km<br>588.8km | 579.5km<br>580.0km<br>584.7km<br>584.8km<br>585.1km<br>585.8km |
| GWYDIR01 | 607.87km | 607.87km | None |

| Model | 39% AEP Event Non-Compliant Impacts | 10% AEP Event Non-Compliant Impacts | 1% AEP Event Non Compliant Impacts |
|---|---|---|---|
| GWYDIR02 | 649.5km<br>650.0km<br>653.15km<br>658.5km | None | None |
| GWYDIR03 | 709.5km | None | None |
| MACINTYRE01 | 716.75km<br>719.15km | 711.4 to 711.5km<br>712.61km<br>716.75km<br>720.3 to 720.8km<br>722.8 to 723km | 716.7km<br>716.55 to 716.75km |
| MACINTYRE02 | 740.96km | None | 733.94km<br>741.5km<br>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. Floor level survey data was not available for these buildings and the afflux impacts relate to increases in flood levels based on ground levels around the buildings defined from the LiDAR data. Consultation with the building owners at the properties determined that the buildings are elevated above the surrounding ground level either on local mounds under the buildings or due to the building foundations. On the basis of these observations it was concluded that the afflux impacts do not cause additional above floor level flooding and the impacts were accepted by the landowners.

#### 5.3.2.3 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. These impacts are a result of the impact balancing process discussed in Section 5.3.2.1. A number of case studies are described in the following section which explain the reasons for these impacts and the risk for ongoing scour and erosion of the land associated with these flow velocity changes.

#### 5.3.2.4 Scour and erosion impacts

##### Scour protection and velocity dissipation

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. Appendix G provides the full list of culverts and associated hydraulic parameters which shows that rock aprons extending beyond the rail corridor are required at 45 locations. At these locations the length of rock apron extending beyond the rail corridor varies from 0.7 to 14.3 metres, with an average extension beyond the corridor of 5.0 metres.

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. Appendix G shows the 1% AEP velocities in the culvert barrels (Column 9) and the velocities at the end of the scour aprons that extend beyond the rail corridor boundary (Column 13). These velocity values demonstrate the effectiveness of the rock aprons in reducing the flow velocities before the flow enters the adjacent land beyond the rail corridor. The average and maximum culvert barrel velocities are 2.28 m/s and 4.97 m/s respectively, which are reduced to average and maximum end of apron velocities of 1.02 m/s and 2.07 m/s respectively.

Appendix G also provides the 1% AEP velocity under existing conditions at the downstream extents of the proposed scour protection measures. For 30 out of the 45 locations the existing conditions velocities are higher than the design case velocities, which demonstrates that the scour protection will result in lower velocities in the adjacent land at these locations. For the other 15 locations the existing conditions velocities are lower than the design case velocities but existing conditions velocities exceeded the QDL threshold of 0.5m/s in all but 3 locations. These 3 locations at 627.43km, 642.38km and 746.60km therefore have most potential to experience erosion in the adjacent land just beyond the scour protection, however the nature of the affected areas is such that these erosion risks are low or unlikely, as described below:

- 627.43km: Impact occurs within the vegetated watercourse of Waterloo Creek. Design case velocity at end of scour protection is 0.72m/s which should not cause erosion within the vegetated watercourse.
- 642.38km: Impact occurs within a vegetated watercourse that is a tributary of Gurley Creek. Design case velocity at end of scour protection is 0.41m/s which should not cause erosion within the vegetated watercourse.
- 746.60km: Impact occurs within a heavily vegetated unnamed watercourse. Design case velocity at end of scour protection is 0.72m/s which should not cause erosion within the vegetated watercourse.

### Potential for scour and erosion impacts beyond the protection measures

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 5.3.2.3 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.

Four areas where the QDL for velocity has been exceeded over significant distances downstream of the rail corridor were selected for further assessment. The four areas are described below along with the reasons that the design resulted in the velocity QDL exceedances at these locations (refer also to Sections 4.4.1 and 5.3.2.1 for further discussion on the design approach and QDL exceedances):

- 579.50 to 580.00km: The Newell Highway is immediately upstream of the rail corridor at this location and the velocity QDL exceedances occur on the agricultural land downstream of the rail corridor where other QDL exceedances for afflux also occur. The design has sought to minimise impacts on the Newell Highway due to its status as critical infrastructure. The sizing of new and upgraded rail cross drainage has ensured no impacts on the highway up to and including the 1% AEP event, with the result of minor reductions in flood levels on the highway and minor increases in flood levels in the agricultural land. The increases in flood levels in the agricultural land are accompanied with increases in flood velocity which exceed the QDL. Providing more cross drainage structures at this location would reduce the velocity impacts but would increase afflux and duration impacts on the agricultural land. The velocity impacts occur on reasonably well vegetated land that is used intermittently / opportunistically for cropping rather than high yield cropping land.
- 585.00km: The Newell Highway is immediately upstream of the rail corridor at this location and the velocity QDL exceedances occur on the agricultural land downstream of the rail corridor where other QDL exceedances for afflux also occur. The design has sought to minimise impacts on the Newell Highway due to its status as critical infrastructure. The sizing of new and upgraded rail cross drainage has ensured no impacts on the highway up to and including the 1% AEP event, with the result of minor reductions in flood levels on the highway and minor increases in flood levels in the agricultural land. The increases in flood levels in the agricultural land are accompanied with increases in flood velocity which exceed the QDL. Providing more cross drainage structures at this location would reduce the velocity impacts but would increase afflux and duration impacts on the agricultural land. The velocity impacts occur on high yield cropping land but mitigation measures have been designed in consultation with the landowner to control the flows through the rail culverts within a diversion channel to direct flows south to the nearest waterway. The net effect is a benefit to the agricultural lot as the area of cropping land that will no longer flood as a result of the mitigation measures exceeds the area of cropping land that will experience afflux and velocity QDL exceedances. The benefit is demonstrated in the figures below which show that there is less land flooded and lower velocities in the cropping part of the paddock in the lot to the west of the rail corridor for the design case. More flooding and higher velocities occur within the waterway in the southern boundary of the lot where there is established vegetation and minimal cropping land. The elevated velocities along the western boundary of the rail corridor will be addressed through scour protection incorporated into the design of the mitigation measures. The mitigation measures and outcomes of the design were agreed in close consultation with the landowner who preferred to direct as much flow as possible away from the cropping land and towards the main waterway along the southern boundary of the property.

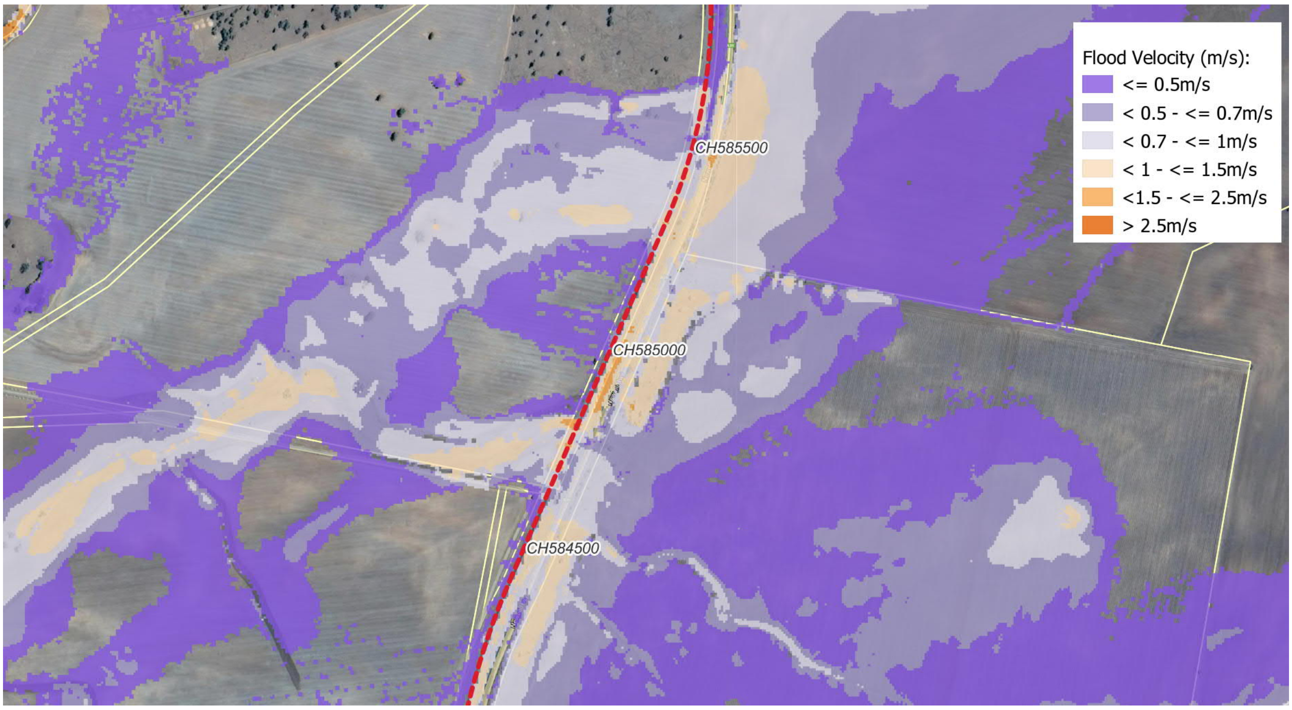



Figure 5.1 Existing conditions flow velocities in 1% AEP event at 585.00km

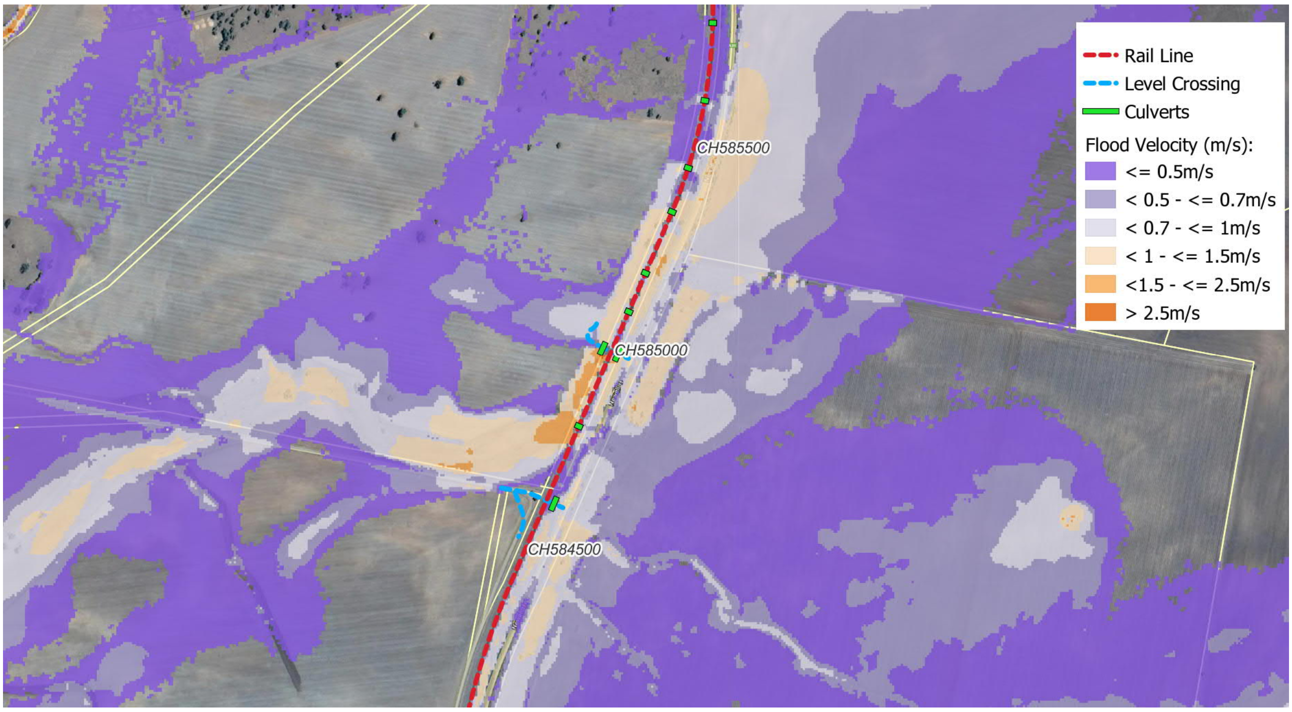



Figure 5.2 Design case flow velocities in 1% AEP event at 585.00km

- 721.00km: Crooble Road is located approximately 200m upstream of the rail corridor and a level crossing where Crooble Road crosses the rail corridor is located approximately 100m north at this location and the velocity QDL exceedances occur on the agricultural land downstream of the rail corridor where other QDL exceedances for afflux also occur. The design has sought to minimise impacts on Crooble Road and the level crossing as it is a critical access road for numerous properties. The sizing of new and upgraded rail cross drainage has ensured no impacts on the road up to and including the 1% AEP event, with the result of minor increases in flood levels in the agricultural land adjacent to the road. The velocity impacts mainly occur within the local vegetated unnamed watercourse with some impacts extending to high yield cropping land. However, the design produces a net benefit to the agricultural lot downstream with the area of the lot that will experience less flooding far exceeding the area of the lot that will experience velocity impacts.

- 730.00km: The Croppa Moree Road crosses the rail corridor via a level crossing at this location with a property access road connecting to Croppa Moree Road approximately 100m upstream of the rail corridor. The velocity QDL exceedances occur on the agricultural land downstream of the rail corridor where other QDL exceedances for afflux also occur. The design has sought to minimise impacts on the Croppa Moree Road and the property access road. The sizing of new and upgraded rail cross drainage has ensured no impacts on the road up to and including the 1% AEP event, with the result of minor increases in flood levels in the road reserve and the agricultural land downstream. The velocity impacts occur within the local vegetated unnamed watercourse with impacts extending to high yield cropping land adjacent to the watercourse. However, the design produces a neutral impact on the agricultural land with similar areas of land receiving increased and reduced flood risk.

Table 5.14 presents the velocities at the four areas for the existing conditions and the design case based on 16 point locations sampled within the flood model domain at each area.

Table 5.14 Velocity results at selected areas where velocity QDL is exceeded

| Location (Rail Chainage) | 39% AEP event velocity ranges | 10% AEP event velocity ranges | 1% AEP event velocity ranges | Comment |
|---|---|---|---|---|
| 579.5 to 580.0km | Existing: 0.41 to 0.92 m/s<br>Design: 0.52 to 0.97 m/s | Existing: 0.52 to 0.98 m/s<br>Design: 0.67 to 1.04 m/s | Existing: 0.30 to 1.22 m/s<br>Design: 0.43 to 1.43 m/s | Presence of vegetation on the existing surfaces should prevent erosion across the majority of the affected area. |
| 585.0km | Existing: 0.20 to 0.84 m/s<br>Design: 0.41 to 1.00 m/s | Existing: 0.36 to 0.92 m/s<br>Design: 0.36 to 1.23 m/s | Existing: 0.27 to 0.95 m/s<br>Design: 0.53 to 1.32 m/s | Risk of bare soil erosion on cropping land. Risk significantly reduced if flooding occurs when established crops are present. |
| 721.0km | Existing: not flooded<br>Design: not flooded | Existing: 0.00 to 0.31 m/s<br>Design: 0.26 to 0.41 m/s | Existing: 0.28 to 0.62 m/s<br>Design: 0.52 to 0.78 m/s | Velocities remain relatively low <1m/s throughout the affected area. Erosion risk is therefore low. |
| 730.0km | Existing: 0.27 to 0.41 m/s<br>Design: 0.23 to 0.45 m/s | Existing: 0.14 to 0.47 m/s<br>Design: 0.26 to 0.56 m/s | Existing: 0.32 to 0.64 m/s<br>Design: 0.42 to 0.81 m/s | Velocities remain relatively low <1m/s throughout the affected area. Erosion risk is therefore low. |

While velocity impacts indicate the potential for increased erosion of the land, the mechanism for increasing erosion is the increased shear stress on the ground surface. The velocity and depth results for the existing conditions and design case have been used to estimate changes in shear stress at the four areas of detailed assessment. The calculated shear stresses are compared against the critical shear stress relationships shown in Figure 5.3 which shows critical shear stress versus particle grain size from Briaud et al, 2009. Soils in the vicinity of N2NS Phase 1 are typically sandy. Referring to the sand region of the chart in Figure 5.3, it can be seen that the critical shear stress for sandy soils varies between approximately 0.1 and 1.0 $N/m^2$, and therefore most significant erosion potential would occur if shear stresses are increased from below 0.1 to 1.0 $N/m^2$ in the existing conditions to above 0.1 to 1.0 $N/m^2$ in the design case.

Figure 5.3 Critical shear stress versus particle grain size (Briaud et al. 2009)

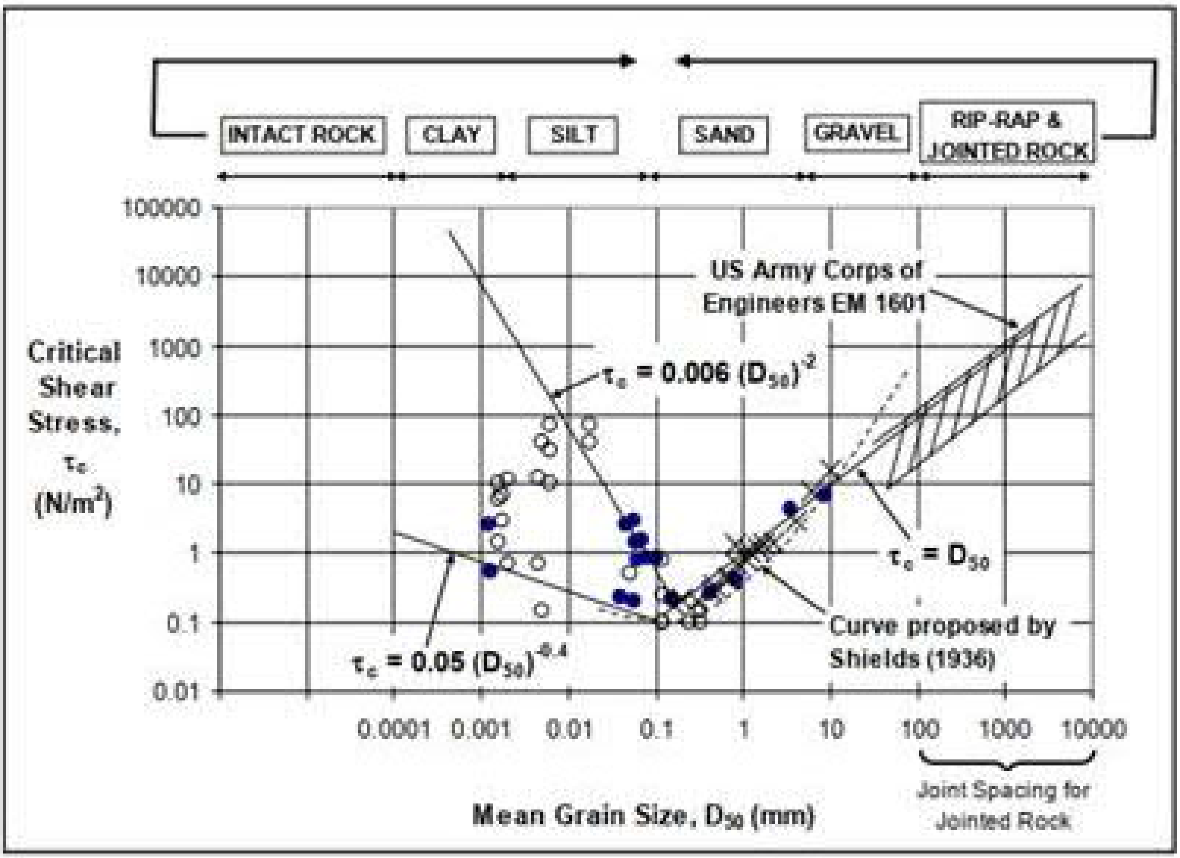



Table 5.15 presents the results of shear stress calculations at the four areas. The ranges of shear stress values were based on the 16 sampling locations used to inspect the velocity impacts in Table 5.14 above. The results show that the shear stresses stay within the same broad range of 1 to 50 N/m2 at all locations which fall within a region of the shear stress chart in Figure 5.3 that is above the critical threshold for sandy soils. The results indicate that shear stress changes in these areas should not produce significant changes in the erosion potential during flood events.

Table 5.15 Shear stress calculation results at selected areas where velocity QDL is exceeded

| Location (Rail Chainage) | 39% AEP event shear stress ranges | 10% AEP event shear stress ranges | 1% AEP event shear stress ranges | Comment |
|---|---|---|---|---|
| 579.5 to 580.0km | Existing: 7.6 to 22.6 N/m$^2$<br>Design: 14.0 to 27.4 N/m$^2$ | Existing: 12.6 to 25.1 N/m$^2$<br>Design: 18.0 to 33.8 N/m$^2$ | Existing: 20.4 to 35.8 N/m$^2$<br>Design: 31.1 to 48.2 N/m$^2$ | Existing shear stresses already well above the critical threshold for sandy soils, increases in design case do not significantly increase erosion potential |
| 585.0km | Existing: 3.1 to 25.4 N/m$^2$<br>Design: 9.7 to 31.4 N/m$^2$ | Existing: 7.7 to 31.0 N/m$^2$<br>Design: 17.2 to 41.3 N/m$^2$ | Existing: 4.1 to 35.7 N/m$^2$<br>Design: 8.2 to 44.7 N/m$^2$ | Existing shear stresses already well above the critical threshold for sandy soils, increases in design case do not significantly increase erosion potential |
| 721.0km | Existing: not flooded<br>Design: not flooded | Existing: 0.0 to 30.5 N/m$^2$<br>Design: 0.0 to 11.3 N/m$^2$ | Existing: 1.6 to 71.5 N/m$^2$<br>Design: 9.4 to 71.9 N/m$^2$ | Existing shear stresses already well above the critical threshold for sandy soils, increases in design case do not significantly increase erosion potential |

| Location (Rail Chainage) | 39% AEP event shear stress ranges | 10% AEP event shear stress ranges | 1% AEP event shear stress ranges | Comment |
|---|---|---|---|---|
| 730.0km | Existing: 6.7 to 24.2 $N/m^2$<br>Design: 3.7 to 27.8 $N/m^2$ | Existing: 2.0 to 31.1 $N/m^2$<br>Design: 3.4 to 33.9 $N/m^2$ | Existing: 5.5 to 36.0 $N/m^2$<br>Design: 8.2 to 41.2 $N/m^2$ | Existing shear stresses already well above the critical threshold for sandy soils, increases in design case do not significantly increase erosion potential |

While the velocity and erosion impacts presented above are considered to be minor, it is accepted that there may be a residual risk of future erosion issues as a result of these impacts. The impacts have been explained to and accepted by the affected landowners (refer to Section 6 on consultation) and should erosion impacts be identified by landowners following construction of the project, these would be considered pursuant to the requirements of Condition of Approval E32.

#### 5.3.2.5 Impacts on flow paths, flow distributions, geomorphology and stream/bank stability

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, including geomorphic characteristics such as stream stability and bank stability, and floodplain flow paths around the project.

A key area of concern with regard to potential changes in the distribution of floodplain flow is the area from Moree to 5km south of Tycannah Creek where any changes in flow distribution may affect the harvesting of floodwaters in the irrigation areas downstream. There are three watercourses in this area which combined in large floods: Halls Creek, Clarks Creek and Tycannah Creek. These watercourses are covered by the GWYDIR02 hydraulic model which extends approximately 10km upstream of the rail to ensure that the model captures a key breakout from Tycannah Creek that transfers flow towards Clarks Creek and Halls Creek to the north. The figure below shows the extent of the GWYDIR02 hydraulic model in this area and the location of the key breakout from Tycannah Creek.

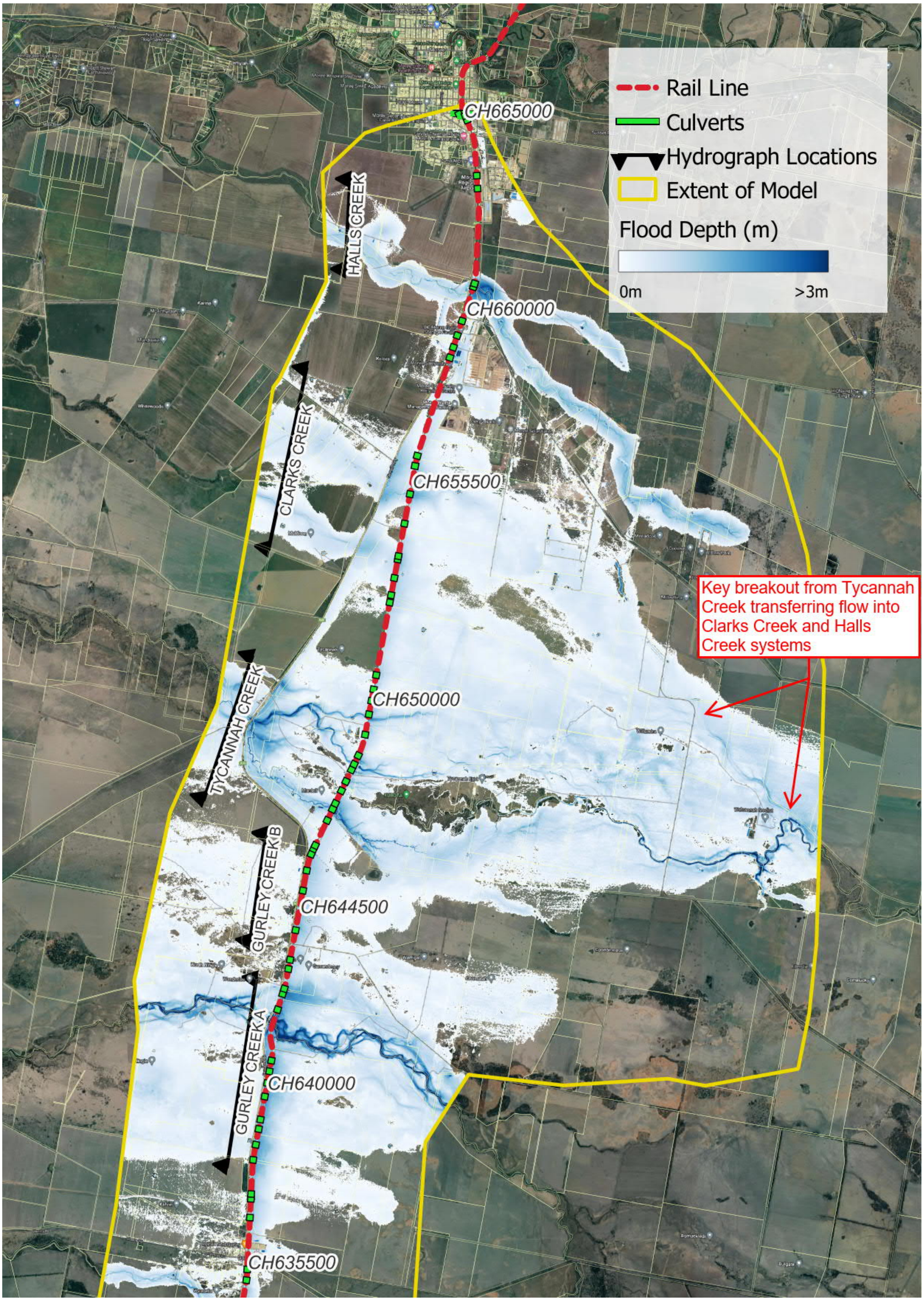



Figure 5.4 1% AEP flood depth and extent in Tycannah Creek system and location of key breakout

Hydrographs were analysed at the 5 locations shown in Figure 5.4 to check for potential impacts on flow distribution within the sub-catchments downstream as a result of localised changes in flow distribution at the rail corridor that are seen in the afflux results. The figures below show the outflows from these systems (including total flow within watercourses and floodplains) downstream of the rail corridor for the 1% AEP event under existing conditions and the design case. For this and all other events the model results show minimal changes in the flood hydrographs and overall flow volume. The results show that the project will not affect the flow distribution in this critical area.

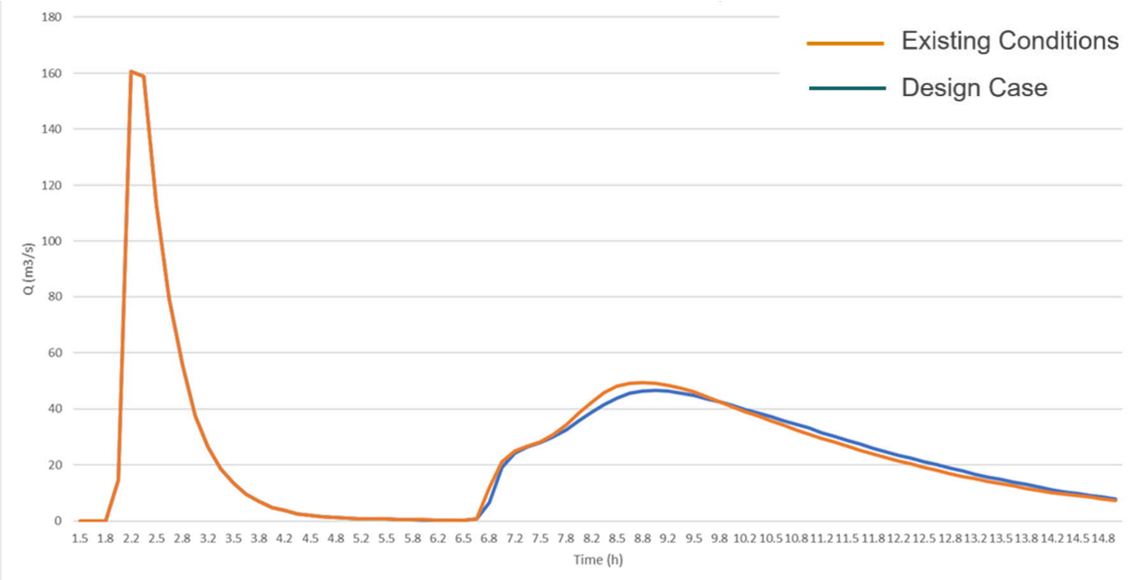



Figure 5.5 1% AEP flows in Halls Creek system downstream of rail corridor for existing conditions and design case

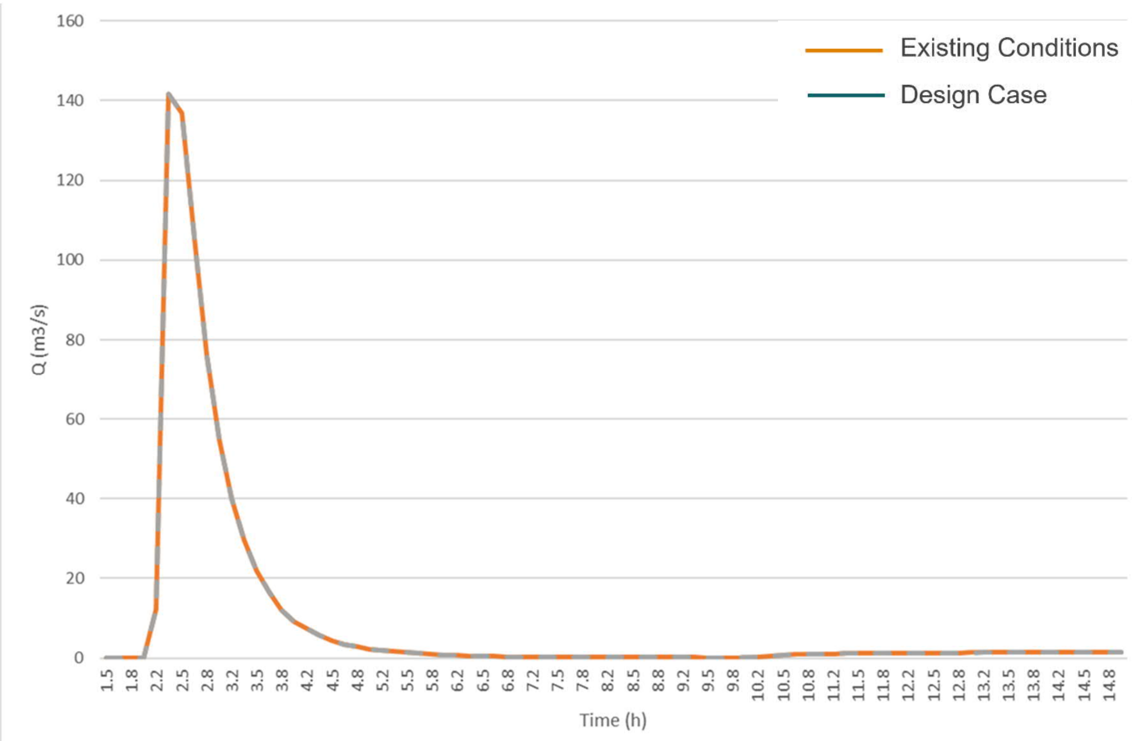



Figure 5.6 1% AEP flows in Clarks Creek system downstream of rail corridor for existing conditions and design case

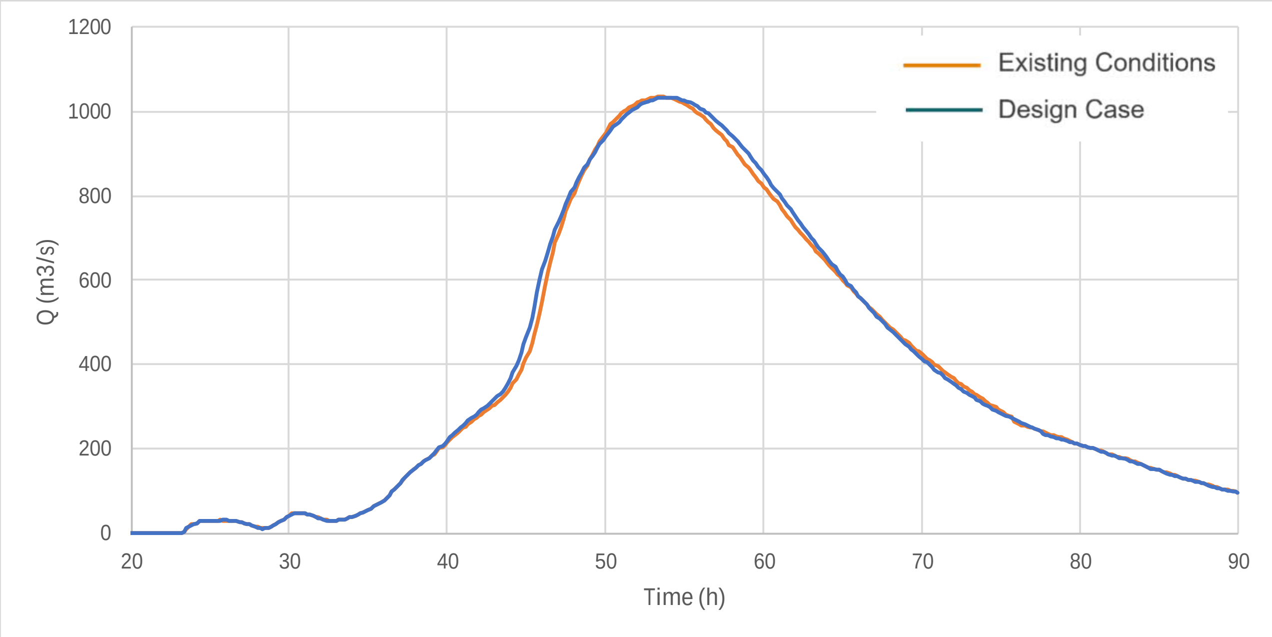



Figure 5.7 1% AEP flows in Tycannah Creek system downstream of rail corridor for existing conditions and design case

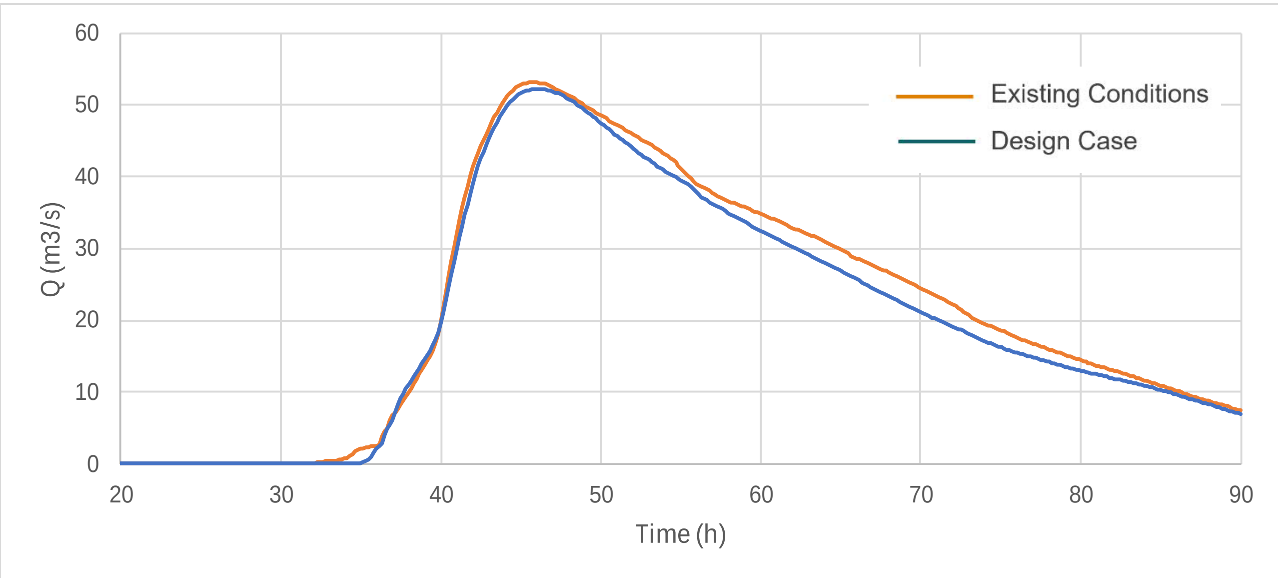



Figure 5.8 1% AEP flows in Gurley Creek B system downstream of rail corridor for existing conditions and design case

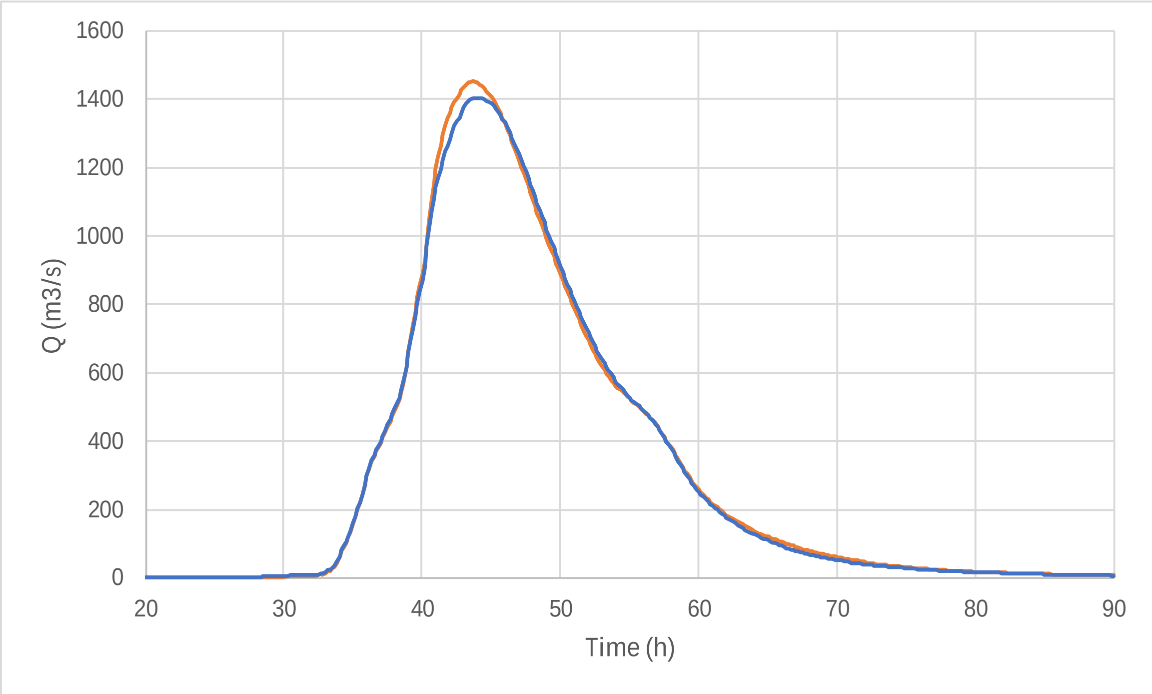



Figure 5.9 1% AEP flows in Gurley Creek A system downstream of rail corridor for existing conditions and design case

### 5.3.2.6 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 5.16 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<br>582.5km<br>584.5km<br>590 to 590.5km | 581.0 to 582.5km<br>584.6km<br>588.5km<br>590.0km<br>591.8km (minor area) | 581.0 to 582.5km<br>584.0km<br>584.6 to 585.0km<br>585.5km<br>587.5 to 588.0km<br>588.5 to 589.0km<br>590.0km<br>591.8km (minor area) |
| GWYDIR01 | 593.8km<br>614.5km (minor area) | 593.8km<br>614.65km (minor area) | 593.8km<br>600.8km (minor area)<br>607.8km<br>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<br>642.3km<br>643.5 to 644.5km<br>658.5 to 660.5km | 627.0 to 627.8km<br>633.5 to 634km<br>634.5km<br>641.5km<br>642.3km (minor area)<br>643.5 to 644.5km<br>645.8km<br>647.0km<br>653.4km<br>656.0km<br>658.5 to 660.5km | 627.0 to 628.0km<br>632.5km (minor area)<br>633.5 to 634.0km<br>634.5km<br>635.0km<br>638.0km<br>639.0km<br>641.5km<br>642.3km (minor area)<br>643.5 to 644.5km<br>645.8km<br>646.5 to 647.5km<br>648.5 to 650.0km<br>653.0 to 654.0km<br>656.0km<br>657.0 to 660.0km |
| GWYDIR03 | 708.5km | 708.5km | 690.5km<br>708.5km |
| MACINTYRE01 | 711.5km<br>716.5km<br>723.5km (minor area) | 711.5km<br>714.5km<br>716.5km<br>720.5km<br>723.5km (minor area) | 711.5km<br>714.5km<br>716.5km<br>720.5km<br>723.0km (minor area)<br>723.5km (minor area) |
| MACINTYRE02 | 737.5km (minor area)<br>752.5km<br>755.0km | 730.0km<br>730.5km<br>733.0km<br>737.5km<br>741.0km<br>744.5km<br>751.0km<br>752.5km<br>755.0km | 730.0km<br>730.5km<br>733.0km<br>737.5km<br>741.0km<br>744.5km (minor area)<br>751.0km<br>752.5km (minor area)<br>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 Figures 5.10 and 5.11.

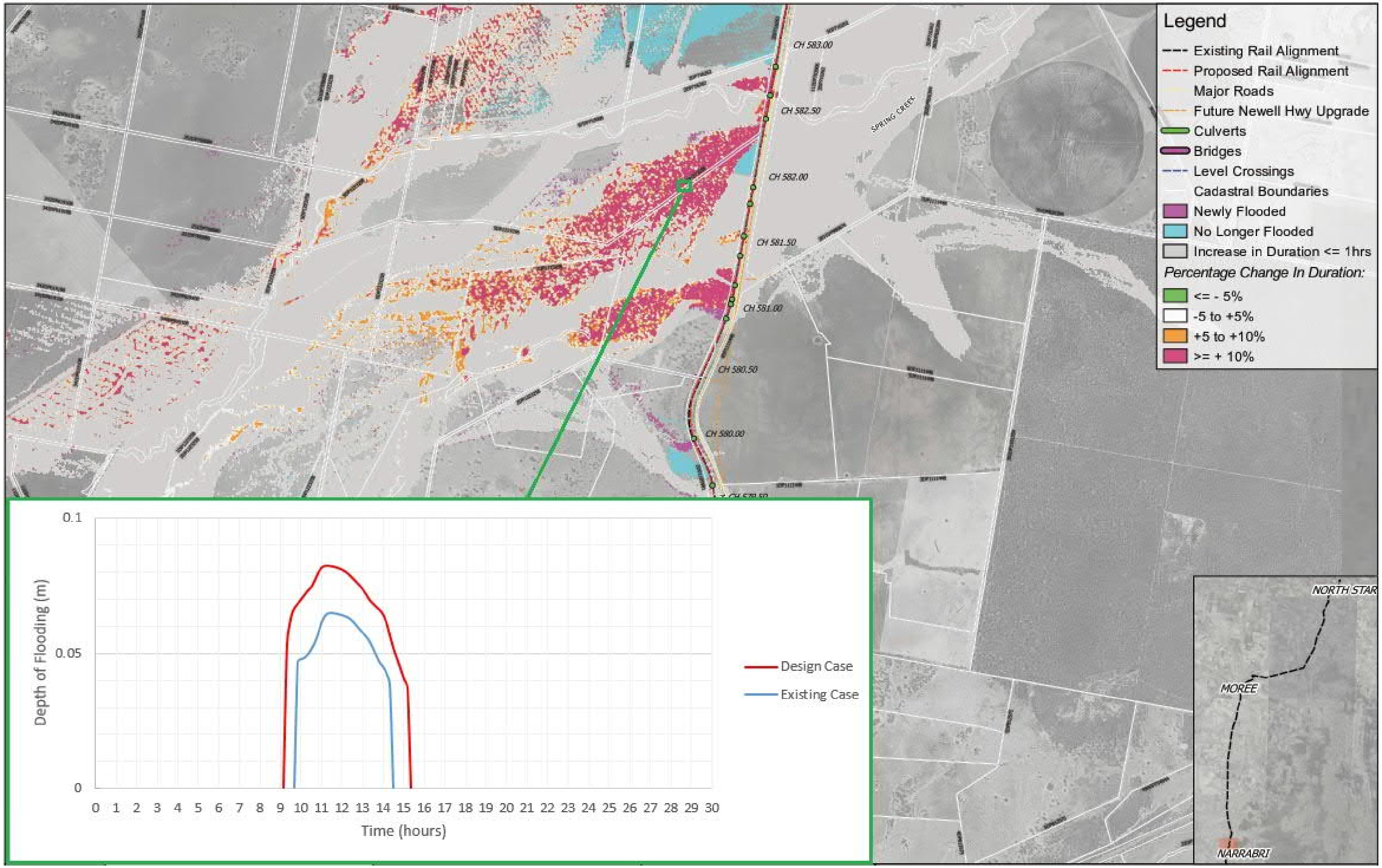



Figure 5.10 Example of 1% AEP duration impact mapping with extracted hydrograph at 582km

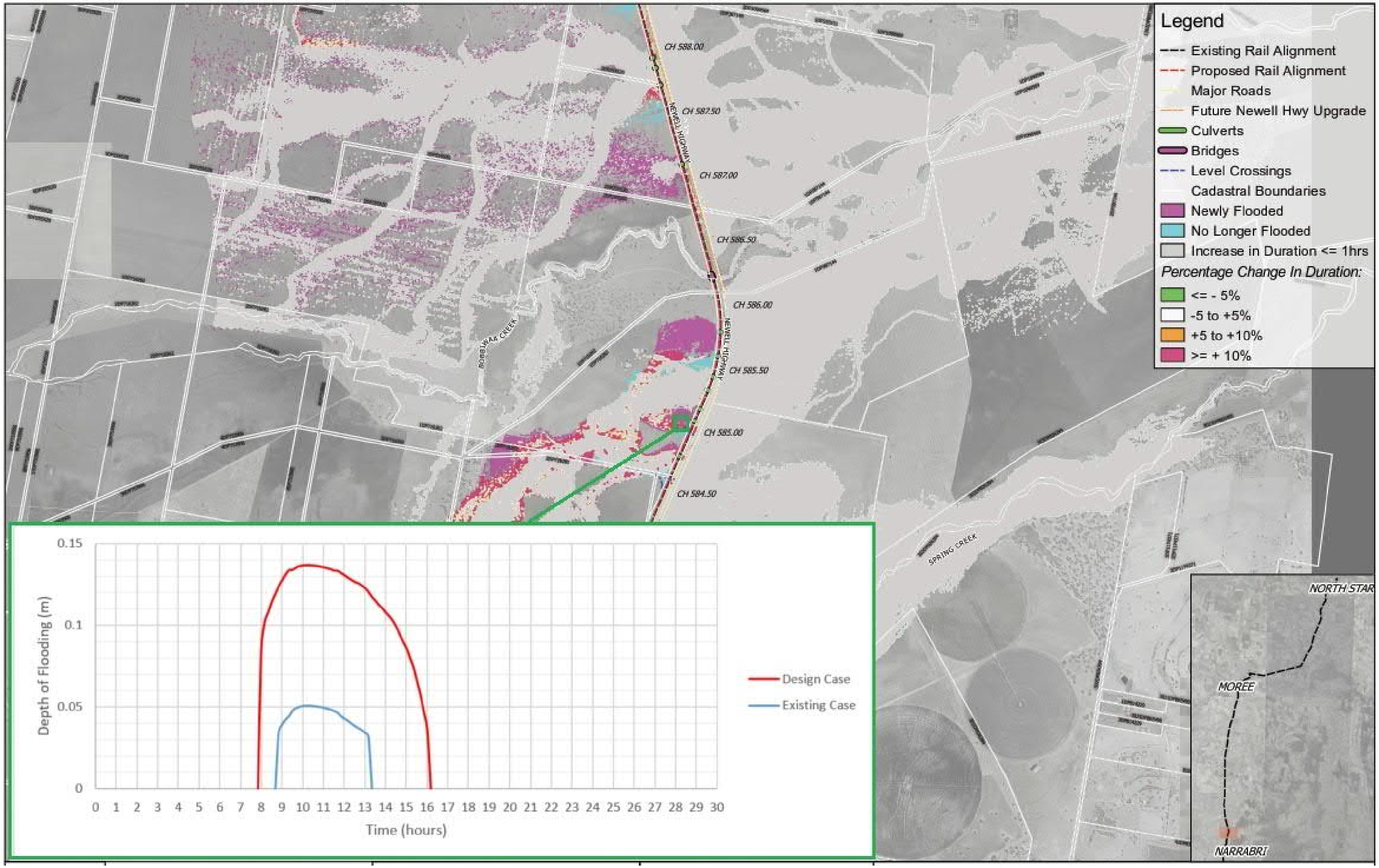



Figure 5.11 Example of 1% AEP duration impact mapping with extracted hydrograph at 585km

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.

#### 5.3.2.7 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 full details of the impact assessment are provided in Appendix J. The key findings of the impact assessment are presented below.

The QDLs set limits for changes to flood level, velocity, duration and hazard on highways and sealed roads and are as follows:

- Flood level change (or afflux): No increase in depth where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase.
- Flood velocity change: 20% increase in velocity where existing velocity already exceeds 1m/s.
- Flood duration change: 10% increase in inundation duration.
- Flood hazard change: 10% increase in velocity x depth where H1 or H2 hazard category. 0% increase in velocity x depth where H3 or greater hazard category.

The QDLs also include a requirement to avoid increasing aquaplaning risk. As aquaplaning is a function of road geometry and can occur for pavement flood depths as low as 5mm, such an assessment would require high resolution survey beyond the resolution of the flood model. In lieu of aquaplaning risk, the impact assessment has focussed on the QDLs for afflux, velocity, hazard and duration, as well as extents of highway pavement that are prone to flooding, noting that the QDLs allow for up to 50mm afflux on the Newell Highway.

As velocity impacts alone do not indicate changes in hazardous conditions on the highway, this assessment has focussed on changes in the hazard value (defined as velocity x depth) and associated hazard categories.

It is considered that the intent of the QDLs for roads and highways is to ensure that the project does not adversely affect the operability of the road network by increasing flood depths, duration and hazard on the pavement and travel lanes. The assessment therefore focussed on the potential impacts on the operability of the highway and changes to flood risk parameters outside of the travel lanes are not considered to be significant issues. For transparency, the full list of impacts and QDL exceedances on or adjacent to the highway are reported in the detailed assessment in Appendix J.

The changed conditions on the highway were assessed by comparing modelled flood risk parameters for the existing conditions to the design case.

## 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 Phase 1 of the N2NS project. Table 5.17 below provides a summary of impacts at the sampled locations.

Table 5.17 Overview of flooding impacts along the existing Newell Highway

| Impact 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 |
| QDL exceedances: points with flood level increase > 50mm | 5 | 11 | 0 | 9 |
| QDL exceedances: points with flow velocity increase > 20% | 70 | 91 | 101 | 128 |
| QDL exceedances: points with duration of flooding increase > 10% | 8 | 15 | 42 | 115 |
| QDL exceedances: points with flood hazard (V*D) increase > 10% for H1 and H2 categories | 38 | 49 | 51 | 111 |
| QDL exceedances: points with flood hazard (V*D) increase > 0% for H3 category and above | 15 | 25 | 25 | 53 |

The assessment found that N2NS Phase 1 has an overall positive impact on the highway by reducing the extent of flood risk and hazard along the entire length of the highway between Narrabri and Moree. This is demonstrated by the net decrease in the number of flooded locations 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.

However, a number of exceedances of the QDLs occur within this section also. The exceedances 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. The majority of the exceedances noted in the bottom four rows of Table 5.17 occur adjacent to the highway on or near the highway verges or in the low-lying areas between the highway and rail embankments rather than on the highway pavement or travel lanes. Figure 5.12 below demonstrates a typical exceedance result for flood duration, where the extended flooding time occurs well below the highway pavement level within the cess/table drains between the rail and highway embankments.

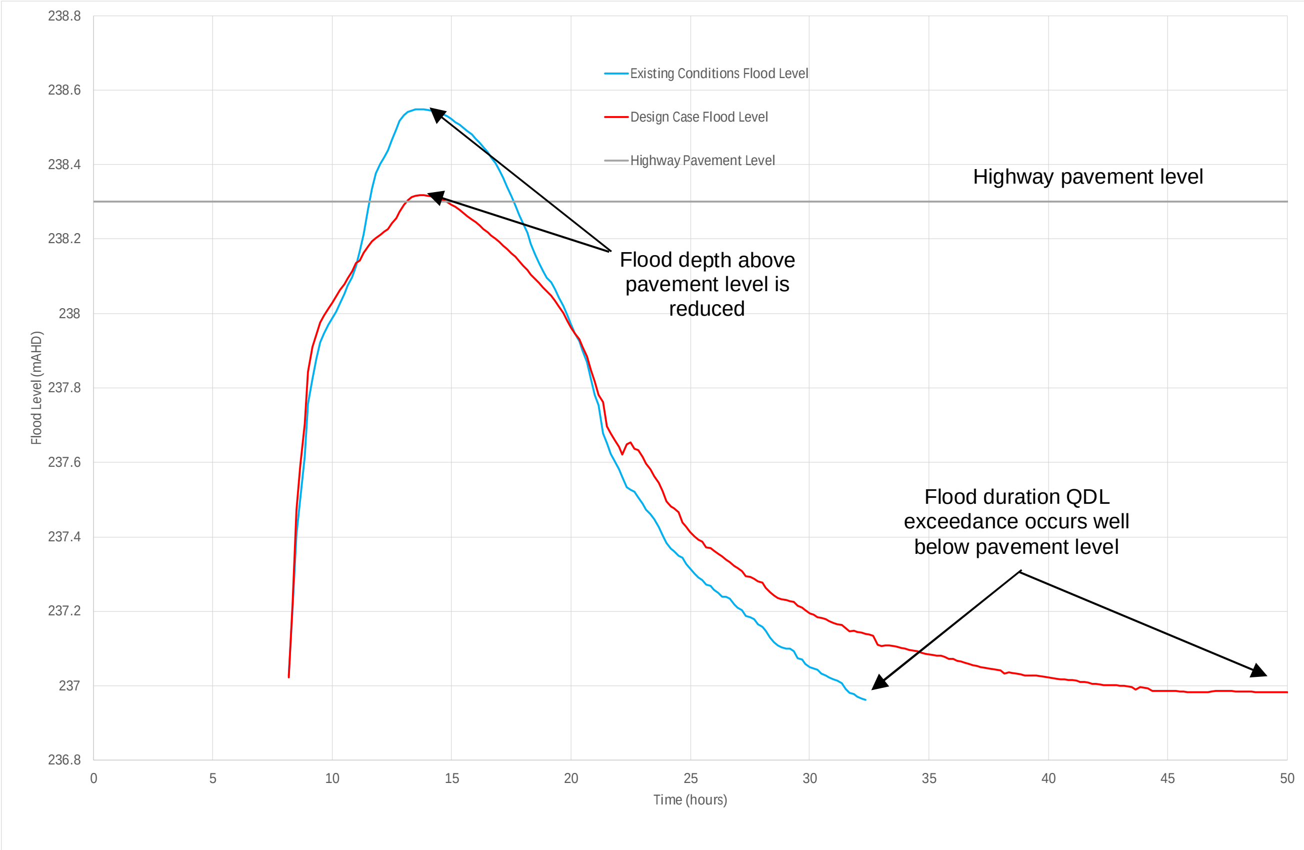



Figure 5.12 Typical example of flood duration QDL exceedance on Newell Highway

The QDL exceedances for each flood risk parameter are discussed below. As noted previously, the assessment focussed on the potential impacts on the operability of the highway and changes to flood risk parameters outside of the travel lanes are not considered to be significant issues.

## Flood level impacts

- The number of exceedances for each flood event is as follows:
  - 10% AEP event: 5 exceedances
  - 5% AEP event: 11 exceedances
  - 2% AEP event: No exceedances
  - 1% AEP event: 9 exceedances
- The majority of the exceedances involve shallow flood depths (<110mm, or <60mm exceedance of the QDL) that will occur for relatively short periods of time (<7 hours).
- With the exception of one area, none of the exceedances are considered to affect the operability of the highway as they relate to shallow trafficable depths persisting for short durations.
- The only area of significant impact is a 100m section of the highway between highway chainages 28510 and 28610 where the highway is located downstream of the rail corridor. In this area the flood depths above the highway pavement level are increased by up to 309mm and flood durations above the pavement level are increased by up to 9 hours in the 5% AEP event.

## Flood velocity impacts

- A detailed assessment of velocity increases that exceed 20% with the design case velocity also exceeding 1m/s was undertaken which concluded that the number of exceedances for each flood event is as follows:
  - 10% AEP event: 10 exceedances
  - 5% AEP event: 11 exceedances
  - 2% AEP event: 7 exceedances
  - 1% AEP event: 6 exceedances
- Assessment of the velocity changes against likely erosive thresholds of the road verges, embankments and pavement concluded that there is increased risk of erosion of the highway infrastructure for all events up to and including the 1% AEP event (refer to memo 3-0001-260-IHY-00-ME-0014 in Appendix J).

## Flood duration impacts

- The number of exceedances for each flood event is as follows:
  - 10% AEP event: 6 low risk exceedances, 2 high risk exceedances
  - 5% AEP event: 12 low risk exceedances, 3 high risk exceedances
  - 2% AEP event: 35 low risk exceedances, 7 high risk exceedances
  - 1% AEP event: 109 low risk exceedances, 6 high risk exceedances
- Most of the flood duration increases occur at a low level between the rail and highway embankments rather than on the highway pavement.
- Most of the exceedances involve positive impacts for highway operability as the depths and durations of flooding above the pavement are reduced.
- Only 5 exceedances result in an increase in flood depth and duration above the pavement. In all cases the exceedances involved very shallow depths of flooding <50mm persisting for relatively short durations of less than 7 hours.
- None of the flood duration exceedances are therefore considered to affect the highway operability.

## Flood hazard impacts

- The total number of exceedances is as follows:
  - 10% AEP event: 35 low risk exceedances, 18 high risk exceedances
  - 5% AEP event: 47 low risk exceedances, 27 high risk exceedances
  - 2% AEP event: 43 low risk exceedances, 33 high risk exceedances
  - 1% AEP event: 92 low risk exceedances, 72 high risk exceedances
- The majority of the exceedances do not result in a change in the hazard category and are marginal exceedances of the QDL.
- Two locations were identified where the hazard category is increased from H1/H2 to H5 and from H3 to H4. Investigation of these locations found that these are minor increases in hazard value around transitional areas of the hazard curve and do not result in significant changes in hazard on the highway pavement or travel lanes.
- There is 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 (noting that the highway would be closed in areas that experience category H3 hazard conditions)
  - net decrease in H4 category at 11 locations
  - net increase in H5 category at 1 location (noting that the highway would be closed in areas that experience category H5 hazard conditions); 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.

## Assessment outcomes

The risk assessment identified only 1 area along the highway where the N2NS Phase 1 project may have a significant impact on the highway operability and safety. The table below summarises these findings and provides recommendations for further investigation to mitigate these impacts.

Table 5.18 Outcomes of Newell Highway impact assessment

| Location (rail chainage | Flood risk impact | Context for impact | Recommendations |
|---|---|---|---|
| 638 to 638.5km | Increased depth of flooding above pavement level of up to 309mm and increased duration of flooding above pavement level of up to 9 hours in the 5% AEP event. Under existing conditions flood depths above the pavement level are in the order of 50mm which increase to 97 to 309mm over 100m of the highway as a result of the project. Both travel lanes are flooded over most of the 100m section in both the existing conditions and the design case. | In the affected area the highway is downstream of the rail corridor. The impact occurs downstream of an upgraded rail cross drainage structure which is a 15 x 2.4m wide x 0.9m high box culvert. There is a highway cross drainage structure immediately downstream of the rail culvert which is a 4 x 2.1m wide x 1.2 m high box culvert. In this area the design of the rail cross drainage has sought to achieve a balanced afflux impact upstream and downstream of the rail from low to high events. For the 1% AEP event significant afflux occurs upstream of the rail corridor within agricultural land, with afflux values exceeding the QDL limit of 300mm for the agricultural land. If less cross drainage is included in the rail corridor to protect the highway from the impact in the 5% AEP event then the afflux exceedances would be significantly worsened in the agricultural land upstream for the 1% AEP event. | Review with TfNSW and determine if mitigation measures are required. Investigate the following possible mitigation options if required:<br>1) Provide baffle weirs at inlets to rail culverts to reduce capacity and through flow to the highway in events up to the 5% AEP.<br>2) Raise road level over affected section to reduce flood level impact.<br>3) Modify road culvert to increase capacity and reduce flood depth on road.<br>Option 1 may increase the flooding and QDL exceedance on the agricultural land upstream of the rail corridor and Option 3 may increase flooding in agricultural land downstream of the highway. These consequences would need to be considered as part of the investigation of the mitigation options. |

## 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. An assessment of the impacts of the project, including potential areas where the rail embankment may fail and implications for downstream land uses and assets is provided in Appendix L. This section summarises the 0.05% AEP impacts of the project at key sensitive locations.

Condition E31 requires the simulation of the PMF to determine changes in flood behaviour that may cause risk to life and property. The 0.05% AEP even has been used as an extreme event in lieu of the PMF as the 0.05% AEP event was simulated to assess hydraulic loads on bridges in accordance with the Bridge Design Code. Figure 5.13 below compares the rainfall depths for the Probable Maximum Precipitation (PMP), which defines the PMF, the 0.05% AEP event and the 1% AEP event. The figure shows that the significantly exceeds the 0.05% AEP event which suggests that the rail embankment would be significantly overtopped / washed away under these conditions and unlikely to have a material impact on the PMF flood behaviour.

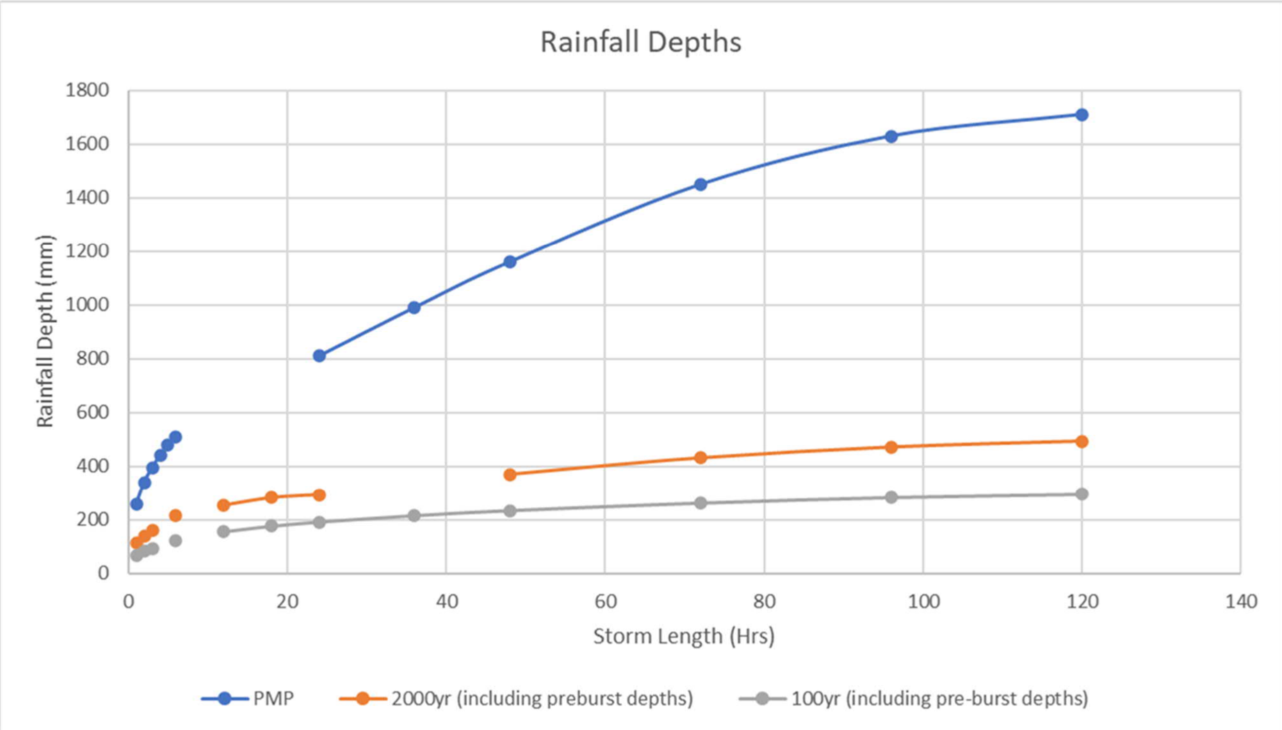



Figure 5.13 Comparison of rainfall depths for extreme events

This is further demonstrated by the maps in Appendix A2 of Appendix L, which show that the rail level is overtopped at all significant watercourses in the 0.05% AEP event, and the following results for the 0.05% AEP event:

- For approximately 70% of the alignment that is prone to flooding in the 0.05% AEP event, the difference in water level across the rail corridor is less than 100mm, indicating that the rail does not have a significant influence on water level in this event. The rail would therefore have even less influence on flood levels in the much higher PMF event.
- In areas where the rail is overtopped in the 0.05% AEP event the flood velocities remain low at <0.5m/s at over 90% of locations. This indicates that the rail embankment would not be subject to sudden failure or breaching with associated damaging flood waves passing downstream in this event. Instead, the low

velocities indicate that the rail would erode gradually, allowing equalisation of water levels across the rail corridor over the duration of the event. This gradual erosion process would also occur during the PMF event.

Figures 5.14 and 5.15 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 5.16 and 5.17 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 5.18 and 5.19 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 5.20 and 5.21 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.

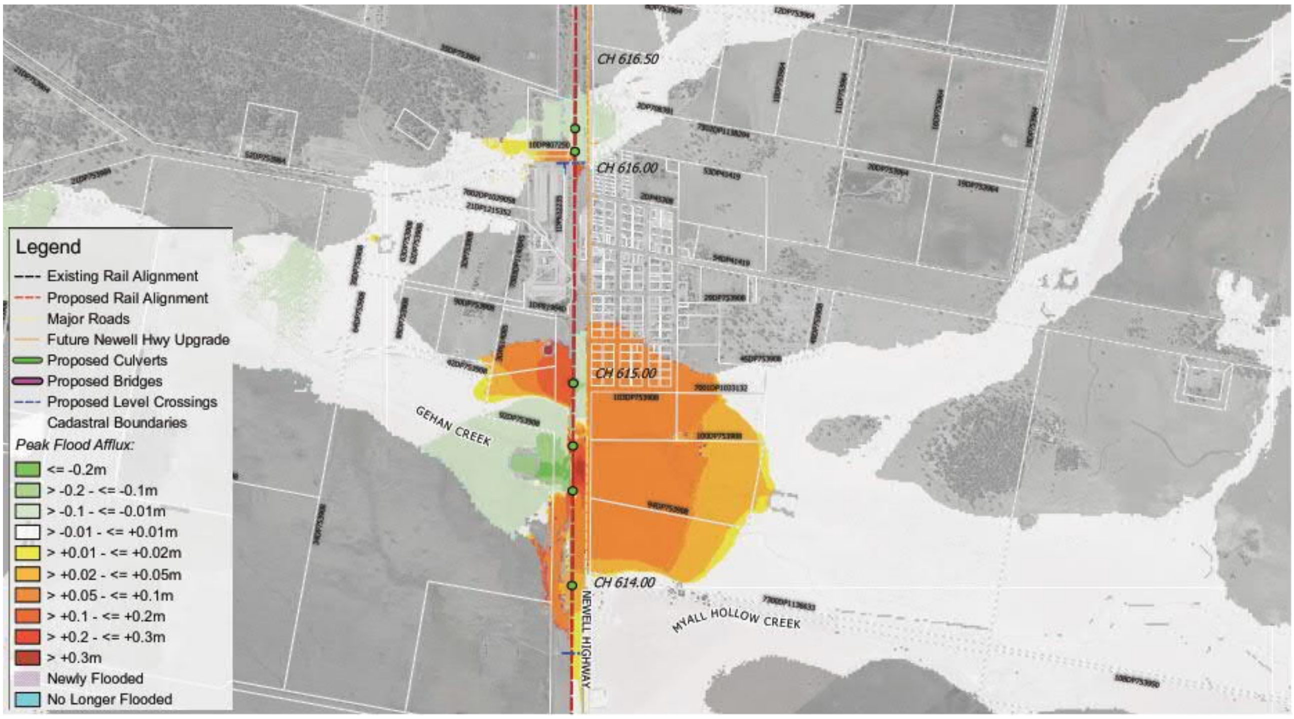



Figure 5.14 0.05% AEP afflux at Bellata

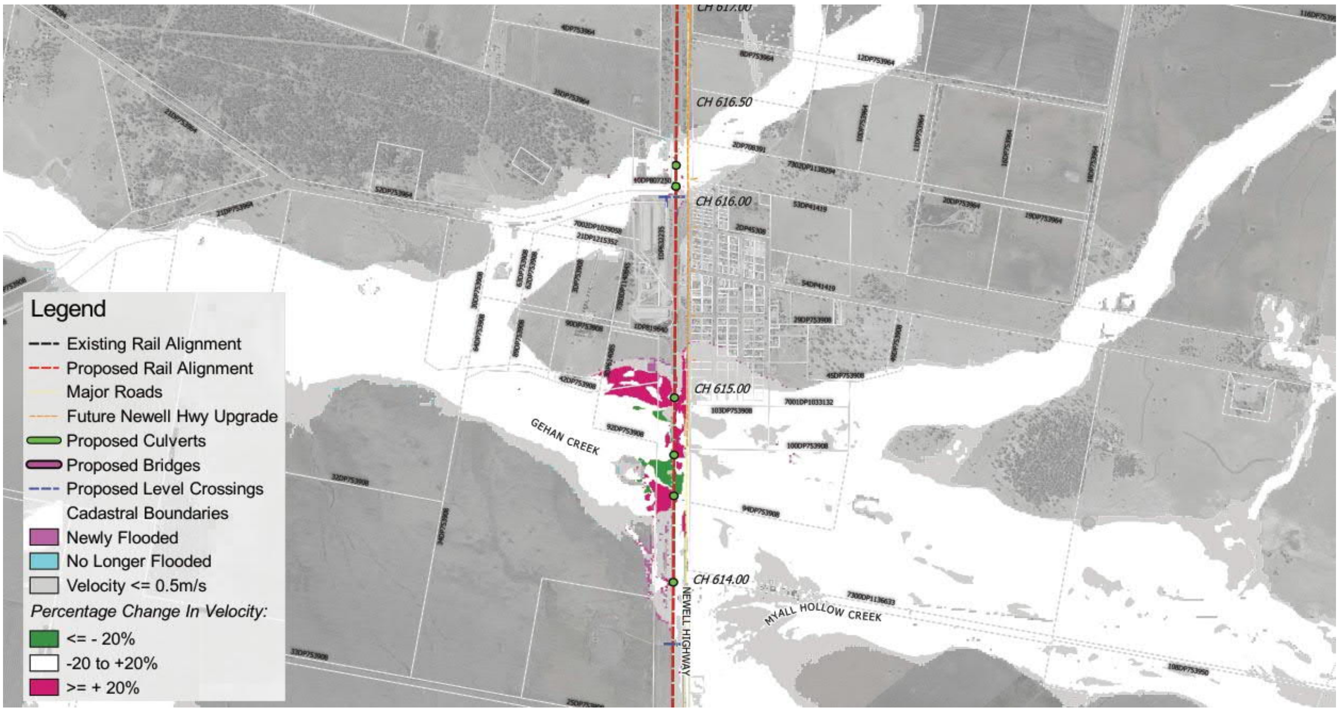



Figure 5.15 0.05% AEP velocity impact at Bellata

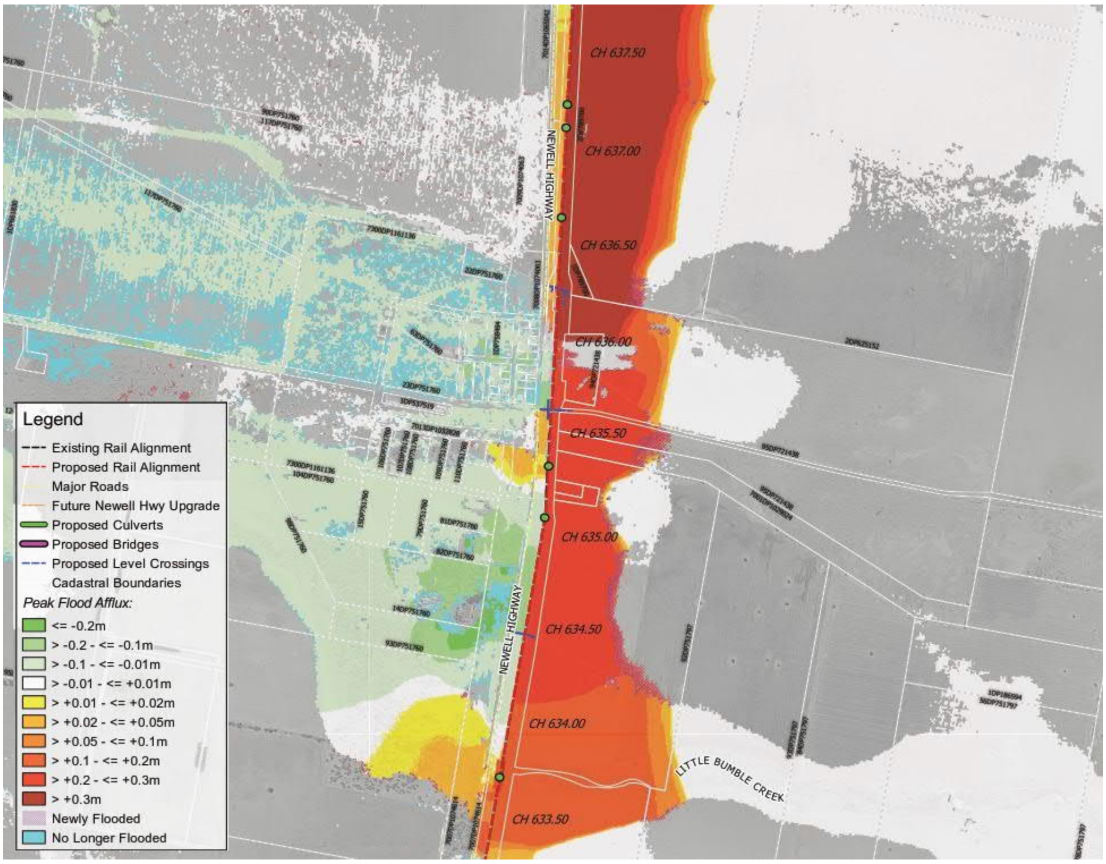



Figure 5.16 0.05% AEP afflux at Gurley

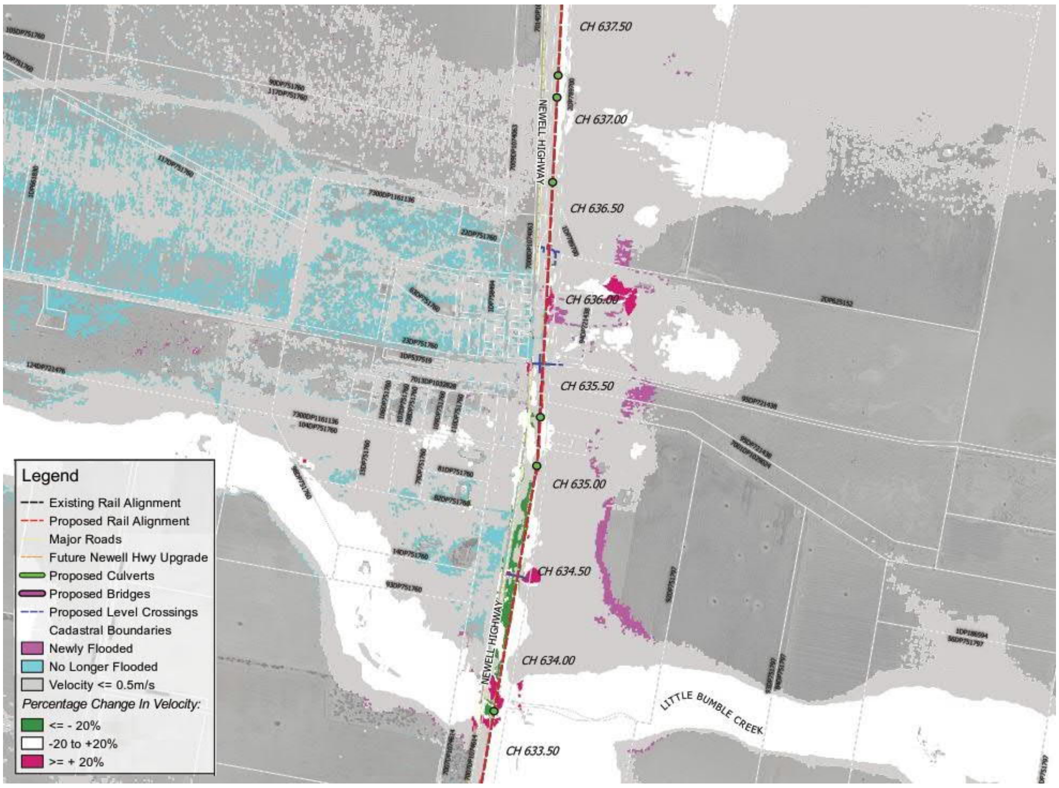



Figure 5.17 0.05% AEP velocity impact at Gurley

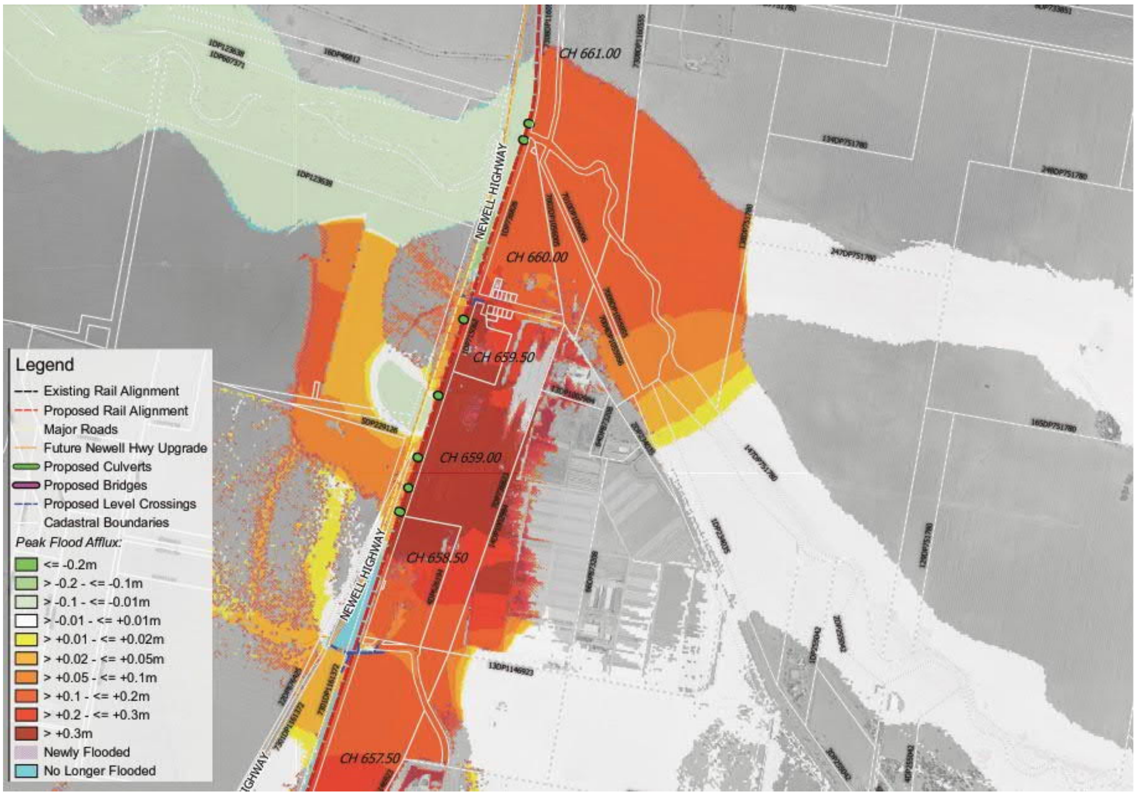



Figure 5.18 0.05% AEP afflux south of Halls Creek

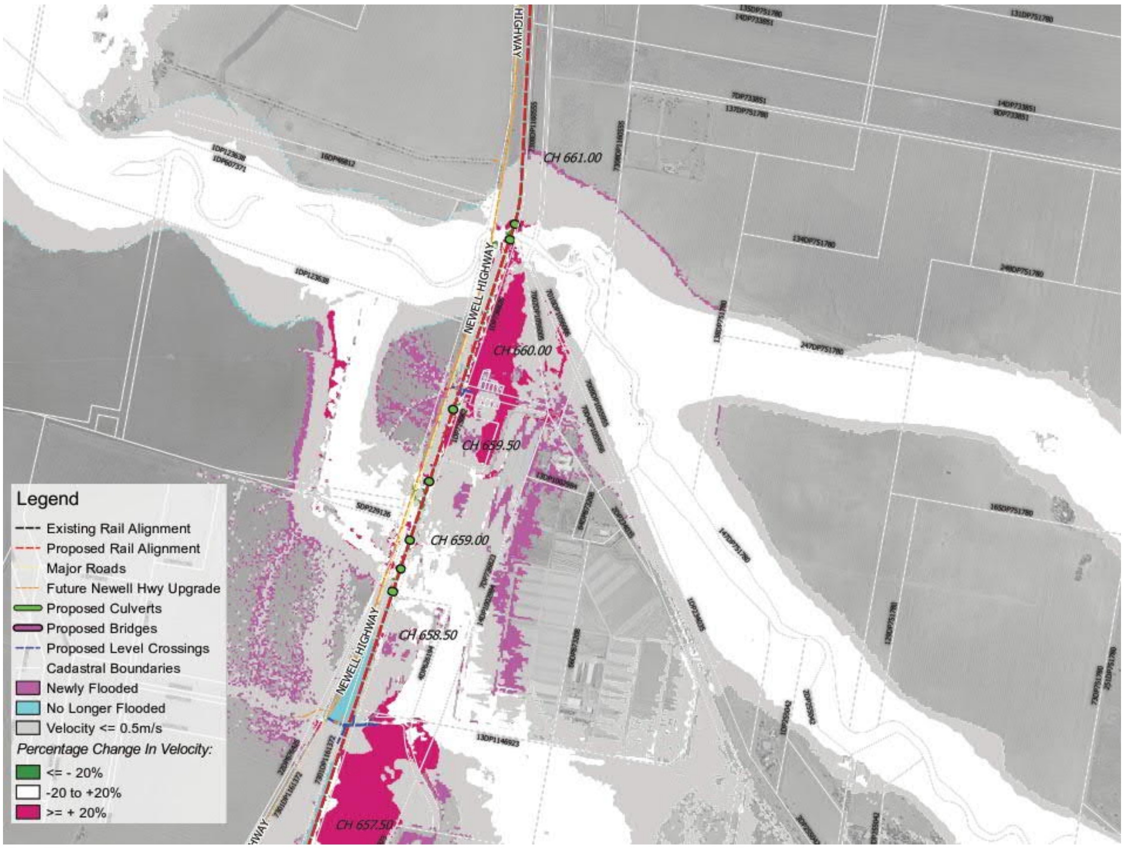



Figure 5.19 0.05% AEP velocity impact south of Halls Creek

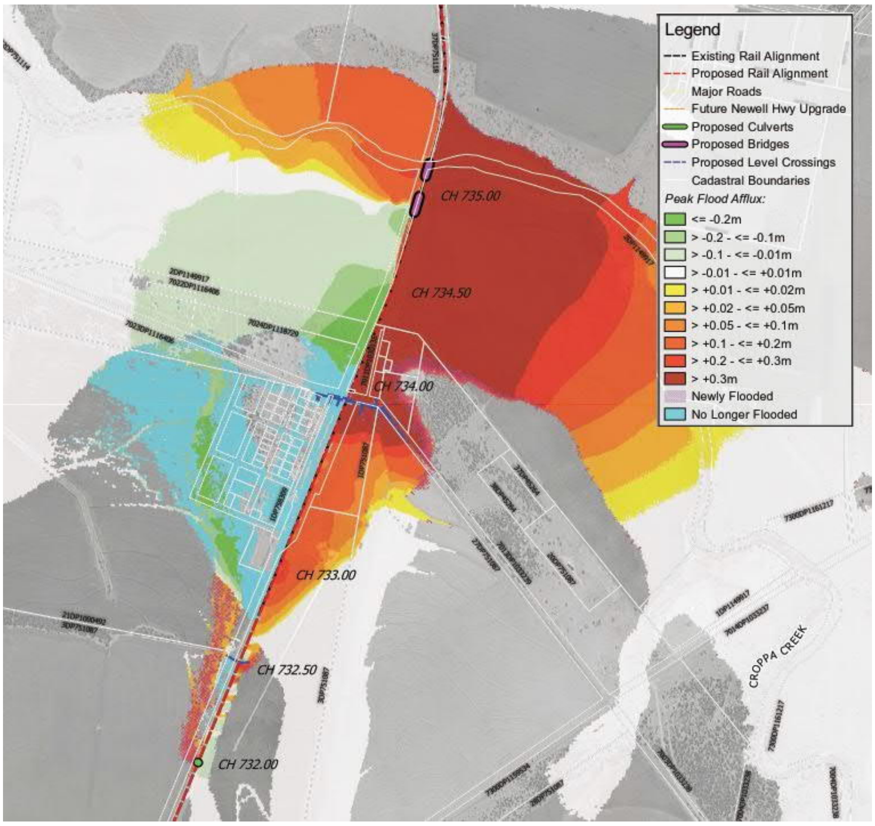



Figure 5.20 0.05% AEP afflux at Croppa Creek

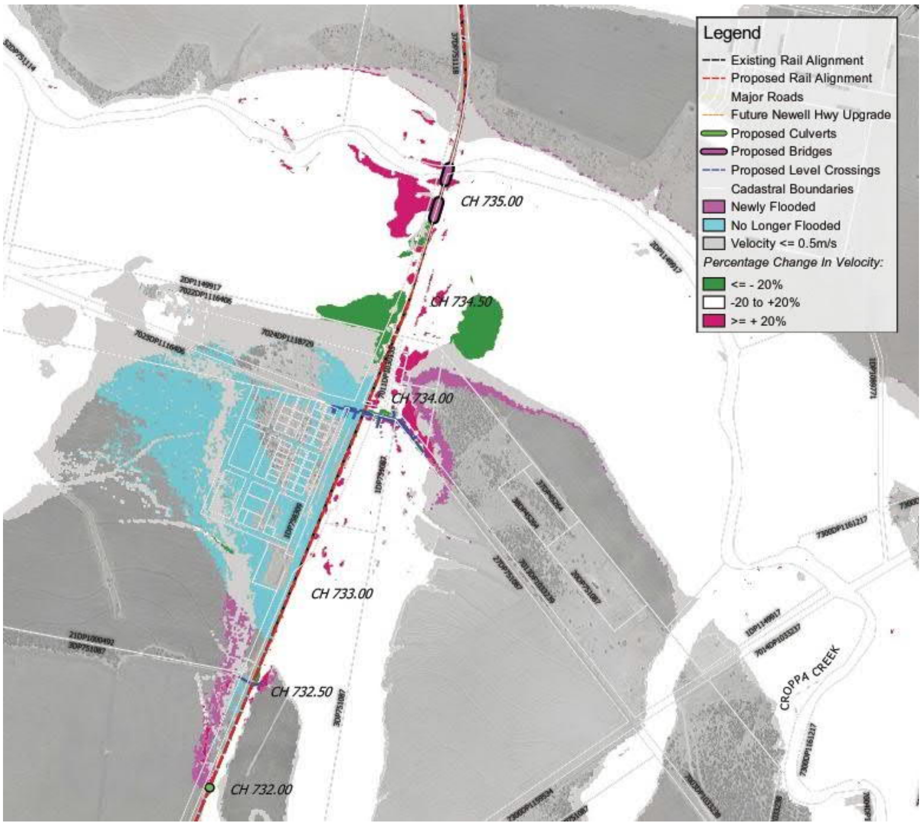



Figure 5.21 0.05% AEP velocity impact at Croppa Creek

## 5.5 Flood emergency response planning

The Flood Emergency Response Plan (FERP) for the project is provided in Appendix H. This includes an assessment of the residual flood risk to the rail infrastructure and how flooding and associated operational impacts and damage to the rail assets will be managed prior to, during and after a flood event.

Appendix N of the NSW Floodplain Development Manual (NSW Department of Infrastructure, Planning and Natural Resources, 2005) provides guidance for emergency response planning for floods and focusses on the roles of the SES and Local Councils. While the Manual does not identify specific requirements for other agencies or asset owners, the FERP is consistent with the general principles of flood risk management contained within the Manual. In addition, ARTC has a responsibility to provide flood risk information to the SES and Local Councils to inform the flood emergency planning processes of these agencies. Through the consultation process with these agencies and the Local Emergency Management Committees, ARTC has committed to providing the flood models and all associated results and outputs to allow the relevant parts of the Local Emergency Management Plans to be updated. This consultation process, outcomes and ARTC's commitments are documented in Section 6.

# 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 |
|---|---|---|---|
| **A5** | Where the terms of this approval require a document or monitoring program to be prepared, or a review to be undertaken, in consultation with identified parties, evidence of the consultation undertaken must be submitted to the Planning Secretary in accordance with the Department's Post Approval Guidance: Defining Engagement Terms (DPIE, 2020). | The evidence must include:<br>a) documentation of the engagement with the party identified in the condition of approval that has occurred before submitting the document for approval;<br>b) a log of the dates of engagement or attempted engagement with the identified party and a summary of the issues raised;<br>c) documentation of the follow-up with the identified party where engagement has not occurred to confirm that they do not wish to engage or have not attempted to engage after repeated invitations;<br>d) outline of the issues raised by the identified party and how they have been addressed; and<br>e) a description of the outstanding issues raised by the identified party and the reasons why they have not been addressed. | This document is evidence of compliance. All stakeholder meetings have associated meeting minutes. Presentations have been provided to agencies post meeting.<br>Dates of engagement are below.<br>See Table 6.2 and 6.5 for non-compliance (NC), mitigation (if required) and if accepted by landowner. |

| 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.<br><br>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:<br>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;<br>b) in every instance of non-compliance with the QDLs, consult with and obtain agreement from the affected land or property owners to either:<br>I. the non-compliance; or<br>II. establish an alternative level of mitigation of impacts for that location through alternative design measures;<br>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<br>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:<br>• 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. See Table 6.2.<br>• Stage 2: undertaken after the CoA and associated QDLs were received in May 2021 with the majority of the consultation being completed by July 2021. See Table 6.2 and 6.4 for non-compliance, mitigation (if required) and if accepted by landowner. For ongoing consultation see Section 6.4.6.<br>- |
| **E31** | Information to Facilitate Management of Flood Emergency Risks beyond the Rail Corridor.<br>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. | 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;<br>b) consideration of changes to flood behaviour that may result from CSSI infrastructure failures or embankment collapses where these may occur during floods;<br>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) | The Flood Emergency Response Plan provided in the FDVR is consistent with the general principles of flood risk management contained within the Manual. ARTC has a responsibility to provide flood risk information to the SES to inform the SES's flood planning processes, which ARTC is committed to and has demonstrated through consultation with the SES and commitment to provide flood models and/or associated outputs for the N2NS project.<br>Emergency Services were engaged with affected third parties (Councils) at the following Flood Risk Management Meetings<br>• Moree: March 2020 and March 2021 |

| Condition | Key extracts from Condition | Consultation requirements | Consultation undertaken to meet Condition |
|---|---|---|---|
| | | to prepare for management of flood emergencies;<br>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. | • Narrabri: March 2020<br>• Bathurst (with SES): July 2020 and June 2022.<br>Final acceptance of the adequacy of the flood model data and outputs by SES and Council LEMCs was received in June 2022 (see Sections 6.4.6 and Table 6.6). |
| **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).<br>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 (see Table 6.8):<br>• ARTC presented flooding impacts to Newell Highway in the same format as that developed for the N2NS SP2 Project – 14th July 2021.<br>• Technical memo issued on Wednesday 21 July 2021.<br>• 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.<br>• ARTC to provide final independent verification report to TfNSW and EES for information.<br>• Senior Leadership from ARTC and TfNSW meet for a PCG Meeting. Agreement was reached for the ARTC detailed assessment of flooding impacts on the existing Newell Highway memo to ensure it highlights the impacts specifically to the operation of the highway and its pavement.<br>• ARTC provided an updated memo highlighting the impacts specifically to the operation of the highway and its pavement.<br>• Workshop to discuss any outstanding comments on the memo issued on 6 December 2021. This workshop was rescheduled at TfNSW request to 11/01/2022. |

| Condition | Key extracts from Condition | Consultation requirements | Consultation undertaken to meet Condition |
|---|---|---|---|
| | | | • ARTC and TfNSW Senior Leaders met to discuss the FDVR and Technical Memos.<br>• TfNSW confirmed receipt of notes from the ARTC and TfNSW Senior Leaders meeting on 22 December 2021.<br>• ARTC issued technical memo to TfNSW (addressing scour and velocity) on 25/03/2022<br>• ARTC /TfNSW Senior leaders meeting to discuss flood exceedances<br>• ARTC issued email correspondence addressing geotechnical assessments – 03/05/2022<br>• ARTC noted ongoing availability regarding any further communication required with TfNSW |
| **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.<br>The FDVR must show evidence of consultation with landholders that are identified as being impacted beyond relevant criteria, referred to as QDL's.<br>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:<br>• 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. See Table 6.2.<br>• Stage 2: undertaken after the CoA and associated QDLs were received in 2021. Stage 2 Consultation began in May 2021 and was completed in July 2021. See Table 6.5.<br>• For ongoing consultation see Section 6.4.6. |
| **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, Energy and Science (EES) and the Department of Planning 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.<br>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.<br>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.<br>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.<br>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.<br>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.<br>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.<br>Additional meetings were held in May 2020 with landowners who had been unable to meet in 2019. | 18 (eighteen) landowners had further investigations required.<br>Stakeholder meetings were held resulting in further design refinements - acceptance was received from 12 landowners.<br>6 landowner mitigation options were under review prior to stage 2 consultation.<br>See Table 6.4. |
| Local Government and State Agencies | Local Government and State Agencies meetings:<br>• Narrabri Shire council<br>• Moree Plains Shire Council<br>• Gwydir Shire Council<br>• Narrabri Flood Plain Committee<br>• Moree Flood Plain Committee<br>• TfNSW<br>• SES<br>• LALC representatives. | Summary presentation of the flood modelling and cross drainage for the project.<br>Analysis of previous key studies which were referred to during the flood modelling methodology.<br>Stream gauge data for each basin within the project area.<br>SP1 model build process and source of the SP2 model and its hydrological and hydraulic extent.<br>SP2 model calibration process.<br>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 RAFTS model.<br>Validation that the kc parameter adopted agreed with the OEH independent models, developed independent to the project.<br>Overview of the design procedure in relation to culvert infrastructure.<br>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.<br>Landowner expressed concern with the validity of flood modelling and demonstrated historic flooding via photographs and markers. | N2NS team organised subsequent meetings.<br>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, Energy and Science and the Department of Planning, and Environment.<br>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.<br>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 | Non-compliances | Mitigations | Outcomes | Reasons Given |
|---|---|---|---|---|
| 1//DP255520 | Duration change at 1% AEP event, scour protection extending to landowner property | Drainage channel | Property has new owner, see Stage 2 Consultation in Table 6.6 | Landowner changeover |
| 125//DP753906 | Duration change at 10% and 1% AEP events | Drainage channel | Property has new owner, see Stage 2 Consultation in Table 6.6 | Landowner changeover |
| 125//DP753906 | Afflux change over <2% of total land area for all events | Earthworks agreed, details to be discussed during construction | Property has new owner, see Stage 2 Consultation in Table 6.6. | Landowner changeover |
| 32//751747 | Afflux change over <2% of total land area for 1% AEP event | Earthworks agreed, details to be discussed during construction | Mitigation accepted 3 December 2019. | NC acceptable with stated mitigation |
| 5//1223258 | Afflux change over <2% of total land area for 10% and 1% AEP events, scour protection extending to landowner property | Likely requires mitigation | Additional design work required.<br>See Stage 2 Consultation in Table 6.6. | Further consultation required in Stage 2 |
| 3//7555984 | Scour protection extending to landowner property | None required | Landowner acceptance received with feedback on culvert placement, 26 November 2019. | NC acceptable with stated mitigation |

## 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 a 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 |
|---|---|---|---|
| Broader Community | Two Community Information Sessions were held - Gurley and Gurley Creek. | The Gurley community was presented with an overview of changes to the flood patterns. IR captured further local data about the March 2021 flood and specifically differences in Gurley and Moree flood patterns. | A Second Community Information Session was held and specific impacts on roads and infrastructure were addressed. This was held with the support of MPSC. |
| Individual stakeholders | **Non-compliance** – 25 landowners were contacted resulting in one-on-one meetings, either in person or via Microsoft Teams.<br>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. | 22 landowners accepted the change in flood behaviour.<br>3 landowners have continued investigations where mitigation consultation is ongoing. These landowners will be engaged February 2022 finalising mitigations. Delays for one property have occurred due to a change of ownership. |

| Stakeholder | Consultee | Information obtained | Outcomes / Mitigations |
|---|---|---|---|
| | **Negligible Impact** – 5 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.<br>This communication included key messages, relevant flood mapping and a description of their impact.<br>No landowners requested a one-on-one meeting. |
| | 4 Gurley landowners with a perceived negligible impact were met onsite. | Onsite meetings were held with engineering and hydrology staff. Investigations were undertaken noting local infrastructure including highway culverts. | New infrastructure was deemed to be an unlikely cause for increased water. Early to mid 2021 was identified as a higher than average rainfall period. |
| Local Government and State Agencies | Local Government and State Agencies meetings:<br>• Narrabri Shire Council<br>• Narrabri Flood Plain Committee<br>• Narrabri Local Emergency Management Committee<br>• Moree Plains Shire Council<br>• Moree Plains Local Emergency Management Committee<br>• Gwydir Shire Council<br>• Gwydir Shire Council Flooding Emergency Management Committee | Councils 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).<br>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.<br>MPSC requested meetings post construction of the Penneys Road to Moree section in December 2021. Issues were investigated to find cause and any actions have been closed out. | FDVR shared via DPIE Portal on 17.05.21. Portal allows 1 month for consultation/response from stakeholders.<br>Appendices zip file for N2NS SP1 Project Flood Design Verification Report (FDVR) issued 1.6.2021<br>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.<br>Moree Plains Shire Council – no further requests for data. Acceptance received.<br>Gwydir Plains Shire Council – no further requests for data.<br>Gwydir Shire Council Flooding Emergency Management Committee acceptance received on June 25 2022.<br>Narrabri Local Emergency Management Committee and the Narrabri Shire contracted Hydrologist has received further FDVR files, March 2022. Final acceptance received on 27 June 2022.<br>Moree Plains Local Emergency Management Committee: final acceptance received on 29 June 2022. |

| Stakeholder | Consultee | Information obtained | Outcomes / Mitigations |
|---|---|---|---|
| | | | SES: Final acceptance received on 20 June 2022 (see Section 6.4.5) |
| | • TfNSW<br>• EES (BCD)<br>• Crown / Local Land Services | 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).<br>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.<br>Local Land Services were presented with flood maps affecting the traveling stock routes on 24 August 2021 and provided no comments on the proposed work. | 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<br>Appendices zip file for N2NS SP1 Project Flood Design Verification Report (FDVR) issued 1.6.2021<br>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.<br>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.<br>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).<br>Additional feedback (minor comments) following meeting provided by BCD on 16.07.2021 and TfNSW on 28.07.2021.<br>ARTC responded to both BCD's and TfNSW's initial feedback (from June 2021) on 05.08.2021.<br>ARTC provided both BCD and TfNSW with an update draft of the FDVR on 9.08.2021.<br>Follow up meeting held with BCD on 17.08.2021 whereby |

| Stakeholder | Consultee | Information obtained | Outcomes / Mitigations |
|---|---|---|---|
| | | | BCD mentioned further feedback would be provided. The latest version of the FDVR provides additional technical findings to respond to feedback received from BCD.<br>ARTC /TfNSW Senior leaders meeting – discuss flood impact criteria exceedances on 24.03.2022.<br>ARTC issued technical memo to TfNSW (addressing scour and velocity) on 25.03.2022.<br>ARTC issued email correspondence addressing geotechnical assessments – 03.05.2022.<br>ARTC noted ongoing availability regarding any further communication required with TfNSW. |

### 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 6.6 Summary of proposed mitigation measures after Stage 2

| Property | Non-Compliances / Design Updates | Report Table References | Mitigations | Outcomes | Reasons given |
|---|---|---|---|---|---|
| 7//DP736823 | Afflux area <2% of total land area in 39% AEP event, 3 new cross drainage features added | 5.9 | None required | Landowner accepted the modelling results 13 July 2021 | NC would not impact farming or access |
| 136//DP751785 | Afflux and duration changes, Afflux area <2% of total land area in 10% AEP event | 5.10, 5.15 | Levee required to protect building | Mitigation agreed 13 July 2021 | NC acceptable with stated mitigation |
| 42//DP753908 | Afflux area <2% of total land area in 10% AEP event | 5.10 | None required | Landowner accepted modelling 13 July 2021 | NC would not impact farming or access |
| 2//DP1106981 | Afflux area <2% of total land area in 1% AEP event | 5.11 | None required | Landowner accepted modelling 13 July 2021 | NC acceptable (only grazing land affected) with given assurances around erosion |

| Property | Non-Compliances / Design Updates | Report Table References | Mitigations | Outcomes | Reasons given |
|---|---|---|---|---|---|
| 1//DP633825 | Afflux affecting two buildings and duration change | 5.13 | None required | Landowner accepted modelling 13 July 2021 | NC acceptable as one building is raised 2m above ground level and the shed is raised 600mm above ground level. |
| 1//DP1080910 | Afflux area <2% of total land area in 39%, 10% and 1% AEP events | 5.9, 5.10, 5.11 | None required | Landowner accepted modelling 14 July 2021 | NC would not impact farming or access |
| 1//DP577012 | 3 cross drainage structures added at 638.920.1, 639.160.1, 640.080.1 | N/A | None required | Landowner accepted modelling 14 July 2021 | Structures would not impact farming or access |
| 2//DP789700 | Afflux area <2% of total land area in 1% AEP event | 5.12 | None required | Landowner accepted modelling 14 July 2021 | NC would not impact farming or access |
| 109//DP751760 | Afflux area <2% of total land area in 1% AEP event | 5.12 | None required | Landowner accepted modelling 16 July 2021 | NC would not impact farming or access |
| 91//DP751797 | Afflux area <2% of total land area in 1% AEP event | 5.12 | None required | Landowner accepted modelling 15 July 2021 | NC would not impact farming or access |
| 92//DP751797 | Building afflux | 5.13 | Levee required to protect building | Mitigation agreed 15 July 2021 | NC acceptable with stated mitigation |
| 15//DP753961 | Duration change | 5.15 | None required | Landowner accepted modelling 15 July 2021 | NC would not impact farming or access |
| 22//DP876425 | Change in duration | 5.15 | None required | Landowner accepted modelling | NC would not impact farming or access |
| 50//DP753919 | Afflux area <2% of total land area in 1% AEP event | 5.11 | Modify waterway earthworks to control flow through rail culverts into waterway | Mitigation agreed 15 July 2021 | NC acceptable with stated mitigation |
| 20//DP751129 | Channel works added to design | N/A | Drainage channel required | Mitigation agreed 13 July 2021 | Acceptable with stated mitigation |
| 12//DP751791 | Duration change in 1% AEP event, afflux area <2% of total land area in 1% AEP event | 5.15 | None required | Landowner accepted modelling 15 July 2021 | NC would not impact farming or access |

| Property | Non-Compliances / Design Updates | Report Table References | Mitigations | Outcomes | Reasons given |
|---|---|---|---|---|---|
| 1//DP1155508 | Duration change at 1 AEP event | 5.15 | Provide low contour banks to preferentially direct flow | Mitigation agreed 16 July 2021 | NC acceptable with stated mitigation |
| 2//DP1155508 | Afflux area <2% of total land area in 1% AEP event | 5.11, 5.12 | None required | Landowner accepted modelling 13 July 2021 | NC would not impact farming or access |
| 21//DP1000492 | Duration change on lot and building afflux | 5.13, 5.15 | Possible bund/levee to protect building and ARTC to also consider noise mitigation and fencing solutions | Mitigation to be amalgamated into noise and vibration mitigation | |
| 11//DP1197268 | Afflux area >2% of total land area in 10% and 1% AEP events | 5.11, 5.12 | None required | Landowner accepted modelling 13 July 2021 | NC would not impact farming or access |

## 6.4.6 Scour protection on adjacent land

Due to cross drainage design requirements, installation of scour protection is required, in some instances, to be extended onto private land. In such cases a Drainage Work Transfer Deed has been executed between ARTC and the landowner which states terms and compensation which satisfies the construction and maintenance of the stated asset. Table 6.7 indicates properties where acceptance has been reached. Table 6.9 outlines a summary of scour protection measures outside the corridor where consultation is still ongoing.

Table 6.7 Summary of consultation relating to scour protection on private land

| Property | Key Issue | Acceptance |
|---|---|---|
| 18//DP751773 | Scour protection outside the corridor | Landowner has accepted and signed Drainage Work Transfer Deed |
| 101//DP1138114 | Scour protection outside the corridor | Landowner has accepted and signed Drainage Work Transfer Deed |
| 2//DP1155508 | Scour protection outside the corridor | Landowner has accepted and signed Drainage Work Transfer Deed |
| 13//DP751129 | Scour protection outside the corridor | Landowner has accepted and signed Drainage Work Transfer Deed |
| 2//DP1122235 | Scour protection outside the corridor | Landowner has accepted and signed Drainage Work Transfer Deed |

### 6.4.7 Ongoing consultation

To address the requirements outlined in the N2NS P1 Conditions of Approval E31, ARTC has met the three local LGAs, key emergency service providers and Emergency Management Committees to present the Flood Design Verification Report findings, enabling stakeholders to prepare their emergency response plans (see Appendix K).

Close-out meetings were held between March and June 2022 in which confirmation was received that all necessary information has been received to update Agencies' flood emergency management plans. This engagement was delayed to due to flood emergencies elsewhere in the state taking precedence over Inland Rail engagement.

3 Landowners have outstanding consultation due to ownership changes and more complicated mitigations. See Table 6.8 for further details.

Table 6.8 Summary of outstanding mitigation measures pending agreement after Stage 2

| Property | Key issue | Outcomes / Mitigations |
|---|---|---|
| 1, 2 //DP1167726; 2 //DP716262; | Increased flooding in waterway | Change of ownership during consultation period. Landowner has accepted design of mitigation works. Accepted works is in final property negotiations with landowner. |
| 1//DP716262 | Mitigate impact of flow through new culverts on cropping land and provide flood protection to new driveway | Channel and scour protection provided to protect cropping land. Determining final driveway design. Potential revegetation of waterway to be considered in consultation with landowner. |
| 5//DP1223258 | Rock apron and new channel works added to design and duration changes and afflux area <2% of total land area in 10% AEP event | Landowner has accepted design of mitigation works (increased height of existing flood levees and provision of new flow control bund and waterway works). Accepted works is in final property negotiations with landowner. |

In addition to outstanding mitigation consultation, conversations are ongoing regarding landowner acceptance of scour protection (both its construction and maintenance) on private land. The below lots are affected (landowners may own multiple lots).

Table 6.9 Summary of outstanding consultation relating to scour protection on private land

| Property | Key issue | Acceptance Status |
|---|---|---|
| 5//DP1223258 and 2//DP716262 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 1//DP716262 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 2//DP255520 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 50//DP753919 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 92//DP753908 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 21 DCDB//DP1121619 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |

| Property | Key issue | Acceptance Status |
|---|---|---|
| 1//DP236207 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 32//DP751747 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 1//DP 869053 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 4//DP751129 & 13//DP751129 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 10//DP751134 & 17// DP755984 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 19//DP755984 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |
| 1//DP222186 | Scour protection outside the corridor | Drainage Works Transfer Deed presented, not yet signed |

ARTC will use reasonable endeavours to consult with and reach an agreement with the relevant landowners to procure a Drainage Works Transfer Deed.

## 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 6.10 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<br>(Exact date not defined. SPIR made available to agencies in December 2019) | Submissions and Preferred Infrastructure Report (SPIR) | Provision of SPIR by ARTC to TfNSW, which included matters relating to hydrology |

| Date | Subject | Context |
|---|---|---|
| 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. |
| 14/09/2021 | N2NS SP1 \| Flood Design Verification Report for Phase 1 - 3-0001-260-IHY-00-RP-0006_D | ARTC provided the current version of the N2NS SP1 Flood Design Verification Report and Independent Peer Review Report as officially provided to DPIE on 25 August 2021. |
| 11/10/2021 | N2NS SP1 FDVR Information for TfNSW | Memo supplied by ARTC to TfNSW regarding impacts on the Newell Highway. |
| 26/10/2021 | TfNSW Feedback on FDVR | Meeting to discuss TfNSW commentary on the memo provided on 11 October 2021. |
| 5/11/2021 | N2NS SP1 FDVR walk through | Meeting between ARTC and TfNSW to discuss the N2NS SP1 QDL non compliances. |
| 11/11/2021 | N2NS SP1 FDVR discussion | Meeting between ARTC and TfNSW to discuss the next steps post TfNSW technical review. |
| 12/10/2021 | N2NS Flooding – Geotechnical Advice | Advice for TfNSW to ARTC regarding geotechnical impacts related to flooding on the Newell Highway |

| Date | Subject | Context |
|---|---|---|
| 12/11/2021 | Proposed Risk Assessment Criteria and sample Hazard Map | ARTC provided a proposed risk assessment for each flood parameter to be implemented for the TfNSW QDL non compliances. |
| 17/11/2021 | RE: Proposed Risk Assessment Criteria and sample Hazard Map | ARTC followed up on feedback from TfNSW on the proposed risk assessment for each flood parameter. |
| 25/11/2021 | PCG Meeting | Senior Leadership from ARTC and TfNSW meet for a PCG Meeting. Agreement was reached for the ARTC detailed assessment of flooding impacts on the existing Newell Highway memo to ensure it highlights the impacts specifically to the operation of the highway and its pavement. |
| 6/12/2021 | RE: Update to Detailed assessment of flooding impacts on the existing Newell Highway memo | ARTC provided an updated memo highlighting the impacts specifically to the operation of the highway and its pavement and applying the proposed risk assessment to the potential QDL non compliances. |
| 10/12/2021 | RE: Update to Detailed assessment of flooding impacts on the existing Newell Highway memo | ARTC followed up with TfNSW to ensure there were no issues accessing the memo issued on 6 December 2021. |
| 20/12/2021 | PLACEHOLDER: IR / TfNSW N2NS SP1 Workshop | Workshop to discuss any outstanding comments on the memo issued on 6 December 2021. This workshop was rescheduled at TfNSW request to 11/01/2022. |
| 22/12/2021 | Inland Rail Narrabri to North Star SP1 Flood Design Verification Report & Tech Memos | ARTC and TfNSW Senior Leaders met to discuss the Inland Rail Narrabri to North Star SP1 Flood Design Verification Report & Tech Memos. Commitment was made to resolve the key non-conformance that was identified in the Summary of flooding impacts on existing Newell Highway Memo (Reference 3-0001-260-IHY-00-ME-0013_B). |
| 11/01/2022 | PLACEHOLDER: IR / TfNSW N2NS SP1 Workshop | Workshop cancelled due to senior leader's meeting between IR and TfNSW held on 22 December 2021. |
| 11/01/2022 | RE: Inland Rail Narrabri to North Star SP1 Flood Design Verification Report & Tech Memos | TfNSW confirmed receipt of notes from the ARTC and TfNSW Senior Leaders meeting on 22 December 2021. TfNSW indicated that further discussion with IR will be required. |
| 24/03/2022 | Meeting: Newell highway flood exceedances | ARTC/TfNSW Senior Leaders meeting to discuss Newell Highway Flood impacts |
| 25/03/2022 | Flood velocity/scour | ARTC issued technical memo to TfNSW - addressing flood velocity/ scour concerns - 3-001-260-IHY-ME-0014_D. Verification by Landscape and Soils Specialist |
| 03/05/2022 | Geotechnical information provided to TfNSW | ARTC issued email correspondence to TfNSW responding to TfNSW request for location coordinates to assist with onsite investigations. ARTC noted ongoing availability regarding any further communication required with TfNSW |

Sections 5.3.2.6 and Appendices D and J 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 between June 2021 and May 2022.

ARTC have provided commentary within the FDVR related to MCoA A5 (e) where a description of the outstanding issues / non-conformances raised by TfNSW and the reasons why they have not been closed is addressed. ARTC and IRDJV have carefully reviewed and considered the outstanding issues / non-conformances raised by TfNSW and do not believe these to be material. In addition to a Hydrology and Drainage signoff, as requested by TfNSW this has also now been evidenced with a signoff by a suitably experienced and qualified Landscape and Soils Specialist, and this written advice has also been provided to TfNSW (Technical memo issued on 25/03/2022).

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 D. Construction of upgrades to the Newell Highway are planned to commence in the second quarter of 2022.

## 6.6 Register of meetings

A register of meetings with key stakeholders excluding TfNSW (see previous section) is provided in the table below.

Table 6.11 Register of meetings with key stakeholders (excluding TfNSW)

| Stakeholder | Date | Subject | Context |
|---|---|---|---|
| Narrabri Shire Council | 12/12/2019, Regular Monthly Meeting Since Nov 2020 | Presentation of flood modelling outcomes, updates | Introductions, how to raise issues, Flood mapping, new impacts, changes in flooding, responses to issues raised |
| Moree Plains Shire Council | 03/12/2022, Regular Monthly Meeting Since Nov 2020 | Presentation of flood modelling outcomes, updates | Introductions, how to raise issues, Flood mapping, new impacts, changes in flooding, responses to issues raised |
| Gwydir Shire Council | 11/12/2019, Regular Monthly Meeting Since Nov 2020<br>17/05/2022 | Presentation of flood modelling outcomes, updates | Introductions, how to raise issues, Flood mapping, new impacts, changes in flooding, responses to issues raised<br>Confirmation of required information for emergency plans |
| Narrabri Local Emergency Management Committee | 11/03/2020, 24/02/2022, 11/03/2022, 25/03/2022, 27/06/2022 | Presentation of flood modelling outcomes | Introductions, changes to flooding, further information requirements to emergency plans (if any)<br>Confirmation of required information for emergency plans |
| Moree Plains Local Emergency Management Committee | 26/11/2020 , 4/03/2021, 24/02/2022*, 29/06/2022 | Presentation of flood modelling outcomes | Introductions, changes to flooding, further information requirements to emergency plans (if any)<br>Confirmation of required information for emergency plans |
| SES | 7/07/2021, 17/02/2022, 11/03/2022, 25/03/2022, 14/06/2022 | Presentation of flood modelling outcomes | Introductions, changes to flooding, further information requirements to emergency plans (if any)<br>Confirmation of required information for emergency plans |
| Gwydir Shire Council Flooding Emergency Management Committee | 9/03/2022, 25/03/2022, 17/05/2022 | Presentation of flood modelling outcomes | Introductions, changes to flooding, further information requirements to emergency plans (if any)<br>Confirmation of required information for emergency plans |

## 6.7 Community enquiry and complaints management

Responding to enquiries and complaints is essential for successful delivery of the project and maintaining a positive reputation within the community. Enquiries and complaints may be received from a range of sources including through phone calls, emails and face-to-face interaction.

Complaints may include any interaction with a community member or stakeholder who expresses dissatisfaction with the project, policies, contractor's services, staff members, actions or proposed actions during the project.

Inland Rail's approach to complaints management is based in part on the governing principles for effective complaint handling stipulated in the Australian Standard AS/NZS ISO 10002:2014 Guidelines for Complaint Management in Organisations.

The Inland Rail Stakeholder Engagement Team will respond to all complaints in the first instance and will remain the point of contact until the complaint is resolved. They will work with the project team, Construction Contractor and complainant to determine a satisfactory outcome.

Where complaints are received in person, including on-site, at community information sessions or at community forums, the details of the complaint and complainant will be recorded. If complaints are not directly received by the Inland Rail Stakeholder Engagement Team, the Inland Rail team member or the Construction Contractor to whom the complaint is made will gather details of the complaint and the complainant's contact details and will immediately pass these details onto the Inland Rail Stakeholder Engagement Team to resolve as per the Complaint Management Process. A complaint is deemed to be resolved when it reaches a conclusion, not necessarily resolved to the satisfaction of the complainant.

The below approach follows the N2NS Phase 1 approved Communications and Engagement Plan – Construction N2NS Phase 1 (5-0000-260-PCS-00-ST-0001_4).

### 6.7.1 Complaints management system

All complaints received during the N2NS project are actioned and recorded through Consultation Manager (CM) and used as an improvement opportunity for Inland Rail and the Construction Contractor.

Inland Rail has already established a Complaints Management System in the lead-up to construction commencing on the project this maintained for the duration of construction and for a minimum for 12 months following completion of construction of the CSSI.

### 6.7.2 Complaints register

All complaints will be tracked and recorded in Inland Rail's CM System. Upon the request of the Secretary of the Department of Planning and Environment, a Complaints Register will be provided, within the timeframe stated in the request.

Upon the request of the Environment Representative, the details of complaints on the N2NS project will be provided in a report format within the agreed time frame. The Environment Representative will also have access to Inland Rail's CM system to see all complaints related to N2NS.

The complaints register provided to the Secretary and Environmental Representative will include number of complaints received, number of people affected in relation to complaint, nature of each complaint, if a resolution was reached and how it was reached.

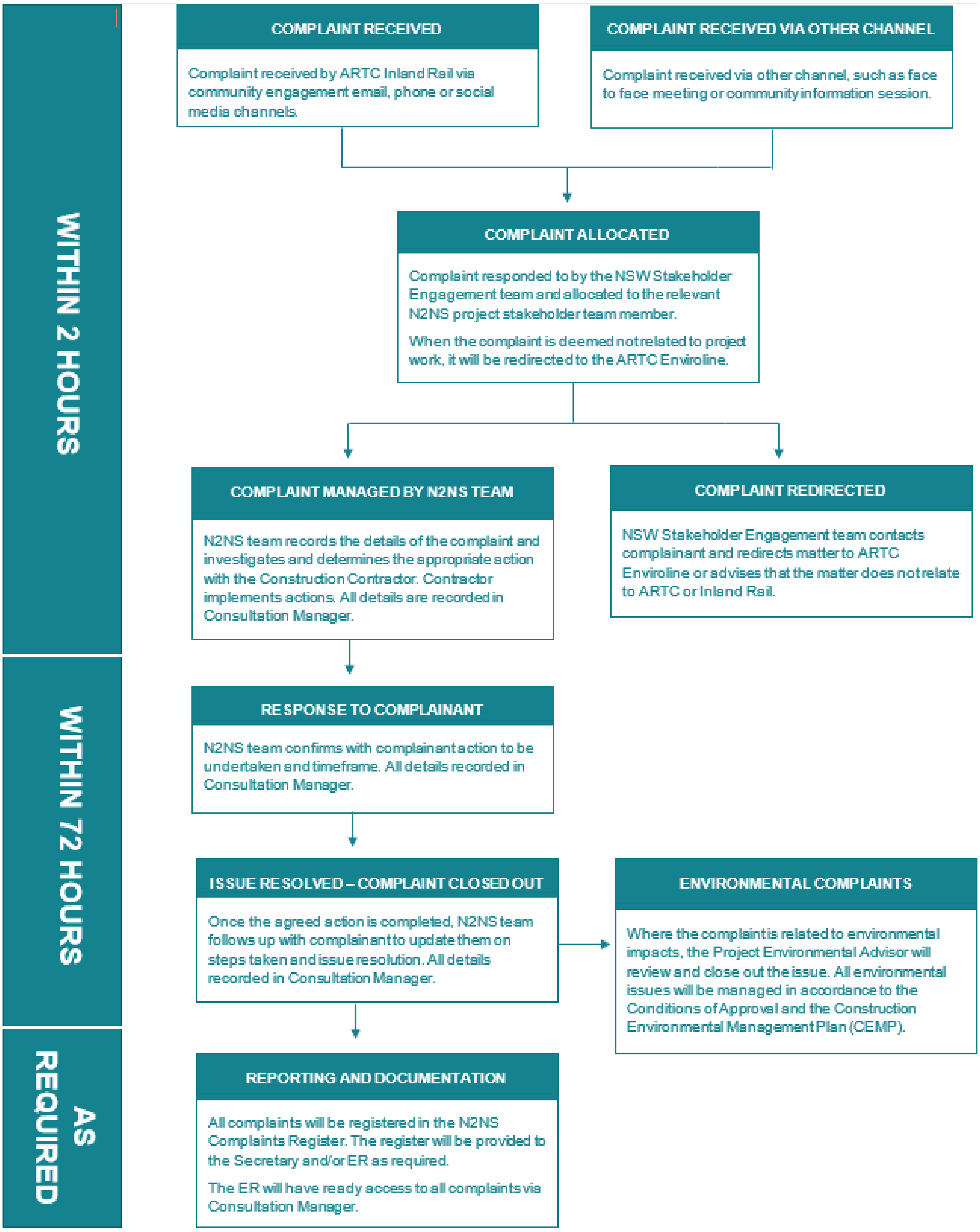



Figure 6.1 Complaints management process

# 7 Conclusions and ongoing engagement

## 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 Ongoing engagement

Further engagement relating to the flooding and cross drainage design to be completed during and following construction includes the following:

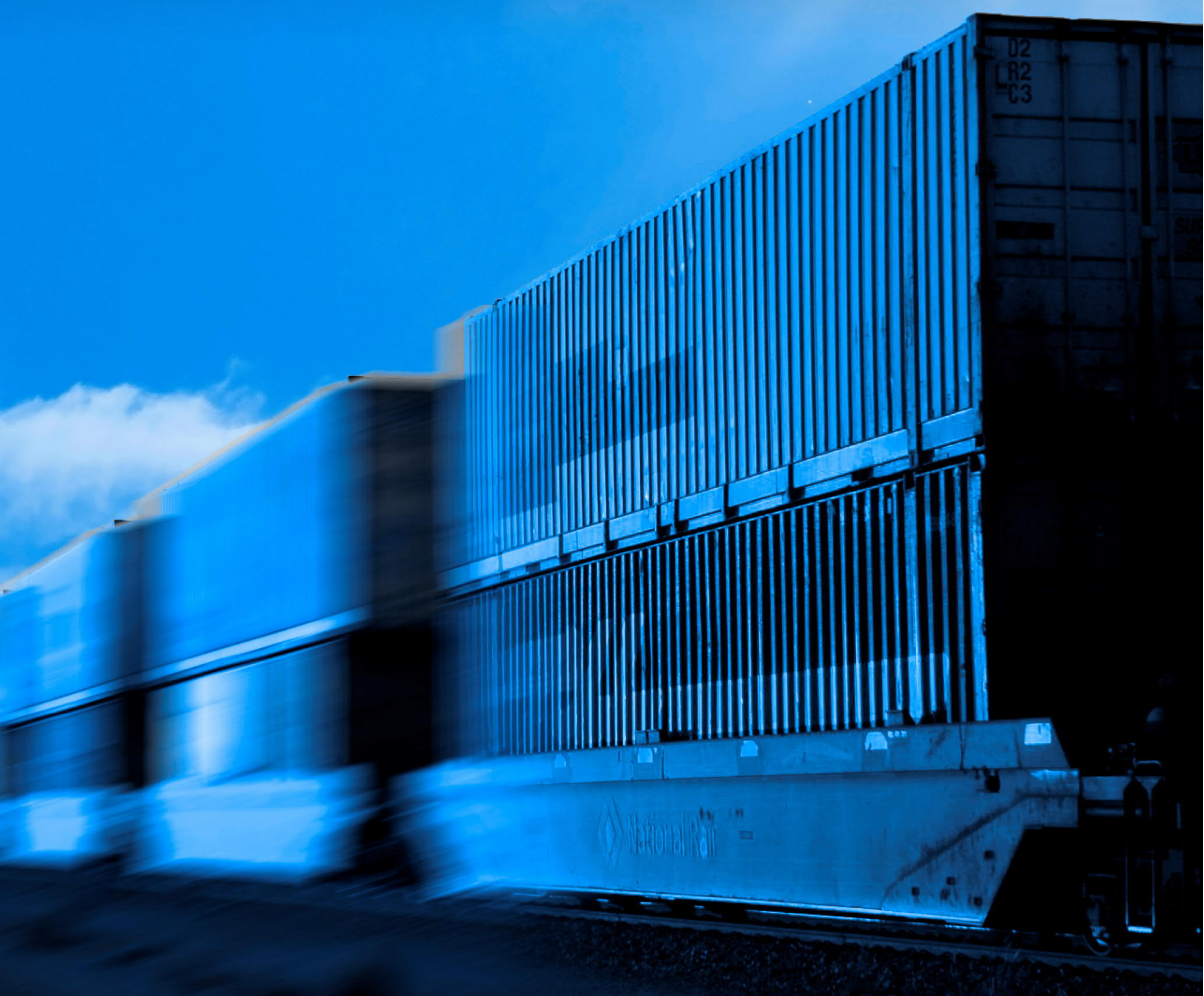
- Further negotiation with landowners to confirm the required mitigation measures identified from the first two stages of consultation.
- Continued consultation with landowners to finalise Scour Protection and Drainage Works Transfer Deeds.
- As required by Condition E32, preparation of Flood Review Reports for all significant flood events that occur within the first 15 years of operation. Where these reports find unforeseen flooding or erosion impacts have occurred on neighbouring land, and where the cause is attributable to N2NS, rectification works will be agreed with the affected landowner and implemented by ARTC.

# 8 References


- Austroads, Guide to Road Design Part 5B: Drainage – Open Channels, Culverts and Floodways, Austroads Ltd, 2013;
- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia), 2016;
- Briaud et al, National Cooperative Highway Research Program Report 24-15 (2), Abutment Scour in Cohesive Materials, October 2009;
- Engineers Australia, Australian Rainfall and Runoff: A Guide to Flood Estimation 1987 (Revised 2001), Commonwealth of Australia, 2001;
- NSW Department of Infrastructure, Planning and Natural Resources, Floodplain Development Manual – The management of flood liable land, NSW Government, 2005; and
- TUFLOW, TUFLOW User Manual Build 2016-03-AE, BMT WBM, 2016.

# Appendix A

## Hydrological and Hydraulic Model Information



## Appendix A Contents

| Item | Contents | Map References |
|---|---|---|
| A01 | RORB Model Layouts | Figures A1.1 to A1.4 |
| A02 | TUFLOW Model Layouts | Figures A2.1 to A2.7 |
| A03 | RORB Model Data Files | N/A |
| A04 | RORB Model Sub-Catchments | Figures A4.1 to A4.37 |

# Appendix B

## Existing Conditions Flood Maps

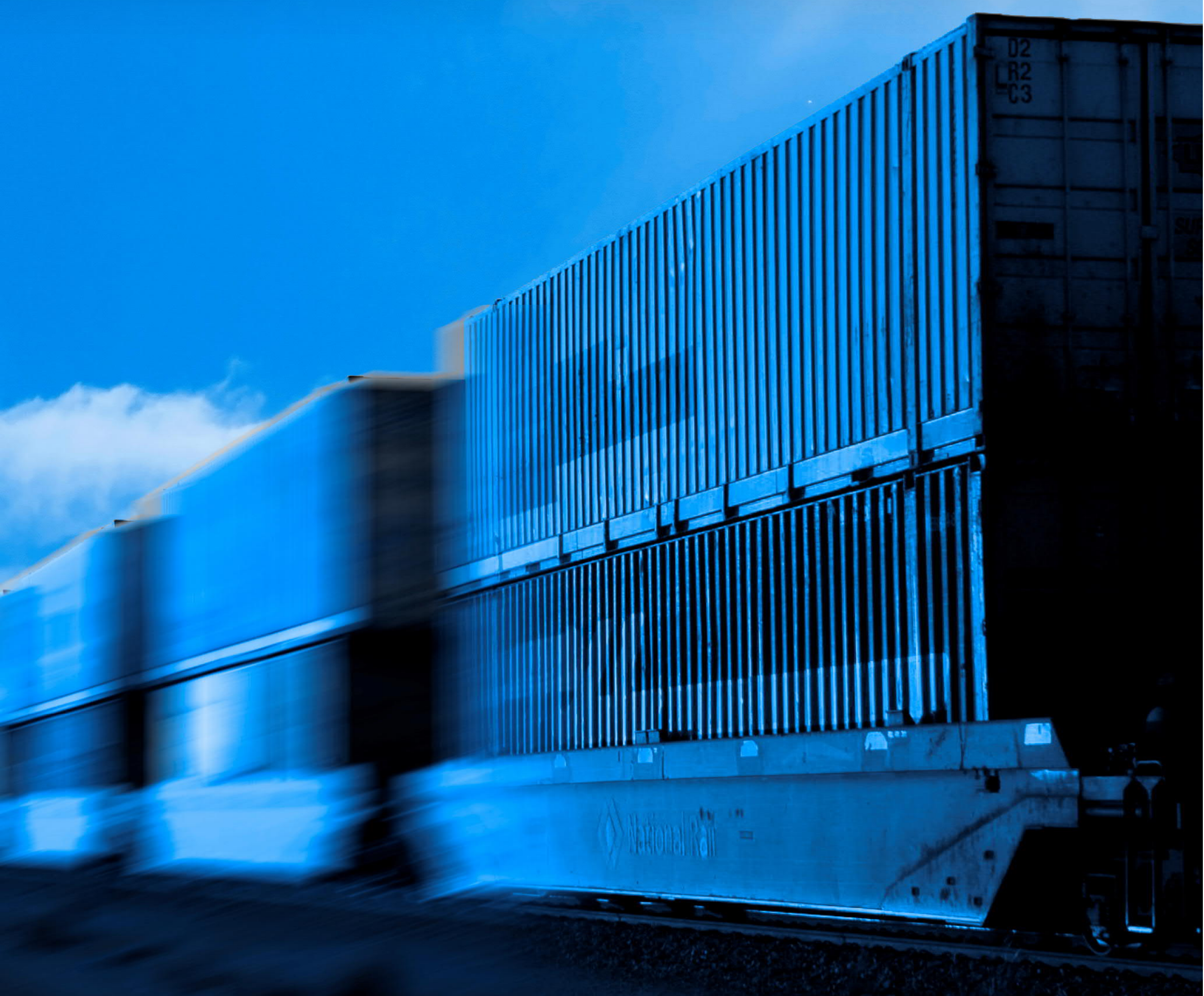
## Appendix B Map List

| Map Set | Map Set Contents | Map References |
|---|---|---|
| B01 | Existing Flood Depth 39% AEP | Figures EX39L1 to EX39L37 |
| B02 | Existing Flood Depth 18% AEP | Figures EX18L1 to EX18L37 |
| B03 | Existing Flood Depth 10% AEP | Figures EX10L1 to EX10L37 |
| B04 | Existing Flood Depth 5% AEP | Figures EX5L1 to EX5L37 |
| B05 | Existing Flood Depth 2% AEP | Figures EX2L1 to EX2L37 |
| B06 | Existing Flood Depth 1% AEP | Figures EX1L1 to EX1L37 |
| B07 | Existing Flood Depth 0.05% AEP | Figures EX0.05L1 to EX0.05L37 |
| B08 | Existing Flood Velocity 39% AEP | Figures EX39V1 to EX39V37 |
| B09 | Existing Flood Velocity 18% AEP | Figures EX18V1 to EX18V37 |
| B10 | Existing Flood Velocity 10% AEP | Figures EX10V1 to EX10V37 |
| B11 | Existing Flood Velocity 5% AEP | Figures EX5V1 to EX5V37 |
| B12 | Existing Flood Velocity 2% AEP | Figures EX2V1 to EX2V37 |
| B13 | Existing Flood Velocity 1% AEP | Figures EX1V1 to EX1V37 |
| B14 | Existing Flood Velocity 0.05% AEP | Figures EX0.05V1 to EX0.05V37 |
| B15 | Existing Flood Duration 39% AEP | Figures EX39D1 to EX39D37 |
| B16 | Existing Flood Duration 18% AEP | Figures EX18D1 to EX18D37 |
| B17 | Existing Flood Duration 10% AEP | Figures EX10D1 to EX10D37 |
| B18 | Existing Flood Duration 5% AEP | Figures EX5D1 to EX5D37 |
| B19 | Existing Flood Duration 2% AEP | Figures EX2D1 to EX2D37 |
| B20 | Existing Flood Duration 1% AEP | Figures EX1D1 to EX1D37 |
| B21 | Existing Flood Duration 0.05% AEP | Figures EX0.05D1 to EX0.05D37 |

| Map Set | Map Set Contents | Map References |
|---|---|---|
| B22 | Existing Flood Hazard 39% AEP | Figures EX39H1 to EX39H37 |
| B23 | Existing Flood Hazard 18% AEP | Figures EX18H1 to EX18H37 |
| B24 | Existing Flood Hazard 10% AEP | Figures EX10H1 to EX10H37 |
| B25 | Existing Flood Hazard 5% AEP | Figures EX5H1 to EX5H37 |
| B26 | Existing Flood Hazard 2% AEP | Figures EX2H1 to EX2H37 |
| B27 | Existing Flood Hazard 1% AEP | Figures EX1H1 to EX1H37 |
| B28 | Existing Flood Hazard 0.05% AEP | Figures EX0.05H1 to EX0.05H37 |

# Appendix C

## Design Case Flood Impact Maps



## Appendix C Map List

| Map Set | Map Set Contents | Map References |
|---|---|---|
| C01 | Flood Level Change (Afflux) 39% AEP | Figures DE39A1 to DE39A37 |
| C02 | Flood Level Change (Afflux) 18% AEP | Figures DE18A1 to DE18A37 |
| C03 | Flood Level Change (Afflux) 10% AEP | Figures DE10A1 to DE10A37 |
| C04 | Flood Level Change (Afflux) 5% AEP | Figures DE5A1 to DE5A37 |
| C05 | Flood Level Change (Afflux) 2% AEP | Figures DE2A1 to DE2A37 |
| C06 | Flood Level Change (Afflux) 1% AEP | Figures DE1A1 to DE1A37 |
| C07 | Flood Level Change (Afflux) 1% AEP with climate change | Figures DE1CCA1 to DE1CCA37 |
| C08 | Flood Level Change (Afflux) 0.05% AEP | Figures DE0.05A1 to DE0.05A37 |
| C09 | Flood Velocity Change 39% AEP | Figures DE39V1 to DE39V37 |
| C10 | Flood Velocity Change 18% AEP | Figures DE18V1 to DE18V37 |
| C11 | Flood Velocity Change 10% AEP | Figures DE10V1 to DE10V37 |
| C12 | Flood Velocity Change 5% AEP | Figures DE5V1 to DE5V37 |
| C13 | Flood Velocity Change 2% AEP | Figures DE2V1 to DE2V37 |
| C14 | Flood Velocity Change 1% AEP | Figures DE1V1 to DE1V37 |
| C15 | Flood Velocity Change 1% AEP with climate change | Figures DE1CCV1 to DE1CCV37 |
| C16 | Flood Velocity Change 0.05% AEP | Figures DE0.05V1 to DE0.05V37 |
| C17 | Flood Duration Change 39% AEP | Figures DE39D1 to DE39D37 |
| C18 | Flood Duration Change 18% AEP | Figures DE18D1 to DE18D37 |
| C19 | Flood Duration Change 10% AEP | Figures DE10D1 to DE10D37 |
| C20 | Flood Duration Change 5% AEP | Figures DE5D1 to DE5D37 |
| C21 | Flood Duration Change 2% AEP | Figures DE2D1 to DE2D37 |

| Map Set | Map Set Contents | Map References |
|---|---|---|
| C22 | Flood Duration Change 1% AEP | Figures DE1D1 to DE1D37 |
| C23 | Flood Duration Change 1% AEP with climate change | Figures DE1CCD1 to DE1CCD37 |
| C24 | Flood Duration Change 0.05% AEP | Figures DE0.05D1 to DE0.05D37 |
| C25 | Flood Hazard Change 39% AEP | Figures DE39H1 to DE39H37 |
| C26 | Flood Hazard Change 18% AEP | Figures DE18H1 to DE18H37 |
| C27 | Flood Hazard Change 10% AEP | Figures DE10H1 to DE10H37 |
| C28 | Flood Hazard Change 5% AEP | Figures DE5H1 to DE5H37 |
| C29 | Flood Hazard Change 2% AEP | Figures DE2H1 to DE2H37 |
| C30 | Flood Hazard Change 1% AEP | Figures DE1H1 to DE1H37 |
| C31 | Flood Hazard Change 1% AEP with climate change | Figures DE1CCH1 to DE1CCH37 |
| C32 | Flood Hazard Change 0.05% AEP | Figures DE0.05H1 to DE0.05H37 |

# Appendix D

## Cumulative Impact Assessment: Design Case with Newell Highway Upgrades

# D.1 INTRODUCTION

This appendix presents the results of the cumulative impact assessment that considers the combined flooding impacts of both the N2NS Phase 1 works and the Newell Highway Upgrade works.

The maps contained in this appendix provide the cumulative impact assessment results for: afflux, velocity change, duration change and hazard change for the 39%, 10%, 1% and 0.05% AEP events. The cumulative impact assessment design case represents the future upgraded rail corridor and new/upgraded/retained cross drainage structures listed in the following sections, and also includes representations of the proposed Newell Highway upgrades described in Section 4.2.1.3. Compliance of the cumulative impact assessment design case is discussed in Section D.3. Impacts on landowners will be addressed in collaboration with TfNSW required under the N2NS Phase 1 Conditions of Approval E36 and E42 – refer to Section 6 for further details on this process.

# D.2 CROSS DRAINAGE INFRASTRUCTURE

### D.2.1 New / upgraded culverts

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

Table D.1 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 |
| 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 |
| 15 | 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 |
| 20 | NAMOI01 | 583.700 | 7 | 2400x1200 4SBC |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 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 | 40 | 1800x900 4SBC (see table footnote) |
| 43 | GWYDIR01 | 595.540 | 4 | 3000x1200 4SBC |
| 44 | GWYDIR01 | 596.450 | 8 | 3000x1500 4SBC |
| | 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 |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| | 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 |
| 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 |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 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 |
| 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 |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 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 |
| 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 |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 157 | MACINTYRE01 | 712.820 | 1 | 1800x600 RCBC |
| 158 | MACINTYRE01 | 713.350 | 11 | 1800x600 RCBC |
| 159 | MACINTYRE01 | 713.500 | 1 | 1800x600 RCBC |
| 160 | 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 |
| 165 | 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 |
| 170 | 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 |
| 175 | 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 |
| 180 | MACINTYRE01 | 723.010 | 2 | 2400x1500 RCBC |
| 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 |
| 185 | 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 |
| 190 | MACINTYRE01 | 726.550 | 2 | 3000x1200 RCBC |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 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 |
| | 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 |
| | 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 |

| No. | Model Area | Kilometrage | Number of cells | Structure Type |
|---|---|---|---|---|
| 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 main design case discussed in Section 5 which does not include representations of the Newell Highway upgrades – refer to Section 5 for further details. | | | | |

### D.2.2 Retained culverts

Retained culverts for the cumulative impact assessment design case are the same as for the main design case described in Section 5. Refer to Table 5.5 for details of these structures.

### D.2.3 Culvert scour protection

Culvert scour protection for the cumulative impact assessment design case was modified from the main design case in some areas to allow for changed hydraulic conditions in the rail corridor caused by the Newell Highway upgrades. Key scour parameters for each culvert are provided in Appendix G.

### D.2.4 New / upgraded bridges

New / upgraded bridges for the cumulative impact assessment design case are the same as for the main design case described in Section 5. Refer to Table 5.6 for details of these structures.

### D.2.5 Retained bridges

Retained bridges for the cumulative impact assessment design case are the same as for the main design case described in Section 5. Refer to Table 5.7 for details of these structures.

### D.2.6 Bridge scour protection

Bridge scour protection designs for the cumulative impact assessment design case are the same as for the main design case described in Section 5 as the Newell Highway upgrades do not change the hydraulic conditions at the bridges significantly. Refer to Table 5.8 for details of the bridge scour protection measures.

# D.3 FLOOD IMPACT COMPLIANCE

## D.3.1 RAATM and BOD

### D.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.

Table D.2 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* | Impacts of >50mm partially on the highway at 579.6 to 579.9km and 588.8 to 589.04km |
| Local Roads* | Localised impact of >100mm on local roads at 581.12km, 590.24km and 591.94km |
| ***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 7 locations but no afflux on highway |
| Local Roads* | Localised impact of >100mm on local road at 660.2 to 660.8km |
| ***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)*** | |
| | None |
| | None |
| | N/A (highway is remote from rail corridor) |
| | 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 D.3 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 | Afflux limit of 10mm exceeded at 1 building |
| Newell Highway* | Impacts of >50mm partially / wholly on the highway at 579.6 to 579.9km, 581.24 to 581.62km, 588.54 to 589.04km, 589.84 to 590.5km and 591.5 to 592.1km |
| Local Roads* | Localised impact of >100mm on local roads at 581.12km, 589.1km, 590.24km and 591.94km |
| ***GWYDIR01 (592.5 to 619 km)*** | |
| Newly inundated properties | None |
| Other Residential/Commercial Buildings and Public Infrastructure | Afflux limit of 10mm exceeded at 2 buildings |
| Newell Highway* | Impact of >50mm partially on the highway at 616.1 to 616.32km |
| Local Roads* | Localised impact of >100mm on local road at 616.12km |
| ***GWYDIR02 (619 to 666 km)*** | |
| Newly inundated properties | None |
| Other Residential/Commercial Buildings and Public Infrastructure | None |
| Newell Highway* | Some impacts of >50mm adjacent to the highway at 9 locations but no afflux on highway |
| Local Roads* | Localised impact of >100mm on local road at 660.1 to 660.9km |
| ***GWYDIR03 (682 to 709 km)*** | |
| Newly inundated properties | None |
| Other Residential/Commercial Buildings and Public Infrastructure | Afflux limit of 10mm exceeded at 1 building |
| 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 D.4 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 | Afflux limit of 10mm exceeded at 1 building |
| Newell Highway* | Impacts of >50mm partially / wholly on the highway at 579.6 to 579.9km, 581.24 to 581.72km, 585km, 587.28 to 587.74km, 588.3 to 589.04km, 589.84 to 590.5km and 591.5 to 592.14km |
| Local Roads* | Localised impacts of >100mm on local roads at 581.12km, 586.52km, 589.1km, 590.24km and 591.94km |
| ***GWYDIR01 (592.5 to 619 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 on the highway at 616.1 to 616.34km |
| Local Roads* | Localised impact of >100mm on local road at 616.12km |
| ***GWYDIR02 (619 to 666 km)*** | |
| Newly inundated properties | None |
| Other Residential/Commercial Buildings and Public Infrastructure | None |
| Newell Highway* | Impacts of >50mm adjacent to or partially / wholly on the highway at 619.3km, 620.3 to 620.9km, 621.8 to 621.9km, 622.95 to 623.15km, 623 to 623.1km, 643 to 643.5km, 654.5 to 659.8km, 655 to 655.2km and 656.3 to 656.4km |
| Local Roads* | Localised impacts of >100mm on local roads at 636.25km and 641km |
| ***GWYDIR03 (682 to 709 km)*** | |
| Newly inundated properties | None |
| Other Residential/Commercial Buildings and Public Infrastructure | Afflux limit of 10mm exceeded at 12 buildings |
| 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.*** | |

#### D.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.

### D.3.2 Quantitative Design Limits

The QDLs are provided in Table 3.1.

#### D.3.2.1 AFFLUX

##### AGRICULTURAL LAND

The afflux non-compliances with the RAATM identified in Tables D.2 to D.4 also constitute non-compliances with the afflux QDLs. In addition to these, the areas identified below in Table D.5 are also non-compliant with the afflux QDLs.

Table D.5 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 | 584.64km<br>584.82km | 580.82 to 581.06km<br>584.64km<br>584.82km<br>585.02km<br>588.48 to 589.14km<br>589.6 to 590.6km<br>591.02 to 592.28km | 579.38 to 579.6km<br>580.82 to 581.14km<br>584.64km<br>584.82km<br>585.02km<br>585.74km<br>588.14 to 589.42 km<br>589.56 to 590.8km<br>591.02 to 592.28 km<br>591.62km |
| GWYDIR01 | None | 593.96km<br>607.8km<br>616.04 to 616.4km | 616.04 to 616.4km |
| GWYDIR02 | 617.95 to 618.15km | 617.9 to 618.2km<br>620.4 to 620.8km<br>622.95 to 623.15km<br>656.3 to 656.4km<br>660 to 661km | 617.9 to 618.25km<br>620.3 to 620.9km<br>656.3 to 656.4km |
| GWYDIR03 | 709.5km | None | None |
| MACINTYRE01 | 716.75km<br>719.15km | 711.4 to 711.5km<br>712.61km<br>716.75km<br>720.3 to 720.8km<br>722.8 to 723km | 716.7km<br>716.55 to 716.75km |
| MACINTYRE02 | 746.96km | None | 733.94km<br>741.5km<br>755.4 to 755.49km |
| *Note:*<br>*Red text denotes locations where non-compliant impacts are a result of the Newell Highway upgrade or a combination of both the rail and highway upgrades* | | | |

### 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 D.6 Locations where afflux exceeds 10mm at buildings

| Model | Property ID | 39% AEP afflux (mm) | 10% AEP afflux (mm) | 1% AEP afflux (mm) |
|---|---|---|---|---|
| NAMOI01 | Lot1DP1038813 (NNS_Rx0738) | Not flooded | 265 | 388 |
| GWYDIR01 | Lot1DP505133 (NNS_Rx0771) | Not flooded | -36 | 16 |
| GWYDIR01 | Lot2DP505133 (NNS_Rx0770) | Not flooded | -36 | 16 |
| GWYDIR01 | Lot9DP758081 (NNS_Rx0768) | Not flooded | -36 | 16 |
| GWYDIR01 | Lot2DP758081 (NNS_Rx0769) | Not flooded | Not flooded | 30 |
| GWYDIR01 | Lot1DP758081 (NNS_Rx0772) | Not flooded | -36 | 16 |
| GWYDIR01 | Lot2DP708391 (NNS_Rx0838) | Not flooded | 317 | 327 |
| GWYDIR01 | Lot1DP758081 (NNS_Rx0837) | Not flooded | 317 | 328 |
| GWYDIR01 | Lot2DP758081 | Not flooded | Not flooded | 308 |
| GWYDIR01 | LOT20DP758081 | Not flooded | Not flooded | 217 |
| GWYDIR02 | Lot142DP751785 (NNS_Rx0875) | Not flooded | Not flooded | 19 |
| GWYDIR02 | Lot1DP633825 (NNS_Rx0872) | Not flooded | Not flooded | 43 |
| GWYDIR02 | Lot7002DP1029062 (SensitiveR12) | Not flooded | 494 | 746 |
| GWYDIR02 | Lot92DP751797(SensitiveR35) | Not flooded | Not flooded | 49 |
| GWYDIR02 | Lot1DP633825 (SensitiveR40) | Not flooded | Not flooded | 42 |
| GWYDIR02 | (SensitiveR44) | Not flooded | Not flooded | 46 |
| GWYDIR02 | Lot1DP736823 (NNS_Rx0892) | Not flooded | Not flooded | 55 |
| GWYDIR02 | Lot1DP222186 (NNS_Rx0878) | Not flooded | Not flooded | 43 |
| GWYDIR02 | Lot3DP222186 (NNS_Rx0879) | Not flooded | Not flooded | 20 |
| GWYDIR02 | Lot7DP748421 (NNS_Rx0882) | Not flooded | Not flooded | 71 |
| GWYDIR02 | Lot6DP748421 (NNS_Rx0883) | Not flooded | Not flooded | 54 |
| GWYDIR02 | Lot5DP748421 (NNS_Rx0884) | Not flooded | Not flooded | 84 |
| MACINTYRE02 | Lot3DP751087 (NNS_Rx2300) | Not flooded | Not flooded | 31 |
| MACINTYRE02 | Lot7010DP1030135 (NNS_REPx0002) | Not flooded | Not flooded | 39 |
| MACINTYRE02 | Lot 7009 DP1030135 (NNS_REAx0019) | Not flooded | Not flooded | 38 |

| Model | Property ID | 39% AEP afflux (mm) | 10% AEP afflux (mm) | 1% AEP afflux (mm) |
|---|---|---|---|---|
| MACINTYRE02 | Lot7010DP1030135 (NNS_Rx2320) | Not flooded | 3 | 39 |
| *Note:*<br>*Red text denotes locations where non-compliant impacts are a result of the Newell Highway upgrade or a combination of both the rail and highway upgrades* | | | | |

A large proportion of the agricultural land and most of the buildings afflux non-compliances are due to either the Newell Highway upgrade or combination of the rail and highway upgrades. Further design coordination and assessment of the combined impacts of both projects is required to determine whether further mitigation measures are needed to resolve the non-compliances, in combination with consultation with the affected landowners.

#### D.3.2.2 VELOCITY

The status of velocity impact compliance for the cumulative impact assessment design case is similar to that of the main design case – refer to Section 5.4.2.2 for details.

#### D.3.2.3 DURATION

Duration impacts were assessed against the QDLs and found to be generally compliant. As for the main design case, 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 D.7 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 | 579.5km<br>581km<br>581.5km<br>582.5km<br>587.5km<br>588.8km<br>590km<br>591.5 to 592km | 579.5km<br>581km<br>581.5km<br>582.5km<br>584.6km<br>588.5km<br>590km<br>591.5 to 592.1km | 579.5km<br>581 to 582.5km<br>584 km (approximately 1km to the west of the rail)<br>584.6 to 585km<br>585.5km<br>587.5 to 588km<br>588.5 to 589km<br>590km<br>591.5 to 592.2km |
| GWYDIR01 | 593.8km | 593.8km<br>614.65km (minor area) | 593.8km<br>600.8km (minor area)<br>607.8km<br>614.45km |

| Model | 39% AEP Event Non-Compliant Impacts | 10% AEP Event Non-Compliant Impacts | 1% AEP Event Non Compliant Impacts |
|---|---|---|---|
| GWYDIR02 | 618 km<br>633.5 to 634km<br>642.3km<br>643.5 to 644.5km<br>660.5km | 618km<br>620.5km (minor area)<br>623km (minor area)<br>627 to 627.8km<br>633.5 to 634km<br>634.5km<br>643.5 to 644.5km<br>645.8km<br>647km<br>653.4km<br>655km<br>660.5km | 618km<br>620.5km<br>623km (minor area)<br>627 to 628km<br>633.5 to 634km<br>634.5km<br>635km<br>639km<br>643.5 to 644.5km<br>645.8km<br>646.5 to 647km<br>648.5 to 650km<br>653km<br>655.5km<br>656km<br>660.5 to 661km |
| GWYDIR03 | 708.5km | 708.5km | 690.5km<br>708.5km |
| MACINTYRE01 | 711.5km<br>716.5km<br>723.5km (minor area) | 711.5km<br>714.5km<br>716.5km<br>720.5km (approximately 1km to the west of the rail)<br>723.5km (minor area) | 711.5km<br>714.5km<br>716.5km<br>720.5km<br>723km (minor area)<br>723.5km (minor area) |
| MACINTYRE02 | 737.5km (minor area)<br>752.5km (minor area)<br>755km | 730km<br>730.5km<br>733km (approximately 1.5km to the west of the rail)<br>737.5km<br>741km (minor area)<br>744.5km (minor area)<br>751km (minor area)<br>752.5km (minor area)<br>755km | 730km<br>730.5km<br>733km (approximately 1.5km to the west of the rail)<br>737.5km<br>741km<br>744.5km (minor area)<br>751km<br>752.5km (minor area)<br>755km |
| *Note:*<br>*Red text denotes locations where non-compliant impacts are a result of the Newell Highway upgrade or a combination of both the rail and highway upgrades* | | | |

As for the main design case, the flood duration impacts that do not comply with the QDLs are considered to be low risk – refer to Section 5.4.2.3 for detailed discussion of the duration impacts.

#### D.3.2.4 FLOOD RISK ASSESSMENT FOR UPGRADED SECTIONS OF NEWELL HIGHWAY

An assessment of the flood risk to the future upgraded sections of the Newell Highway was undertaken. The results are summarised in the tables below.

Table D.8 Key flood risk parameters for Newell Highway upgrade section 1: rail chainage 574.9 to 581.8km – highway upstream of rail

| Risk parameter | Flood event | | | |
|---|---|---|---|---|
| | 10% AEP | 5% AEP | 2% AEP | 1% AEP |
| Number of points assessed (10m intervals) | 676 | 676 | 676 | 676 |
| Number of points flooded | 61 (9.0%) | 74 (10.9%) | 85 (12.6%) | 92 (13.6%) |

| Risk parameter | Flood event | | | |
|---|---|---|---|---|
| | 10% AEP | 5% AEP | 2% AEP | 1% AEP |
| Number of points with flood depth > 50mm | 35 (5.2%) | 56 (8.3%) | 67 (9.9%) | 70 (10.4%) |
| Number of points with flood hazard > 0.1 $m^2/s$ | 4 (0.6%) | 11 (1.6%) | 32 (4.7%) | 33 (4.9%) |

Table D.9 Hazard categories for Newell Highway upgrade section 1: rail chainage 574.9 to 581.8km – highway upstream of rail

| Flood event | Number of points (10m intervals) in hazard category | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | H5 | H6 |
| 10% AEP | 61 | 0 | 0 | 0 | 0 | 0 |
| 5% AEP | 74 | 0 | 0 | 0 | 0 | 0 |
| 2% AEP | 84 | 1 | 0 | 0 | 0 | 0 |
| 1% AEP | 91 | 1 | 0 | 0 | 0 | 0 |

Table D.10 Key flood risk parameters for Newell Highway upgrade section 2: rail chainage 586.1 to 594.2km – highway upstream of rail

| Risk parameter | Flood event | | | |
|---|---|---|---|---|
| | 10% AEP | 5% AEP | 2% AEP | 1% AEP |
| Number of points assessed (10m intervals) | 807 | 807 | 807 | 807 |
| Number of points flooded | 104 (12.9%) | 145 (18.0%) | 193 (23.9%) | 227 (28.1%) |
| Number of points with flood depth > 50mm | 50 (6.2%) | 93 (11.5%) | 134 (16.6%) | 171 (21.2%) |
| Number of points with flood hazard > 0.1 $m^2/s$ | 3 (0.4%) | 6 (0.7%) | 39 (4.8%) | 72 (8.9%) |

Table D.11 Hazard categories for Newell Highway upgrade section 2: rail chainage 586.1 to 594.2km – highway upstream of rail

| Flood event | Number of points (10m intervals) in hazard category | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | H5 | H6 |
| 10% AEP | 104 | 0 | 0 | 0 | 0 | 0 |
| 5% AEP | 145 | 0 | 0 | 0 | 0 | 0 |
| 2% AEP | 193 | 0 | 0 | 0 | 0 | 0 |
| 1% AEP | 227 | 0 | 0 | 0 | 0 | 0 |

Table D.12 Key flood risk parameters for Newell Highway upgrade section 3: rail chainage 614.7 to 626.3km – highway upstream of rail to chainage 619.0km, highway downstream of rail from chainage 619km

| Risk parameter | Flood event | | | |
|---|---|---|---|---|
| | 10% AEP | 5% AEP | 2% AEP | 1% AEP |
| Number of points assessed (10m intervals) | 1,175 | 1,175 | 1,175 | 1,175 |
| Number of points flooded | 47 (4.0%) | 69 (5.9%) | 101 (8.6%) | 122 (10.4%) |
| Number of points with flood depth > 50mm | 35 (3.0%) | 56 (4.8%) | 82 (7.0%) | 100 (8.5%) |
| Number of points with flood hazard > 0.1 $m^2/s$ | 5 (0.4%) | 4 (0.3%) | 27 (2.3%) | 40 (3.4%) |

Table D.13 Hazard categories for Newell Highway upgrade section 3: rail chainage 614.7 to 626.3km – highway upstream of rail to chainage 619.0km, highway downstream of rail from chainage 619km

| Flood event | Number of points (10m intervals) in hazard category | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | H5 | H6 |
| 10% AEP | 47 | 0 | 0 | 0 | 0 | 0 |
| 5% AEP | 69 | 0 | 0 | 0 | 0 | 0 |
| 2% AEP | 96 | 5 | 0 | 0 | 0 | 0 |
| 1% AEP | 114 | 8 | 0 | 0 | 0 | 0 |

Table D.14 Key flood risk parameters for Newell Highway upgrade section 4: rail chainage 655.2 to 663.0km – highway downstream of rail

| Risk parameter | Flood event | | | |
|---|---|---|---|---|
| | 10% AEP | 5% AEP | 2% AEP | 1% AEP |
| Number of points assessed (10m intervals) | 786 | 786 | 786 | 786 |
| Number of points flooded | 43 (5.5%) | 62 (7.9%) | 106 (13.5%) | 170 (21.6%) |
| Number of points with flood depth > 50mm | 28 (3.6%) | 35 (4.5%) | 60 (7.6%) | 122 (15.5%) |
| Number of points with flood hazard > 0.1 $m^2/s$ | 14 (1.8%) | 15 (1.9%) | 22 (2.8%) | 33 (4.2%) |

Table D.15 Hazard categories for Newell Highway upgrade section 4: rail chainage 655.2 to 663.0km – highway downstream of rail

| Flood event | Number of points (10m intervals) in hazard category | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | H5 | H6 |
| 10% AEP | 42 | 1 | 0 | 0 | 0 | 0 |
| 5% AEP | 60 | 2 | 0 | 0 | 0 | 0 |
| 2% AEP | 98 | 8 | 0 | 0 | 0 | 0 |
| 1% AEP | 161 | 9 | 0 | 0 | 0 | 0 |

The results in the tables above demonstrate the following:

- Some parts of the upgraded highway sections flood at the 10% AEP, as follows:
  - 9.0% of the alignment in section 1
  - 12.9% of the alignment in section 2
  - 4.0% of the alignment in section 3
  - 5.5% of the alignment in section 4
- Some parts of the upgraded highway sections flood at the 5% AEP, as follows:
  - 10.9% of the alignment in section 1
  - 18.0% of the alignment in section 2
  - 5.9% of the alignment in section 3

  - 7.9% of the alignment in section 4

- Where sections of the highway upgrades are at risk of flooding, the flood hazard is predominantly in the lowest category of H1 (generally safe for people, vehicles and buildings) with small numbers of occurrences of the H2 category (unsafe for small vehicles). There are no occurrences of the higher hazard categories H3 to H6 for all events up to and including the 1% AEP.

- A summary of the hazard categories is as follows:

  - Section 1 from rail chainage 574.9 to 581.8 km:
    - 1 occurrence of H2 category for 2% AEP event
    - 1 occurrence of H2 category for 1% AEP event
    - No occurrences of H3 and above categories for all events up to and including 1% AEP
  - Section 2 from rail chainage 586.1 to 594.2 km:
    - No occurrences of H2 and above categories for all events up to and including 1% AEP
  - Section 3 from rail chainage 614.7 to 626.3 km:
    - 5 occurrences of H2 category for 2% AEP event
    - 8 occurrences of H2 category for 1% AEP event
    - No occurrences of H3 and above categories for all events up to and including 1% AEP
  - Section 4 from rail chainage 655.2 to 663.0 km:
    - 1 occurrence of H2 category for 10% AEP event
    - 2 occurrences of H2 category for 5% AEP event
    - 8 occurrences of H2 category for 2% AEP event
    - 9 occurrences of H2 category for 1% AEP event
    - No occurrences of H3 and above categories for all events up to and including 1% AEP

The results demonstrate that the upgraded sections of the highway will have generally low flood hazard for all events up to and including the 1% AEP, with only localised occurrences of conditions that may be hazardous for small vehicles.

#### D.3.2.5 EXTREME EVENT IMPACTS

As for the main design case, 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. The 0.05% AEP flood maps for the cumulative impact assessment design case are provided in the maps contained in this appendix. This section summarises the 0.05% AEP impacts of the project at key sensitive locations.

Figures D.1 and D.2 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 D.3 and D.4 show the 0.05% AEP afflux and velocity impacts at Gurley. The figures show that the developed areas on the western side of the rail line do not experience afflux or velocity impacts; while the agricultural land on the eastern side of the rail line experiences extensive areas of afflux in excess of 200mm. Therefore, flood impacts to Gurley under extreme events are considered to be low provided the land east of the rail line remains under agricultural use.

Figures D.5 and D.6 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 D.7 and D.8 show the 0.05% AEP afflux and velocity impacts at Croppa Creek. The figures show that the developed areas on the eastern side of the rail line will experience afflux in excess of 200mm with no significant change in velocity. The flood impacts to this area under extreme event conditions are therefore considered to be 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.

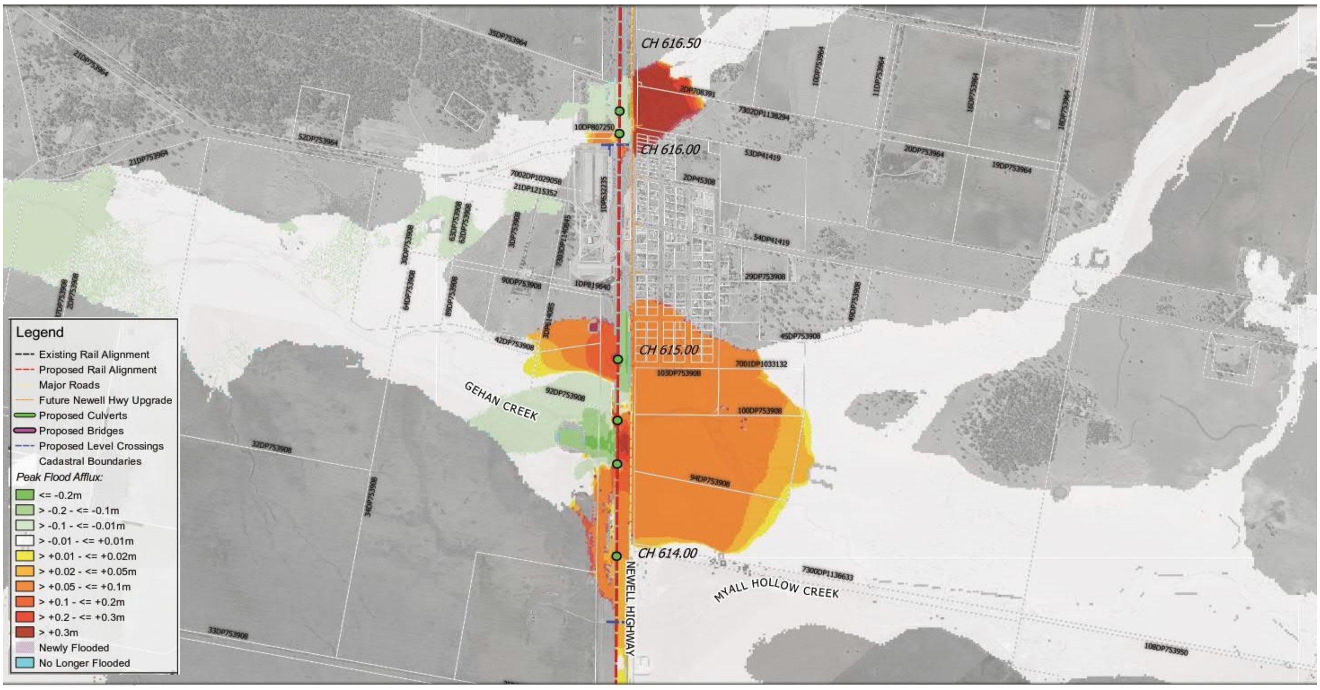



Figure D.1 0.05% AEP afflux at Bellata

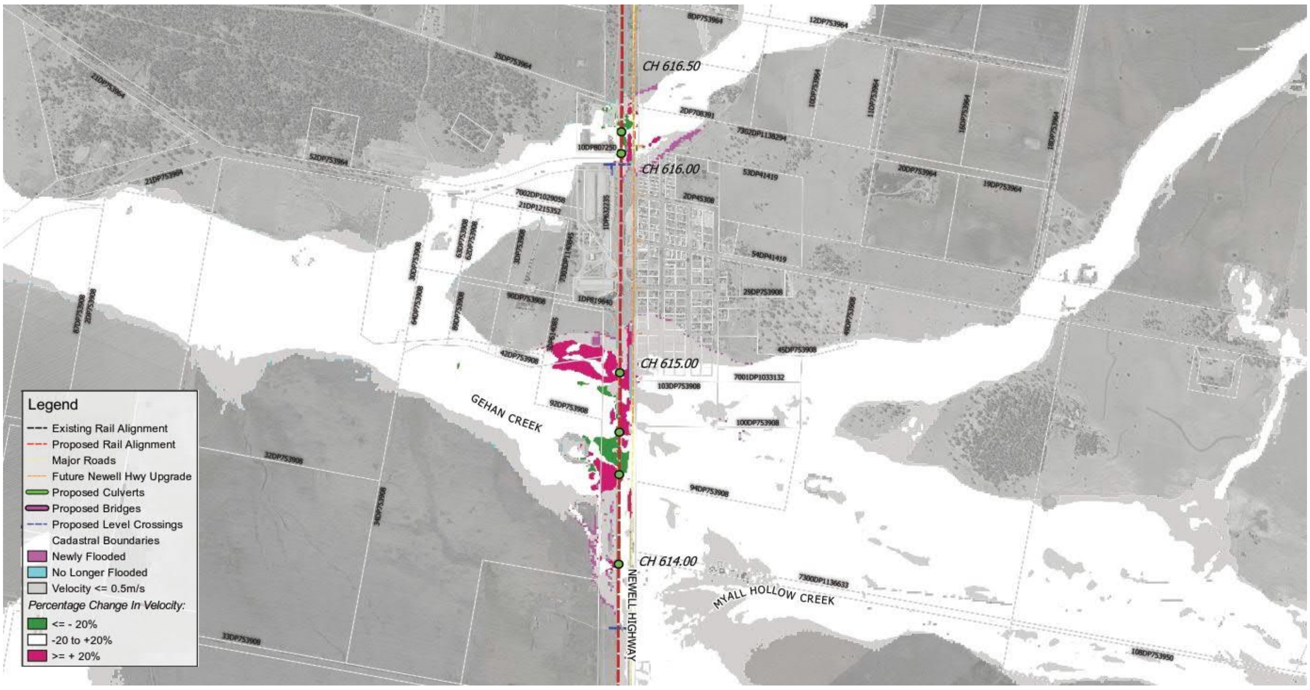



Figure D.2 0.05% AEP velocity impact at Bellata

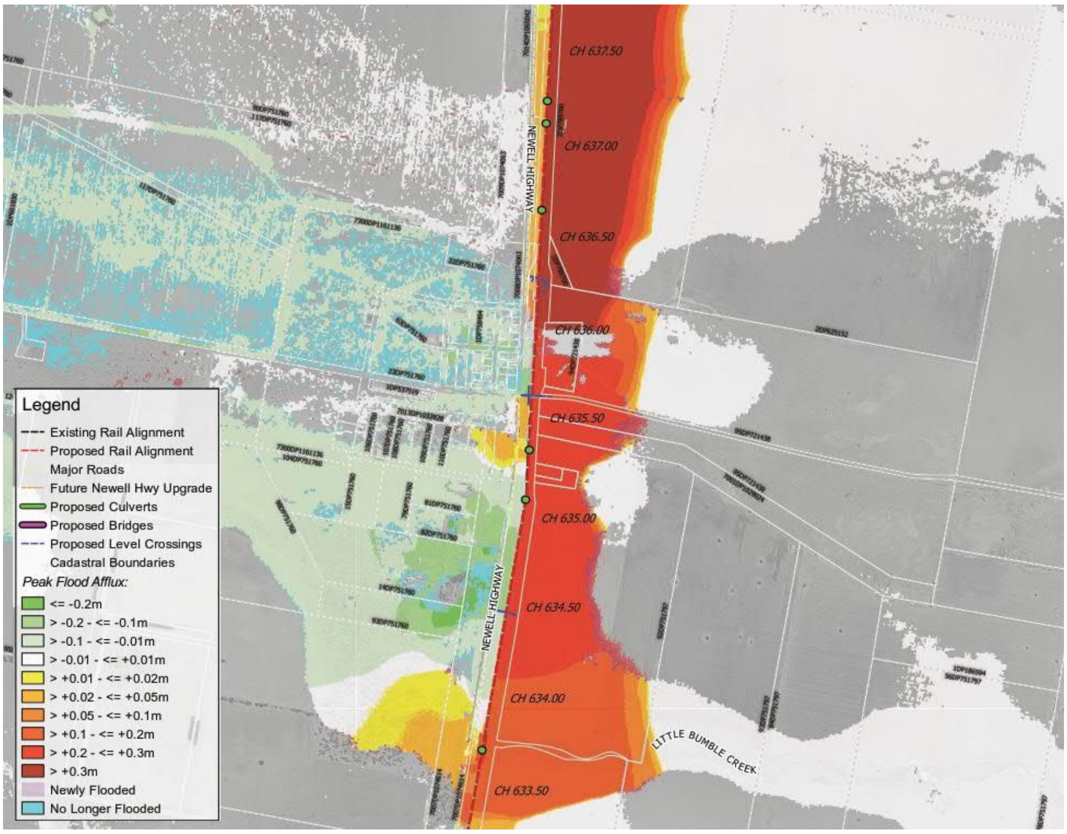



Figure D.3 0.05% AEP afflux at Gurley

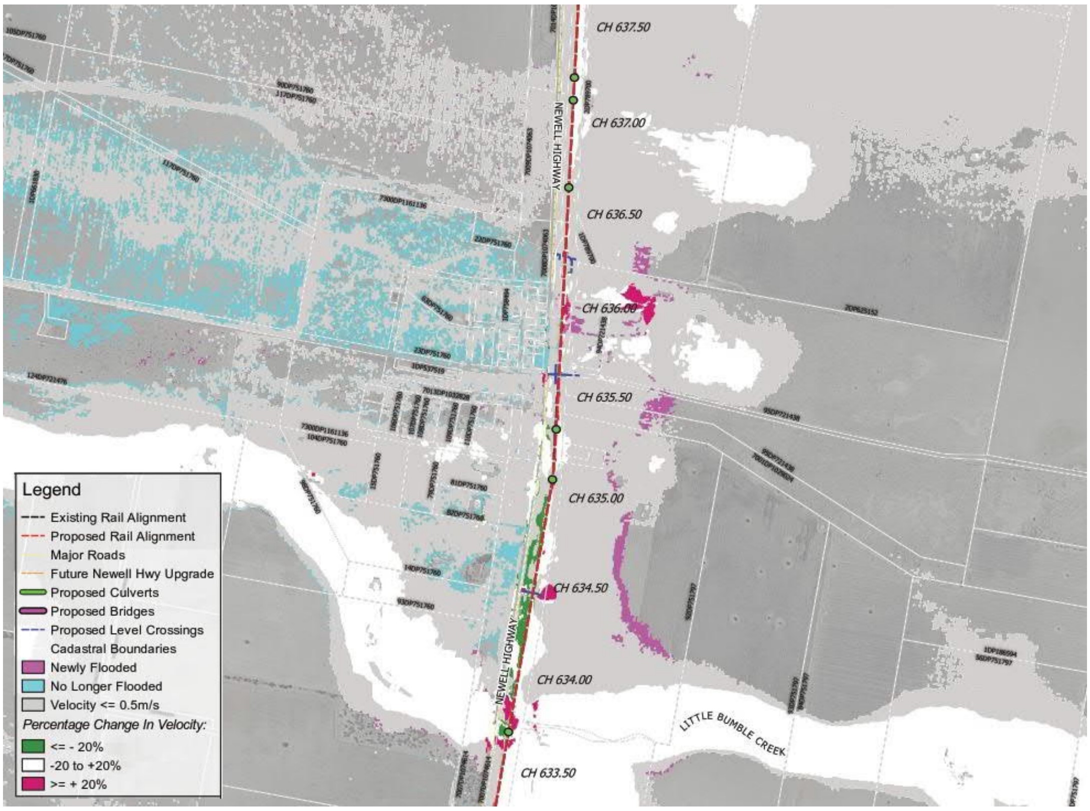



Figure D.4 0.05% AEP velocity impact at Gurley

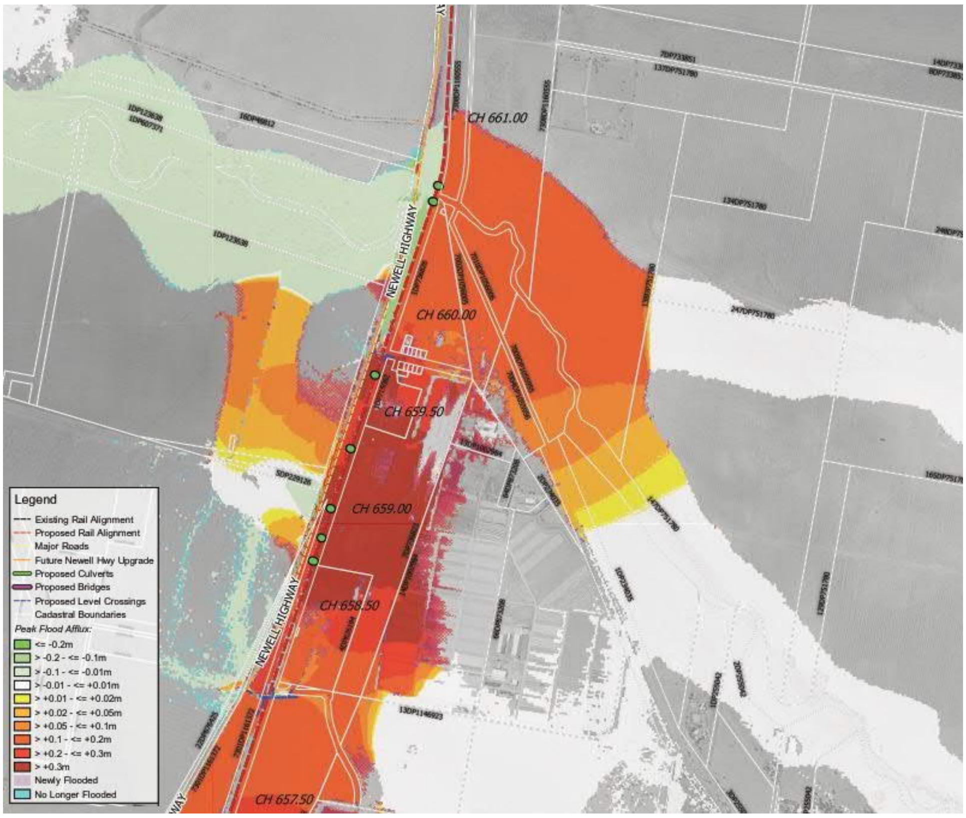



Figure D.5 0.05% AEP afflux south of Halls Creek

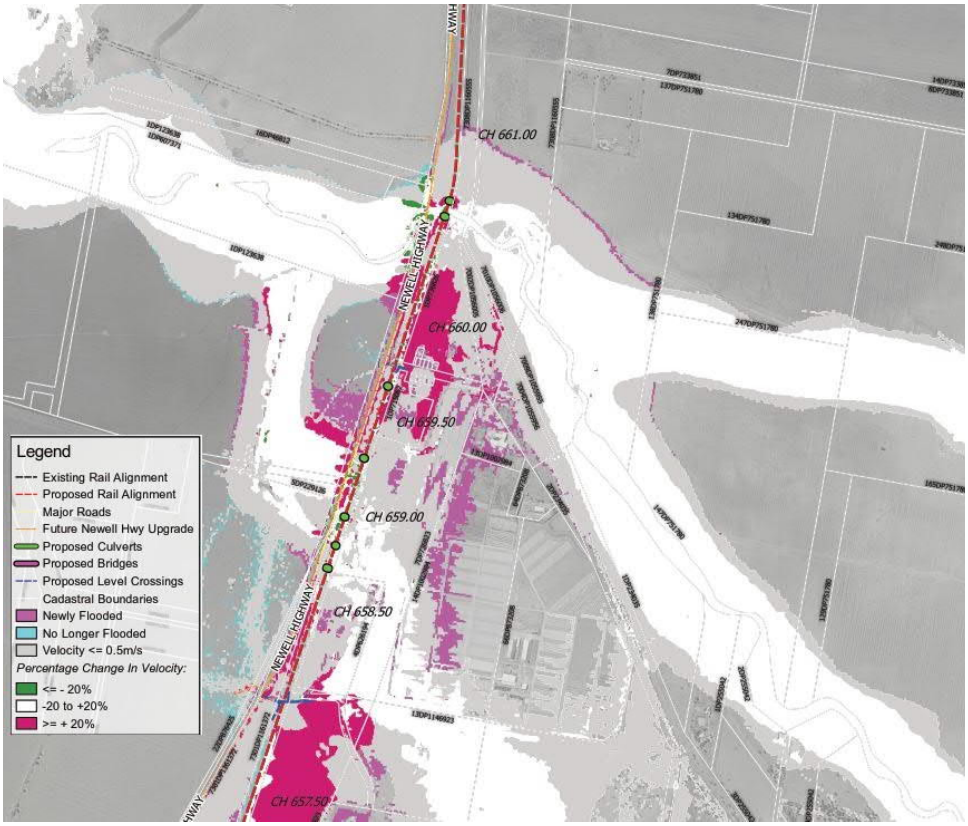



Figure D.6 0.05% AEP velocity impact south of Halls Creek

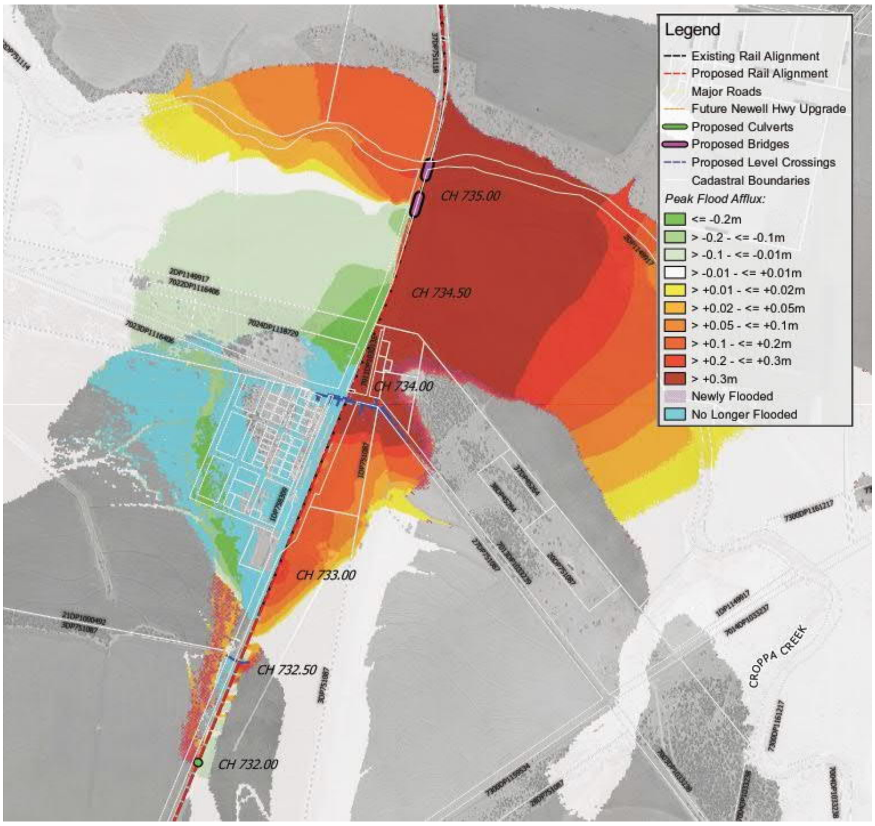



Figure D.7 0.05% AEP afflux at Croppa Creek

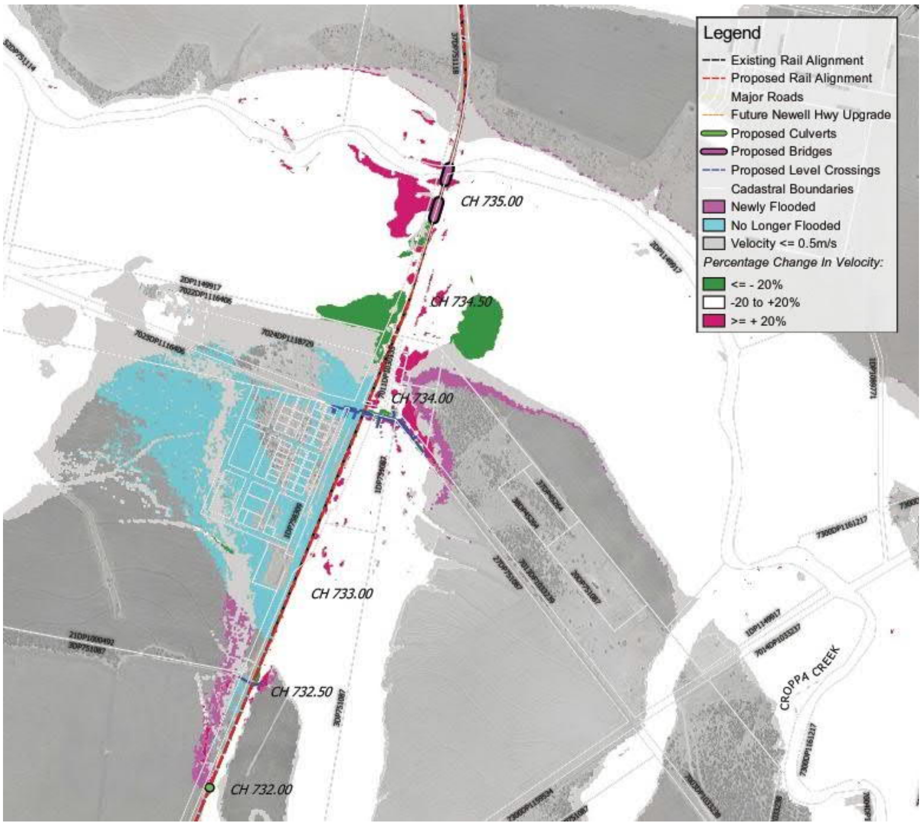



Figure D.8 0.05% AEP velocity impact at Croppa Creek

# Appendix D Map List

| Map Set | Map Set Contents | Map References |
|---|---|---|
| D01 | Flood Level Change (Afflux) 39% AEP | Figures DENH39A1 to DENH39A37 |
| D03 | Flood Level Change (Afflux) 10% AEP | Figures DENH10A1 to DENH10A37 |
| D06 | Flood Level Change (Afflux) 1% AEP | Figures DENH1A1 to DENH1A37 |
| D08 | Flood Level Change (Afflux) 0.05% AEP | Figures DENH0.05A1 to DENH0.05A37 |
| D09 | Flood Velocity Change 39% AEP | Figures DENH39V1 to DENH39V37 |
| D11 | Flood Velocity Change 10% AEP | Figures DENH10V1 to DENH10V37 |
| D14 | Flood Velocity Change 1% AEP | Figures DENH1V1 to DENH1V37 |
| D16 | Flood Velocity Change 0.05% AEP | Figures DENH0.05V1 to DENH0.05V37 |
| D17 | Flood Duration Change 39% AEP | Figures DENH39D1 to DENH39D37 |
| D19 | Flood Duration Change 10% AEP | Figures DENH10D1 to DENH10D37 |
| D22 | Flood Duration Change 1% AEP | Figures DENH1D1 to DENH1D37 |
| D24 | Flood Duration Change 0.05% AEP | Figures DENH0.05D1 to DENH0.05D37 |
| D25 | Flood Hazard Change 39% AEP | Figures DENH39H1 to DENH39H37 |
| D27 | Flood Hazard Change 10% AEP | Figures DENH10H1 to DENH10H37 |
| D30 | Flood Hazard Change 1% AEP | Figures DENH1H1 to DENH1H37 |
| D32 | Flood Hazard Change 0.05% AEP | Figures DENH0.05H1 to DENH0.05H37 |

# Appendix E

Cross Drainage Structure Blockage Assessment

# Appendix F

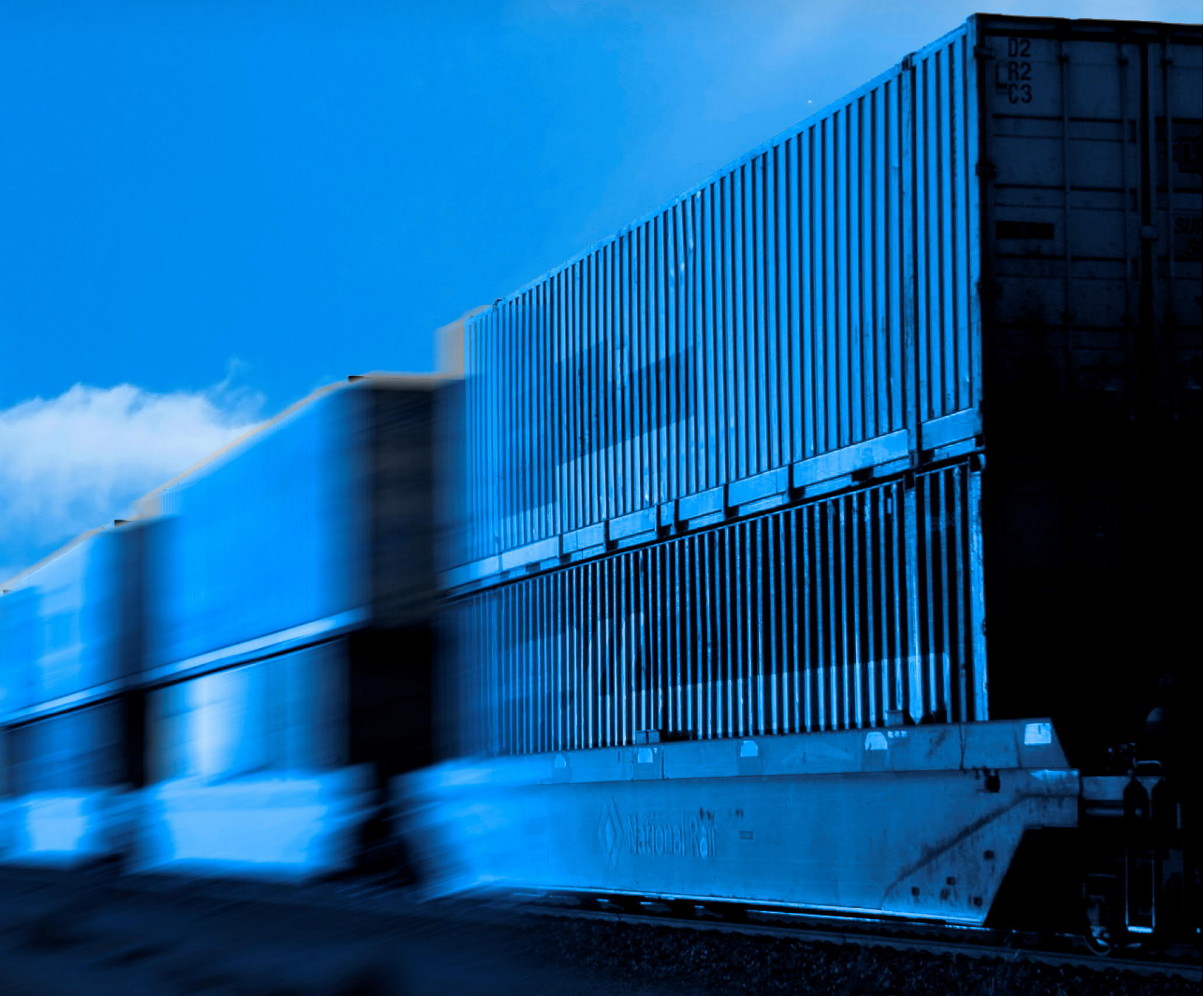
## Bridge Scour Assessments

# Appendix G

## Cross Drainage Hydraulic Parameters

# Appendix H

## Flood Emergency Response Plan



# H.1 FLOOD EMERGENCY RESPONSE PLAN REQUIREMENTS

Condition of Approval E30 sets out the requirements of the Flood Emergency Response Plan, as follows:

| Condition | |
|---|---|
| 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.<br>(a) The FERP must be prepared by an experienced flood emergency response specialist who has extensive experience in preparation of these plans.<br>(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.<br>(c) The FERP must be appended to the Flood Design Verification Report.<br>*Note: Nothing in this condition prevents the adaptation of an existing flood management or emergency plan to satisfy this condition.* |

The residual flood risk to the rail corridor following the upgrade is described in Section H.2. Existing ARTC operating procedures, codes and works instructions that address emergency management of flood risk before, during and after a flood event are described in Section H.3 and included in this appendix.

# H.2 FLOOD RISK TO THE RAIL CORRIDOR

## H.2.1 Rail flood immunity

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 Top Of Rail (TOR) 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 Work Group through application of ARTC's *Flood Risk Assessment Procedure – Upgraded Sections of Inland Rail*. The application and outcomes of the procedure are documented in the Flood Design Verification Report (3-0001-260-IHY-00-RP-0006).

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 H.1 Breakdown of TOF flood immunity

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

### H.2.2 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 H.2 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 H.2 can be used to identify areas most likely to experience damage during a flood event to inform the flood emergency response activities.

Table H.2 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<br>575 to 592.5km | Low risk: 0.25 km (1.5%)<br>Medium risk: None<br>High risk: None | None | None |
| GWYDIR01<br>592.5 to 619km | Low risk: 0.5 km (1.9%)<br>Medium risk: 0.15 km (0.6%)<br>High risk: None | 607.650 to 607.750 km | None |
| GWYDIR02<br>619 to 666km | Low risk: 8.8 km (18.7%)<br>Medium risk: 0.25 km (0.5 %)<br>High risk: None | 648.300 km<br>650.100 km<br>650.700 km<br>653.100 km<br>653.400 km | None |
| GWYDIR03<br>682 to 709km | Low risk: 0.3 km (1.1%)<br>Medium risk: None<br>High risk: None | None | None |

| Flood model | Extent of flood damage risk | Locations of medium flood damage risk | Locations of high flood damage risk |
|---|---|---|---|
| MACINTYRE01 709 to 727km | Low risk: 0.35 km (1.9%)<br>Medium risk: None<br>High risk: None | None | None |
| MACINTYRE02 | Low risk: 0.1 km (0.3%)<br>Medium risk: None<br>High risk: None | None | None |

# H.3 RELEVANT ARTC OPERATING PROCEDURES, CODES AND WORK INSTRUCTIONS

The following documents are used by ARTC to monitor and respond to flood events and manage inspections and repairs to the rail assets following flood events:

- **Monitoring and Responding to Extreme Weather Events**: This Procedure discusses the range of factors that should be considered to determine flooding and when response is required. It provides a risk matrix resulting in alert level for accessing the corridor in a range of rainfall and flooding scenarios across different geographical areas as well as action required for each alert level.
- **Engineering (Track and Civil) Code of Practice - Section 10 Flooding**: This Code of Practice refers to the design rating, construction, maintenance and inspection requirements of structures in flood impact zones and other special locations (as determined by detailed flood design). Although the Code of Practice (the Code) does not describe the detailed design process, nor lists specific structures subject to the Code, the Code references Australian Standards and design manuals to be considered. The Code indicates what inspections are imposed under different conditions as well as associated actions when identifying defects. The assessment list covers defects ranging from scour to failure and collapse.

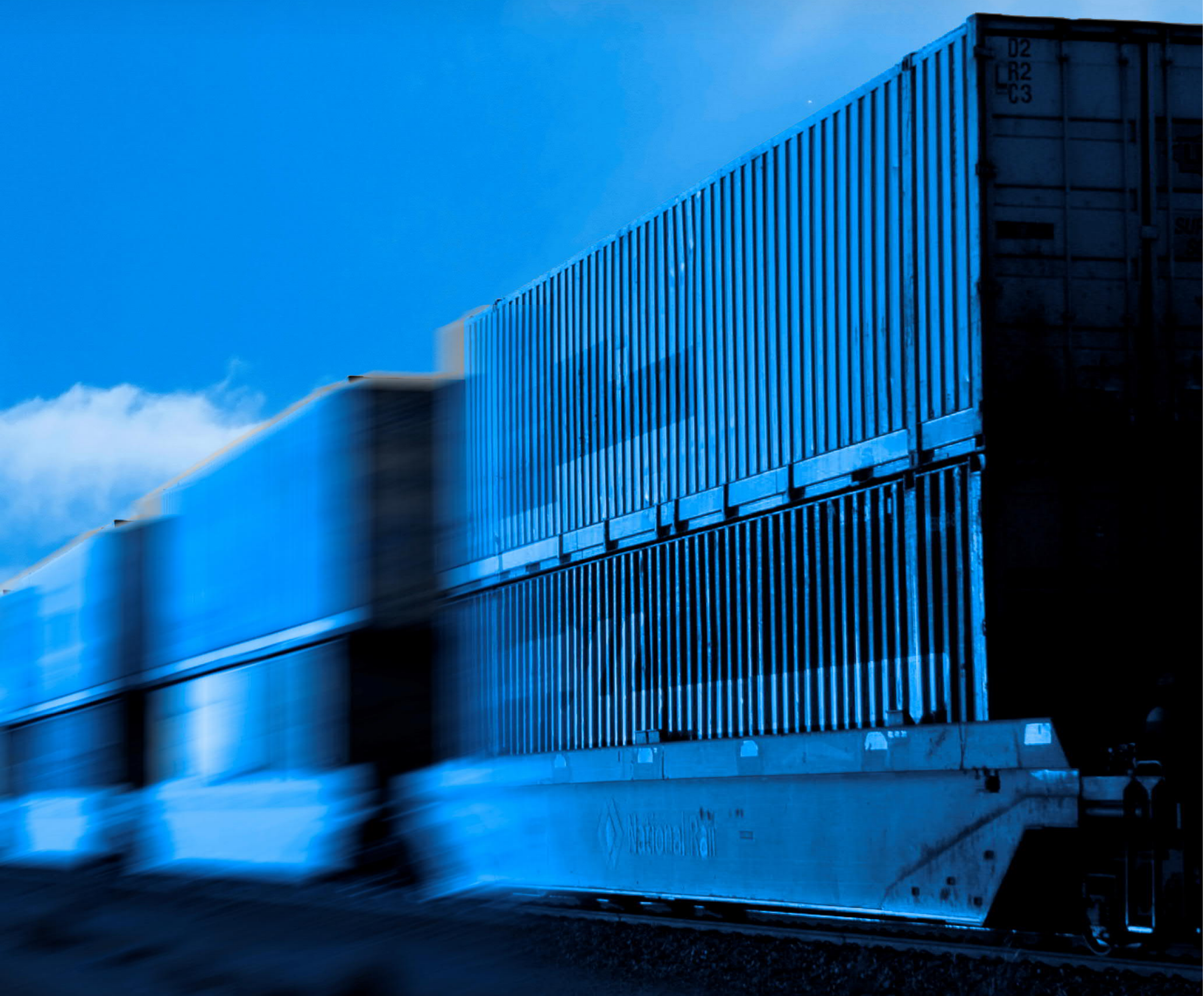
The following additional documents are also relevant to ARTC's management of emergencies and pollution incidents that may arise from damaging flood events:

- **RLS-PR-044 Emergency Management Procedure**: This Procedure applies to the whole ARTC network. It details key organisational and site management responsibilities to enable a coordinated response to emergencies on the ARTC network. The Procedure details interactions with emergency services and rollingstock operators and considers emergencies such as derailment, rollingstock or infrastructure failure, dangerous goods spill and natural disasters.
- **ENV-WI-002 Pollution Incident Response: T**his Work Instruction provides instruction on external notification of pollution incidents to regulatory authorities, notification to the affected community and engaging ARTC's environmental incident response contractor. The aim of the work instruction is to avoid and manage pollution incidents within the rail corridor and avoid offsite impacts. The Work Instruction fulfils ARTC's obligations under Part 5.7A of the NSW Protection of the Environment Operations Act with regard to preparation of a Pollution Incident Response Management Plan but applies to the entire ARTC network.

These documents are provided as attachments to this appendix.

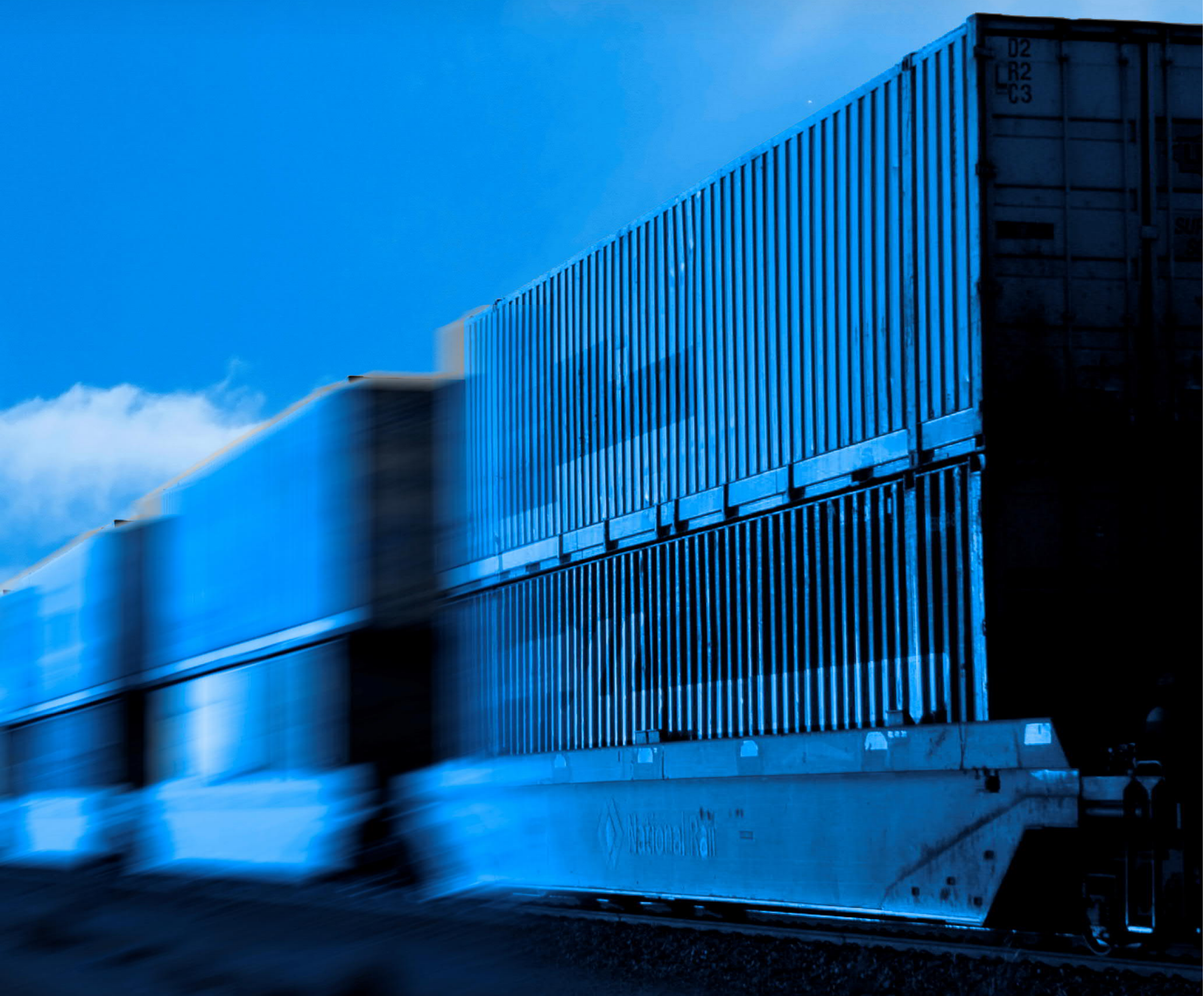
# Appendix I

## Independent Peer Review Report and IRDJV response document



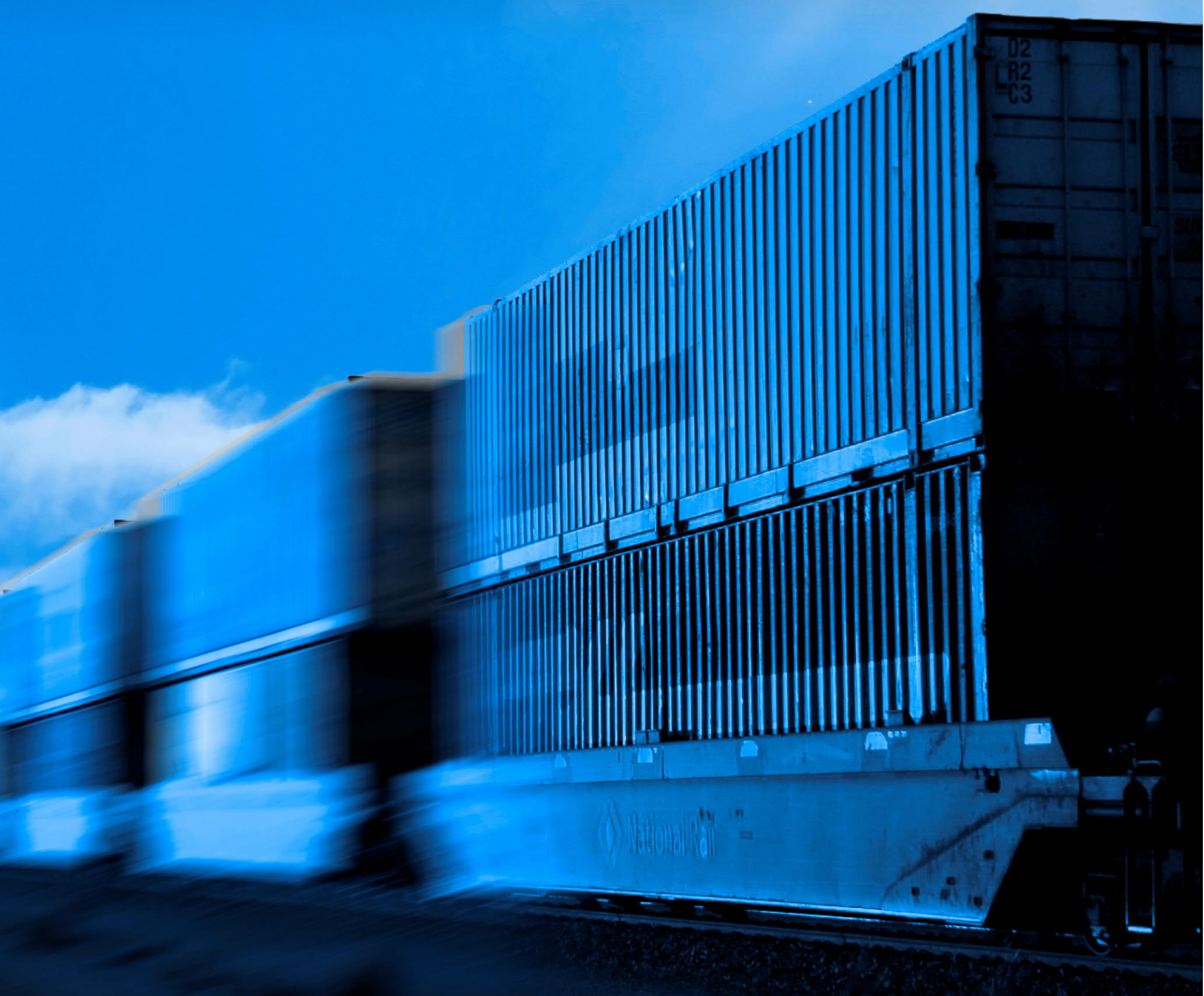
# Appendix J

## Newell Highway Impact Assessment Reports



# Appendix K

## Flood Design Verification Report Consultation Plan



# Appendix L

## Extreme Event Flood Impact Assessment