Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland

Draft Report on Review of Helidon to Calvert Section

May 12, 2021

Document History

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1	15/04/2021	Draft for review
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Executive Summary

This report details the review of the Inland Rail Helidon to Calvert (H2C) Project Flood Studies including the draft Environmental Impact Statement (EIS), design reports and supporting documents. The review has been undertaken by the Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland.

ARTC has undertaken a substantial amount of work to identify existing flooding characteristics and to assess and mitigate potential impacts associated with the H2C project alignment. This work has been reviewed thoroughly by the Panel and found to be predominately in accordance with both national guidelines and current industry best practice. However, issues have been identified, with the Panel advising that some issues be addressed within the EIS phase and others addressed in future project stages.

Significant infrastructure projects, like Inland Rail, are accomplished through an iterative process. As such, it is normal practice for iterative improvements and changes to occur through the various project stages. Therefore, it is normal for issues to be identified throughout the project, such as those identified by the Panel and for them to be progressively addressed.

The H2C section of the alignment covers two major catchments:

- Lockyer Creek
- Western Creek

Two regional flood models have been developed and fall within these catchment areas, with additional local flood models developed for minor waterways or tributaries. A review of the regional flood models has been undertaken, with model-specific details provided in Appendix A and Appendix B for Lockyer Creek and Western Creek respectively.

Review items pertaining to the two regional flood models are detailed within the report. The review items include:

- Amount of detail in the reports
- Verification to previous design stages
- Justification for level increases in the design process
- Local and regional flood modelling
- Adoption of flood models for final design
- Estimation of flows
- Model setup
- Model calibration and validation (including selection of gauging stations, event selection and use of available data)

It is stressed that all the identified issues are capable of resolution, either by adjustments to the models developed to date, or by modification to design.

1 Introduction

1.1 Abbreviations and Definitions

Abbreviation	Meaning/Definition
1D	One-dimensional
2D	Two-dimensional
AAToS	Average annual time of submergence
ARF	Areal reduction factor
ARR 2016	Australian Rainfall and Runoff: A Guide to Flood Estimation, edition current at commencement of EIS process
ARR 2019	Australian Rainfall and Runoff: A Guide to Flood Estimation, current edition
ARTC	Australian Rail Track Corporation Ltd
B2G	Border to Gowrie section
BoM	Bureau of Meteorology
BRCFS	Brisbane River Catchment Flood Study
C2K	Calvert to Kagaru
Ch	Chainage
CSSI	Critical State significant infrastructure under NSW Environmental Planning & Assessment Act 1979
D&C	Design and construct
DSDTI	Queensland Department of State Development, Tourism and Innovation
DTMR	Queensland Department of Transport and Main Roads
EIS	Environmental Impact Statement
FDR	Feasibility Design Report
FFA	Flood frequency analysis
FFJV	Future Freight Joint Venture
FIO	Flood impact objective
G2H	Gowrie to Helidon section
H2C	Helidon to Calvert section

Abbreviation	Meaning/Definition
ICC	Ipswich City Council
IFD	Intensity – Frequency – Duration
JWG	The Joint Working Group of DTMR and IA
K2ARB	Kagaru to Acacia Ridge and Bromelton
LGA	Local government area
LiDAR	Light Detection and Ranging, a method of remote airborne laser scanning
LVRC	Lockyer Valley Regional Council
NS2B	North Star to Border section
OCG	Office of the Queensland Coordinator General, DSDTI
PMF	Probable Maximum Flood
PPP	Public private partnership
QDL	Quantitative design limits, from other sections of Inland Rail
QR	Queensland Rail
RCBC	Reinforced concrete box culvert
RCP	Reinforced concrete pipe
RFFE	Regional Flood Frequency Estimation approach[1]
RISSB	Rail Industry Safety and Standards Board
ToR	Terms of reference

1.2 The Panel

An Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland (the Panel) has been appointed for the Queensland Department of Transport and Main Roads' (DTMR) Rail Planning Directorate out of Policy, Planning and Investment Branch and the Australian Government Department of Infrastructure, Transport, Regional Development and Communications (IA). The Panel reports to a Joint Working Group (JWG) from the two departments.

[1] ARR 2019 design flood estimate approach for projects on small to medium sized ungauged catchments

Table 1-1: Panel Details

Name	Company
Mark Babister (Chair)	WMA Water
Ferdinand Diermanse	Deltares
Tina O'Connell	HDR
Martin Giles	BMT
Steve Clark	Water Technology

1.3 Terms of Reference

ARTC has taken various steps to ensure it has accurate and representative flood modelling across four packages in Queensland: Border to Gowrie (B2G), Gowrie to Helidon (G2H), Helidon to Calvert (H2C) and Calvert to Kagaru (C2K). It has:

- engaged specialist flood modelling firms Aurecon and AECOM (the Future Freight Joint Venture, FFJV) to develop customer place-based flood models;
- extensively upgraded its flood modelling to consider contemporary LiDAR topographical data; and
- engaged with the LGAs, community and individuals to calibrate and validate the hydrology and hydraulic modelling.

The Panel has focused on identifying whether, and to what level, industry best practice has been applied to flood modelling techniques and outputs that created the existing flood models in four core areas: extent, assumptions, application and interpretation. The table below shows specifics and where these topics are addressed in this report.

Table 1-2: Addressing the Panel's ToR

Topic	Section Addressed
Extent	
Applicability and appropriateness for the relevant design stage (e.g. reference/detailed etc.)	Appendices A to B
Appropriateness of tool/s selected for flood modelling	Sections 6 and 7
Confirmation that key design criteria are considered reasonable and appropriate compared with typical similar linear infrastructure projects	Section 3 and 4
Assumptions	
Appropriateness of model arrangements and input parameters	Sections 6 and 7
Appropriateness of model calibration process	Section 8, Appendices A to B
Appropriate application of input data (including addressing data gaps)	Appendices A to B

Topic	Section Addressed
Assumptions around land-use (crops etc.)	Appendices A to B
Appropriateness of blockage/debris assumptions	Appendices A to B
Appropriateness of future events application, e.g. climate change	Section 2.7
Appropriateness of assumed soil conditions	Appendix C
Application	
Appropriate sensitivity analysis to various items e.g. flow inputs, coefficients	Sections 3, 4, 5
Appropriateness of change indicators	Section 3
Appropriateness of structure and embankment representation (depending on the stage of the design)	Section 7
Flood frequency analysis	Section 6.6
Interpretation	
Achievement of Design Criteria	Appendices A to B
Appropriateness of relevant sensitivity analysis	Appendices A to B
Confirm Inland Rail-related flood impacts, if any, are comprehensively quantified and interpreted to their local property context	Appendices A to B
Appropriateness of the alignment, with regard the related flood impacts, within the current EIS Study Corridor	Appendices A to B
Consider whether reasonable and practical steps have been taken to mitigate flood impacts, if any, outside of the project boundary	Appendices A to B
Additional information that would be required to be addressed in the detailed design phase of the program.	Section 13

1.4 Overview of the Flood Models Reviewed

The H2C section of the alignment has been split into two regional catchment flood models, as shown in Figure 1-1:

- Lockyer Creek
- Western Creek

Lockyer Creek directly flows into the Brisbane River, whilst Western Creek flows into the Bremer River, which passes through Ipswich before also joining the Brisbane River. The Western Creek model is part of the larger Bremer River model that was reviewed when the Panel considered the C2K section. The detailed review of the Bremer River model is provided in Appendix A of the *Draft Report on Review of Calvert to Kagaru Section.*

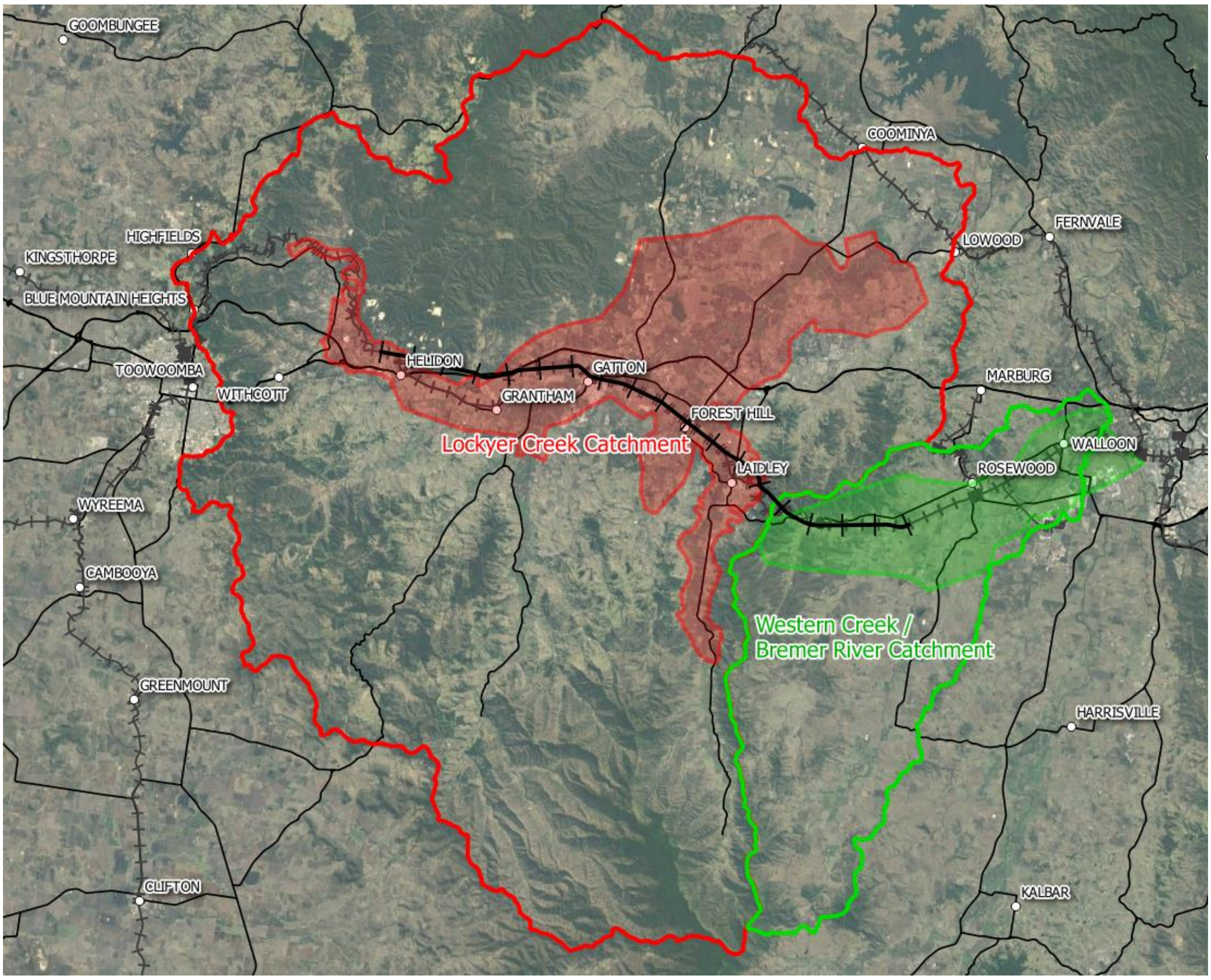

Figure 1-1: Site Location. The coloured areas represent the hydraulic model extents.

The H2C alignment largely follows the existing Queensland Rail (QR) West Moreton Line alignment.

This report outlines the findings of the Panel's review of the regional flood models. Further details on the specific findings for each of the regional catchment flood models can be found in Appendix A and Appendix B.

The Terms of Reference lists, and FFJV through ARTC have provided, the following flood models to be reviewed by the Panel.

Table 1-3: Helidon to Calvert (H2C) Hydrologic Models Reviewed

ToR Listing	Hydrology			
	Software & Version	Short Name	Long Name	Model Date
1. Lockyer Creek, large	URBS	LOC	Lockyer Creek	August 2020
2. Western Creek, large	URBS	WEC	Western Creek	August 2018

Table 1-4: Helidon to Calvert (H2C) Hydraulic Models Reviewed

ToR Listing	Hydraulics			
	Software & Version	Short Name	Long Name	Model Date
1. Lockyer Creek, large	TUFLOW	LOC	Lockyer Creek	June 2020
2. Western Creek, large	TUFLOW	WEC	Western Creek	June 2019

Appendix C deals with the geomorphology across the entire H2C section.

1.5 Reports and Other Documents

The Panel has completed an extensive review of the Environmental Impact Statement (draft EIS) documents, specific sections of the Feasibility Design Report (FDR) and other technical memorandum prepared for the H2C section of the proposed Inland Rail alignment along with the corresponding hydrological and hydraulic models that underpin this work.

1.5.1 Main Draft EIS Documentation

The following documents were mainly examined as part of the review:

- *Inland Rail Helidon to Calvert EIS, Chapter 13 Surface Water and Hydrology*, Revision 0.1, 18 March. (Future Freight Joint Venture, March 2020)
- *Inland Rail: Phase 2 – Helidon to Calvert EIS, Appendix M – Hydrology and Flooding Technical Report*, Revision 4, 9 February. (Future Freight Joint Venture, February 2021)
- *Inland Rail: Phase 2 – Helidon to Calvert, Volume 1: Feasibility Design Report, Section 8 Drainage*, Revision 0, 25 February. (Future Freight Joint Venture, February 2020)

The FDR details the methodology and corresponding results used to assess the longitudinal drainage and cross drainage for the local catchments along the rail alignment that are located within the regional catchments but removed from the main waterways. According to Table 42 of the FDR, local catchments are defined as those catchments less than 100 km^2 in area and regional catchments are those greater than 100 km^2. Catchments with areas less than 10 km^2 were classified as minor and catchments between 10 km^2 and 100 km^2 were classified as moderate.

It is important to note that the FDR does not form part of the flood models to review under the ToR of the Flood Panel.

The FDR states:

> *"Cross drainage structures outside the regional floodplains were sized based on the flows generated from the local drainage catchments. Cross drainage structures that have a well-defined local catchment boundary and are located within or near the regional floodplains were assessed for both the local catchment flows and regional floodplain conditions to determine the governing design conditions.*

> *The structures which are governed by the regional floodplain flows have been assessed within the regional flood models and have been marked as "Regional" in the Cross-Drainage Register."*

The results of the local catchment assessment and the flood impact associated with the adopted drainage structures at a local level have been included in the draft EIS and the Technical Report at the behest of the Panel. The Panel was not provided with copies of the flood models developed with respect to the local catchments and therefore the review of local catchment modelling only used the information that is presented in the FDR.

1.5.2 Supporting Draft EIS Documentation

Additional supporting documentation that was provided to the Panel included:

- *Inland Rail Helidon to Calvert EIS, Rail Civil – Plan and Profile – Sheets 1 to 16*, Revision 0, 29 November. (Future Freight Joint Venture, November 2019)
- *Inland Rail Helidon to Calvert EIS, Chapter 5 Stakeholder Engagement*, 13 November. (Future Freight Joint Venture, November 2020)
- *Inland Rail Helidon to Calvert EIS, Chapter 6 Project Description*, 30 October. (Future Freight Joint Venture, October 2020)
- *Inland Rail Helidon to Calvert EIS, Chapter 9 Land Resources*, 29 October. (Future Freight Joint Venture, October 2020)
- *Inland Rail Helidon to Calvert EIS, Chapter 20 Hazard and Risk*, 29 October. (Future Freight Joint Venture, October 2020)
- *Inland Rail Helidon to Calvert EIS, Appendix C – Consultation Report*, 13 November. (Future Freight Joint Venture, November 2020)
- *Inland Rail Helidon to Calvert EIS, Appendix G – Directly Impacted Properties*, 11 July. (Future Freight Joint Venture, July 2020)
- *Inland Rail Helidon to Calvert EIS, Appendix L – Surface Water Quality Technical Report*, 9 February. (Future Freight Joint Venture, February 2021)

1.5.3 Other Supporting Documentation

Other internal reports made available for review include:

- *Results for 330 Helidon to Calvert – Change Notice 330-CN-0062: Forest Hill Extreme Events*, 26 June. (Future Freight Joint Venture, June 2019)
- *Review – Inland Rail: Phase 2 Helidon to Calvert Hydrology and Flooding Technical Report Memorandum*, 28 June. (WMAwater, June 2019)
- *Technical Note: H2C Value Engineering – Structures – Flood Requirements*, 25 October. (Future Freight Joint Venture, October 2019)
- *Waters Road – Potential Options to Reduce Impacts Noted by Ipswich City Council*, 6 February. (Future Freight Joint Venture, February 2020)
- *WMAwater – Phase 2 Helidon to Calvert Hydrology and Flooding Technical Report Review*, 20 February. (Future Freight Joint Venture, February 2020)
- *Comparison of Ipswich Rivers and FFJV Bremer River Flood Studies*, March 2020. (Future Freight Joint Venture, March 2020)

- *Ipswich Rivers and FFJV Flood Study – Impacts Comparison*, March 2020. (Future Freight Joint Venture, March 2020)
- *FFJV Response to Expert Flood Panel questions (25/03/21) on Helidon to Calvert Package,* March 2021. (Future Freight Joint Venture, March 2021)

2 Relevant National and State Guidelines for Flood Modelling and the Design of Structures

ARTC produced an *Inland Rail Basis of Design Report* (Australian Rail Track Corporation, July 2020) and specifically Chapter 8 of that report deals with hydrology and hydraulics. This section deals with flood modelling and bridge and waterway design guidelines discussing usual and best international practice.

2.1 ARR 2016

In Australia, best practice design flood estimation is defined by Australian Rainfall and Runoff. Australian Rainfall and Runoff was recently updated in 2016/2019. The document and supporting software provide methodologies and inputs to the design process. For example, intensity frequency duration (IFD) information, how rainfall falls in space, how rainfall falls in time (temporal patterns) and losses.

The EIS process has used the 2016 version whilst in the meantime ARR 2019 has been published. ARR 2019 is a result of extensive consultation and feedback from practitioners. Noteworthy updates are listed in Table 2-1.

Table 2-1: Key Technical Updates in ARR 2019

Update	ARR2016	ARR 2019
Book 9 Runoff in Urban Areas	Available as “rough” draft	Peer reviewed and completed
Climate change	Reflected best practice as of 2016 Climate Change policies	Updated to reflect current practice
PMF chapter	Updated from the guidance provided in 1998 to include current best practice	Minor edits and reflects differences required for use in dam studies and floodplain management
Figures		Updated, reflecting practitioner feedback

While ARR 2016 represents a stepwise change from the 1987 edition, based on the above table there is little difference in applying the methodology of 2016 or 2019 for the H2C EIS process.

Any new project would be expected to use the ARR 2016/2019 design inputs. Projects that began between 2013 and 2019 may use some of the new design inputs and methodology but may also use the older ARR 1987. A change to the newer inputs may be expected in a future phase of a linear infrastructure project.

2.2 Flood Modelling Guidelines

Flood modelling is a powerful tool that is used in flood forecasting, understanding flood risk, the impact of development and flood behaviour where no data has been recorded. Flood models are mathematic representations of the natural and manmade environment that represent all the key processes that cause and affect flood behaviour. Flood modelling is usually divided into hydrologic and hydraulic modelling with hydrologic models providing the input into hydraulic models.

Hydrologic models, which in case of flood modelling are also called rainfall runoff models, represent the process of rainfall producing runoff and the routing of this runoff down gullies and drainage lines to creeks and rivers. The key output of these models is flow hydrographs that describe how flow varies with time at key locations during a flood event. Whilst flow hydrographs represent the overall catchment response, they do not provide information on the level of flooding or how obstructions or changes to the floodplain affect local flood behaviour. Hydraulic models are used for that objective.

Hydraulic models represent the complex process of flow in rivers and floodplains and the flow through bridges or culverts. Flood modelling is generally carried out using two dimensional schematisations of the area that contain a detailed representation of the terrain and waterway structures. These model schematisations cover an area where detailed flood behaviour is desired, plus sufficient additional area upstream and downstream so that assumptions at the model boundaries do not affect the area of interest. Hydraulic models provide very detailed spatial information on:

- Flood depths and levels
- Velocities
- Flows through a waterway opening
- Flow distributions between waterways and floodplains

These models are used to work out how new or upgraded bridges, culverts, embarkments and levees change flood behaviour.

Hydrologic and hydraulic models are setup using data such as rainfall or ground levels that can be measured and parameters that are adjusted within a typical range to reproduce observed flood behaviour. This process of parameter adjustment is called calibration where the model is “tuned” or adjusted to match observed behaviour. This usually involves modelling several historical floods to ensure the key process are being reproduced correctly. Good flood modelling practice is to calibrate to several events and then validate the model using several other events. This process ensures that the models can be used as predictive tools.

To undertake flood modelling on floodplains in Queensland, the national guideline is ARR 2019 *Book 7: Application of Catchment Modelling Systems* (Ball, et al., 2019)

Supplementing this is *Hydrologic and Hydraulic Modelling Technical Guideline* (Queensland Department of Transport and Main Roads, 2019).

2.3 Background on Bridge and Waterway Design and Guiding Principles

In Australia, bridge waterway hydrology and design has been the remit of Austroads (formerly NAASRA) for many years. In early 2019, Austroads modernised its guide on waterway structures into its Guide to Bridge Technology as *Part 8: Hydraulic Design of Waterway Structures* (Austroads, 2019). This publication provides guidance on the probability of design floods that should be utilised for the design of the various aspects of a stream crossing; the methods available to a design engineer for estimating design flood discharges in accordance with *Australian Rainfall and Runoff:*

A Guide to Flood Estimation (Ball, et al., 2019); the hydraulic design of bridges; the estimation of scour at bridges and the design of works for the protection of bridges, culverts and floodways from the effects of scour.

DTMR has a suite of relevant supplementary guidelines:

- *Bridge Scour Manual* (Queensland Department of Transport and Main Roads, 2019)
- *Design Criteria for Bridges and Other Structures* (Queensland Department of Transport and Main Roads, 2020).

2.4 Rail Infrastructure

ARTC has produced the *Engineering (Track & Civil) Code of Practice* (Australian Rail Track Corporation Ltd, 2011), which in turn references the RISSB National Code of Practice (not available to the Panel and JWG): *Australian Standard Rail Networks Code of Practice Volume 4, Track, Civil and Electrical Infrastructure* https://www.rissb.com.au/products/code-of-practice-track-civil-and-electrical-infrastructure/

- Part 1 - Infrastructure Management
- Part 2 – Principles Issue
- Part 3 - Infrastructure Guidelines

Section 10: Flooding of ARTC's Code of Practice requires the waterway and drainage design to be undertaken in accordance with ARR and Australian Standards, specifically AS 5100 *Bridge Design* and *Waterway Design Manual*[2]. A further Australian Standard is AS 7637:2014: *Railway Infrastructure – Hydrology and Hydraulics*.

2.4.1 Corridor Cross Drainage

The Basis of Design Report lists the following additional internal specifications as key documents for corridor cross drainage:

- ARTC: ETC-08-03 Earthworks Materials Specification
- ARTC: ETC-08-04 Earthworks Construction Specification

2.4.2 Corridor Longitudinal Drainage

The Basis of Design Report lists the following additional internal specifications as key documents for corridor longitudinal drainage:

- RTS 3430 Track Reconditioning Guidelines (Interim)
- RTS 3432 Track Drainage – Inspection and Maintenance (Interim)

[2] The ARTC Code of Practice – Flooding, 2011, additionally references in section 10.1.1 a manual called "Waterway Design Manual". The ARTC technical library links the reference to the now superseded Austroads document from 1994 titled "Waterway Design: A guide to the hydraulic design of bridges, culverts and floodways". The FFJV technical reports for Hydrology and Flooding, Section 4.4 lists the Relevant Standards and Guidelines. This superseded Austroads document is not listed. (Foster, D. (2020). [EXT] RE: B2G review - International Independent Flood Panel - preliminary feedback. [Email])

- RTS 3433 Track Drainage – Design and Construction
- ETC-08-04 Earthworks Construction Specification

2.4.3 Corridor Diversion Drainage

The Basis of Design Report lists no specific standards for corridor diversion drainage, however, the standards referenced for hydrology (flooding) and corridor longitudinal drainage are both specifically relevant to the consideration of any potential diversion drainage works.

2.5 Usual and Best Practice

The flood models that were provided were reviewed by the Panel to see if they followed best practice, including recommended parameters, as outlined in this document, in addition to the specific software manuals.

In Australia, best practice design flood estimation is defined by Australian Rainfall and Runoff. Best practice hydraulic modelling is defined by *Australian Rainfall and Runoff Revision Project 15: Two-dimensional Modelling in Urban and Rural Floodplains* (Babister and Barton, November 2012). ARR Project 15 was written by the leading practitioners in the field and provides guidance on how to develop a hydraulic model.

2.5.1 Floodplain Management

Whilst H2C Inland Rail will not explicitly impact on management of the floodplains in the two regional catchments, the designer should be familiar with common floodplain management practices. The references listed in the Panel's ToR for this include:

- *Australian Government (2013) Managing the floodplain: a guide to best practice in flood risk management in Australia, Australian Emergency Management Handbook Series*, Canberra. Australian Institute for Disaster Resilience (2017) https://knowledge.aidr.org.au/resources/handbook-7-managing-the-floodplain/
- *State Planning Policy – State Interest Guidance Material – Natural hazards, risks and resilience – Flood*, Department of Infrastructure, Local Government and Planning (2017), https://dilgpprd.blob.core.windows.net/general/spp-guidance-natural-hazards-risk-resilience-flood.pdf
- *Planning for Stronger, More Resilient Floodplains Part 1 Interim Measures and Part 2 – Measures to support floodplain management in future planning schemes*, Queensland Reconstruction Authority; 2014.

2.5.2 Assessing Linear Infrastructure in Australia

Typically for linear infrastructure, a flood model may be developed from scratch or an existing model used by Council for floodplain management may be modified. Modifications to the flood models are expected to be:

- Split of the hydrologic model subcatchments where the project splits or diverts flows;
- Modification of the hydraulic model terrain to represent the rail/road embankment; and
- Addition and/or removal of culverts and bridges.

The impact of the linear infrastructure is assessed by comparing the existing conditions with the post-construction scenario. There is no national guidance on the assessment of impacts. ARR Project 15 authors recognised that some guidance was required on the reporting of flood level impacts. At the time of writing of the two-dimensional flood modelling guides, there was a trend to report impacts to the nearest 1mm. The authors of the two-dimensional flood modelling guidelines recommended that impacts should not be reported below 10mm except when reporting contribution to a cumulative impact.

The following factors were identified as requiring consideration when reporting impacts (Babister and Barton, November 2012):

- scale and extent of the impact;
- accuracy of flood model;
- accuracy of topography; and
- spurious impacts that are not real.

It is also noted that Part 5 of the draft update to Austroads *Guide to Road Design* has a specific discussion on acceptable flood impacts for linear infrastructure, including infrastructure in rural areas.

2.5.3 International Practice

The references listed in the Panel's ToR for this include:

- *Evaluating Scour at Bridges*, Hydraulic Engineering Circular Number 18 (HEC-18), Fourth Edition, US Department of Transport – Federal Highway Administration, Virginia, USA, Richardson, EV and Davis, SR: 2001
- *Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular Number 14 (HEC-14)*, Third Edition US Department of Transport – Federal Highway Administration, Virginia, USA, Thompson, PL & Kilgore, RT; 2006

2.5.4 European Approaches

In 2017, a comparison was made between adopted approaches in various countries in Europe regarding water management in relation to linear infrastructure[3]. The comparison was made on the following topics:

- Cross-drainage;
- Longitudinal drainage; and
- Precipitation on the road.

Climate change is explicitly considered in the design in only some European countries, by adopting stricter standards of assuming an increase in precipitation intensity in the IFD curves.

[3] CEDR WATCH project, country comparison report, June 2017 (https://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2015/call-2015-climate-change-desk-road/)

2.5.4.1 Cross-drainage

Two main approaches are applied for calculation of design flows for bridges and culverts. These are:

- **Flood Frequency Analysis**: deriving extreme value statistics from the use of gauge flow data in combination with (extreme value) statistical methods; and
- **Design Event Approach**: an estimation of the design flows based on rainfall statistics in combination with runoff models (or runoff coefficients).

Design standards for cross-drainage structures are generally stricter compared to those for longitudinal drainage and precipitation on the road. In most European countries, design standards are return periods in the order of 100 to 200 years, but in some countries return periods of 10 to 25 years are used.

2.5.4.2 Longitudinal Drainage

The standard approach to manage longitudinal drainage is the use of ditches (referred to as table drains in Australia). Manning's equation is often used to obtain design dimensions of the ditches. Runoff computations are carried out with relatively straightforward hydrological methods, of which, the Rational Method is the most commonly used. Precipitation input for these calculations is in the form of IFD curves. Design standards range between 25 years and 100 years return period.

2.5.4.3 Precipitation on the Road

The standard approach for drainage and conveyance design is the use of dynamic calculations. Input regarding precipitation for those calculations is mostly in the form of IFD curves. Design standards vary substantially between countries; some countries use return periods of 5 years or even less, while other countries use return periods of 200 years. Dynamic calculations are made for several durations. In general, the prevailing duration of precipitation for the design of the road surface is in the order of 5 to 10 minutes and for the design of storm water management systems (conveyance) in the order of minutes to 6 hours.

Issues of embankment drainage and aquaplaning associated with direct precipitation on the formation are not applicable to the ballast and rail of the H2C alignment.

2.5.5 Summary

This review of the flood studies of Inland Rail for the H2C section by the independent Panel gives assurance for concerned stakeholders of this “point in time” design being best practice.

2.6 Greenfields and Brownfields Linear Infrastructure Philosophy

When new or upgraded infrastructure is designed across a floodplain or crossing a defined watercourse, two types of flood modelling are warranted: flood immunity studies and flood impact assessment.

In addition to the standards and guidelines previously identified in this section, the following apply to flood impact and immunity studies:

- *Guide to Road Design Part 5: Drainage – General and Hydrology Considerations*, Sydney (Austroads, 2013)
- *Guide to Road Design Part 5B: Drainage – Open Channels, Culverts and Floodways*, Sydney (Austroads, 2013c)
- *Road Drainage Manual* (Queensland Department of Transport and Main Roads, 2019)
- *Guidelines for Road Design on Brownfield Sites* (Queensland Department of Transport and Main Roads, 2013)

2.7 Climate Change Risk Assessment

DTMR has recently published guidance on undertaking climate change risk assessments on infrastructure projects. With regard to the application of climate change to the design of infrastructure within Transport Act corridors in Queensland, DTMR has *Climate Change Risk Assessment Methodology* (Queensland Department of Transport and Main Roads, March 2020) which was first published as an interim draft in July 2019.

Climate change risk assessments are assessments of the consequence and likelihood of climate-related hazards and opportunities (direct, indirect and transitional) to an asset occurring during a nominated timeframe or an asset's design life. Climate projections are used to identify hazards, or changes in hazards, that may affect an asset, and to identify the consequence and likelihood of that hazard occurring. The department's Climate Change Risk Assessment guidance has been developed to complement and support climate change assessment requirements within Infrastructure Australia's *Assessment Framework* (Infrastructure Australia, March 2018).

For this major project, if applying the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability Rating Scheme[4] and meeting the DTMR risk assessment method, it is difficult to achieve climate credits without incorporating appropriate climate change induced rainfall intensities to hydrologic/hydraulic design of the flood immunity of Inland Rail.

DTMR's climate change risk assessment methodology was published after this EIS process began. However, DTMR has always required the most up-to-date application of climate change impacts to the planning and design of its projects (*Roads Drainage Manual* (Queensland Department of Transport and Main Roads, 2015).

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[4] An Infrastructure Sustainability (IS) rating scheme for planning, design, construction and operations of infrastructure assets.

3 Design Criteria – Flood Impact Objectives

3.1 Overview

The draft EIS includes inward-facing hydraulic design criteria and outward-facing flood impact objectives. The design criteria address the serviceability and longevity requirements adopted for the asset, whilst the objectives reflect the need to protect the environment and minimise impacts to existing infrastructure (such as roads), land uses and buildings.

At this time in the project progression, the objectives necessarily do not reflect absolute requirements and provide guidance with respect to the impact that is likely to be acceptable. Due to the length of the corridor and the variable nature of flooding, it is not feasible to define impact limits that can be rigidly applied to the entire route. Local, site specific conditions will need to be considered to confirm whether an impact at a particular location that does not nominally meet the objectives is acceptable.

Despite this, it is necessary for the objectives with respect to relevant flood-related criteria to be sufficiently well defined to allow potential adverse impacts to be identified, trigger further investigation and then further considered relative to the objectives and local conditions.

A summary of the Panel's comments on the Flood Impact Objectives is provided in the following sections.

3.2 Adopted Flood Impact Objectives

Table 3-1 shows the Flood Impact Objectives (***FIOs***) extracted from Chapter 13 of the draft EIS.

Table 3-1 Flood impact objectives

Parameter	Objectives				
Change in peak water levels[1]	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops, etc.)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses, etc.)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm	≤ 50 mm	≤ 100 mm	≤ 100 mm	≤ 200 mm with localised areas up to 400 mm
	Changes in peak water levels are to be assessed against the above proposed limits. It is noted that changes in peak water levels can have varying impacts upon different infrastructure/land and flood impact objectives were developed to consider the flood sensitive receptors in the vicinity of the Project. It should be noted that in many locations the presence of existing buildings or infrastructure limits the change in peak water levels.				
Change in duration of inundation[1]	Identify changes to time of inundation through determination of time of submergence (ToS). For roads, determine the average annual time of submergence (AATOS) (if applicable) and consider impacts on accessibility during flood events. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.				
Flood flow distribution[1]	Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas. Identify any changes and justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.				
Velocities[1]	Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures taking into account existing soil conditions. Justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.				
Extreme event risk management	Consider risks posed to neighbouring properties for events larger than the 1% AEP event to minimise unexpected or unacceptable impacts.				
Sensitivity testing	Consider risks posed climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with Project alignment for both scenarios.				

Table note:

1 These flood impact objectives apply for events up to and including the 1% AEP event.

It is important to note that the objectives were only used to guide the project design. The objectives were not used as absolute design criteria. Further, the objectives do not nominate acceptable durations of inundation.

Section 13.5.2.2 of Chapter 13 of the draft EIS notes that *'acceptable impacts will ultimately be determined on a case by case basis with interaction with stakeholders/ landholders through the community engagement process using these objectives as guidance'*.

Whilst such an approach is reasonable, it does rely on the development of appropriate solutions given local constraints and open liaison with key stakeholders and landowners.

It also potentially relies on key stakeholders and landowners having a reasonable degree of understanding of hydraulic processes. Whilst landowners tend to have a wealth of knowledge regarding flooding conditions, this understanding may not extend to an appreciation of the impact of development on the use of their land based on the information supplied in the draft EIS.

Following discussions with representatives of ARTC, it is understood that there is an expectation that flood impact design criteria will be nominated where appropriate as part of the conditions of approval and that it will be necessary for the detailed design to be adjusted subsequent to the approval as necessary to satisfy the conditions. The conditions will therefore have to recognise consultation undertaken with stakeholders and landowners whilst also ensuring that the flood impacts of the works will ultimately be acceptable.

3.3 Observations Regarding Flood Impact Objectives

The following observations are made by the Panel regarding the FIOs that have guided the flood modelling and feasibility design completed with respect to H2C.

3.3.1 Change in Peak Water Level Constraint

The FIOs nominate flood impact limits with respect to a range of scenarios. This approach is appropriate because the ability to tolerate changes in flood level will depend on the situation being considered. The reasonableness of the nominated tolerances is discussed below:

- **Habitable/commercial buildings:** The nominated 10 mm or less impact is generally in accordance with standards in urban areas with stringent planning schemes (for example Brisbane City Council LGA) and may be more severe than some of the LGA requirements that the alignment traverses. For habitable areas, the nominated tolerance is reasonable. The FIO agree with performance criteria from the Basis of Design (Australian Rail Track Corporation, July 2020), which states *"the increase in flood level above the floor level of buildings must be less than 0.01 m"*. With floor levels and building type of all buildings within the flooded extent yet to be surveyed, in this phase of design, it is appropriate not to differentiate between over floor and under floor flooding criteria.
- **Areas associated with residential or commercial/industrial buildings (for example yards):** The adopted constraint of 50 mm or less where flooding does not impact dwellings/buildings is less stringent than some urban areas (for example Brisbane City Council LGA). Although an increase in flood level of this order could be unacceptable in certain situations (that is, where new building works or subdivisional approval is already granted under local planning schemes), the adopted tolerance is considered to be sufficient for the purpose of initial guidance.
- **Existing non-habitable structures:** The constraint of 100 mm or less may not be appropriate and needs to be considered on a case-by-case basis. However, the adopted tolerance is sufficient for the purpose of initial guidance. The FIO does not agree with performance criteria from the Basis of Design (Australian Rail Track Corporation, July 2020) which states *"the increase in flood level above the floor level of buildings must be less than 0.01 m*", with no differentiation between habitable and non-habitable floors.

- **Roadways:** The constraint of 100 mm or less may not be appropriate depending on the situation being considered**.** The matters to be considered in relation to the acceptability of an impact at a road include:
  - What is the relative importance of the road (e.g. is it a main road or a critical escape route where there is a reduced ability to accept increases in flood level) and are there alternate flood free routes?
  - Would an increase in depth of 100 mm change the flood hazard classification?
  - Would an increase of less than 100 mm result in changes in flood immunity or time of submergence?
  - The impact on the duration or frequency of inundation (see Section 3.3.3).

  Whilst the nominated tolerance is sufficient for initial assessment purposes, it is noted that Councils and the State could require reduced impacts depending on the particular road being considered. The FIO does not agree with performance criteria from the Basis of Design (Australian Rail Track Corporation, July 2020), which states that impacts *“must be less than 0.01 m and this impact criterion must also apply to other sensitive infrastructure […] including changes to any associated roads*”.

  Current ToS has only been assessed at locations where an increase in water level of 100 mm to 200 mm occurs. It is recommended that locations where ToS is increase by more than 20% should be reported to ensure that roadways submerged by floodwaters (not just at locations where an increase greater than 100 mm occurs) are captured.

- **Agriculture and grazing:** Although the constraint of 200 mm or less with isolated areas of up to 400 mm provides initial guidance and reflects the expected higher tolerance for increases on rural land, whether or not the impact is acceptable will depend on the current and potential future use of the land and will require consideration of factors including:
  - Does this level of afflux result in altered flow patterns (particularly for more frequent events) or increased scour?
  - What is the impact on the agricultural viability of the land?
- **Critical infrastructure:** The FIOs are silent on level impact suitable for critical infrastructure. Some examples include telecommunication towers, local authority pump stations and electricity authority sub-stations. This infrastructure relies on flood free access and/or operation.

3.3.2 Inundation Extent

One important criterion is a change in flood fringe. Buildings or lots that go from being dry in a certain sized flood to being within the flood extent for the same sized flood when the rail line is built should be considered. Those areas plotted as “Was Dry Now Wet” on the developed case afflux maps should be considered under a flood impact objective. These mapped areas, combined with the “Was Wet Now Dry” areas, also give indication of changed flood flow distribution (see Section 3.3.4).

3.3.3 Change in Duration Constraint

The FIOs do not nominate a quantitative limit with respect to changes in the duration of inundation. Whilst it is appreciated that whether a change in the duration of inundation is acceptable will depend on the use being considered (for example a road or an agricultural area) and the nature of the activity (e.g. the use of the road or the type of crop being grown), it would be beneficial to provide guidance in relation to the change in duration that would be considered to be acceptable.

Alternatively, a no worsening criteria could be adopted with added criteria that if the duration must be increased, the Consultant must demonstrate that this increase in duration does not cause any adverse impacts on the existing and future use of the land.

The objectives adopted for the Inland Rail in New South Wales (as discussed in Section 3.4) could be considered for this purpose.

3.3.4 Flood Flow Distribution

The FIOs do not provide a quantitative objective in relation to changes in the distribution of flow. This is considered to be acceptable given that changes to flood flow distribution will be associated with the adopted locations for drainage structures and provided that the change in flow distribution at each crossing is considered.

Given the rural nature of much of the H2C alignment, the consideration of impacts on flood flow distribution will necessarily need to focus on the lower flows associated with more frequent events because these will be of relevance to local landholders. Farm drain connectivity is a significant issue for agricultural landowners.

An example criterion from a DTMR project is provided below:

> *"All existing flow paths through the Site or existing transverse drainage that are conveying runoff from adjoining farmland or minor watercourse and gullies should be maintained such that the Project Works do not cause ponding of water or increased duration of inundation on the farmland, even during small local catchment storm events. Modelling of these minor drainage systems is not required but it should be demonstrated that capacity of existing open channels and transverse drainage is maintained as a minimum."*

3.3.5 Velocities

No specific objective is nominated in relation to locations where an increase in velocity will occur, with the objective aiming for the retention of existing velocities and nominating the use of scour protection where increases occur.

Given the potential for scour to occur given the soil types documented for the area, it is considered preferable to adopt a desirable limit for the change in velocity or velocity magnitude. A desirable limit encourages the development of solutions that minimise the requirement for scour protection and clear identification of the cases where it will be required.

The limits used for the Inland Rail in New South Wales (as discussed in Section 3.4) could be considered for this purpose. Further, given the known erodibility of the "black soils" present within the H2C section, the consideration of more soil-specific limits could be considered.

3.3.6 Extreme Event Risk Management

The FIOs require an assessment of risks posed to neighbouring properties for events larger than the 1% AEP event to *"ensure no unexpected or unacceptable*" impacts. Whilst the intent of the objective is understood, it is not clear what the implications of this objective are. In particular, the assumptions with regards to immunity to the crest level adopted in the flood model (the top of rail or the formation level) need to be considered.

Furthermore, there is no definition of what would constitute an “unexpected or unacceptable” impact, although impacts in terms of water level are quantified for all events.

The panel recommends that in areas the alignment joins population centres, such as towns, the impact in extreme events (e.g. 1 in 2000 AEP) should not significantly increase for both flood levels and the number of affected properties. A target objective of < 200 mm increase in flood levels would achieve this objective. Furthermore, the design should ensure that there is no significant increase in flood hazard to the community.

It is recommended that additional guidance be included in the objectives in relation to acceptable changes in extreme events.

3.3.7 Sensitivity Testing

The FIOs require the risk to impacts posed by climate change or blockage to be assessed. The nominated objective is considered to be both good practice and acceptable[5].

3.4 Flood Impact Objectives for Approved Sections of Inland Rail

The adopted Flood Impact Objectives have been compared to relevant standards in the previous section. For context, it is worth considering the flood impact objectives that have been adopted within the NSW sections of the Inland Rail Project (Quantitative Design Limits (QDLs)). The QDLs from the Narrabri to North Star section of the northern NSW portion of the Inland Rail alignment are presented in Table 3-2. These QDLs have been published as conditions with the infrastructure approval of the Critical State Significant Infrastructure (CSSI) under NSW Environmental Planning & Assessment Act.

[5] Refer Section 5.4 for a discussion on the application of climate change in the sensitivity modelling.

Table 3-2: Quantitative Design Limits – Conditions of Approval for Inland Rail – Narrabri to North Star

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

The notes for that table are also reproduced here.

[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.

Whilst conceptually similar, there are several key differences between the FIOs adopted for the feasibility design work considered within the draft EIS and the QDLs adopted in NSW. These differences are summarised below.

3.4.1 Change in Peak Water Level (Afflux) Constraint

Regarding buildings, the FIO's afflux constraint refers to the location and type of building, whereas the QDLs refer to habitable and non-habitable floors.

When the FIOs and the QDLs are compared:

- The habitable floor level afflux constraint is the same (i.e. 10 mm afflux limit).
- Although logistically more difficult to assess, there are advantages in referencing floor levels, rather than simply location. The reason for this is that below floor flooding is likely to be of far less concern than above floor flooding (particularly in rural areas where buildings may have been constructed specifically with the knowledge of previous flood events). It is noted for this draft EIS phase that a floor level database for buildings within the flooded extent has not been developed.
- The agricultural afflux constraint is of the same order, noting the NSW QDLs have a limit of 200 mm whilst the FIOs nominate 200 mm and an upper limit of 400 mm.
- The QDL for highways and sealed roads (no increase in depth where aquaplaning risk exists, otherwise 50mm increase) is more stringent than the 100 mm limit specified in the FIOs.
- The QDLs have an additional category (forest and unimproved grazing land) of 300 mm increase. Channels in H2C are steeper and more likely to be incised and hence the QDL may not be relevant.

3.4.2 Scour/Erosion Potential Criteria

The QDLs explicitly specify scour/erosion potential limits and place quantitative limits on velocities and potential increases in velocities.

In contrast, the FIO express velocity increase constraints in qualitative terms, requiring the designers to *maintain existing velocities where practical* and to *justify acceptability of changes through assessment of risk.*

The QDLs place specific limits for differing land uses, for example:

- *20% increase in velocities; and*
- *no velocities to exceed 0.5m/s unless justified by site-specific assessment.*

Providing quantitative limits on velocity increases is seen as advantageous over a purely qualitative criterion, particularly given the black soils present in the H2C section (refer Section 10).

3.4.3 Flood Hazard Criteria

While the equivalent FIO limits are expressed in terms of depth, the QDLs provide specific limits on the increase in hazard (incorporating the combination of depth and velocity).

Providing quantitative limits on hazard increases is seen as advantageous over only having a simple increase in peak flood level constraint.

3.4.4 Flood Duration

The QDLs explicitly specify quantitative limits on the potential increases in flood duration or time of inundation.

In contrast, the FIO require consideration of potential increases in flood duration in qualitative terms requiring the designers to *identify changes to time of inundation through determination of time of submergence […]*, *consider impacts on accessibility during flood events* and *justify acceptability of changes through assessment of risk with a focus on land-use and flood sensitive receptors.*

The QDLs place specific limits for differing location or land uses for example:

- *No increase in inundation duration above floor level for habitable floors*
- *10% increase in inundation for highways and sealed roads.*

Providing quantitative limits on time of inundation increases is seen as advantageous over a purely qualitative criterion. It is noted, however, that a floor level database does not exist in this project phase.

3.4.5 Sensitivity Testing

The FIOs require additional sensitivity testing for climate change and blockage scenarios, although the results of the sensitivity testing have not resulted in changes to the adopted design in the results reviewed to date.

There is no equivalent requirement in the QDLs. However, appropriate blockage for each cross-drainage structure is included in the design for North Star to Narrabri. No reference to the inclusion of climate change induced rainfall intensity increases is provided in the conditions of approval but may be indirectly found in the guidelines it refers to.

3.5 Recommendation

It is recommended that the FIOs be amended to consider the additional guidance with respect to:

- Impact at roads
- Duration of inundation
- Velocity
- Flood hazard
- Extreme events

In adding quantitative guidance, the QDLs adopted for the Conditions of Approval for Inland Rail in New South Wales are considered to be generally reasonable (subject to adjustment to accommodate local context).

4 Design Criteria – Hydraulic Design

4.1 Overview

The draft EIS includes inward-facing hydraulic design criteria and outward-facing flood impact objectives. The design criteria address the serviceability and longevity requirements adopted for the asset while the objectives reflect the need to protect the environment and minimise impacts to existing infrastructure (such as roads), land uses and buildings.

A summary of the Panel's comments on the Hydraulic Design Criteria is provided in the following sections.

4.2 Flood Immunity

The Panel makes no comment on the flood immunity criterion of 1% AEP plus 300 mm freeboard to formation level. This is a prerogative of the proponent. A significant proportion of the alignment coincides with the existing West Moreton Railway, so providing an immunity higher than the existing alignment could require additional cross-drainage structures to mitigate impacts.

4.3 Extreme Events

Consideration of implications for structural/geotechnical stability of the rail/rail embankment itself under extreme events as a result of water ponding upstream of the embankment is covered via the design criteria.

4.4 Sensitivity Testing

Whilst it is important to consider climate change and structure blockage, it is likely at the end of the design life of cross-drainage and associated embankment that both climate change induced rainfall intensity increases and blockage are combined for assessment of flood vulnerable locations along the alignment for future asset managers.

5 Cases Assessed

5.1 Background

The flood modelling has been undertaken with the intent to identify high-risk watercourse crossings or floodplain locations that may be impacted by the project alignment as well as a quantitative assessment of existing flooding and mitigation of impacts.

To satisfy this intent, it is necessary to develop flood models that reliably reflect the flooding behaviour of the catchment being considered, whilst also recognising the uncertainty associated with modelling natural events. All catchments are inherently dynamic in nature and flood events can physically alter a catchment.

For the catchments where stream gauge data is available, flood model parameters were adjusted via a calibration process until the models provided a suitable level of agreement to data that was recorded for historic events.

The 1974, 1996, 1999, 2011 and 2013 events were modelled for both the Lockyer Creek and the Western Creek regional models.

The resultant flood models were used to model design flood events.

Design flood events are theoretical events based on a statistical analysis. This statistical analysis includes analysis of long-term rainfall data by the Bureau of Meteorology. This data is combined with other design inputs, such as temporal patterns of rainfall (how rainfall is distributed in time), spatial patterns of rainfall (how rainfall is distributed in space over the catchment), losses, and pre-burst rainfall (rainfall that occurs before the rainfall burst that causes the worst flooding) to produce a design flood estimate.

5.2 Terminology on Likelihood of Events

Australian Rainfall and Runoff (Ball, et al., 2019) (ARR 2019) recommends the use of terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. This can be misleading because rare events may occur in clusters. For example, there are several instances of a events with a 1% or less chance of occurring within a short period, for example the February 1893 floods at the Brisbane River Port Office.

Historically, the term Average Recurrence Interval (ARI) has been used to describe the severity of a flood event. ARR 2016 recommends the use of Annual Exceedance Probability (AEP) instead of ARI. Annual Exceedance Probability is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP (1 in 10 AEP).

While ARI and AEP are similar for large events (for example the 1% AEP event is equivalent to the 100 year ARI event), this is not the case for events equal to or more frequent than the 10% AEP (1 in 10 AEP). The 20% AEP event considered in the flood modelling is equivalent to a 4.48 year ARI event.

The Probable Maximum Flood is the largest flood that could possibly occur in a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding, a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

5.3 Design Events Assessed

The investigation has assessed the impact of the alignment on flood behaviour for the following design events:

- 20% AEP;
- 10% AEP;
- 5% AEP;
- 2% AEP;
- 1% AEP;
- 1 in 2,000 AEP;
- 1 in 10,000 AEP; and
- Probable Maximum Flood.

The events were calculated in accordance with the 2016 version of Australian Rainfall and Runoff. Although all these events have been modelled, reporting assessment of results is primarily focussed on the 1% AEP event because it represents the rarest event assessable against flood impact objectives and is the defined flood for immunity of the rail formation.

The smallest event assessed, the most frequent flood, is a 20% AEP. It may be possible to assess interference with watercourses, floodplain areas and wetlands although it is likely that only an investigation of more frequent events will provide sub-major waterway scale assessment.

5.4 Sensitivity Modelling

Sensitivity testing is undertaken to assess the sensitivity of flood model results to changes in flood model parameters and to provide confidence in the model results. Sensitivity testing is typically undertaken by practitioners on the defined flood event, in this case the 1% AEP event. Sensitivity modelling was separately undertaken for the 1% AEP design event for both climate change rainfall increase and blockage in accordance with ARR 2016. Climate change rainfall increases were modelled as a Representative Climate Pathway (RCP) 8.5 for 2090, in line with DTMR general requirements and resulted in 18.7% increase in rainfall intensities across the section.

Impacts for the climate change scenario were calculated relative to a base case (i.e. without the railway) that also included climate change.

The blockage sensitivity flood modelling focuses on the blockage of the drainage structures to be constructed as part of Inland Rail to identify the additional afflux associated with the blockage of these drainage structures. For this assessment, all existing culverts in the regional flood models stay unblocked (blockage equal to 0%) in the existing case, the 0% blockage sensitivity case, the 25% blockage design case and the 50% blockage sensitivity case. The impact assessment is defined as:

> *Change in peak water surface level = peak water surface level (design case with design culverts blocked plus existing culverts unblocked) – peak water surface level (existing case with culverts unblocked).*

6 Hydrology

The following sections highlight the general approach adopted and potential issues associated with the hydrologic modelling undertaken for the H2C section. It should be noted that detailed discussion for each hydrologic model is provided in Appendix A and Appendix B for the two catchments considered in this report.

Where parts of the hydrologic modelling were assessed as appropriate and fit for purpose, they are not mentioned in this main report.

6.1 IFD Focal Points and Areal Reduction Factors

Focal points are used to extract appropriate rainfall intensity, frequency and duration (IFD) data and Areal Reduction Factors (ARFs) to be applied within the hydrologic models. As the size of a catchment increases, the ARF allows the design rainfall applied to a catchment to be reduced to account for the reducing likelihood of the design rainfall occurring simultaneously across the entire catchment. The choice of focal point is also relevant with respect to the selected critical duration and temporal pattern of the design rainfall event.

Documentation outlining the focal point selection for both rainfall IFD data and ARFs and details regarding sensitivity testing of this location is limited. The URBS hydrologic model showed that IFD data was extracted for each subcatchment and ARFs were calculated based on the catchment area to the Glenore Grove gauge (for Lockyer Creek) and Walloon gauge (for Western Creek).

The alignment in both catchments includes several crossings for which the contributing catchment area is less than that of the catchment to Glenore Grove or Walloon. The adopted ARF value may not be relevant to the other crossings. As a result, some structures could be undersized.

The Panel appreciates that for alignments with multiple points of interest, it is impractical to incorporate ARF values for each location. However, sensitivity testing should be documented showing minimal variance in results by adopting an ARF that is more appropriate for those locations. Justification for the chosen focal point and consideration of the potential change in conditions away from the focal point is warranted, together with either the consideration of a range of storm durations or a sensitivity assessment using a general ARF value of unity, given the uncertainty associated with the calculation of flow.

For the Lockyer Creek catchment, it was noted that a recent study has been undertaken to update local design rainfalls for Brisbane, Ipswich, Lockyer Valley and Moreton Bay. It is recommended that this study be reviewed and if applicable, updated rainfall data be adopted in future stages of the project.

For Western Creek, the Panel concludes that the design flows are too low. This could be at least partially attributed to the IFD data for the catchment. In the case of Western Creek, the difference could be addressed by factoring flows rather than updating rainfall data.

6.2 Rainfall Losses

For the Lockyer Creek catchment, which has an area of approximately 3000 km^2, there was limited discussion regarding loss parameters and their impacts on design flows. A single loss value was adopted for the entire catchment, with the value obtained from the ARR Data Hub. It is unclear whether spatial variation of losses was considered.

Whilst a reasonable fit to the FFA occurs at the Glenore Grove gauge in Lockyer Creek using the adopted losses, this was only following modification of the catchment lag-parameter beta in the design model. No comparisons were presented for other gauge locations in Lockyer Creek.

Whilst no specific rainfall loss issues were noted for Western Creek beyond those previously identified with respect to the Bremer River in the C2K review, concerns exist in relation to the fit to the FFA at the Walloon gauge and the modification of the beta parameter when deriving inflows to the hydraulic model.

6.3 Subcatchment Delineation

The subcatchment delineation adopted for the hydrologic modelling was left unchanged from the Brisbane River Catchment Flood Study (BRCFS). No changes were made between existing and developed catchment delineation to account for the location of the rail alignment. The typical procedure for the development of a hydrologic model for a linear infrastructure project is to divide the subcatchments at the project alignment. This allows for any redirection of flow or storage of flow upstream of the alignment to be properly accounted for. Such an approach is typically undertaken in both the existing and design case to allow a valid comparison of options. This has not been undertaken for the current study. It was expected by the Panel that subcatchment division at the alignment would have been undertaken.

The BRCFS URBS model, which was used as the basis for the hydrologic modelling in Lockyer Creek and Western Creek, lacks detail around the alignment.

6.4 Temporal Pattern and Critical Duration Selection

Temporal pattern selection, like rainfall data and ARF selection, requires an assessment of peak flow rates, levels, velocities and affluxes based on appropriate point(s) of interest to ensure that a suitable pattern is selected. For all hydrologic models, the documentation generally reports either the median or Rank-6 (R6) (the temporal pattern producing a flow closest to but greater than the median) temporal pattern was adopted. Furthermore, documentation states that critical duration and temporal pattern selection was undertaken based on gauge and ‘alignment crossings’ locations with limited additional details provided.

The Panel understands that for alignments with multiple points of interest it is impractical to assess temporal pattern selection at each location. However, sensitivity testing against select points of interest not used in the temporal pattern selection should be documented showing minimal change in results in order to justify the approach adopted.

Based on the supplied information, it would appear that the critical duration assessment was for the largest mean peak flows in the hydrologic model, not necessarily the highest levels, velocities and affluxes in the hydraulic model.

Notwithstanding that the critical duration was only assessed for flow rate and not level, the duration/temporal pattern combination that was found to be critical in the hydraulic models is not reported, even to say if it is the same as the critical storm combination from the hydrological models.

Importantly, mapping in the Technical Report for the full suite of figures[6] for each flood model does not say whether it is for one particular storm duration/temporal pattern combination or for the envelope of all durations assessed.

It is noted that the TMR *Hydrologic and Hydraulic Modelling Guidelines*, which was released after the hydrologic and hydraulic modelling commenced for this design stage, provides guidance on temporal pattern selection. This guideline should be followed in the next design stage.

For Western Creek, the areal temporal patterns corresponding to a catchment area of 500 km^2 were adopted. The two main Inland Rail crossings within the Western Creek catchment have contributing catchment areas of approximately 200 km^2. This could be altering peak flows and the timing of flood peaks within the models.

6.5 Interaction of Systems

For the Lockyer Creek catchment, it was identified that the interaction of local and regional flooding mechanisms may not be adequately captured with the current modelling approach. The Panel notes that independent local catchment modelling, undertaken for the FDR, may be an appropriate approach. However, this is only reasonable if catchments are independent of one another or if coincident flooding and interconnectivity of flow between catchments is accurately represented. Preliminary analysis by the panel indicates that there is interaction of flow between catchments at locations such as Laidley and Gatton.

The flood interaction issues were raised by the Panel with FFJV on the 25/03/2021 with a Technical Note response provided on the 31/03/2021. The Technical Note provided commentary specific for the Gatton and Laidley areas. Although the commentary demonstrated logical assessment, neither demonstrated that the flooding (regional and local) is independent of one another and can be assessed in this manner. Therefore, the Panel recommended further documentation and potential sensitivity modelling to ensure flood impact objectives are met is required with respect to the incorporation and assessment of flood interaction between the local and regional models.

Some parameters of the local catchment models were not documented in the FDR. The local catchment models developed in support of the FDR were not subject to review as the local models are outside the scope of the Terms of Reference. The severity of the inconsistencies is therefore uncertain in some instances.

Cross-drainage for catchment watersheds less than 10 km^2 in size are reported in the FDR, with hydrology calculated outside of the calibrated URBS hydrologic model using ILSAX methodology with Bransby Williams calculations of time of concentration. This is acceptable, however where a calibrated runoff routing model exists, ARR 2019 recommends its use before employing regional methods for ungauged catchments. Having two hydrologic models covering the same subcatchment can also lead to inconsistency in design rainfall and discharge methodologies.

For the Western Creek catchment, the local catchment model developed for the area to the west of Grandchester could give rise to issues associated with the overlap of

[6] Existing Case inundation extent, Developed Case afflux, Developed Case velocity, Developed Case difference in velocity, Developed Case difference in time of submergence

the local and regional model and associated drainage structures in the vicinity of Grandchester.

6.6 Flood Frequency Analysis

Where long flood records exist, the records have been captured at a gauge nearby to the point of interest and the catchment has not changed considerably during the period of record, flood frequency analysis (FFA) is the most robust method of estimating the probability of flooding. It is a direct approach where a statistical distribution is fitted to the largest flood in a continuous annual series. FFA is the foundation of nearly every design flood estimation technique used in Australia. Nearly every method is directly derived from FFA results or is verified and calibrated to FFA results. Whilst it is necessary to use rainfall runoff modelling techniques to estimate design inflows to cross-drainage, flood models should be verified to a FFA where good long-term records exist. Where the alignment crosses the upper reaches of the catchment, emphasis should be given to gauges in these locations.

For Lockyer Creek, the FFA was only presented for one stream gauge location within the Technical Report. Whilst the adopted gauge appears to have high quality data, there is still a risk of inaccuracy, which is typically mitigated by completing an FFA at multiple gauges (where available). The single FFA issue was raised by the Panel with FFJV on the 25/03/2021 with a Technical Note response provided on the 31/03/2021. It noted that a FFA was undertaken for Gatton and Helidon. As such, the Panel has recommended these be included within the Technical Report along with comparison of hydraulic model design event peak flow rates to FFA.

For Western Creek, no major issues were identified with respect to the FFA as the FFA was completed at the only gauge for which a sufficiently long record and a reasonable rating curve exists (i.e. the Walloon gauge),

7 Hydraulic Modelling

The following sections highlight the general approach undertaken and potential issues associated with hydraulic modelling undertaken for the H2C section. It should be noted that detailed discussion for each hydraulic model is provided in Appendix A and Appendix B for the two catchments considered in this report. Where parts of the hydraulic modelling were assessed as appropriate and fit for purpose, they are not mentioned in this main report.

7.1 Model Setup and Extents

Regional hydraulic modelling to assess flooding in the H2C section has been undertaken using the 1D/2D hydrodynamic modelling package TUFLOW incorporating the latest Heavily Parallelised Compute (HPC) solver. TUFLOW is widely used across Australia, with the HPC version used on new projects due to its high computational speed. The higher computational speed compared to that achieved using older (non-HPC) versions of the software allow larger models and/or finer model resolutions to be adopted to consider a wider range of flood events. It is an appropriate tool for assessing the two-dimensional flows, levels and velocities experienced across the wider regional catchment and the potential impacts associated with the rail alignment.

Due to the continuing advancement of the efficiency of the HPC model, it is recommended that flood modelling, in support of future design, be undertaken using the latest release of the HPC solver. Because the use of different releases of software can produce slight changes in calculated flood levels and flows and the hydraulic models consider large floodplain areas, the use of the latest release will also entail a review of the calibration and design impacts to confirm that the hydraulic models continue to provide an acceptable representation of the catchment and that calculated impacts do not significantly change from those obtained previously.

7.2 Boundary Conditions

Inflows to the TUFLOW hydraulic models have generally been applied through source area polygons, which apply the flows generated from the hydrologic models over a defined area. Whilst this is generally standard practice, there are several locations where the manner in which inflows have been applied results in an unrealistic distribution of flow.

As previously raised, subcatchments have not been subdivided in the hydrologic model at the alignment. Local catchment inflows for Lockyer Creek have been split and applied at multiple locations, with some coarse proportioning based on area and some coarse adjustments to routing. In several locations, flow is applied upstream or downstream of the alignment contrary to the subcatchment delineation and flow extraction location. The subcatchments are simply too large and the application method is contradictory to the hydrologic model's calculations. This can result in inaccurate replication of flows in design events and therefore improper structure sizing.

Inflows are generally applied inconsistently in the Lockyer Creek model and route the flows twice (once in the hydrologic model and once in the hydraulic model). Furthermore, varying values of catchment lag-parameter beta for local and routed inflows has been applied. Varying beta values to account for local and regional responses is not common practice. The approach is applied in the joint calibration model which implies the hydrologic and hydraulic models do not provide consistent results and weakens the joint calibration approach.. Sensitivity testing and clarification is required to justify the approach.

Additionally, the Lockyer Creek model, at a small number of locations, adopted different source-area inflow locations between the calibration model and the design event models. This undermines the calibration of the model and should be corrected or justified.

Finally, the downstream boundary condition in the Lockyer Creek model has a significant amount of ponding immediately upstream of the boundary, which may not accurately reflect flood conditions at the model outlet. Whilst it is unlikely to alter design outcomes due to its distance downstream of the alignment, it should be addressed in future design stages.

For Western Creek, the TOT034 subcatchment inflow for the main flow path is located too far within the hydraulic model and results in backwater flooding upstream of the inflow point. This results in the overestimation of storage and the underestimation of flood levels. Noting that the affected area is relatively small and not subject to flood level impacts, it is recommended that the inflow point be relocated as part of further design.

7.3 Representation of Key Structures

Culverts have been represented within the hydraulic model as 1D network elements. Standard Entry and Exit Losses of 0.5 and 1.0 respectively were applied to each culvert. Standard height and width contraction coefficients were used for both box and piped culverts. A 25% blockage factor was applied for proposed culverts with none applied to existing culverts, as this is a conservative approach for flood impact assessment.

For the Lockyer Creek model, a minimum nodal storage area of 200 m^2 was adopted. This parameter is typically modified to stabilise 1D elements of a TUFLOW model. Other individual structures within the model have additional nodal area applied. This value is regarded as high and it may be generating artificial storage within the model. Further justification should be provided for its use.

The Lockyer Creek model is missing several existing structures, which could be having minor impacts on flows and levels. It also contains several culverts in the existing and design case that are unstable, which has the potential to impact results.

Finally, the representation of the 1D/2D structure and channel connections within the Lockyer Creek model contained several issues. The issues are discussed in further detail in Appendix A. They result in over-connection of structures, artificial lowering of cell elevations, artificial blockages at the confluence of waterways and duplication of storage areas. Whilst it is unlikely that the issues would have widespread impact on the model results, they could alter reported results.

For the Western Creek model, the representation of structures is considered to be generally acceptable, subject to the use of survey data to represent existing bridges for future modelling and to consider the losses associated with bridge decks if affected by flooding in extreme events.

7.4 Roughness

The roughness within a hydraulic model attempts to replicate the retardation of flow. For densely vegetated terrain, this retardation (and roughness) is high, whilst for a concrete-lined channel, it is low.

In the Lockyer Creek model, some issues with the roughness application were identified. There was limited documentation surrounding the use of both typical and depth-varying Manning's 'n' values and the design case model's roughness was not updated to include the proposed rail alignment. Further details should be provided around these roughness values, including how they were derived and the sensitivity of the model to roughness changes.

For the Western Creek model, only minor roughness issues were identified. These issues can be reviewed as part of further design.

7.5 Topography

2015 ARTC LiDAR topographic data was adopted within the hydraulic models via use of a 1m DEM. Whilst this data is suitable for this stage of design, it is best practice to use the latest available data to ensure that new developments and other changes to the floodplain are captured within the models. The Lockyer Valley LGA LiDAR dataset was captured in 2018 and should be considered for modelling in future design stages for Lockyer Creek.

For the Western Creek system, the discrepancy between the various sources of topography identified in the review of the Bremer River catchment needs to be considered with respect to model calibration and potential impacts on flood levels for the design case.

7.6 Model Results

For the Lockyer Creek model, three issues were identified:

- Model instabilities were identified at multiple culverts that should be addressed in the next design stage.
- Insufficient justification was provided with respect to flood level impacts and changes in duration of inundation, including impacts at sensitive receptors.
- Increases in flood level in the Gatton and Forrest Hill areas for extreme events are significant and an alternative drainage configuration may need to be considered to reduce this flood risk.

For the Western Creek model, three issues were identified:

- A model instability was identified at one culvert, which should be addressed in the next design stage.
- Insufficient justification was provided with respect to flood level impacts and changes in duration of inundation, including impacts at sensitive receptors.
- Increases in flood level in the Grandchester area for extreme events are significant and an alternative drainage configuration may need to be considered to reduce this flood risk.

8 Joint Hydrology & Hydraulic Assessment

The following sections highlight the general approach undertaken and potential issues associated with the joint assessment undertaken for the H2C section. It should be noted that detailed discussions for each hydraulic model are provided in Appendix A and Appendix B for the two catchments considered in this report.

Where parts of the joint assessment were assessed as appropriate and fit for purpose, they are not mentioned in this main report.

8.1 Calibration

The Lockyer Creek models and the Western Creek models were calibrated to the 1974, 1996, 1999, 2011 and 2013 events. These events represent an acceptable range of flood magnitude, with stream gauge data available for calibration purposes for each event.

For Lockyer Creek, several issues were identified with the calibration:

- The hydrologic models were initially calibrated as part of the Brisbane River Catchment Flood Study (BRCFS). The BRCFS model did not primarily focus on the Lockyer Valley or Western Creek areas, so the models should adopt minor alterations to better represent the area of interest for Inland Rail (particularly splitting of subcatchments at the proposed alignment to better represent flow conditions).
- Local catchment flooding was not detailed sufficiently in either the Technical Report or Section 8 (Drainage) of the FDR.
- There is limited documentation on the FFA and verification.
- There is poor flow correlation at Glenore Grove stream gauge in the TUFLOW model, in addition to poor correlation with historic gauge levels and recorded flood levels between Helidon and Grantham.
- The calibration event hydrologic models adopt different parameters to the design event models, which undermines the calibration process.

For Western Creek, one issue additional to the issues raised in relation to the Bremer River model in the C2K review was identified with the calibration:

- Additional calibration information is available for the 2011 flood event (specifically a recorded stage hydrograph at Grandchester), yet it does not appear to have been utilised.

Specific comments on the calibration processes undertaken with respect to each catchment are provided in the relevant appendices.

9 Local Catchments

9.1 Overview

The catchments crossing the proposed rail alignment were categorised by contributing catchment area. This was used to determine the hydrologic method used for the design of the corresponding drainage structures and the subsequent hydraulic method to determine levels and velocities through the structure and further hydraulic method to assess flood impact. Table 9-1 shows the drainage catchment classification criteria and the number of catchments relating to each classification.

All of the local catchments for which flood modelling was undertaken in support of the FDR were in the minor and moderate classifications (i.e. less than 100 km^2 in size). Detailed flood modelling was completed for all major catchments, with the results of modelling presented in the draft EIS. These flood models were reviewed by the Panel. The appendices to this report detail the findings of the review for each of these catchments.

Table 9-1: H2C Drainage Catchment Classification (Table 42 from FDR) (Future Freight Joint Venture, February 2020)

Catchment Size	Drainage catchment classification	Number of Catchments
Less than or equal to 10 km^2	Minor	41
Greater than 10 km^2 and less than or equal to 100 km^2	Moderate	2
Greater than 100 km^2	Major	2

9.2 Inclusion of Local Catchment Results and Impacts in Draft EIS

The FDR presents the results of modelling of local catchments. The presented results include impact mapping and tabulated model results.

Whilst a number of catchments are relatively small in area compared to the main catchments, the Panel is concerned regarding the exclusion of the larger of the local catchments, particularly the two catchments with areas in excess of 10 km^2 (the largest local catchment is approximately 49 km^2 in area), and the consequent potential for some landowners to not be aware that their land is impacted.

At meetings with the authors of the draft EIS, the Panel was advised that consultation had occurred with all affected landowners so that they are aware of impacts associated with local catchment drainage works. To further ensure that impacts are appropriately defined, Appendix M of the draft EIS contains a tabulation (Appendix E) of impacts (level and time of submergence) to give visibility to all impacts and not just those associated with the main catchments considered for the draft EIS.

9.3 Design Methodology

The 1% and 0.05% AEP catchment flows for the minor catchments were generated in accordance with the 2016 version of Australian Rainfall and Runoff using ILSAX within the 12d[7] Drainage Network Editor. For moderate catchments, flows were generated using URBS hydrologic models, typical ARR 2016 IFD, temporal pattern and ARF parameters, and some catchment parameters equal to their nearest major catchment hydrologic model.

Initial sizing of minor catchment drainage structures was undertaken using the 12d Dynamic Culvert. Subsequent TUFLOW hydraulic modelling was used to determine flood level impacts (Section 8.3.9 of the FDR). 12d Drainage, 12d Dynamic Culvert and TUFLOW are generally considered to be suitable tools for local drainage analysis.

9.4 Focal Points for Minor Catchments

The FDR indicates that two design rainfall locations were adopted for all minor catchments across the 47 km length of the H2C section (Table 43 of the FDR).

These locations were used to derive rainfall intensity data, temporal patterns and aerial reduction factors. Instead of adopting the rainfall losses nominated by the ARR Data Hub at these locations, recourse was made to the loss values adopted for the nearest major catchment hydrologic models.

The use of only two locations may not be adequate for representing 41 catchments.

It is recommended that further checks be completed (using the RFFE and considering the potential variation in IFD data across the catchment) to confirm that the calculated peak flow rates are reasonable.

9.5 Roughness for Minor Catchment Models

Australian Land Use and Management values were used to spatially vary Manning's 'n' in the ILSAX and TUFLOW flood models for minor catchments (Section 8.2.2 of the FDR). The FDR does not refer to where land use delineation comes from to support the variation, although it is assumed to be confirmed using available aerial imagery.

9.6 Cross-Drainage

9.6.1 Culverts

Although the FDR deals with catchments that are classified as minor and moderate (refer Section 9.1), the drainage requirements for a number of the catchments are significant. Whilst the FDR provides initial information regarding the drainage required for local catchments, additional detailed hydraulic modelling will be required as part of further design to ensure that an appropriate design outcome is achieved.

9.6.2 Bridges

The local catchment drainage works nominated in the FDR include a number of bridges that are not nominated for the drainage of regional-scale flow in the Technical Report:

- 330-BR02: (Ch 32.58 km) 445 m long bridge with associated catchment area of 372 ha

[7] 12d Model is a civil design package by 12d Solutions Pty Ltd.

- 330-BR03: (Ch 33.57 km) 427 m long bridge with associated catchment area of 4693 ha
- 330-BR33: (Ch 58.85 km) 78 m long bridge with associated catchment area of 49 ha
- 330-BR17: (Ch 59.38 km) 102 m long bridge with associated catchment area of 218 ha
- 330-BR-19: (Ch 64.39 km) 159 m long bridge with associated catchment area of 291 ha

In many if not all cases, it is expected that the selection of a bridge rather than a pipe or box culvert is due to other factors such as the desire to reduce required embankment fill volumes to cross valleys.

However, given the length of the bridges nominated, it will be necessary to consider hydraulic requirements for each bridge in detail as part of further design.

9.7 Local Drainage Impacts

The flood level impact calculated at each culvert group is tabled in Table 3 Hydraulic Details of Appendix D3 of the FDR.

Although the mapping provided in Appendix D5 of the FDR indicates that the maximum increase in level will be greater than the nominated values, the increase occurs within the railway corridor; the quoted values reflect the increase at the rail corridor boundary and therefore the increase that land owners will experience.

Table 54 of the FDR presents a summary of the afflux at sensitive receptors for the 1% AEP event. Whilst the afflux at most sensitive receptor locations is considered to be reasonable, the table notes an increase in level in excess of 10 mm at a number of roads. For example, an increase in level of 50 mm is nominated with respect to Doonans Road (receptor 831).

For State controlled roads in particular, the normal requirement is to achieve no increase in flood level. If an increase in level is proposed, it requires careful justification in terms of the flood hazard on the road and the change in hazard and period of inundation of the road.

It is recommended that, as part of further design, options to remove the increase in level at roads be adopted or that detailed justification be provided in the event of an increase in level being proposed and determined to be impracticable to remove.

At multiple locations, the calculated flood level impact is in excess of the nominal 200 mm limit and approaches the 400 mm localised area limit nominated as the flood impact objective with respect to agricultural and grazing land in Table 53 of the FDR.

As the modelled flood waters do not appear to severely impact most sensitive receptors and only affect relatively localised areas, the impacts in terms of level and period of inundation could be considered to be both minimal and acceptable within agricultural/grazing areas. The Panel agrees with the statement in Section 8.3.9 of the FDR that *‘acceptable impacts will ultimately be determined on a case by case basis with interaction with stakeholders/ landholders through the community engagement process using these objectives as guidance’*. Provided affected stakeholders/landholders are appropriately consulted and ultimately accept the nominated increases in level (and any other associated changes in conditions), then an appropriate outcome will be achieved.

Similarly, the flow velocity/shear stress associated with the discharge from the culverts should be manageable during detailed design by the provision of suitable scour protection measures. Noting the types of soil present within the railway corridor (refer to Section 10), particular attention will need to be paid to scour protection during detailed design and it may prove necessary to adopt allowable velocity limits lower than those nominated in Table 73 of the FDR depending on the actual conditions present at a particular crossing location.

Finally, the impacts associated with multiple crossings are not nominated due to the crossing being included in the relevant regional flood model and its associated reporting. Whilst it is expected that floodplain flow associated with a major event in a regional catchment will produce a flow and impacts well above those associated with the local catchment draining to a particular culvert and that some culverts will only provide a relief drainage function for regional flooding, the regional models include many relatively small drainage structures. As part of detailed design, it will be necessary to confirm that the local catchment draining to each culvert does not produce a higher flow and therefore greater impact than that calculated for the regional case.

9.8 Flow diversion

The FDR states that diversions are required where a rail cutting, or embankment intersects an existing drainage path. Diversions are included at these locations to redirect flow, ultimately returning flow to an existing flow path.

Four diversions are proposed, as summarised in Table 9-2.

Table 9-2: Diversion Drain Details (from Table 4 of Appendix D4 of the FDR)

Channel Information								Catchment Hydrology			Channel Geometry						Channel Hydraulics		
Drain ID	Side (Note 1)	Design AEP	Channel Chainage Start	Channel Chainage End	Flow Direction Up/Down (Note 2)	Diversion of Waterway (Y/N)	Channel Lining	Catchment Area A	Time of Concentration t_c	Flow Q	Design Channel Slope S	Batters 1 in X_1	Batters 1 in X_2	Channel Bed Width B	Channel Depth H	Channel Top Width	Normal Depth y_n	Average Velocity V	Freeboard y_{fb}
			m	m				ha	min	m^3/s	m/m	m/m	m/m	m	m	m	m	m/s	m
332DD02	R	1%	59,665	59,570	D	N	Rock	47.8	35	14.6	0.018	2	2	8	1.2	12.8	0.72	2.15	0.48
332DD01A	L	1%	62,020	61,770	U	N	Grass	3.0	5	1.9	0.005	2	2	2	1.2	6.8	0.57	1.09	0.63
332DD01	L	1%	63,440	63,530	U	Y	Rock	116.5	29	37.6	0.016	2	2	12	2.2	20.8	1.05	2.55	1.15
332DD03	L	1%	63,530	63,750	U	Y	Rock	243.0	52	59.0	0.016	2	2	20	3.0	32	1.01	2.66	1.99
332DD05	L	1%	64,045	64,165	U	Y	Rock	254.5	52	61.8	0.008	2	2	20	2.3	29.2	1.26	2.17	1.04

9.8.1 Diversion Drain 332DD02

The trapezoidal channel 332DD02 is intended to divert runoff from Ch 59.67 km where the alignment crosses a waterway at an acute angle, returning flow to the original flow path at Ch 59.57 km.

Although nominally within the Laidley Creek catchment (part of the Lockyer Creek catchment), the diversion is located in the upper reaches of the catchment away from the main flow path and associated drainage structures.

Flood model impact results for the diversion are presented in the FDR and subject to detailed design, the adopted channel dimensions are considered to be reasonable.

9.8.2 Diversion Drain 332DD01A

This diversion is not well documented in the FDR. Its location coincides with a tunnel. Further details on this diversion drain should be provided in the FDR.

9.8.3 Diversion Drains 332DD01 and 332DD03

The trapezoidal channels 332DD01 and 332DD03 divert a waterway between Ch 63.44 km and Ch 63.75 km due to the proposed rail alignment approximately coinciding with the existing waterway.

Flood model impact results for the diversion are presented in the FDR and subject to detailed design, the adopted channel dimensions are considered to be reasonable.

9.8.4 Diversion Drain 332DD05

The trapezoidal channel 332DD05 diverts flow from Ch 64.05 km to Ch 64.16 km. The 120 m diversion is required at this location due to the proposed rail alignment approximately coinciding with the existing waterway.

Flood model impact results for the diversion are presented in the FDR and subject to detailed design, the adopted channel dimensions are considered to be reasonable.

10 Waterway Processes (Geomorphology, Active Sediment Transport, Diversion)

Provision of railway infrastructure across floodplains and waterways needs to consider and make appropriate allowances for ongoing waterway/geomorphic processes that:

- are already occurring along the proposed alignment, and
- may be impacted by the proposed infrastructure.

As discussed in *A Guide to Bridge Technology* (Austroads, 2019) frequently, environmentalists and hydraulic engineers consider a river to be static (i.e. unchanging in shape, dimensions and pattern). However, an alluvial river continually changes its position and shape as a consequence of hydraulic forces acting on its bed and banks. These changes may be slow or rapid and may result from natural environmental changes or from changes by human activities.

Consideration of fluvial geomorphic processes within, upstream and downstream of a waterway crossing prior to design is rapidly becoming best practice within the industry (Queensland Department of Transport and Main Roads, 2019). A geomorphic assessment of the channel and floodplain characteristics, particularly when combined with hydraulic modelling results of the existing case, allow for an appreciation of the natural dynamism of fluvial environments and prevent catastrophic damage to rail, waterways crossings and other infrastructure.

The provision of railway infrastructure generally involves some degree of encroachment onto river crossings and floodplains along the alignment. Such works have the potential to divert and concentrate flow, raising velocities and altering active geomorphic processes of scour and deposition that are already occurring along the alignment.

Understanding of the current geomorphic processes operating within a waterway, and thus identification of the waterway's trajectory for change at the site, is an important component of assessing the potential impacts of the construction of embankments and culvert/bridge crossings. Such considerations generally involve the creek/soil conditions and effects of the modified hydraulic conditions imposed by the proposed, existing, or upgraded crossing.

This assessment identifies the risk of any future movement of the channel to a structure's integrity, and/or measures to mitigate this risk (i.e. creek/channel protection measures), including the likely ongoing maintenance associated with scour and changes to channel geometry and planform.

It is widely recognised that a geomorphic assessment of proposed crossing locations can provide valuable information for crossing design and placement. Conducting a geomorphic assessment of a waterway crossing (location and preliminary design options) prior to a detailed design phase gives a greater understanding of the limitations and potential risks associated with a particular crossing. This gives better control when detailing design and construction specifications, and ultimately reduces risk and cost.

In this case, black vertosol soils are prevalent within the study area (sometimes referred to as black earths or cracking clays). In general, these soils can extend to between 1 and 4 m deep and have very little resistance to erosion through flowing water or immersion. These soils are readily observed in the bank profile along many waterways in this area.

Vertosol soils must be considered in detail through any design process for the following reasons:

- These sediments, combined with the concentration of flow in the channel, have led to significant incision in this area.
- Exposed vertosol bank sediments, especially but not only when combined with incision are a significant problem in this area and lead to bank collapse and channel widening.
- Concentrated overland flow has led to large floodplain gullies throughout the Lockyer Valley. As with the bank collapse and channel widening, this is an escalated problem in this area due to the easily erodible nature of the vertosol bank sediments.
- Hard structures such as concrete or rock are known to be problematic with respect to erosion in these soils.

Given these conditions, particular attention will need to be paid to the specification of appropriate scour protection throughout the length of the H2C alignment during detailed design. This is further discussed in Appendix C.

11 Implications/Constraints for Future Stages

At this stage, it is expected that of the five Inland Rail sections in Queensland, two are to be delivered using a Design and Construct (D&C) contract method, B2G and K2ARB, and three to be delivered as a combined Public Private Partnership (PPP).

In 2017, the Australian Government confirmed the combined Gowrie to Kagaru section of Inland Rail in Queensland will be designed, built, managed and paid for by a PPP.

Although it is appreciated that the drainage structures and embankment levels presented in the draft EIS and the FDR are subject to detailed design and adjustment to satisfy conditions of approval, for either method of delivery, it is important that drainage and embankment requirements are reasonably well defined prior to detailed design commencing, as a 'reference' for that design team.

The review by the Panel has identified a number of issues with the current flood modelling. Whilst most of these can be resolved through the normal iterative design process, several items require clarification and testing. It is recommended that the key areas of concern that are identified in the review be addressed and drainage structures revised as appropriate to minimise the potential for issues to arise in the detailed design phase.

12 Community Concerns

12.1 Submissions to the Panel

The Panel has received no submissions from the public on the H2C section at this time.

Discussions were held with Lockyer Valley Regional Council and Ipswich City Council to detail the issues of relevance to each Council.

12.2 Submissions on the draft EIS

The draft EIS Public Exhibition Period has not closed at the date of this report.

13 Conclusions/Recommendations

13.1 Overview

ARTC has undertaken a substantial amount of work to identify existing flooding characteristics and to assess and mitigate potential impacts associated with the project alignment. This work is, for the most part, in accordance with both national guidelines and current industry best practice. However, through the Panel's thorough review process, issues have been identified.

Significant infrastructure projects, like Inland Rail, are accomplished through an iterative process. As such, it is normal practice for iterative improvements and changes to occur through the various project stages. Therefore, it is normal for issues to be identified throughout the project, with the Panel advising that some be addressed within the EIS phase and others addressed in future project stages. All of the identified issues are capable of resolution, either by adjustments to the flood models developed to date, or by modification to the design.

The key issues found by the Panel are summarised below.

13.1.1 Lack of Detail in Report

The Panel appreciates that ARTC has undertaken significant work and it is difficult to provide an all-inclusive document that captures all of the work that was undertaken. However, the Technical Report is not sufficiently comprehensive to meet the Panel's ToR. Additional details are required in relation to the calibration of the flood models (for example agreement to recorded levels) and the modelling of design events (for example critical duration analysis).

13.1.2 Lack of Justification for Level Increases in the Design Process

The Technical Report notes multiple instances of increases in level occurring that are in excess of the flood impact objectives. Very limited justification is provided in relation to the impacts. The Panel would like to see more details on the iterative process (the journey) that was applied to derive the current solution.

13.1.3 Local and Regional Flood Modelling

The FDR is clear that there are two distinct hydraulic model types (and hence treatments) delineated on catchment area:

- regional floodplain flood models; and
- local flood models for local catchment types or local drainage catchment classification.

The Technical Report/draft EIS is not as clear. It variously refers to:

- hydraulic sub-models
- regional catchments and regional flooding
- major waterways and associated major waterway models, major waterway catchments, major drainage structures and major waterway crossings,
- minor/moderate catchments

- local catchment flooding and local catchment drainage outside the regional floodplain extents.

The flood modelling presented in the Technical Report/draft EIS reflects the regional flood modelling that has been undertaken. In addition to this regional flood modelling, flood modelling of local catchments has also been completed. However, the details of methodology for the local catchments are not included in the Technical Report/ draft EIS. Whilst it is agreed that many small catchments are too small to warrant inclusion in a draft EIS (and any impacts are very localised), in this case, many of the local flood models cover relatively large areas and could potentially be included.

The Panel is concerned that the potential exists for an impacted landowner to not be aware that the Inland Rail will result in a flood impact on their land as a result of this approach to delineate between local and regional flooding. Whilst the draft EIS includes a tabulation of impacts associated with local catchments (level and time of submergence), the impact mapping provided in the FDR is not included.

At meetings with the personnel responsible for the flood modelling presented in the draft EIS, the Panel was advised that consultation has occurred with all affected landowners and therefore all impacted landowners will be aware of a predicted impact in level on their properties. The Panel was advised that the consultation was discussed in other parts of the draft EIS.

Although the consultation process is a positive means for appropriately dealing with identified impacts, the Panel remains concerned about the exclusion of mapped results for large local catchments from the presented results and the consequent potential for some landowners to not be aware that their land is impacted.

13.1.4 Model Calibration

A number of issues have been identified with the model calibration process and reporting for the H2C package. There is uncertainty and a partial lack of confidence in the outcomes of the calibration process. Further reporting and justification are required regarding the calibration to add confidence to the models and their ability to replicate design events appropriately.

13.1.5 Flood model Setup Issues

A number of model setup issues have been identified for each regional flood model.

While a number of issues are minor and can be resolved as part of further design, for other issues, without additional sensitivity modelling it is uncertain whether the issues will make a material difference to the results achieved to date (and therefore whether changes to the flood model need to be completed as part of the draft EIS finalisation or can be included as a condition of approval).

One example in this regard is the calculation of critical storm durations for each catchment. The alignment includes several crossings for which the contributing catchment area is less than that of the overall catchment. The storm duration resulting in peak conditions at the main crossing may not produce peak conditions throughout the length of the alignment. Similarly, the focal point adopted for the calculation of design rainfalls and aerial reduction factors may not be relevant to all drainage structures in a particular catchment.

13.2 Method for Tabulation of Individual Issues

The review identified several areas where additional work is required, either as part of further design or to allow the draft EIS to be revised. The items identified in the review are summarised in tables at the end of Appendix A, Appendix B and Appendix C.

To facilitate the resolution of the identified issues, each issue has been assigned a level of importance, as described below.

- ***Low Importance***

  Additional work is required that will not significantly affect the findings of the draft EIS. The work can be completed as part of further design (prior to the use of flood models for detailed design) and the requirement to complete the work can be included as a condition of approval.

- ***Medium Importance***

  Clarification or confirmation is sought in relation to an aspect of the supplied reports and flood models. Depending on the response to the issue, the issue can be addressed via conditions of approval if required (i.e. it is deemed to be of low importance) and prior to the use of models for detailed design or via sensitivity testing (i.e. it is deemed to be of high importance as a result of the response).

- ***High Importance***

  Sensitivity testing is recommended to determine the significance of the issue to the interpretation of Inland Rail related flood impacts and for documentation and flood modelling regarding the results of the sensitivity testing to be supplied to the Panel to confirm whether the issue can be dealt with (if necessary) by conditions of approval (i.e. the item is deemed to be of low importance on the basis of the sensitivity assessment) and prior to the use of models for detailed design or whether the issue affects the interpretation of results.

- ***Very High Importance***

  An issue of significance that warrants the revision of the documentation provided to the Panel to include either the documentation of additional justification regarding a conclusion drawn or amended flood modelling. Such issues will need to be addressed prior to the models being used for detailed design.

Figure 13-1 presents a flow chart indicating the process by which it is proposed to resolve each issue relative to its assigned level of importance. The colour-coding used in the figure was applied to the tables at the end of Appendices A to C to allow the relative importance of each issue to be readily identified.

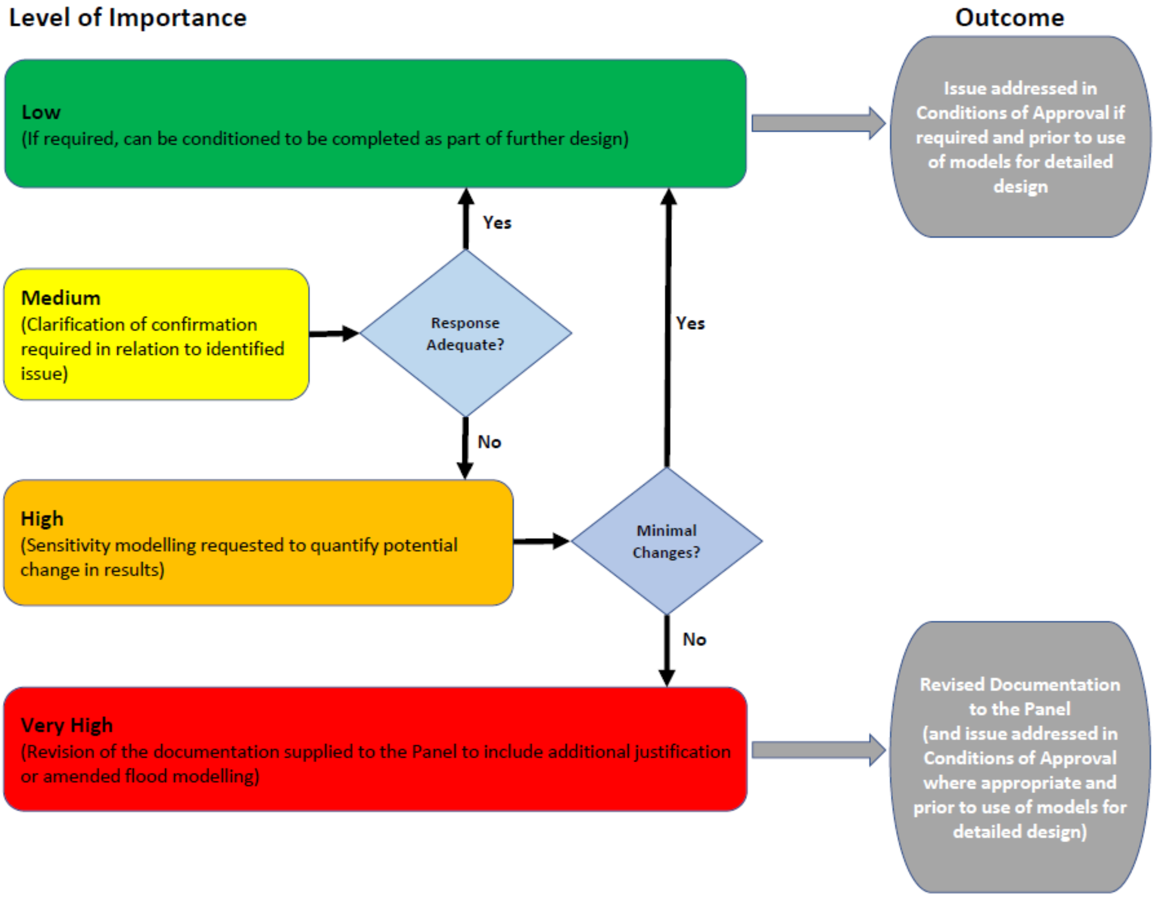

Figure 13-1: Flow Chart for Resolution of Identified Issues

To ensure that the issues relevant to each catchment are clearly defined, a separate list of issues has been prepared with respect to each catchment. Whilst this approach was adopted to facilitate the resolution of issues and ensure that all of the issues relevant to the flood modelling of each catchment are considered, it does result in the nomination of issues that are common to a number of catchments. This commonality can give rise to the perception that the number of identified issues is greater than is actually the case.

Minor issues identified as being of low importance were nominated to ensure that appropriate action is undertaken by conditioning and/or additional flood modelling as part of detailed design. The minor issues comprise about a third (31%) of the identified issues.

Issues identified as being of medium importance could potentially be resolved subject to the provision of additional information. Over half (54%) of the identified issues are either low or medium importance.

About a third (35%) of the issues identified were classified as being of high importance. Depending on the outcome of recommended sensitivity modelling for issues of high importance, a number of the issues could potentially be resolved by either no action or appropriate conditioning of the approval.

The remainder of issues (12%) were considered to be of very high importance. The very high importance issues relate to the level of detail provided in the draft EIS reports (of relevance to the Panel due to its ToR) and the justification for proposed flood impacts.

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Appendix A Lockyer Creek Model Review

Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland

Appendix A: Lockyer Creek Models Review - Draft Report on Review of Helidon to Calvert Section

May 12, 2021

Contents

Tables

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1 Introduction

1.1 Overview

This report presents the findings of the review by the Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland of the flood modelling of Lockyer Creek completed by the Future Freight Joint Venture (FFJV) in support of the draft Environmental Impact Statement (EIS) and Feasibility Design Report (FDR) for the Helidon to Calvert (H2C) section of the Inland Rail Project.

A summary of the issues identified in the review is provided in Section 7.5. A summary of the model review items can be found in Appendix 1.

The following FFJV reports were included in this review:

- Inland Rail Helidon to Calvert, Chapter 13 Surface Water and Hydrology, Revision 0.1, 18 March. (Future Freight Joint Venture, March 2020)
- Inland Rail Helidon to Calvert, Appendix M – Hydrology and Flooding Technical Report, 09 February. (Future Freight Joint Venture, February 2021)
- Helidon to Calvert Feasibility Design Report, Section 8 Drainage, Volume 1, Revision 0, 25 February. (Future Freight Joint Venture, February 2020)

ARTC supplied the URBS hydrologic and TUFLOW hydraulic models that accompanied the Hydrology and Flooding Technical Report. These models were included in the review.

The TUFLOW hydraulic models and the 12d models containing the ILSAX calculations that accompanied the FDR, which were used to assess catchments less than 100 km^2 in size, were not part of this review.

1.2 Catchment Extent

Figure 1 shows the Lockyer Creek catchment extent against the Inland Rail alignment and some of the stream gauges in the vicinity. The catchment feeds into the Brisbane River immediately downstream of Wivenhoe Dam.

The corresponding hydraulic model covers Lockyer Creek and the proposed rail alignment between Postmans Ridge and Laidley (excluding part of the alignment at Helidon and Grantham) (G2H Ch 21.50 km to Ch 26.30 km and H2C Ch 26.00 km to Ch 60.00 km).

The hydrologic and hydraulic models are mostly within the Lockyer Valley Regional Council local government area.

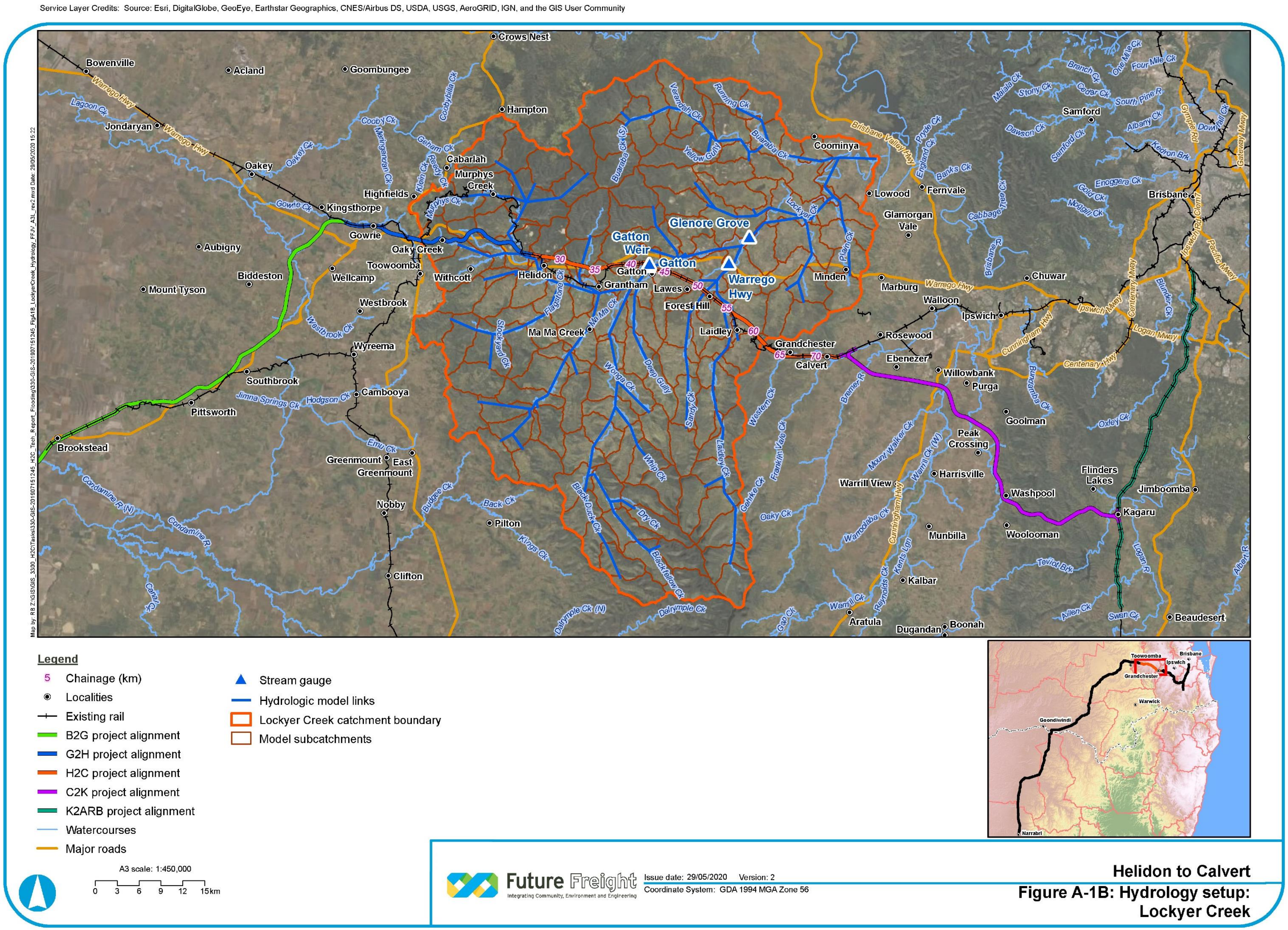

Figure 1: Lockyer Creek Catchment Extent (Future Freight Joint Venture, February 2021)

1.3 Methodology

1.3.1 Overall

Overall, the methodology for the modelling of regional flooding (see Section 2 of the Hydrology and Flooding Technical Report (Future Freight Joint Venture, February 2021) and Section 13.5.2.3 of Chapter 13 (Future Freight Joint Venture, March 2020)) was considered acceptable by the Panel. The adopted methodology is summarised below:

1. Determine and consider existing flood studies.
2. Consult with relevant parties to obtain flood data and to discuss model behaviour and impacts.
3. Develop and calibrate hydrologic and hydraulic models of the catchment.
4. Determine design inflows for design events (20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and Probable Maximum Flood) based on the 2016 version of Australian Rainfall and Runoff (ARR).
5. Use hydrologic and hydraulic models to calculate flood levels, flows, velocities and inundation times for the existing catchment conditions.
6. Add the proposed Inland Rail design and determine appropriate mitigation measures. These measures were primarily drainage structures.
7. Consider the sensitivity of the model to climate change and blockage.
8. Identify residual impacts and undertake engagement with the community and relevant stakeholders.

Although the overall methodology was considered appropriate, there were several concerns about:

- The application of the methodology.
- The sizing of drainage structures.
- The assessment of the impacts.
- The level of detail provided in the Hydrology and Flooding Technical Report (Future Freight Joint Venture, February 2021) to justify assumptions made in the modelling.
- The conclusions drawn in the report (and subsequently repeated in Chapter 12 of the draft EIS), because they were lacking details of how they were derived.

1.3.2 Community Consultation

It is understood that ARTC, in conjunction with FFJV, have undertaken consultation with all affected landowners as contained in *Appendix C – Stakeholder Engagement and Community Consultation Report* of the EIS. It is assumed that this consultation included a discussion of site-specific impacts for minor and major catchments with reference to the flood impact objectives.

1.4 Previous Studies

The Hydrology and Flooding Technical Report listed three relevant previous studies that were coincident with the Lockyer Creek study area:

- *Brisbane River Catchment Flood Study Hydrology Phase Final Report* (Aurecon, 2015)
- *Lockyer Valley Flood Model Update Stage 2* (Jacobs, 2016)
- *The Big Flood: Will It Happen Again, Final Report* (The Big Flood Project Team, 2016)

The Brisbane River Catchment Flood Study Hydrology Phase Final Report (Aurecon, 2015) involved the development of hydrologic models for the entire Brisbane River Catchment. This modelling included the Lockyer Creek and the models were calibrated against a range of historical events including the 1974, 1996, 1999, 2011 and 2013.

The Lockyer Valley Flood Model Update Stage 2 (Jacobs, 2016) incorporated amending the original Lockyer Valley flood model that was developed for LVRC. This model was originally tasked with investigating development control and assessment of flood mitigation options. It is noted that this model was not developed using the Australian Rainfall and Runoff 2016 methodology.

The Big Flood: Will It Happen Again Report (The Big Flood Project Team, 2016) provided analysis of historical flood records from non-stream gauge data sources such as paleoflood data. This data was used to develop an understanding of channel and floodplain geomorphic flood risks, particularly in the Lockyer Valley region.

1.5 Scope of the Review

This review assessed the regional flooding model of Lockyer Creek between H2C Ch 26.00 km and Ch 60.00 km. Specifically, the Lockyer Creek URBS models and the Lockyer Creek TUFLOW model.

Within these same chainages, there are several TUFLOW models that use flows derived using 12d ILSAX to assess flows for catchments less than 100 km^2 in size as part of the drainage package. These models overlap the regional Lockyer Creek TUFLOW model that is subject of this review

The overlapping models mean that culvert and bridge sizes between Ch 26.00 km and Ch 60.00 km, in some cases, were not sized with the flows, levels or impacts of the Lockyer Creek TUFLOW model, despite being within that model. Flows or impacts in the other models may have been the controlling factor on the sizes. This report reviews the Lockyer Creek models independently of the other models, though it does still check the sizes of all structures within its extent that may have been sized in the other models.

2 Hydrologic Model Review

2.1 Overview

The FFJV adopted the Brisbane River Catchment Flood Study (BRCFS) hydrological model (URBS) for the Lockyer Creek catchment. This is an appropriate approach using a suitable modelling package (URBS). Seven separate sub-models were developed for the BRCFS, with a specific model developed for Lockyer Creek. The Technical Report notes that minor modifications were made to the hydrologic model to produce flow estimates at locations of interest along the project alignment. However, there is limited documentation in the Technical Report on these changes.

The Technical Report notes that no additional calibration of the hydrologic models has been undertaken from the BRCFS study. There is further documentation highlighting the comparisons undertaken to match the hydrologic model to the BRCFS study. However, there is minimal discussion regarding the limitations of the BRCFS in the Lockyer Valley. The Lockyer Valley is within the study area but was not a focal point of the BRCFS, with the study noting that the area may be subject to higher localised creek flooding. As such, the study recommends that flood levels for design and planning purposes should be checked with the local council and may not be appropriate for comparative purposes.

2.2 Data

2.2.1 Stream Gauge Data

Five streamflow gauges were used for calibrating the Lockyer Creek model, as detailed in Table 1.

Table 1: Stream Gauges Adopted for Calibration (Table 7.7 from Technical Report)

Catchment	Hydrologic modelling approach	Hydraulic modelling approach	Calibration events	Stream gauge data used
Lockyer Creek	URBS (BRCFS)	TUFLOW	1974, 1996, 1999, 2011, and 2013	Helidon, Gatton Weir, Gatton, Warrego Highway, and Glenore Grove
Western Creek (Bremer River)	URBS (BRCFS)	TUFLOW	1974, 1996, 1999, 2011, and 2013	Walloon, Rosewood, Kuss Road, Adam's Bridge, and Rosewood WWTP

The Technical Report does not note the total number of gauges available within the Lockyer Creek catchment, nor discusses why other gauges were not utilised in the study. Preliminary investigation by the Panel identified that there are approximately 22 stream gauges within the catchment. Further discussion within the Technical Report is required to address why available gauge data was not appropriate to be included in the assessment.

2.2.2 Rainfall Data

Rainfall Intensity, Frequency and Duration (IFD) data used in the study was obtained from the Bureau of Meteorology (BoM) Data Hub. The report indicates that this data is based on the 2016 IFD data release which was the latest available data at the time of project inception. However, it should be noted that a recent study has been undertaken to update local design rainfalls for Brisbane, Ipswich, Lockyer Valley and Moreton Bay. It is recommended that this study be reviewed and if applicable, updated rainfall data be adopted in future stages of the project.

2.3 Catchment Delineation

Subcatchment areas in the hydrological model range from 0.4 km^2 to 51.9 km^2. Subcatchments in URBS should be kept as similar in size as possible to ensure consistent routing through the model. A large variance in catchment size may negatively impact the model results. However, this is not considered a significant issue because catchments areas are predominately between 15 km^2 and 30 km^2.

There appears to be a minor discrepancy with the catchment areas utilised in the URBS model compared to the provided GIS catchment file. The discrepancies range between -0.1 km^2 to 0.6 km^2 with a total difference of 25 km^2 (0.9%). This is unlikely to have significant impact on the results but should be addressed in the next stage of the project. The URBS sub-model and sub-catchment layout is shown in Figure 2.

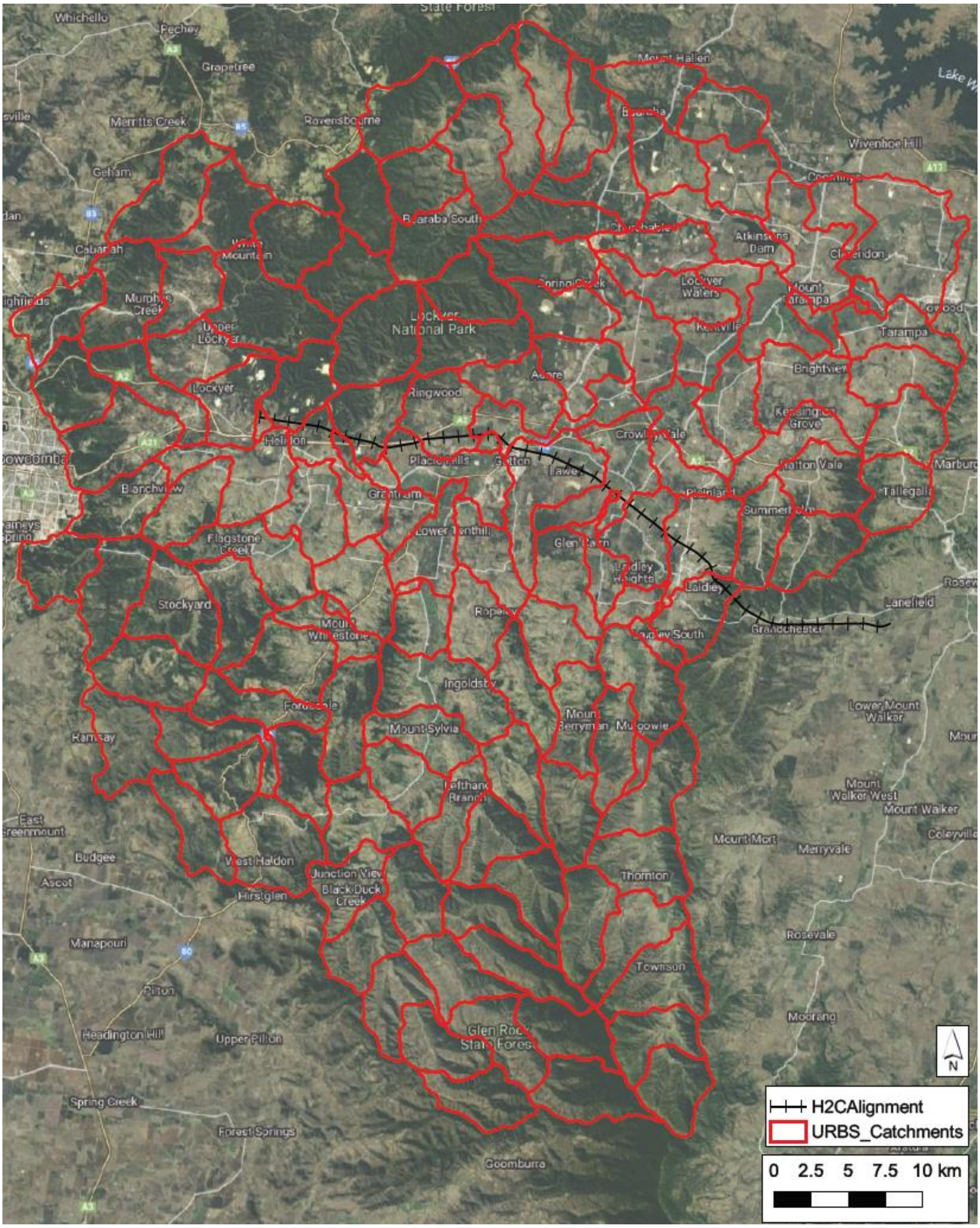

Figure 2: Lockyer Creek URBS Catchment Layout

No changes were made to the sub-catchment delineation to represent the developed condition model. There are several sub-catchment areas that cross the proposed rail embankment, as shown in Figure 3. As noted previously, it is standard practice to keep sub-catchment areas a similar size, with the exception being when it is necessary to split the area because of an embankment. Where a rail or road embankment splits a sub-catchment, splitting the sub-catchment ensures that the correct upstream and downstream flow is modelled. The split would be consistent between the existing and development models where practical to ensure consistent flow estimation.

The chosen approach of not splitting sub-catchments may cause issues with where flows are being applied within the hydraulic model. This can result in crossings at several locations being missed or inflows incorrectly allocated to enable informed assessment. However, due to the flat nature of the terrain surrounding the alignment and the significant upstream catchment area, this issue may only be problematic in minor events where breakouts do not occur. It should also be noted that the inflows of the hydraulic model were often split near the rail alignment, with flows apportioned upstream and downstream based on subcatchment area upstream and downstream of the alignment. This attempted to replicate actual subcatchment splitting.

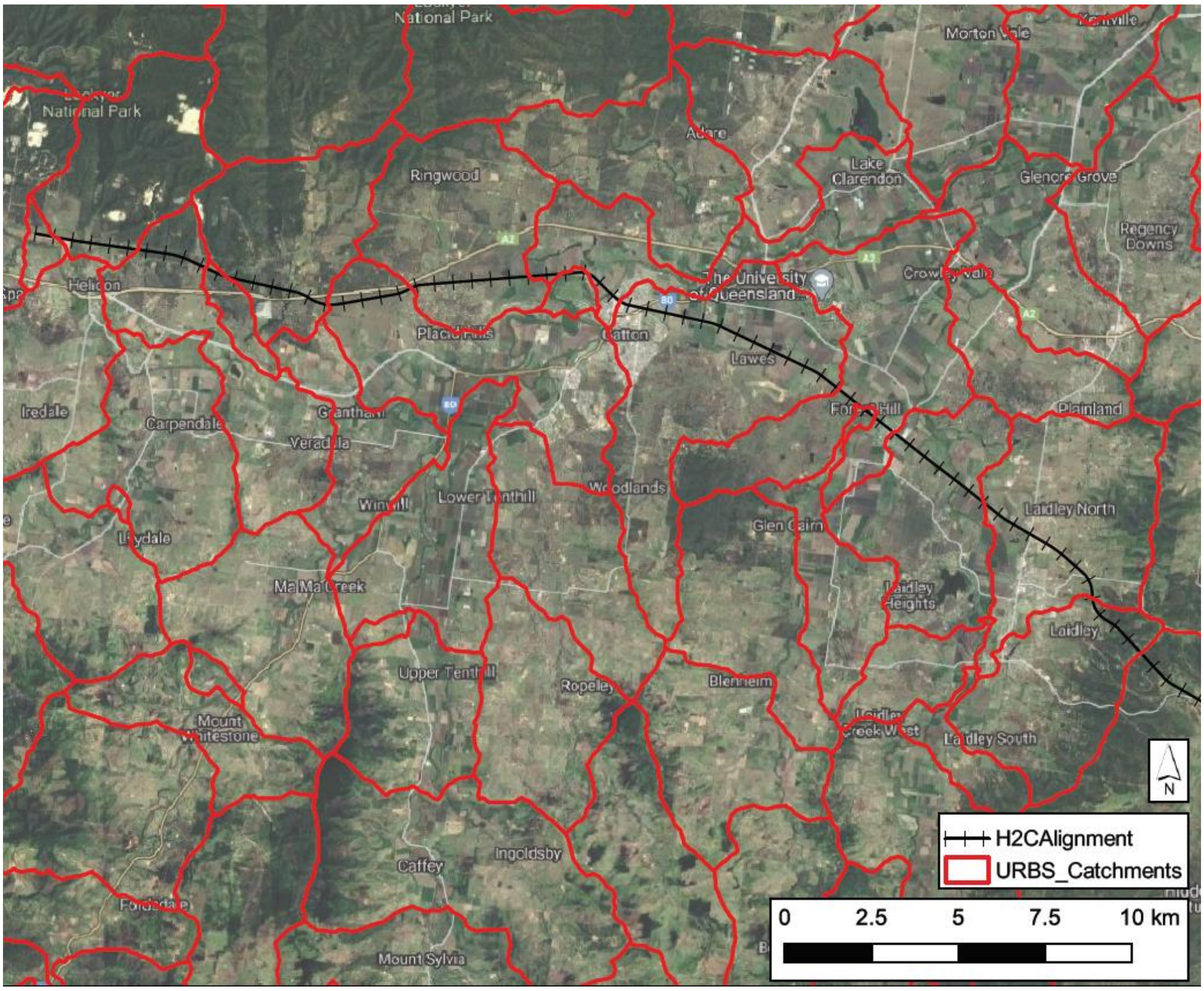

Figure 3: Corridor Alignment Through Lockyer Creek Subcatchments

2.4 Model Parameters

URBS is a runoff-routing networked model of subcatchment-based centroidal flows. The Lockyer Creek URBS model is a “split” model (separate catchment and channel storage). Typical values for storage/channel lag parameter alpha range between 0.1 and 0.3. The alpha value that was selected by FFJV (0.49) is outside the normal range. This does not necessarily mean that the value is incorrect because local calibration can result in the requirement of a value outside the normal range. However, this may also be an indication of the parameter choice correcting for other misrepresentations within the model. All other control parameters applied to the

Lockyer Creek URBS model were within typical ranges and are they presented in Table 2.

Table 2: Lockyer Creek Adopted URBS Parameters

Parameter	Description	URBS Model
alpha	Storage/channel lag parameter	0.49
beta	Catchment lag parameter	3.1 for routed, 1.5 for local
m	Catchment non-linearity parameter	0.8
x	Muskingum translation parameter	0.25
n	Channel roughness	0.85

Although most parameters are within typical ranges, the approach of varying beta values to account for local and regional responses is not common practice. This approach indicates a disparity in the model representation at a local level. The use of a lowered beta value for local inflows in the joint calibration hydraulic model implies the hydrologic and hydraulic models do not provide consistent results. As a joint calibration approach is used to validate both models, the need to vary the hydrologic parameters between the two models to achieve a reasonable calibration raises questions of the validity of the joint calibration approach. Further explanation and justification for this approach should be provided.

2.5 Design Discharges

Ten different temporal patterns were modelled per AEP to assess the impact of temporal patterns on peak flows. This approach is consistent with the latest Australia Rainfall and Runoff (ARR) guidance.

Several Flood Frequency Analyses (FFA) utilising ARR2016 methodology were reported to have been completed. The Technical Report implies that at locations where reliable gauge records (in terms of both rating and record length) were available, FFA results were used to assess hydrologic model peak flow estimates. However, the Technical Report only provides a comparison at one gauge location (Glenore Grove), with limited documentation detailing what other gauges were utilised in the assessment. This is further discussed in Section 4.

The Technical Report states that initial and continuing loss values were originally based on a single value extracted from ARR Data Hub. The FFJV reported that this resulted in higher flows for frequent events compared to the BRCFS, so the loss values were subsequently adjusted. These losses are presented in Table 3.

Table 3: Lockyer Creek ARR2016 Data Hub and Adopted Loss Values (Table 8.2 from Technical Report)

Catchment	ARR Data Hub		Adopted	
	Initial loss (mm)	Continuing loss (mm/h)	Initial loss (mm)	Continuing loss (mm/h)
Lockyer Creek	31	1.3	31 (>=1% AEP) 56 (2% AEP) 110 (<2% AEP)	2.0
Bremer River	23	1.5	23 (>=20% AEP) 46 (<20% AEP)	1.5

There is limited discussion provided regarding the ARR Data Hub loss values and it is unclear if spatial variation was considered in the approach. This should be included in the reporting because the Lockyer Creek URBS model covers an area of approximately 3000 km^2. Furthermore, the modifications to loss values was undertaken to match the BRCFS, whose focus point was not the Lockyer Valley. Additionally, there is limited discussion regarding where flow rates were compared to the BRCFS study. The Technical Report does include a comparison of URBS flows to the Glenore Grove FFA, but no other locations were assessed. This issue is further discussed in Section 4.

Temporal pattern and critical duration selection have been undertaken based on five locations within the Lockyer Creek model. Three of these locations are noted to be at the alignment, with the remaining two locations based on gauges at the Warrego Highway and Glenore Grove, located 5 km and 10 km downstream of the alignment, respectively. The Technical Report further notes that the Rank 5, Rank 6 and Rank 7 inflows were tested at these locations within the hydraulic model to determine the most appropriate combination. Although there is reasonable documentation, a figure detailing the chosen assessment locations and flow rate plots at these locations would add rigor to the Technical Report. Furthermore, a sensitivity review of the potential change in critical duration and temporal pattern under development conditions (within the hydraulic model) would provide greater confidence in the outcomes of the assessment and ensure the correct critical duration(s) have been considered.

The Panel re-calculated the critical duration and rank-6 temporal patterns to confirm the findings of the FFJV. It was found that the values reported in Table 8.5 of the Technical Report were generally consistent with the re-calculation. Some differences were noted. The Warrego Highway location for the 1% AEP event was found to have a critical duration of 720 minutes and Rank 6 temporal pattern of TP08, rather than what was reported (2880 minutes and TP09). Similar differences were identified for Glenore Grove in the 0.01% AEP event and the Probably Maximum Flood (PMF) event for Warrego Highway and Glenore Grove. Clarification should be provided by the FFJV for these differences.

The Areal Reduction Factor (ARF) calculation, unlike the critical duration and temporal pattern selection, is noted to have been based on a single location, the Glenore Grove gauge. Standard practice is to ensure that for the design assessment, the focal location of the design is used to inform the ARF. As the gauge location has been used in this assessment, noting the gauge is downstream of the alignment, the peak flows at the alignment will be underestimated. A flow check comparing the outcomes at locations of interest should be undertaken to ensure this variation is not significant.

Additionally, because the alignment in this catchment contains many smaller catchments whose flows would be greatly affected by the ARF parameter, consideration should be given to undertaking a sensitivity assessment of the impacts using an ARF of 1.0.

3 Hydraulic Model Review

3.1 Overview

The Lockyer Creek hydraulic model was adapted from the Lockyer Valley Regional Council (LVRC) model created by Jacobs in 2016. The original model was a nested grid TUFLOW Classic model containing eight separate sub-model areas with varying degrees of terrain resolution. ARTC have consolidated this model into a single grid size of 10m. This cell size is adequate for this type of model where the streams are generally represented as 1D cross-sections.

3.2 Software Version

The TUFLOW model was updated to the Heavily Parallelised Compute (HPC) solver using TUFLOW version 2018-03-AB. It is recommended that in future stages of the project a later version of TUFLOW be used to incorporate all bug fixes since this version. Furthermore, future modelling could take advantage of benefits including Sub-Grid Sampling (SGS), Quadtree mesh refinement and an updated turbulence scheme.

3.3 Topography

The Lockyer Creek TUFLOW model utilises multiple 1 m Digital Elevation Models (DEMs) that are based off LiDAR survey of the area. The Technical Report notes that ARTC undertook a LiDAR survey in 2015, which has been utilised in the model and supplemented with data from Geoscience Australia with surveys flows between 2009 and 2015.

No field survey data was used in the development of the TUFLOW model.

The TUFLOW model reads in numerous GIS files to enforce existing railway levels, roadway levels, waterway embankment levels and various other topographic features.

The topographic setup is deemed acceptable for the purposes of the assessment undertaken. However, future stages of the project should utilise the latest available LiDAR data which includes, but not limited to, the Lockyer Valley LGA LiDAR dataset flow in 2018.

3.4 Roughness

The provided hydraulic model adopted the roughness values shown in Table 4.

Table 4: Adopted Hydraulic Model Roughness Values (Table 7.2 from Technical Report)

Land use	Manning's n
Roads and paved areas	0.025 to 0.030
Water bodies/farm dams etc	0.025 to 0.045
Channels and low vegetated creeks	0.045 to 0.060
Low-medium vegetation	0.045 to 0.070
Medium vegetated creeks	0.060 to 0.080
Riparian and dense vegetation	0.080 to 0.110
Demolished buildings	0.030 to 1.000
Farmland, pasture and crops	0.050 to 1.000
Urbanised areas	0.090 to 0.500
Fences	1.200
Buildings	4.000

The initial roughness values were based on the previous nested LVRC model, with adjustments made by ARTC through the joint calibration process. There are many differing roughness categories and ranges of Manning's values that are applied within the model. However, most Manning's 'n' values are considered to be within typical ranges for each land use/vegetation type and density.

A large portion of the domain has an applied depth varying roughness where a roughness coefficient of 0.08 is applied for depths below 0.3 m and 0.05 for depths above 1 m (linearly interpolated between). Where the default material is not used, the dominant roughness coefficient is 0.05 for all depths. This is not documented and justification for the approach is not provided in the Technical Report. The Panel recommends that the Technical Report be updated to address this given the extent of application.

Material 32 is identified as WIT Highway, has a roughness coefficient of 0.05, which is higher than the reported value for "roads and paved areas", and is outside the normal range. This is unlikely to have significant impact on the model results but it should be amended in future project stages.

The hydraulic roughness has not been updated to incorporate the rail alignment. However, minor roughness changes were made to the design scenario where grading is planned to incorporate new drainage areas. Although it is unlikely to cause material change to the results, it is recommended that roughness changes to incorporate the design be made in future stages of the project.

3.5 Boundary Conditions

The Lockyer Creek model boundary locations and URBS catchment delineation is presented in Figure 8. The boundary conditions applied within the Lockyer Creek model are complex and varying. Inflows within the model have been applied using four different approaches including 1D inflow points, 1D inflow regions, 2D line boundaries and 2D source area regions. Furthermore, the model included a 1D downstream boundary along Lockyer Creek (height vs time), a 2D downstream boundary (stage discharge) that allows flow to leave to the north near Mount Tarampa and multiple 1D to 2D boundaries.

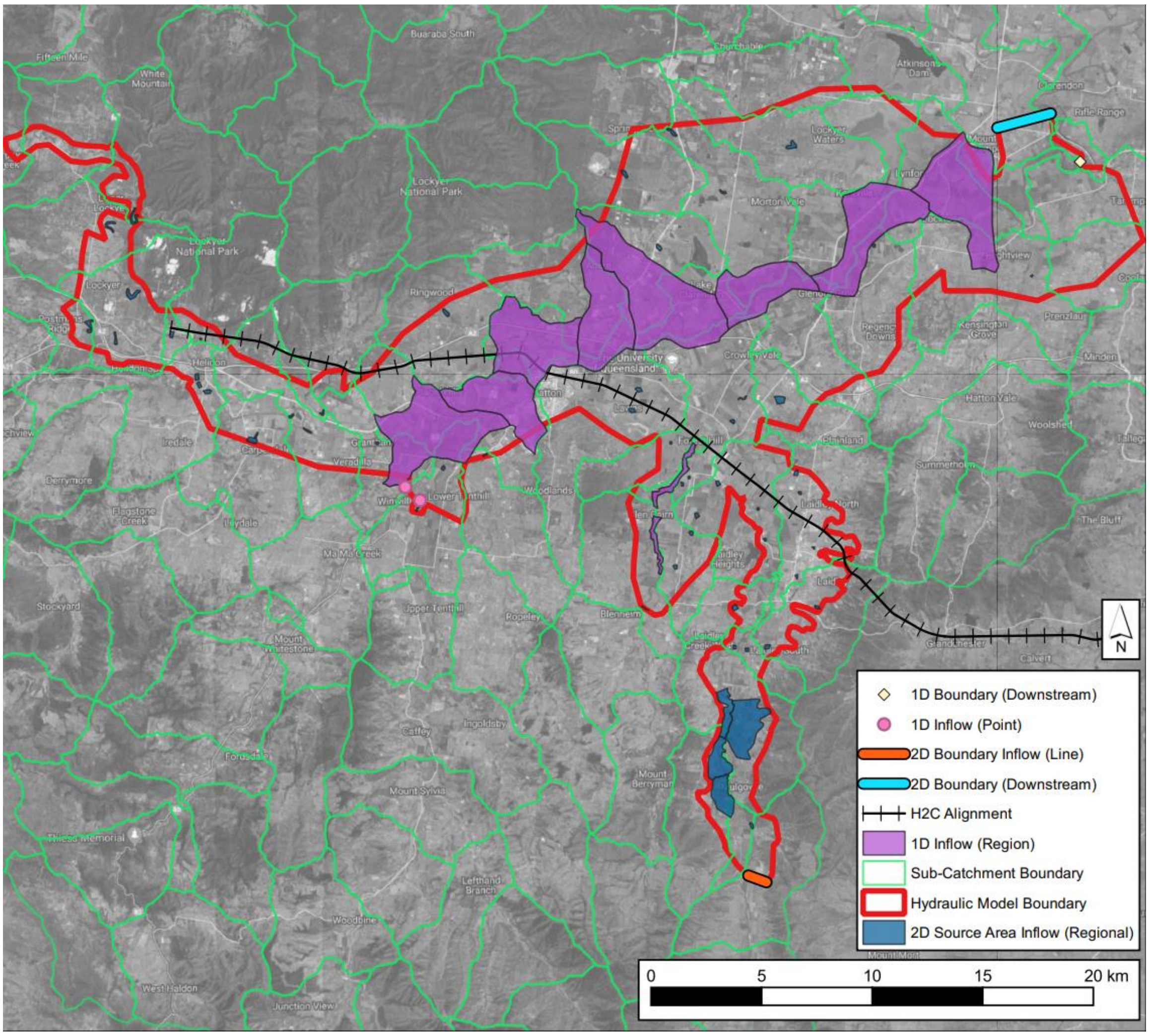

Figure 4: Lockyer Creek Model Boundary Configuration

The downstream boundary is a sufficient distance from the area of interest to not impact results at the alignment. However, there are some concerns with the downstream boundary. The internal (subcatchments within the hydraulic model extent) inflows, generated by the lowered beta hydrologic model, have been applied using either 1D inflow regions or 2D source areas. The application of flow is either applied across 1D nodes within a given area (when using 1D inflow regions) or at point inflow locations (2D source areas). The following issues were identified:

- 2D source area inflows are not applied in a consistent manner (e.g. not consistently at the subcatchment centroid or outlet)
- 1D inflow region extents span over several subcatchments

Based on these characteristics, it appears that several of the subcatchment inflows are “double routed”, meaning inflow routing is accounted for in both the hydrologic and the hydraulic model which is likely attributing to the use of a lower beta value. It also appears that there has been an attempt to address this in the TUFLOW boundary condition database, which controls the applied flow to the model, with time variation (increases and decreases in flow timing) applied to several inflows. However, this does not appear to be mentioned in the Technical Report and appears to have been undertaken using 0.25 hour blocks. It is unlikely that real-world adjustments would be this unsophisticated. Additionally, the 1D inflow regions do not align with the subcatchment delineation and therefore impact the application of inflow hydrograph in comparison to the subcatchment delineation. Justification regarding inflow locations, particularly the 2D source area inflows and the extents of the 1D inflow regions is required.

Several of the subcatchment inflows have been split across several locations within each subcatchment. The use of large subcatchments within the hydrologic model made this the only viable approach for replicating minor flow paths and avoiding proportioning too much flow upstream or downstream of hydraulic controls, such as roads and railways, which could result in unrealistic hydraulic model results. This proportioning was not always applied proportional to area and topography, resulting in some inflows receiving too much flow and others too little. Consideration should be given to reducing subcatchment sizes and/or refining the flow proportioning. Note that also manual adjustments to inflow timings were made to these inflows in an attempt to account distances between inflow locations, which were often several kilometres apart.

The 2D source area inflow locations are slightly different between the calibration model and the design storm event models (existing case and design case). This should be corrected.

The 1974 event URBS model results that were provided do not match what was adopted within the 1974 event hydraulic model. This should be checked by the FFJV.

There are several locations throughout the Lockyer Valley Local Government Area that are potentially impacted by the proposed rail alignment, including but not limited to Helidon, Placid Hills, Gatton, Forest Hill and Laidley. Analysis of the provided hydraulic model results shows that the current model inflow methodology does not adequately capture the inflow characteristics of several areas. The Panel notes that independent local catchment modelling, undertaken for the FDR, may be an appropriate approach. However, this is only reasonable if catchments are independent of one another or coincident flooding and interconnectivity of flow between catchments is accurately represented. The Technical Report and FDR report have limited discussion addressing this matter. A preliminary investigation by the Panel indicates there may be issues with the current approach and either further justification or investigation of this issue is required.

For example: the interaction between the local and regional flooding at Gatton is presented in Figure 5. It is unclear if the local model incorporates inflow from the regional model. Additionally, the regional flood extent (represented in blue) has not been represented on the eastern side of the model where impacts in the local modelling are noted. Figure 6 represents a similar scenario, but in reverse, where the local flood model extents are not represented in the regional modelling. Furthermore, the local model has been terminated in this area upstream of the Valley Vista estate where there is a documented history of flooding. LVRC local flood extents demonstrate the expected 1% AEP flood extent in this area and have been overlayed against local and regional flooding and presented in Figure 7. This shows a reasonable correlation between the ARTC local modelling and LVRC local model, but there is a clear disparity between the regional flood extents. This has the potential to result in underestimated impacts surrounding the rail alignment.

The flood interaction issues were raised by the Panel with FFJV on the 25/03/2021 with a Technical Note response provided on the 31/03/2021. This Technical Note identified that the local model at Gatton was a direct rainfall model with a significantly shorter critical duration (than the regional model). As such, a regional tailwater was not applied. Additionally, it was noted that the Laidley local model was developed with a discharge curve as a downstream boundary condition which result in a tailwater level several meters higher than the regional 1% AEP flood level from Lockyer Creek. Although both these justifications may be logical, neither demonstrates that the flooding (regional and local) is independent of one another and can be assessed in this manner. Furthermore, the issue of flood representation in the Valley Vista estate area has not been addressed. Therefore, further documentation and potential sensitivity modelling to ensure flood impact objectives are met is required with respect to the incorporation and assessment of flood interaction between the local and regional models.

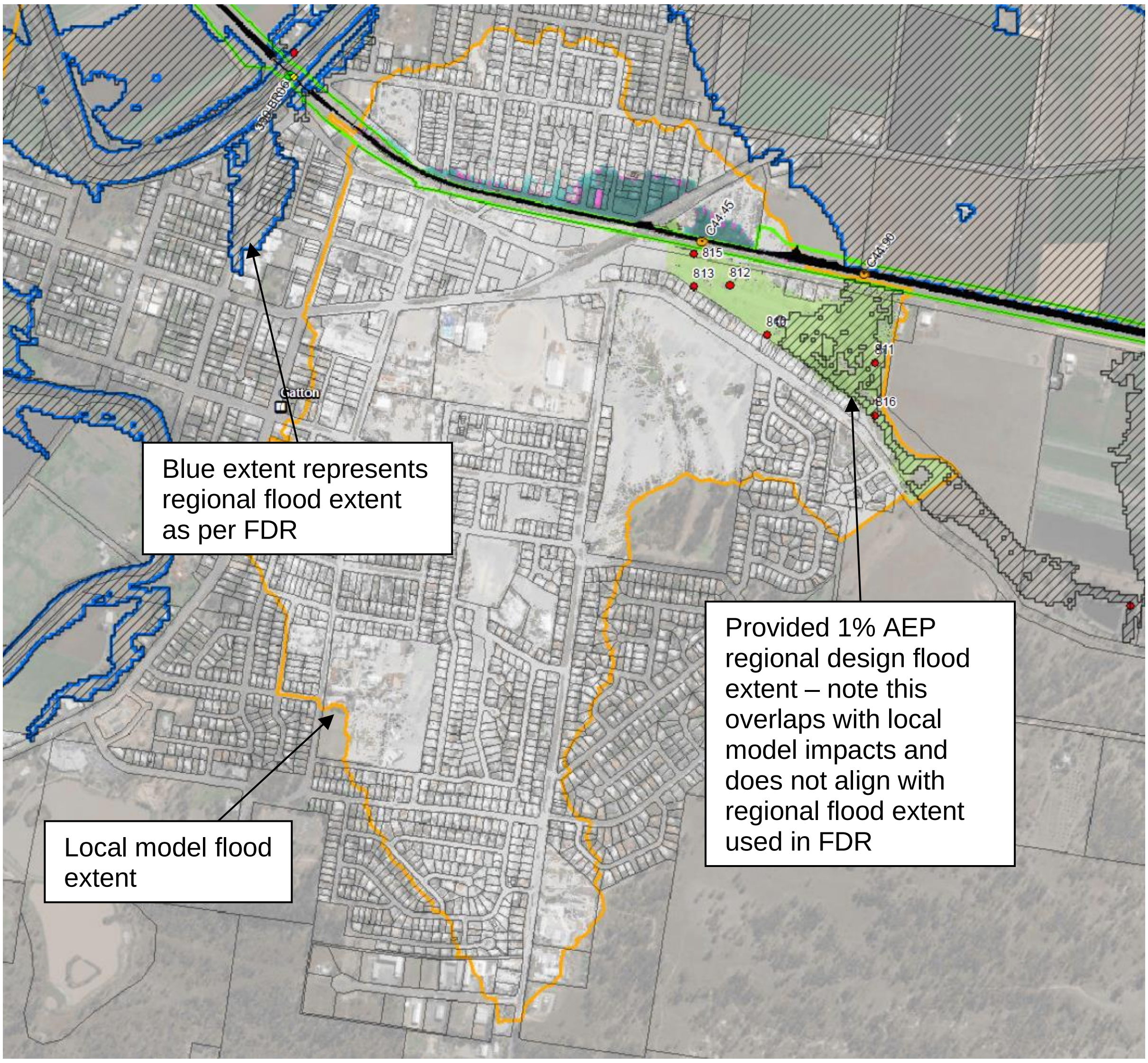

Figure 5: Gatton Local Model Interaction with Regional Model – Local Model 1% AEP Impact Results

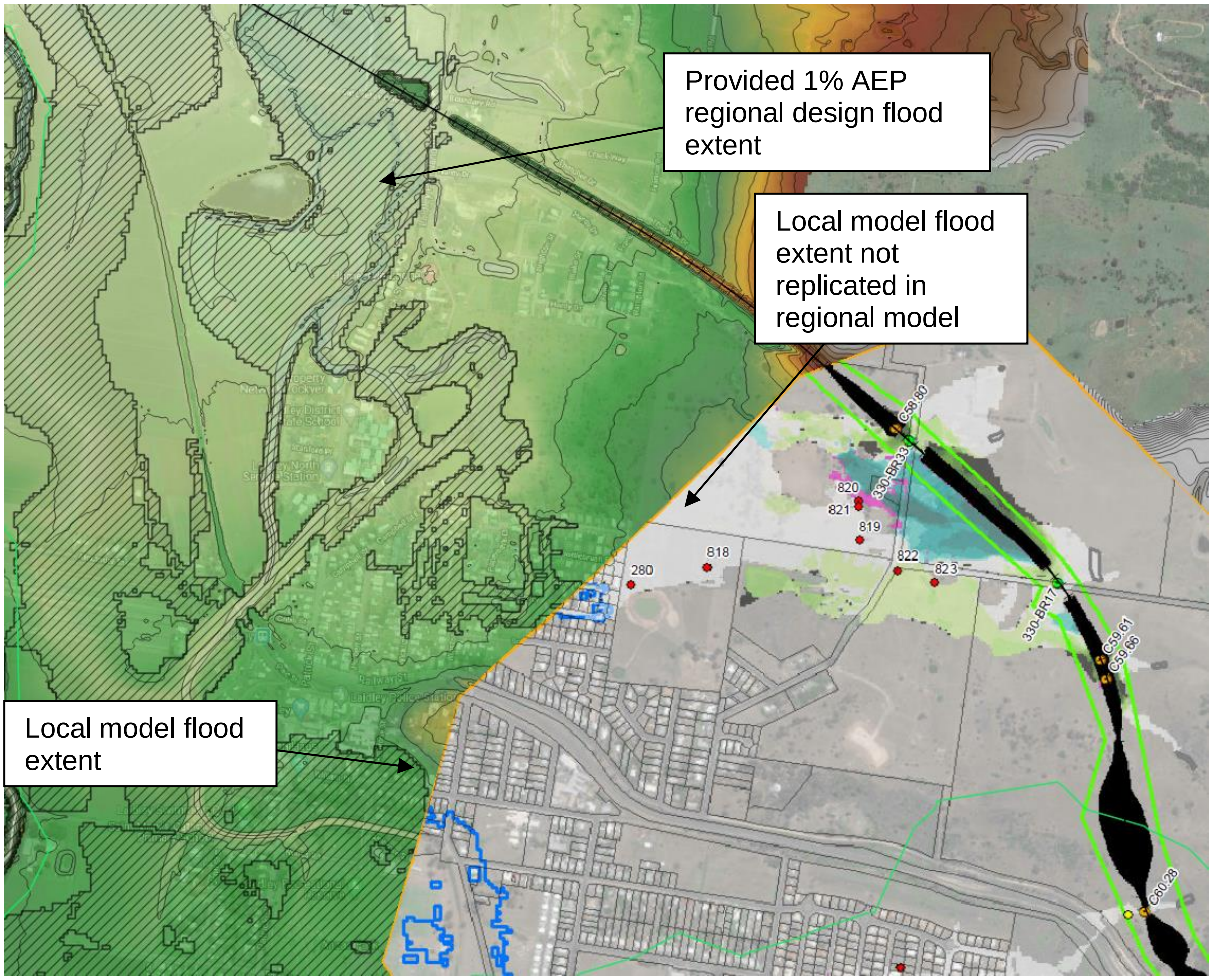

Figure 6: Laidley Local Model Interaction with Regional Model – Local Model 1% AEP Impact Results

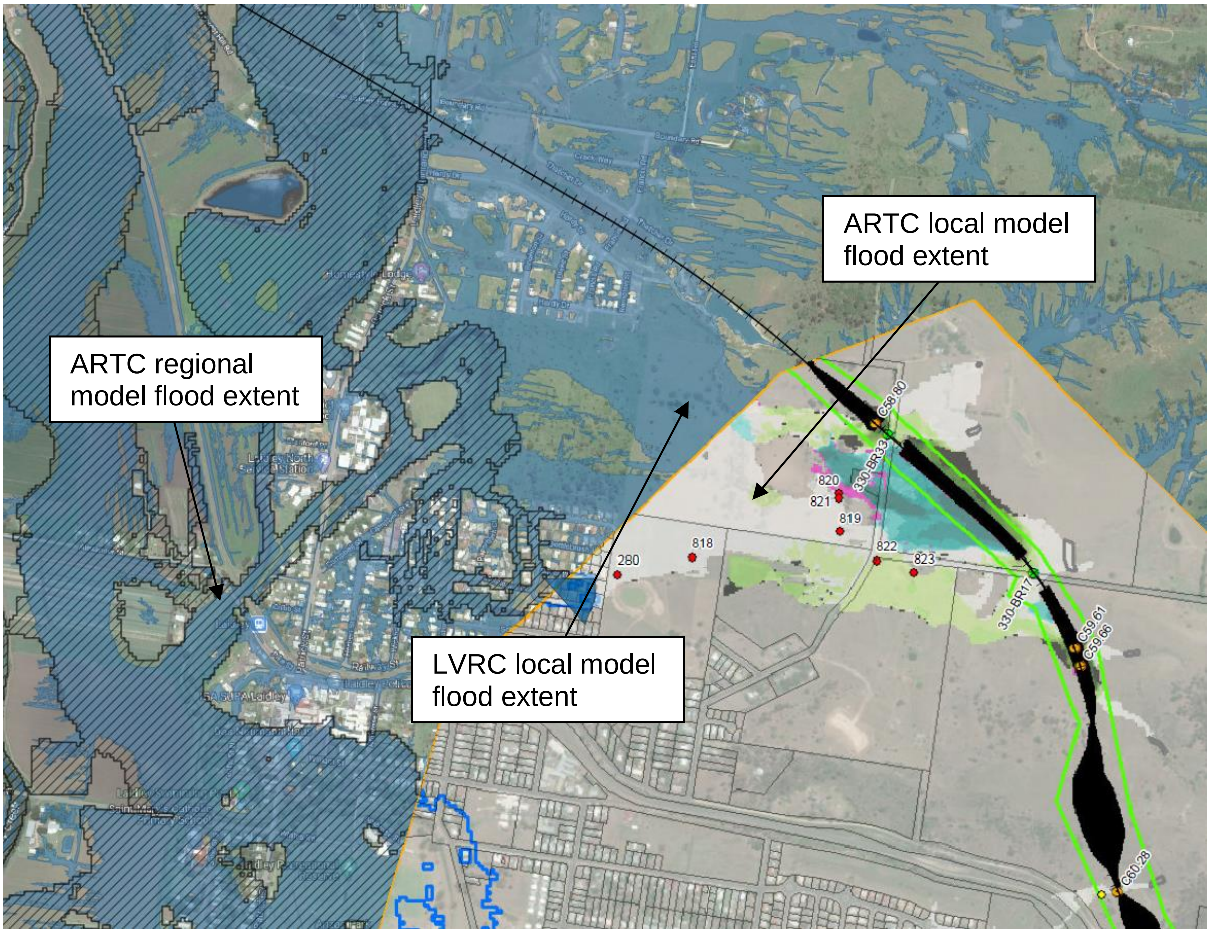

Figure 7: Laidley Local Model with LVRC 1% Local Flood Extent

The 1D downstream boundary on Lockyer Creek uses a constant Water Surface Elevation (WSE) throughout the run even though the boundary is used for dynamic simulations with significant differences in flowrates. Additionally, the constant WSE assigned provides an unreasonably small flow depth of 0.1 m. The boundary node level is also questionable as it has a much higher bed elevation than other nodes just upstream. It is noted that the boundary is located a significant distance from the area of interest, but it is recommended that a rating curve be adopted for future project stages.

Figure 8 shows the configuration of the downstream boundaries overlayed with the PMF flood extents. The 1D downstream boundary is not located at the downstream end of the 2D model domain and as such, flows in the floodplain or from Plain Creek are not able to exit the model via the boundary. This is unlikely to have impact at the rail alignment but it is recommended that in future project stages the boundary is moved downstream of Forest Hill Fernvale Rd and additional 1D/2D connections are added.

The 2D HQ downstream boundary allows flow to exit the model to the north of Lockyer Creek. However, there is still a significant amount of water ponding against the model boundary in extreme events, as shown in Figure 8.

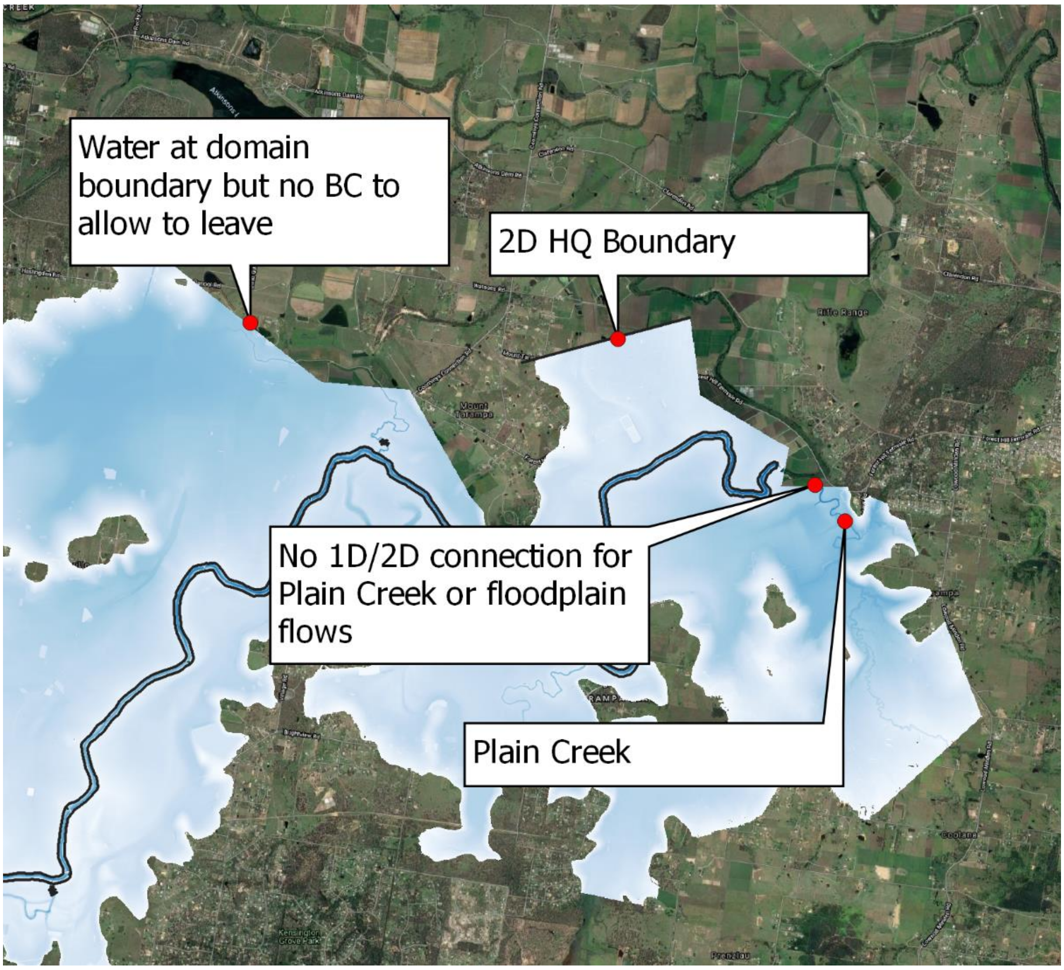

Figure 8: Downstream Boundary Configuration with PMF Flood Extent

There are noted connection issues with culverts throughout the model where culverts are overconnected (connected to a significantly higher number of cells compared to the structure width) and artificial lowering of cells is being applied. An example of this is presented in Figure 9. The orange dots indicate that the elevations have been lowered by more than 0.3 m. The rectangular culvert in this situation is 28 m wide and should be connected to approximately 3 (10m) cells on the upstream and downstream sides. However, the number of connected cells significantly exceeds this number. The connection has also been input using a “zig-zag” pattern, which generates significant artificial topographic changes.

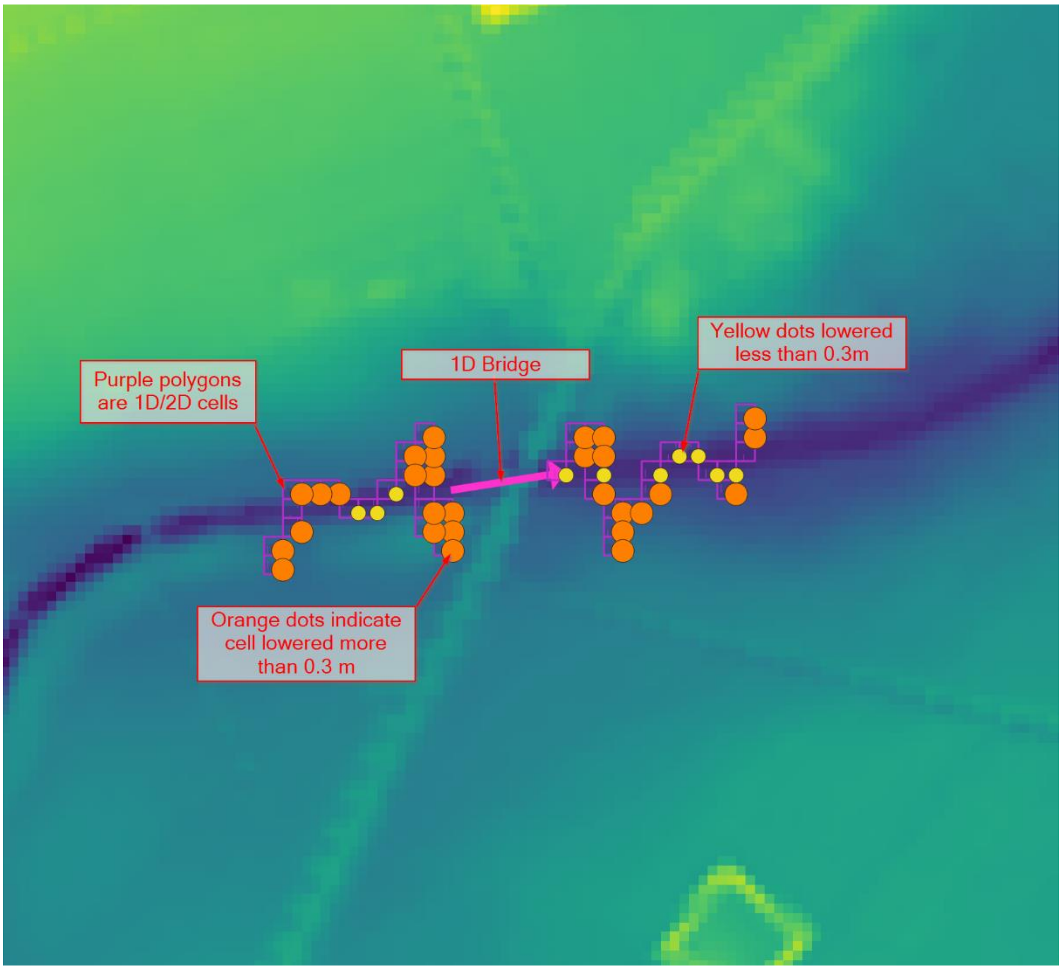

Figure 9: 1D/2D Connection Issue

There are also reoccurring issues at the 1D waterway confluence points throughout the model. Figure 10 demonstrates this issue occurring at the confluence of Woolshed Creek and Lockyer Creek. The connection cells have high elevations across the incoming creek hindering water from flowing from the unnamed creek into Lockyer Creek. Understanding that Lockyer Creek is a perched waterway, the model should correctly represent the tributary connections by lowering the cell(s) at confluence locations throughout the model.

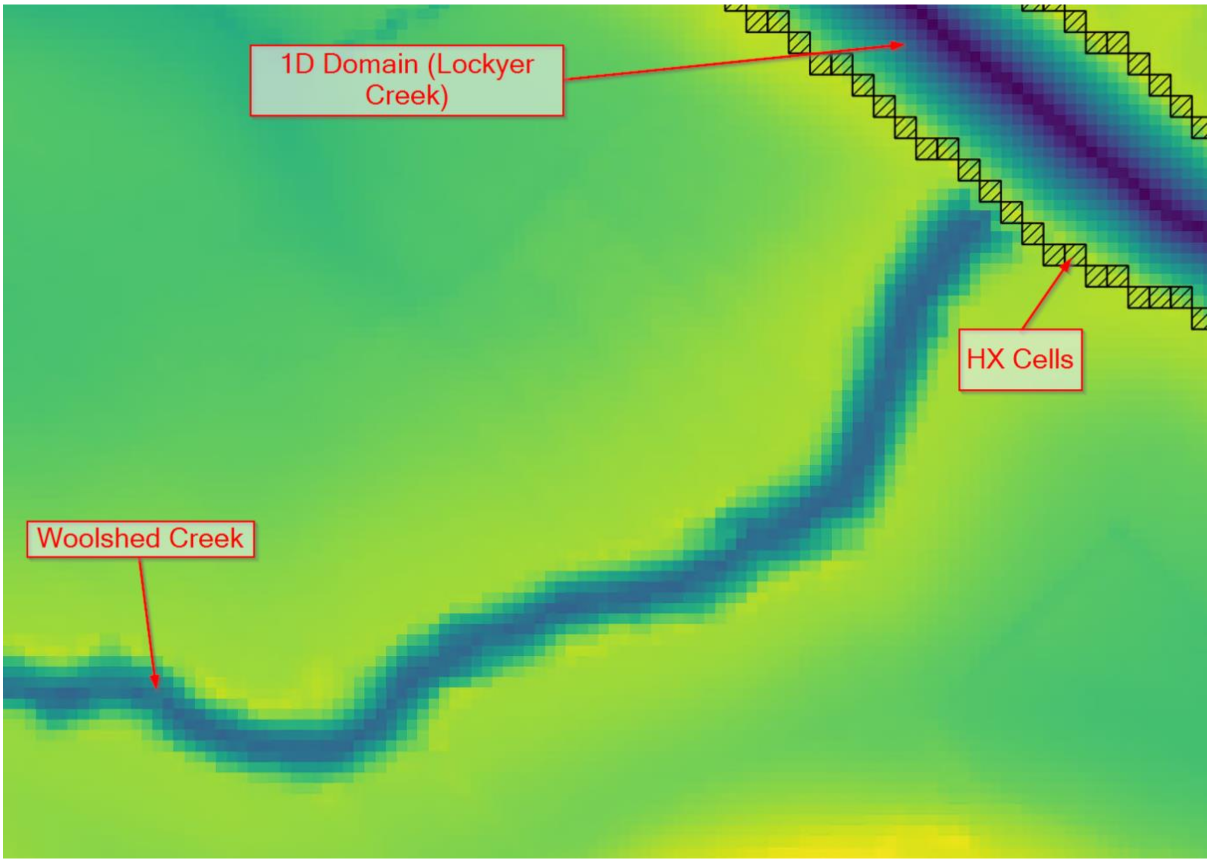

Figure 10: 1D HX Connection Issue at Confluence Locations

There are multiple issues identified in the area where Sandy Creek meets Laidley Creek as shown in Figure 11. These issues are not limited to this location; similar issues have been identified in other areas of the model. The issues identified are:

- Connection issues at the 1D bridge for Laidley Creek
  - The bridge is modelled as 20m wide (as per TUFLOW check file) but is only connected to one 10m cell on the upstream and downstream sides of the bridge.
- 1D/2D culvert connection issues
  - Two adjacent culverts have SX cells which are connected to cells situated on top of the embankment. These should be connected north of the embankment.

The identified issues, which are shown on Figure 8 to Figure 11, are not isolated issues and are prevalent throughout the model extent. The identified issues are unlikely to have significant bearing on the overall model results. However, they may undermine confidence in the modelling approach and be addressed in future project stages.

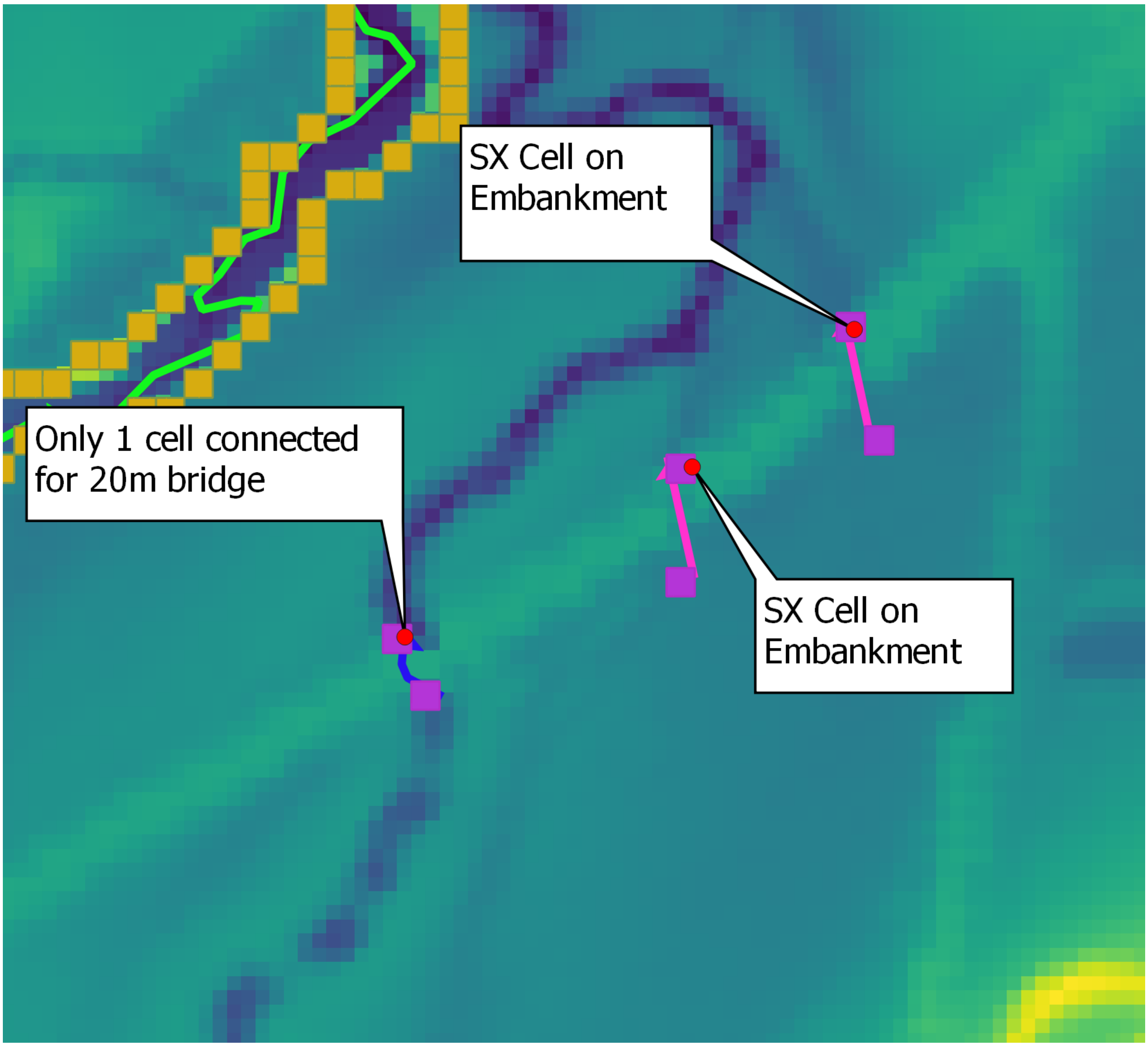

Figure 11: 1D/2D Connection Issues at Laidley Creek and Sandy Creek Confluence

There are several connection issues identified at the downstream end of Ma Ma Creek as presented in Figure 12. The current model setup (1D/2D boundaries) is configured so that there are areas represented in both 1D and 2D. This area should be reconfigured to eliminate duplicate representation and isolated 2D cells.

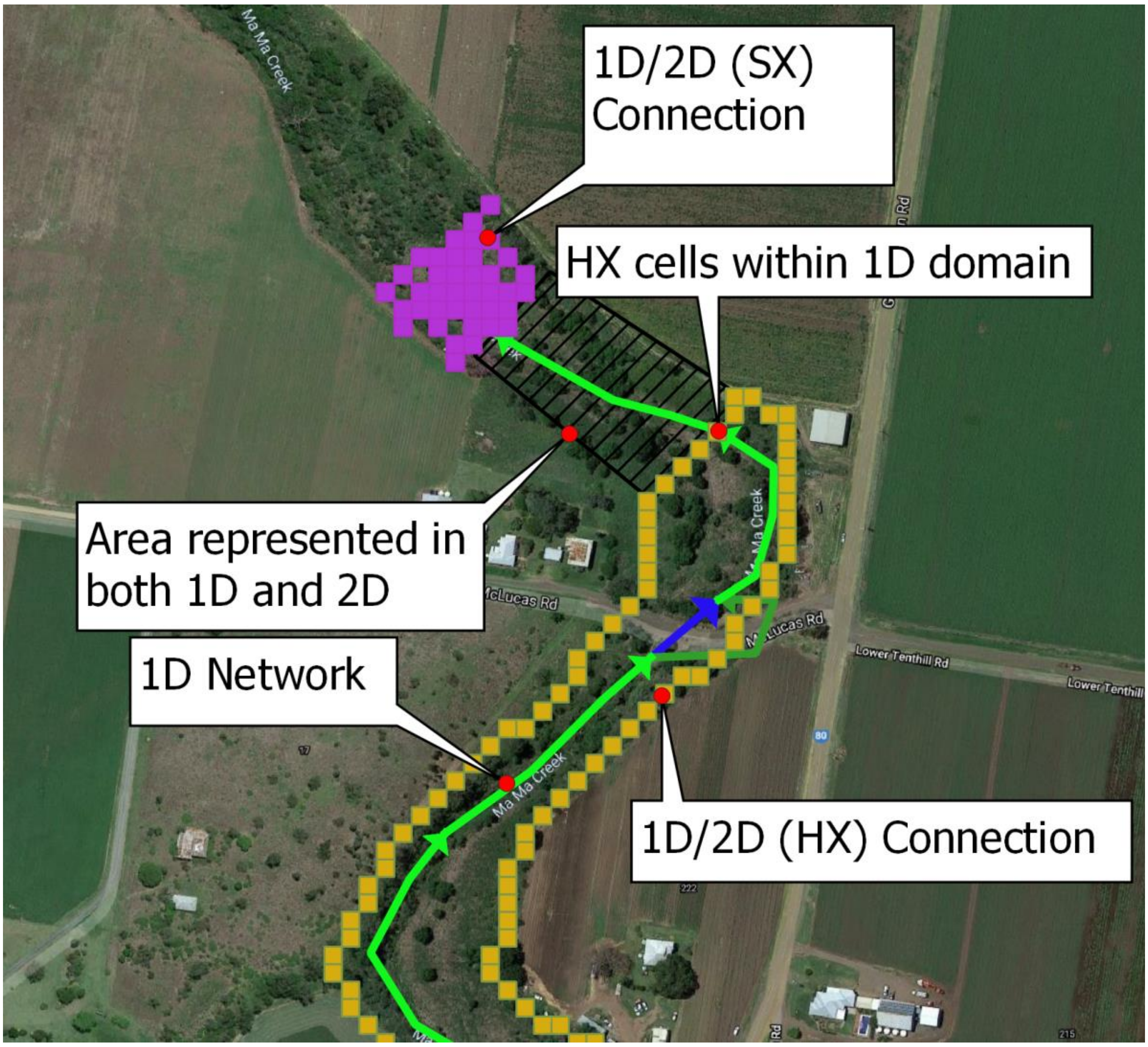

Figure 12: 1D Network Issues at Downstream End of Ma Ma Creek

Connection issues have been identified at the Deep Gully and Tenthill Creek confluence point as shown in Figure 13. The connection between Deep Gully and Tenthill Creek is duplicated with two methods being applied (both HX and SX connections used). Furthermore, Deep Gully is poorly represented in the model (represented in 2D) which may impact the potential conveyance of the waterway. Additionally, similar to the issue previously identified, the SX connection covers an area much larger than is reasonable.

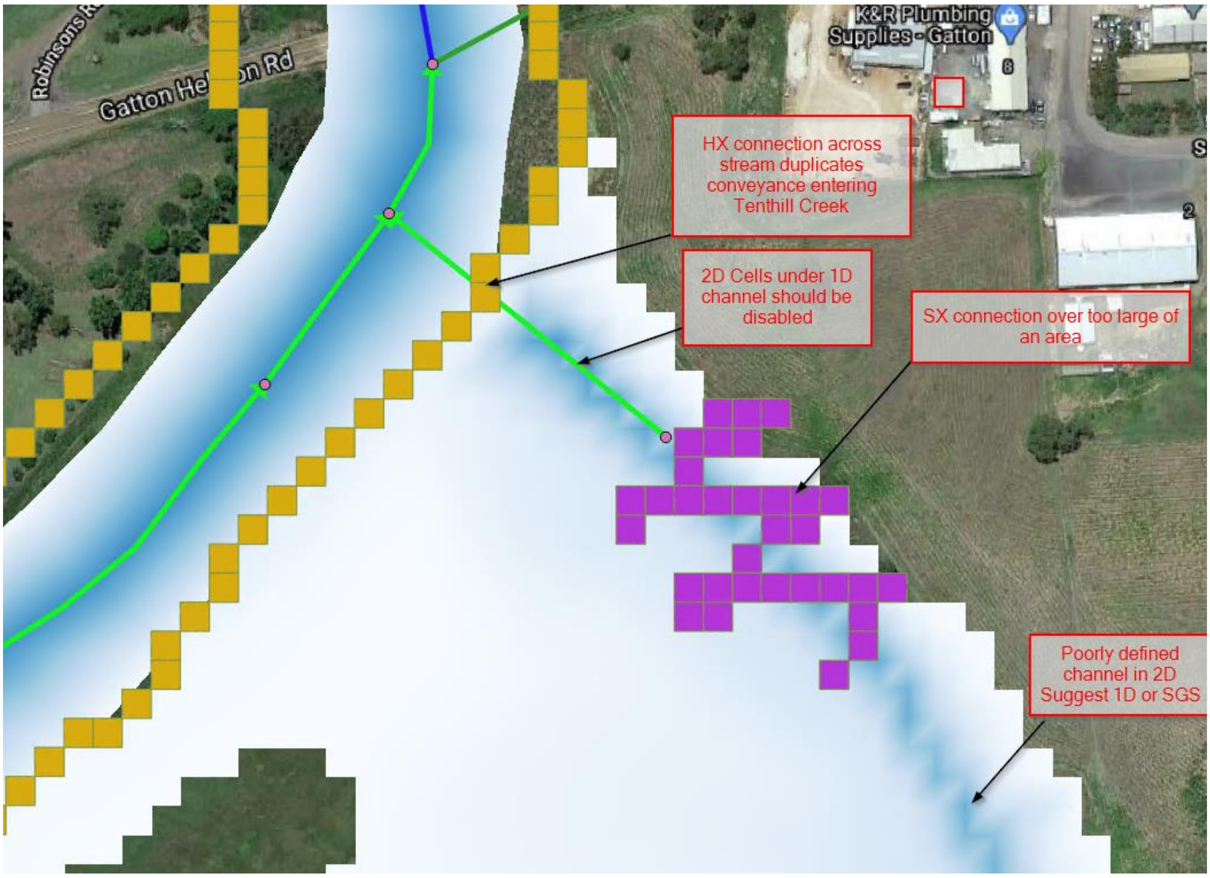

Figure 13: Connection Issues Deep Gully and Tenthill Creek Confluence

3.6 1D Channels

There is a significant number of 1D channels used within the Lockyer Creek model to represent waterways including the Lockyer Creek. The 1D channels provide better lateral resolution in certain areas where waterway representation in 2D may be constrained by the model cell size. As such, the 1D portions of the model are generally appropriate but minor connection issues have been noted as detailed in Section 3.5.

The TUFLOW model has an applied minimum nodal area of 200 m. Furthermore, some nodes within the model have additional nodal areas applied. These values seem relatively high and it is recommended that further justification or sensitivity analysis be undertaken to ensure that these additional nodal areas are not attenuating flow.

3.7 Existing Structures

3.7.1 Culverts

There is limited documentation included in the Technical Report addressing the inclusion of existing hydraulic structures within the model extent. The model incorporates approximately 138 cross drainage structures which are located throughout the model extent. Preliminary review of the modelling indicates that several minor waterway crossing culverts are not included in the modelling. An example of this the Laidley Creek crossing upstream of Forest Hill Fernvale Road as shown in Figure 14.

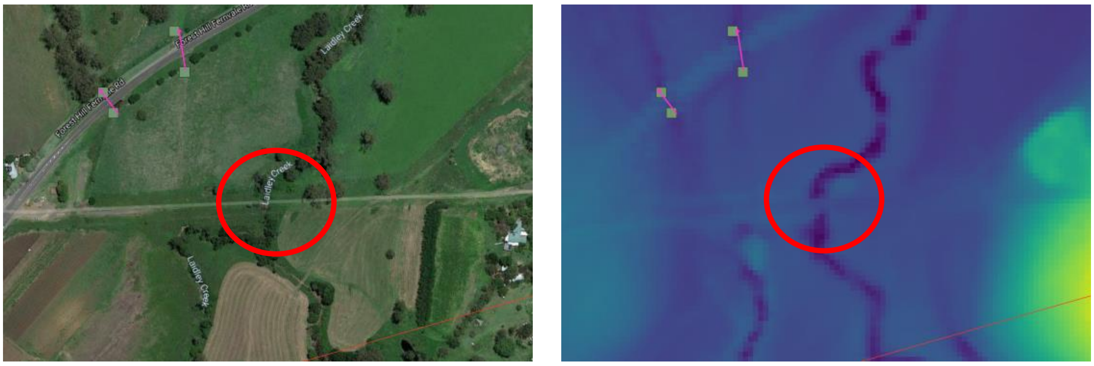

Figure 14: Missing Culvert Structure

The identified missing culvert infrastructure is generally situated on minor waterways and is unlikely to significantly impact large flood events such as the 1% AEP. As such, the impact may only be to minor events and unlikely to have significant bearing on the current model results. However, it is recommended that a review of missing culvert infrastructure be undertaken in the next phase of the project to ensure that existing cross drainage infrastructure is included.

Review of the existing drainage structure modelling shows there are more than ten culverts that demonstrate flow instabilities. An example of this flow instability is shown at Culvert 84.000 located under the existing rail alignment downstream of Whitehouse Road as shown in Figure 15.

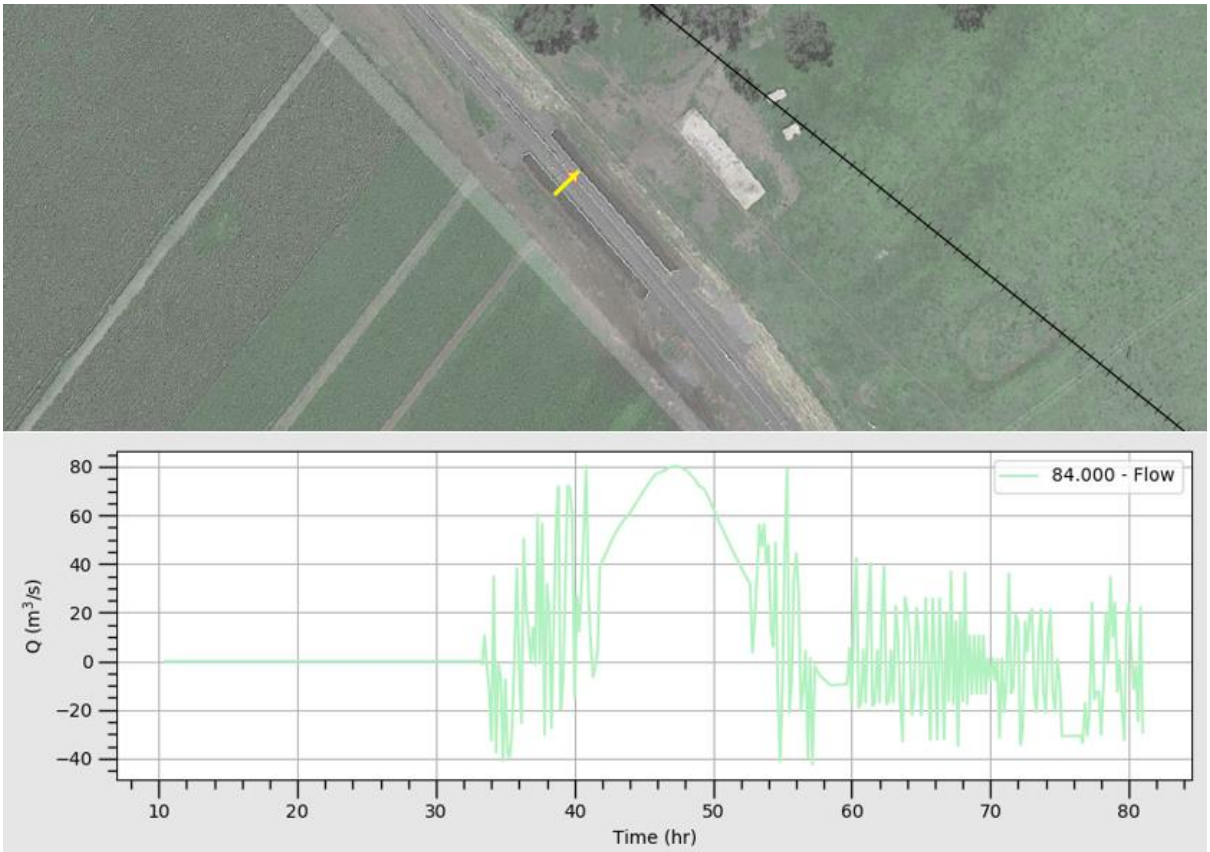

Figure 15: 1% AEP Existing Scenario Culvert Instability

The Panel notes that this issue is impacting around 10% of included culverts, with many of these being located a significant distance away from the alignment. It is recommended that a review of existing culvert stability be undertaken in the next stage of the project to ensure that modelling of culverts, particularly those immediately upstream of the proposed rail alignment, is undertaken correctly.

3.7.2 Bridges

The existing bridge structures have been maintained from the LVRC model with the exception of a drainage structure (Ch 49.56 km) which was originally modelled as a culvert but has been updated to a bridge based on QR as-built drawings. Maintaining existing bridge structures from the LVRC model is deemed appropriate as the original study is expected to have undergone a thorough review process.

3.8 Developed Conditions Model

3.8.1 Culverts

The inclusion of design culvert structures and model representation is generally reasonable. However, some instabilities were noted. Figure 16 shows the discharge time-series for culvert C52.67 near Forest Hill that oscillates significantly. Only a few of the culverts experienced significant oscillations but the culverts should be identified and stabilized.

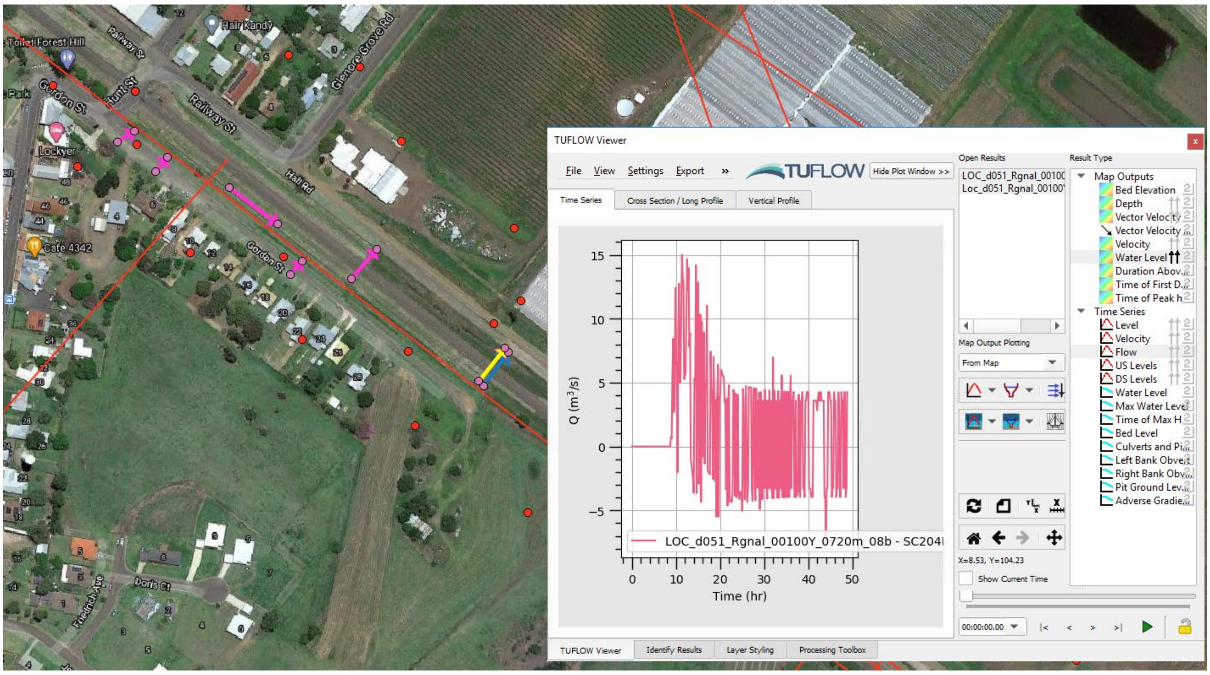

Figure 16: 1% AEP Developed Scenario Culvert Instability

Similar to the existing culvert structures, it is recommended that a review of proposed culvert stability be undertaken in the next stage of the project to ensure that modelling of culverts is undertaken correctly.

3.8.2 Bridges

The proposed reference design includes 11 bridge structures throughout the Lockyer Valley area. The proposed bridges in the model are represented by either 1D network layers or layered flow constriction shapes (LFCSH). However, the Technical Report provides limited discussion on how form loss has been calculated and included in the

LFCSH. Furthermore, bridges 330-BR06 and 330-BR10, do not appear to have been updated in the proposed design scenario to represent the rail duplication. As such, these bridges may not be represented in the design scenario. No justification for their omission is presented in the Technical Report.

The form loss applied to bridges represented using LFCSH is the same for each bridge. Acknowledging that this is a preliminary design stage of the project, it would still be expected that not all bridges would have the same form loss due to differences in pier configurations. Furthermore, the direction of flow at each bridge is not expected to be uniform which would also result in differences in form loss values. Further justification on these choices is required.

3.8.3 Other Items

The model has many warnings and checks reported in the TUFLOW messages file. Models often have warnings and often warnings can be safely ignored. However, some warnings indicate problems with the model that should be corrected. Reviewing all warnings is recommended to ensure that they are not identifying a real problem. The warnings in Table 5 are significant warnings that suggest created features are not used in the model.

Table 5: Significant TUFLOW Warnings

Warning	Significance
WARNING 2073 - NONE object ignored. Only Regions, Lines, Polylines & Multiple Polylines used	This warning indicates that there were GIS objects created but not used in the model. This could be because curved “arc” features are used instead of polylines with straight segments.
WARNING 2079 - 3D breakline failed to modify any Zpts. Check elevations, snapping and correct GIS projection	This warning indicates that some breaklines were not used with the “Read GIS Z Lines Gully” command. In some cases it appears that this warning occurs because endpoints are within the 1D portions of the model. This should be avoided because TUFLOW disregards these lines including portions that cross the 2D domain leaving the terrain unmodified.
WARNING 2073 - Object ignored. Only Points, Lines, Polylines & Region Centers used. GIS Object = PLINE MULTIPLE	This warning indicates that one or more features are not being represented because they are unsupported multi-part features. These features should be identified and replaced with single-part features.

4 Calibration

4.1 Joint Calibration

It is understood that the primary objectives of the calibration process have been:

- Comparison of the TUFLOW hydraulic model prediction of the relationship between level and flow with gauge ratings.
- Comparison of TUFLOW hydraulic model level and flow hydrographs for the calibration events to confirm if they match both the shape and timing of observed flow
- Comparison of TUFLOW hydraulic model levels with anecdotal flood level data from local councils and the stakeholders.

The Technical Report notes the following:

> "*Detailed calibration of the URBS hydrologic models was undertaken for the BRCFS. These hydrologic models have been adopted for the current investigation with minimal changes. No additional calibrating of the hydrologic models has been undertaken."*

The Technical Report does not appear to discuss the limitations of the BRCFS where the Lockyer Valley is within the study area but was not the focal point of the BRCFS. The Technical Report also does not appear to discuss the BRCFS statement that the area may be subject to higher localised creek flooding and recommends that flood levels for design and planning purposes should be checked with local council within the Lockyer Valley area. The ARTC study has targeted calibration adjustments in the hydraulic model only and has made no change to the hydrologic model. Issues with the joined calibration approach are discussed in Section 4.5.

4.2 Assessed Events

The project has focused on the 1974, 1996, 1999, 2011 and 2013 events for joint calibration as these events were used in the BRCFS. These events suited the purpose of the BRCFS. Although the focus of the BRCFS did not include the Lockyer Valley area, the selected events, for calibration purposes are reasonable.

4.3 Gauge Selection

Within the Lockyer Creek catchment there are approximately 22 stream gauges and numerous recorded flood levels for both the 2011 and 2013 events. However, for the purposes of the calibration, the Technical report notes only 5 gauges have been used. There is limited documentation surrounding the omission of gauges and it would provide rigor if to the calibration process if detailed in the Technical Report.

4.4 Rating Curves and Uncertainty

As part of the flood modelling assessment, FFJV undertook a review of the flood model against the BRCFS rating curves. This identified reasonable representation between the TUFLOW hydraulic model and rating curves at Glenore Grove, Gatton, Gatton Weir, Warrego Highway and Helidon. However, the Technical Report does note that at the Glenore Grove gauge, larger flows (exceeding 1000 m^3/s) overflow away from the channel and result in a very flat curve sensitive to changes in water level. Furthermore, the Technical Report notes a deviation between the model and the rating curve at the Warrego Highway gauge for flows greater than 1000 m^3/s. Noting these limitations, flow rate calibration has been undertaken by FFJV. This is deemed a reasonable approach by the Panel.

4.5 Results and Justification

The Technical Report notes a reasonable calibration to the selected events at the majority of gauges based on both peak flow rate and shape. A notable exception is the fit at the Helidon gauge to the 2011 event. Technical Report references the Grantham Flood Commission of Inquiry (GFCOI) report that undertook extensive assessment of the rating curve at Helidon and modelling of the 2011 flood in this area. The ARTC study does not adopt the findings or modelling of the GFCOI, stating “placing undue weight on attempting to replicate the characteristics of a flash flood may be to the detriment of the overall model calibration, given the significant uncertainties regarding the event”. Furthermore, the analysis against flood markers, as presented in Figure 17, shows a significant underestimation of flood levels between Helidon and Grantham. This is further supported by the 2013 event, presented in Figure 18, which shows a similar bias towards underestimation, albeit at a lesser magnitude than 2011. This indicates that the calibration in this area will result in an underestimation of levels within the design model. The Panel does note that Lockyer Creek flows away from the alignment in this area and the alignment is unlikely to be subjected to regional flooding. Yet, the regional model has been used to inform the local modelling in the area and therefore replicating the regional model parameters in the local modelling may result in underestimation of design flow rates.

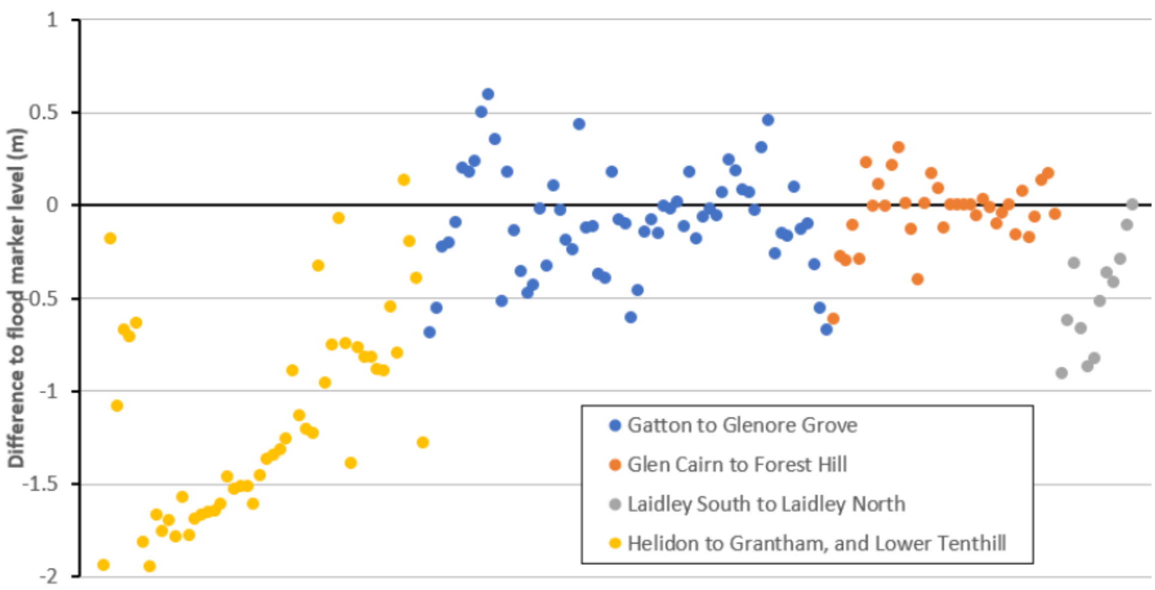

Figure 17: Lockyer Creek – 2011 Event – Flood Marker Difference (Figure 7.24 from Technical Report)

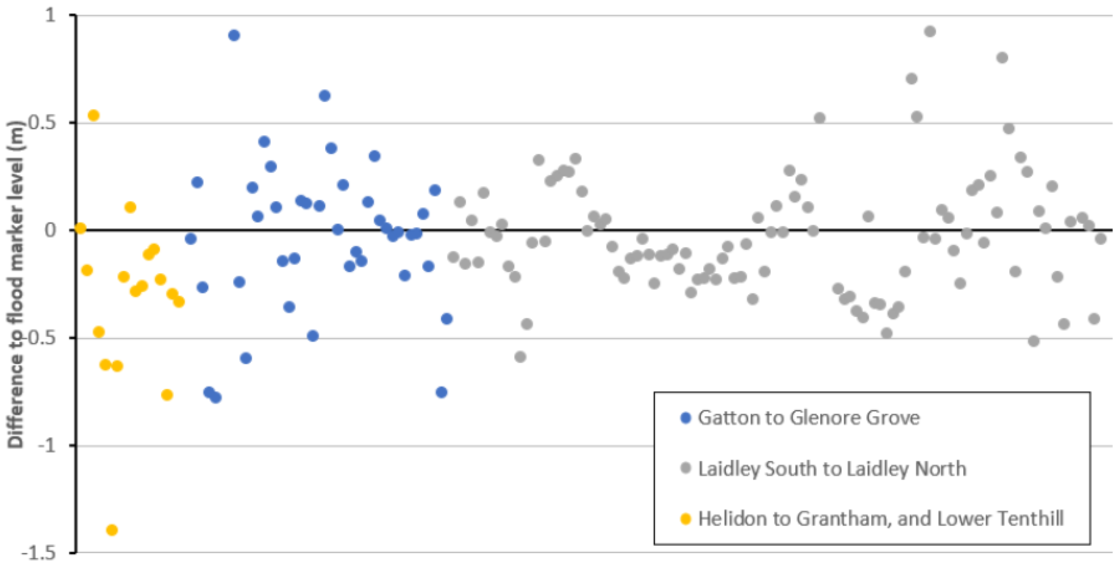

Figure 18: Lockyer Creek – 2013 Event – Flood Marker Difference (Figure 7.29 from Technical Report)

As noted previously, the Technical Report notes uncertainty at both the Warrego Highway and Glenore Grove gauges for flow rates above 1000 m^3/s. As several of the historic events (e.g. 2011 and 2013) significantly exceed these flow rates, both flow hydrograph and level assessments should be presented for model calibration events. However, only flow hydrograph comparisons have been provided within the Technical Report. The Technical Report does include Table 7.5 which presents peak water level comparisons between recorded gauge, URBS and TUFLOW levels. Analysis of this data has been undertaken by the Panel and presented as a level difference plot and level difference distribution as shown in Figure 19 and Figure 20. These plots show that there is agreement between the historic URBS and TUFLOW modelling. However, there are notable peak water level differences at the gauge locations between modelled and recorded levels with 36% of differences >±0.5 m and 23% of differences >±1 m. Noting that the Lockyer Creek catchment is a complex system comprising of multiple braided waterways and perched channels, the differences in recorded and modelled peak water levels are significant. Further justification and potentially refinement of calibration regarding these differences and the poor calibration match between Helidon and Grantham is required.

In addition to the aforementioned calibration issues, the approach of varying beta values to account for local and regional responses is not common practice. As noted previously, this approach indicates a disparity in the model representation at a local level. The use of a lowered beta value for local inflows in the joint calibration hydraulic model implies the hydrologic and hydraulic models do not provide consistent results. Noting the use of a joint calibration approach to validate both models, the need to vary the hydrologic parameters between the two models to achieve a reasonable calibration raises questions of the validity of the joint calibration approach.

Furthermore, the Panel has undertaken an assessment of the TUFLOW design flow rates against the reported URBS and FFA estimated peak flow rates at Glenore Grove as presented in Figure 21. Even with the modification to the beta value, there are significant differences (underestimation) between the TUFLOW peak design flow estimates and the FFA for the 5%, 2% and 1% AEP events. The Panel notes that the

Glenore Grove location is approximately 10 km downstream of the alignment and there is uncertainty in the rating curve for flows above 1000 m^3/s. However, this is the only gauge where a FFA has been presented within the Technical Report.

The FFA multiple location presentation and comparison of peak flow rates issues were raised by the Panel with FFJV on the 25/03/2021 with a Technical Note response provided on the 31/03/2021.This Technical Note identified that the FFA was also undertaken at Gatton and Helidon gauges. Furthermore, justification for the exclusion of several gauges such as Laidley Creek at Warrego Highway and Lyons Bridge and Rifle Range Road gauges was also provided. However, no justification for omission from the technical report of the FFA for Gatton and Helidon gauges was provided. The Technical Note stated that only peak flow rates had been compared for the Glenore Grove FFA but comparisons could be undertaken if requested. In the interest of efficiency, the Panel did not request these, instead opting for this to be addressed with all other items raised as part of this review process.

The culmination of the calibration issues presented highlight potential deficiencies in the calibration approach undertaken. As such, the Panel recommends that further justification, including FFA at multiple gauge locations (e.g. Gatton and Helidon), hydraulic model design event peak flow rate comparison to FFA, and historic level comparison be included within the Technical report to provide rigor to the calibration approach. Further, potential refinement of the calibration may be required if the aforementioned data is not found to improve confidence in the calibration.

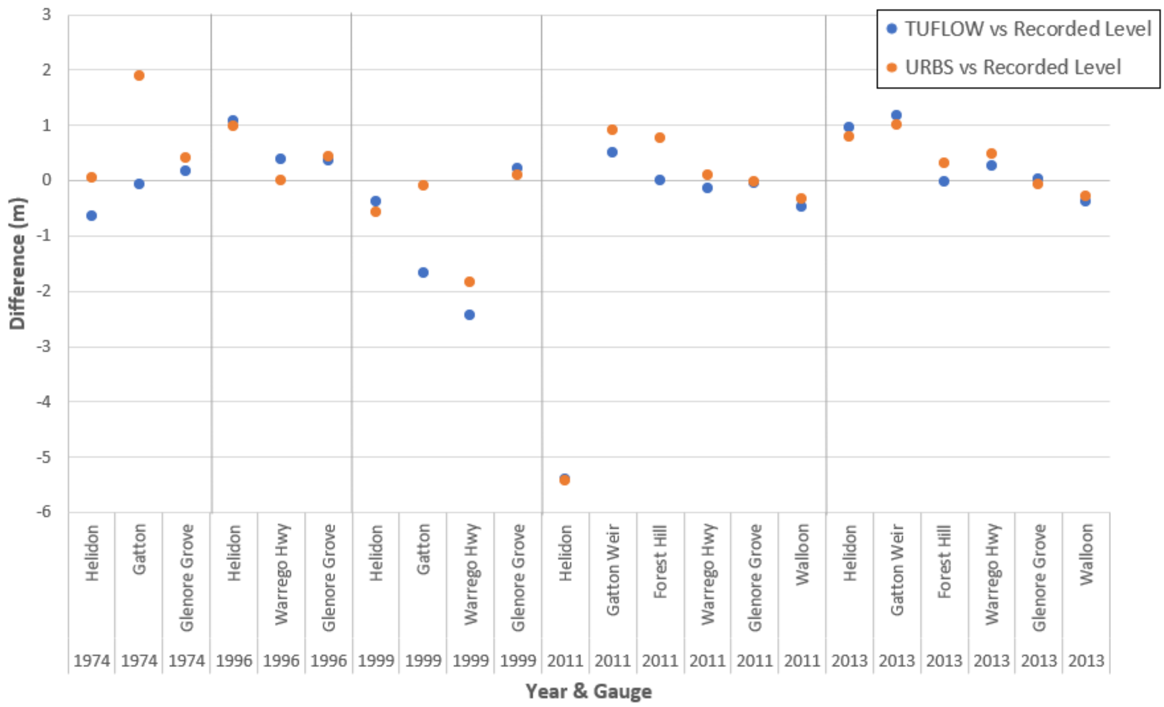

Figure 19: URBS and TUFLOW Level Difference to Recorded Levels (based on values from Table 7.5 of the Technical Report)

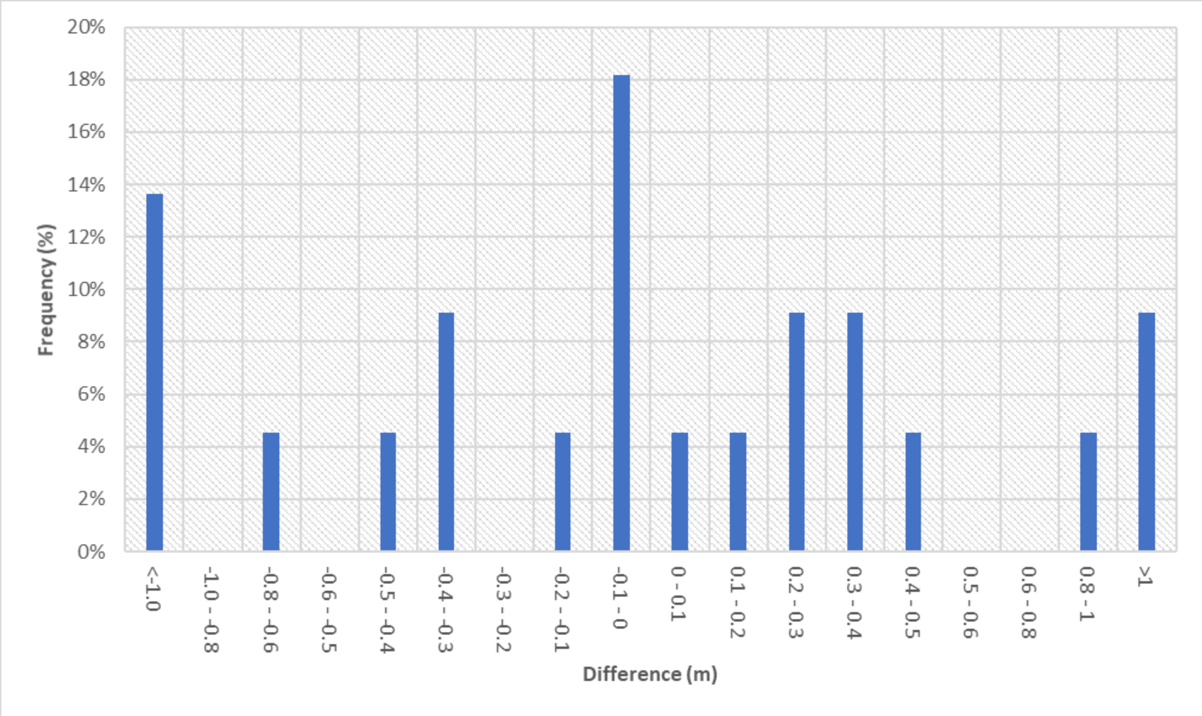

Figure 20: TUFLOW Level Difference to Recorded Levels Frequency Distribution (based on values from Table 7.5 of the Technical Report)

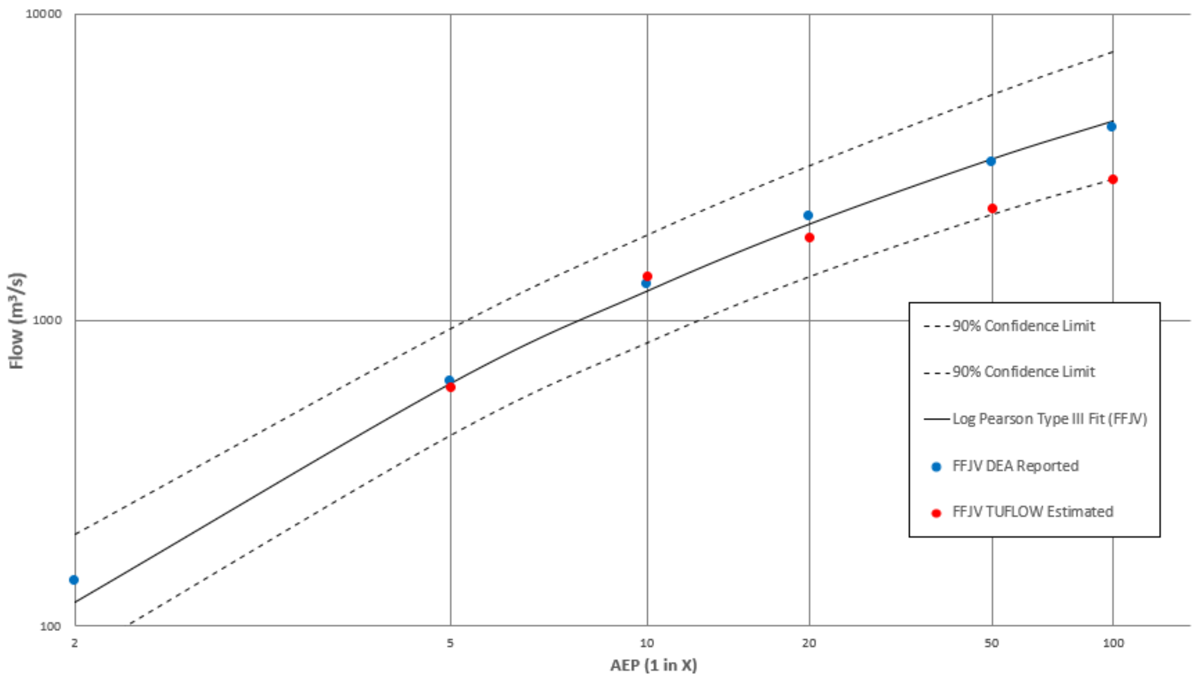

Figure 21: Peak Flow Rate Comparison at Glenore Grove TUFLOW Model versus URBS and FFA from Technical Report

5 Proposed Design Results

5.1 General

The proposed design and associated results are provided within the report. In general, the results of the modelling indicate that the impacts of the rail alignment are manageable or acknowledged. However, as noted in Section 3.5, there are areas upstream of the alignment which have not considered the influence of local flow and vice versa. As such, if the raised issues in these areas are correct, could result in a change to flood model results.

5.2 Timestep

Review of the TUFLOW HPC timestep and adaptive timestep control number results found that there was a minor variance in the simulation timestep for at least one event (as shown in Figure 22). It is expected that this can be attributed to the version of the software available when modelling commenced (2018-03-AB-iSP-w64). Limited testing undertaken by the Panel using the latest version of TUFLOW (2020-10-AA-iSP-w64) suggested that its adoption would improve the modelling with respect to timestep. Subsequently, the Panel recommends that the latest version of TUFLOW be adopted for future project stages.

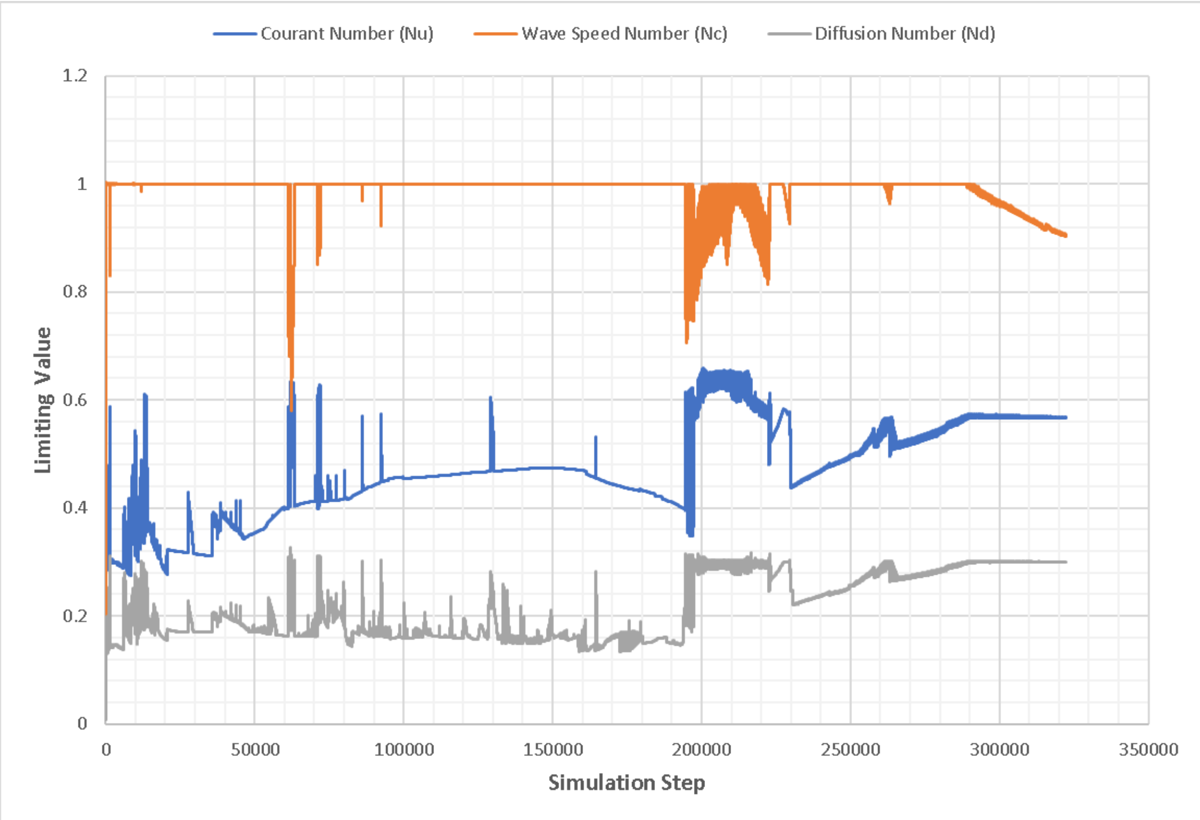

Figure 22: Design Case 1% AEP 48hr Temporal Pattern 09 HPC Timestep

5.3 Embankment Height

Aside from the need to connect to the existing rail line, most of the embankment has been set well above the calculated 1% AEP flood level to meet the project design requirement of 1% AEP flood immunity plus 300 mm freeboard. The embankment has a freeboard of 300 mm (Section 9.1.2.2 of the Technical Report).

The potential overtopping during extreme events such as the PMF, as detailed in Section 9.1.2.1 of the Technical Report, indicates that a significant depth of overtopping of up to 4.3m as shown in Table 6.

Table 6: Rail Overtopping Details During Extreme Events (Table 9.4 from Technical Report)

Approximate chainages (km)	1 in 2,000 AEP event overtopping depth (m)[1]	1 in 10,000 AEP event overtopping depth (m)[1]	PMF event overtopping depth (m)[1]
Ch 38.48 to Ch 41.79	0.30	0.50	4.30
Ch 44.05 to Ch 44.26	0.60	1.00	4.20
Ch 44.47 to Ch 46.24	0.50	0.65	1.65
Ch 48.09 to Ch 49.90	0.25	0.45	2.20

Table note:

1 Depths vary over the length of the rail that overtops. The length of rail that overtops increases with event rarity.

5.4 Flood Level Impacts

No locations within the Lockyer Creek catchment have been identified in the Chapter 13 Surface Water and Hydrology Report (Future Freight Joint Venture, March 2020). However, Table 7 which presents afflux at sensitive receptors, identifies several locations which exceed the afflux criteria such as Hall Road. These impacts are identified as isolated and often within the project alignment (e.g. Hall Road) but it is recommended that they be included in Chapter 13 for transparency.

Table 7: Afflux at flood sensitive receptors during the 1% AEP event (Table 9.16 from the Technical Report)

Location	Afflux (mm)	Comment
Dodt Road (330-BR11, Ch 50.30 km. West of Greyfriars Road)	45	Afflux at this location impacts on Dodt Road and adjacent rural land.
Agricultural land (Ch 51.57 km)	400	Agricultural land appears to be open cropping land. Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events. Dissipates to less than 100 mm within 100 m downstream of the Project alignment.
Hall Road (Ch 52.68 km)	175	Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Dissipates to less than 100 mm within 30 m downstream of the Project alignment.
Agricultural land (Ch 52.68 km)	100	Agricultural land appears to be a mix of open cropping land and raised outdoor hydroponics under scaffold-shade coverings. Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Area around dwelling in the western corner of the block appears to experience shallow (<45 mm) sheet flow. Ground survey of this dwelling will be sought in detailed design.
Hall Road (Ch 53.40 km)	200	Afflux caused by introduction of culverts to minimise impacts to Forest Hill township during extreme events and prevent QR West Moreton System rail corridor overtopping present in the existing case. Immediately dissipates to less than 100 mm on the adjacent agricultural land.
Agricultural land (Ch 54.40 km)	90	Agricultural land appears to be open cropping land. Afflux resulting from the Project alignment filling floodplain area. Dissipates to 35 mm within 30 m of the Project alignment.
Rural Land (Ch 54.87 km)	260	Resulting from the Project alignment filling floodplain area. Dissipates to 50 m within 110 m of the Project alignment.
Agricultural land (Ch 55.00 km)	80	Agricultural land appears to be open cropping land. Afflux caused by bridge arrangement and western end of Project alignment (embankment) filling a low area in LiDAR survey.
QR West Moreton System rail corridor (Ch 55.85 km)	160	Caused by shallow sheetflow being trapped behind the Project alignment. Localised impacts.
Project alignment/ agricultural land (Ch 56.70 km)	135	Agricultural land affected by +100 mm afflux at this location is within the Project boundary (i.e. nominally 30 m from the toe of Project alignment, varying in locations; within the rail corridor but not part of the permanent infrastructure). Afflux dissipates to below 30 mm around the downstream end (west) of bridge 330-BR26.
Old Laidley-Forest Hill Road diversion (Ch 57.15 km)	180	Afflux is 80 mm in exceedance of the 100 mm criteria for roads. However, the ground level of the road diversion has increased by approximately 100 mm as compared to the previous road level. This results in a reduction of time of inundation whilst maintaining previous immunity levels for frequent events.
Between Old Laidley-Forest Hill Road and Project alignment (Ch 57.25 km)	360	The afflux is concentrated against the Project alignment and dissipates to less than 100 mm afflux immediately west of the partial Old Laidley-Forest Hill Road diversion. The Project alignment provides a reduction in peak water levels of 125 mm to community facilities (cricket pitch and associated grounds) and local access.
Residential lot – 2RP25655 (approximately Ch 57.45 km)	-	The residential structure is located 30 m from the toe of the Project alignment. This property is included as part of the Project boundary.

The Technical Note: H2C Value Engineering – Structures – Flood Requirements, 25 October. (Future Freight Joint Venture, November 2019) presents the results of value engineering process which included (Section 2 of the Technical Note):

- Treating only flooding at habitable dwellings as a constraint, with higher tolerances adopted for other types of flood sensitive receptors; and
- Increase the peak water level impact up to the 400 mm limit (noting that the Flood Impact Objectives nominate an increase of less than 200 mm with “localised areas up to 400 mm”.

The above relaxations would allow the size of drainage structures to be reduced.

The Technical Note indicates that it will be necessary to engage with stakeholders and the community in relation to any changes in design. Further, there is no indication that the reduced drainage structures will be adopted for further design.

Given the size of the project, the completion of value engineering exercises is to be expected. However, it highlights the need for the increases in level nominated in the Technical Report to be appropriately justified for any revision to drainage design in the future to be similarly justified, including consultation with stakeholders and the community.

5.5 Sensitive Receptors

Figure 23 indicates the location of sensitive receptors (houses etc.) identified by the FFJV within the Lockyer Creek catchment that are potentially impacted by the railway. Sensitive receptors are considered in greater detail by the FFJV when the afflux is greater than 10 mm for the event under consideration. Based on Figure 23 and Appendix D of the Technical Report, only ten receptor locations, 210, 700, 876, 877, 925, 943, 947, 973, 1031 and 1032, have an impact greater than 10 mm.

Figure 23: Sensitive Receptors (Figures 13.8a, 13.8b and 13.8c of draft EIS)

Table 8 lists the sensitive receptors affected by events up to the 1% AEP event including climate change with >10 mm afflux. Although all impacted receptors were listed in Appendix D of the Technical Report, Table 8 has been shortened for succinctness.

Table 8: Sensitive Receptors – 1% AEP Event with Climate Change (Appendix D of Technical Report)

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
210	Sheds and rural free	Lockyer	-	-	-	-	42	66	42	42	42
700	Sheds and rural free	Lockyer	-	0	1	4	10	12	10	9	10
876	Water tank	Lockyer	-	-	-5	-33	71	80	54	96	70
877	Sheds and rural free	Lockyer	-	-	-5	-34	75	84	57	101	74
925	Rail infrastructure	Lockyer	2	33	48	51	53	56	53	53	54
942	Rail infrastructure	Lockyer	-	-	-	-	-	17	-	-	-
943	Sheds and rural free	Lockyer	-	7	28	64	68	90	66	69	91
947	Roads	Lockyer	-	-1	1	26	22	23	21	22	22
973	Roads	Lockyer	-	-	-	20	31	40	30	32	33
1031	Roads	Lockyer	-	-	-	15	27	32	26	28	27
1032	Residential dwelling	Lockyer	-	-	-	228	230	227	227	232	225

With reference to the table above, increases range between 10 mm and 230 mm at the aforementioned receptors for the 1% AEP event. no justification is provided for the increase in level, particularly at receptor 1032. It is recommended that discussion regarding these flood sensitive receptors and the works undertaken to minimise impacts be documented within Chapter 13 of the draft EIS report.

Further, while there is no strict criterion for the consideration of flood level impacts for extreme events, it is recommended that extreme events also be tabulated for the next phase of the assessment. For example, the impact maps for the PMF event, shown in Figure 10, demonstrate that impacts at some receptors could be in excess of 0.5m.

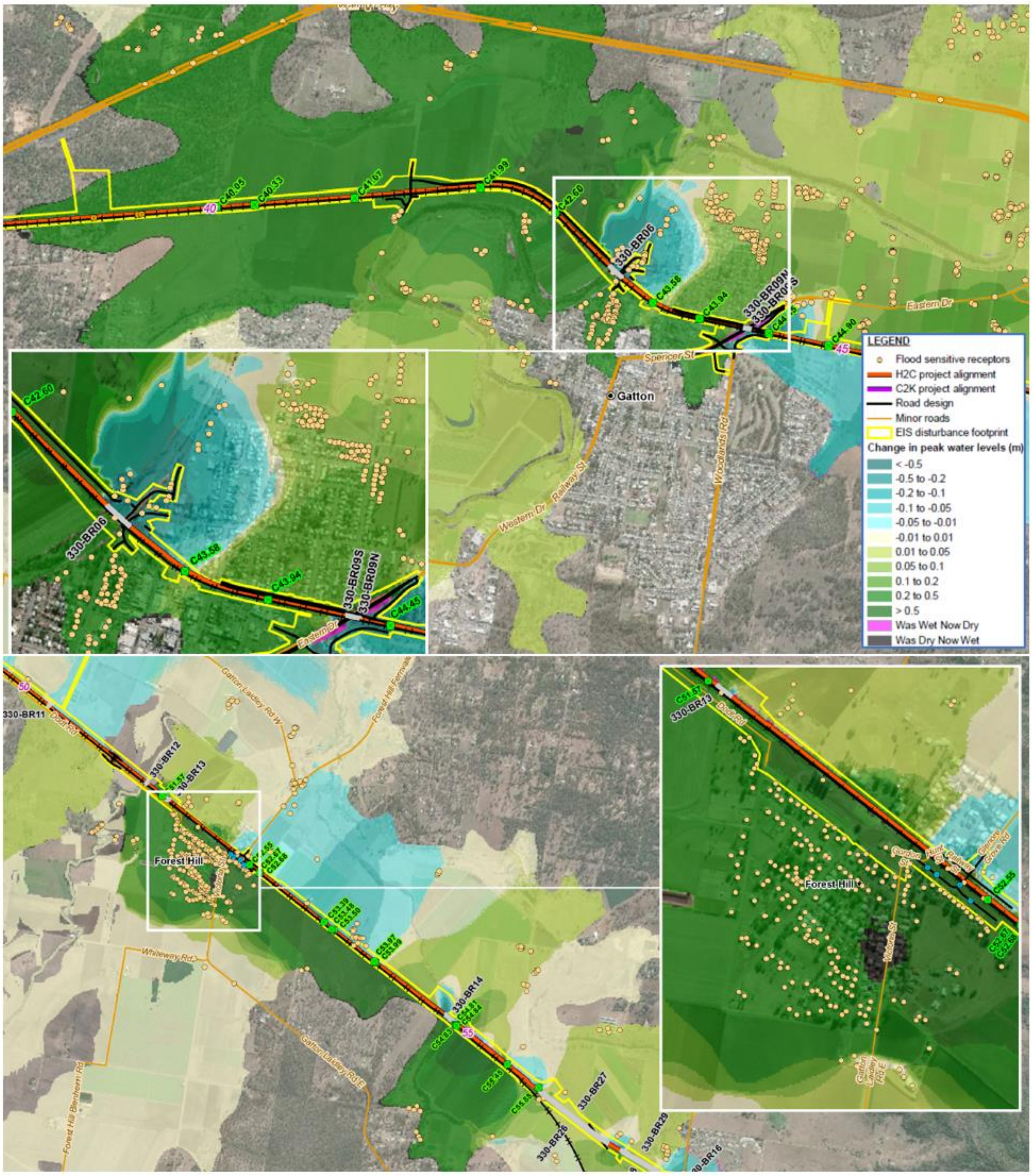

Figure 24: Change in Water Level for PMF Event at Sensitive Receptors (Figures A-10B-1 and A-10B-2 from the Technical Report)

The Tables and figures do not list the relevant flood level (or at least ground level if no survey data is available) at each receptor. This makes the assessment of any increase in level difficult as the proximity of flood waters to the floor of a structure and the depth of water over the floor are key criteria for the consideration of impacts. It is recommended that flood/ground level information be surveyed and added to the tables as part of further design stages in order for change in flood level at each receptor to be assessed.

5.6 Duration of Flooding and Time of Submergence

No locations are noted for the Lockyer Creek catchment within Chapter 13 of the draft EIS report. No tabulated impacts on the Annual Average Time of Submergence (AAToS) were provided and should be included in future phases to allow for a comprehensive review of potential impacts on submergence times.

It is also considered necessary to confirm that the change in time of submergence will not affect the viability of any crops. Form this perspective, it is also necessary to consider the change in time of submergence for more frequent events as it is the more frequent events that have the potential to impact on crops or grazing land.

Similarly, it is necessary to consider whether the use of higher flows in the model will significantly affect the duration of inundation.

5.7 Roads

Insufficient information is provided in relation to the impact (in terms of flood level impacts, ToS and AAToS) of the alignment on road immunity and flooding.

The Technical Report nominates an increase in level at Dodt Road but does not provide sufficient justification for the increase.

Current ToS has only been assessed at locations where an increase in water level of 100 mm to 200 mm occurs. It is recommended that locations where ToS is increase by more than 20% should be reported to ensure that roadways submerged by floodwaters (not just at locations where an increase greater than 100 mm occurs) are captured.

5.8 Flow Velocities

In accordance with the modelling undertaken using the adopted design flows, velocities at each crossing are generally less than 2 m/s. While such velocities would appear to be manageable (in particular in cases where large bridge spans are proposed), it is necessary to consider the potential for erosion and whether large or amended drainage structures are required.

The report considers the potential for scour in terms of flow velocities. Bed shear stress and stream power, which typically informs the changes to the geomorphology of the waterways, should also be referred to provide further details as to the potential impacts of the proposed works. Velocity is the pseudo parameter generally relied upon where these outputs have not been generated. For example, one of the bridge crossings has a design flow velocity of 2.5 m/s. While this is lower at the adopted tolerance of 2.5 m/s, it would be beneficial to know the shear stress associated with the velocity and the change in velocity/shear stress from the current situation. The velocity and shear stress of flow in the vicinity of proposed culverts will be of interest as there will be less ability to deal with erosion at these locations compared to the bridges where the significant proposed width provides a degree of flexibility.

In addition, climate change induced increase in rainfall intensity and the use of increased flows will result in higher velocities than those presented with respect to the 1% AEP event as calculated by the FFJV. It will be necessary to ensure as part of detailed design that the potential for scour including climate change and increased flows is addressed, with the adoption of larger drainage structures if necessary.

Overall, the acceptability of flow conditions will require a site by site consideration of the velocity and associated shear stress/ stream power relative to the soil conditions at the point the velocity occurs. Given the erodibility of the soils in the area, it will be necessary to pay close attention to the management of flow velocity as part of detailed design.

5.9 Extreme Events

The draft EIS and Technical Report present the results of modelling completed with respect to events greater than the 1% AEP design event, namely the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF.

For such events, flood impact objectives are not readily applicable. The focus of the review of extreme events is to ensure that the flooding behaviour does not change significantly as a result of the development and result in an increased flood risk. In this case, the increase in flood levels in the vicinity of Gatton and Forrest Hill is of significance as the embankment directs more flow to the south of the railway (refer Figure 24). It is recommended that additional justification be provided with respect to the increase in flood risk for these events and whether it is possible to provide additional drainage to partially mitigate the increase.

5.10 Design Criteria Outcomes and Associated Impacts

5.10.1 Sensitivity Tests

Sensitivity testing of bridge blockage (approx. 20%) has been undertaken as well as no blockage and 50% blockage of culverts sensitivity runs. These tests were only undertaken for the 1% AEP event and show similar impact results to the design case scenario.

5.10.2 Climate Change

The rail alignment formation levels are higher than the 1% AEP plus climate change scenario. The rail freeboard is presented in Table 9.17 and 9.18 of the Technical Report.

6 Proposed Design – Local Catchments

The review of the proposed drainage documented in the model was limited to a review of the results presented in the FDR and Appendix E of the Technical Report.

The local catchment drainage associated with the Lockyer Creek catchment is significant, with bridge structures and culverts proposed to drain catchment areas of up to 46.93 km^2.

The flood impacts presented in Table 3 of Appendix F3 of the FDR (and Appendix E of the Technical Report) indicate that the proposed culverts will result in an increase in level for the 1% AEP event of up to 0.4 m. The table indicates that the change in time of inundation for the 1% AEP event will be up to 3.4 hours.

The mapping presented in Appendix F5 of the FDR indicates that the maximum increase in level will be up to 400 mm, outside the railway corridor. The FDR notes that this is acceptable given the impacts are considered ‘localised’ in comparison to regional flood impacts. Aerial imagery assessment of the impacted land indicates that it is classed as agricultural and therefore are within the flood impact objective requirements.

The flow velocity/shear stress associated with the discharge from the culverts should be manageable during detailed design by the provision of suitable scour protection measures.

7 Conclusions

7.1 Overview

A review has been completed of the Lockyer Creek regional flood model and reporting, plus the local catchment drainage for the same area, for the Helidon to Calvert section of the Inland Rail project.

Tables of the model review items are provided in Appendix 1. Section 7.5 presents a summary of the key findings and identified issues.

7.2 Major Crossings

An assessment of the hydrologic and hydraulic modelling used to assess the proposed Inland Rail structures located within the Lockyer Creek catchment has been undertaken. The hydrologic model and hydraulic models assessed were URBS and TUFLOW respectively. The following Sections show the most significant findings of the assessment:

7.2.1 Hydrology

The hydrologic model is generally appropriate with the following comments:

- The BRCFS hydrologic model has been used with minimal alterations to account for local features and does not consider the presence of the rail alignment.
- Minor catchment area discrepancies were found between the provided GIS catchment layer and the URBS model.
- The applied ARF is based on a single gauge location, downstream of the alignment. This approach may result in an underestimation of design flow rates.

7.2.2 Hydraulics

In general, the hydraulic model setup is deemed appropriate with the following comments:

- There are several issues associated with the representation of 1D-2D boundary connections that may affect water levels and impacts present at culverts, bridges and channels.
- 2D source area inflows are not applied in a consistent manner (e.g. not at catchment centroids) and 1D inflow region extents span over several catchments (not consistent with catchment delineation).
- Unstable flow is noted in both existing and proposed culvert structures. This can result in incorrect model results and may influence the flood impact assessment of the rail alignment.
- Interconnectivity of local and regional models does not seem to be accounted for. This issue is occurring in populated areas such as Gatton and Laidley.
- There is significant “glass walling” occurring in extreme events, such as the PMF, where flow artificially ponds against the model boundary which will influence the model results.

- There is no notable difference between the modelling of existing and proposed 1D bridges within the model which, if incorrect, will affect the flood impact assessment at the alignment once corrected.

7.2.3 Joint Calibration

There are notable issues identified with the joint calibration approach which may undermine the applicability of the assessment. Primarily, the BRCFS modelling has been adopted for this study with minimal change. The BRCFS was purposed with assessing flooding in the Brisbane River downstream of the Lockyer Valley and the study notes that area may be subject to higher localised creek flooding. Furthermore, there is an inconsistent modelling approach undertaken whereby the hydrologic model parameters used in the design event modelling differ from the jointly calibrated model. In addition, the calibration modelling, although showing reasonable alignment to estimated peak flows, shows significant level differences across multiple historic events and differing gauge locations.

7.3 Minor Crossings

Minor crossings are presented within the hydraulic model but assessed via a local drainage model. These have been included for large flood events where flow from several of the waterways may cause inundation of the structures. However, the provided flood extents in both the FDR report and Technical Report (detailing local and regional models) shows that the models are not independent, and the approach may not be appropriate.

7.4 Advice and Recommendations

Based on the review of the Lockyer Creek model, the following advice and recommendations are made in accordance with the *Terms of Reference for an Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland* (Queensland Department of Transport and Main Roads, June 2020).

7.4.1 Relevant Guidelines

Whether the development of the models and their application accords with the relevant requirements of national and state guidelines/manuals (guidelines) for flood estimation and design of structures in flood prone environments.

While general best practice approaches are followed by the study, the study has not considered the interaction of flow between the local and regional models across all events including the 1% AEP event.

7.4.2 Floodplain Extent

Whether the extent of the floodplain covered by the flood model is appropriate, and if not recommendations as to what additional extent would be appropriate.

The extent of the hydraulic model may not be suitable as it does not account for the interaction of flow between local and regional catchments. Furthermore, analysis of extreme event modelling shows water ponding ("glass walling") at the downstream model boundary.

7.4.3 Calibration

Whether the method, and extent of calibration of the model accords with guidelines and industry standards for calibration.

The calibration approach shows discrepancies between recorded and modelled water levels. Furthermore, level assessment and further FFA could be presented within the Technical Report to add rigor to the calibration process.

7.4.4 Validation

Whether the method for validation of the model accords with guidelines and industry standards and whether the assumptions used underpin the validation process, and the data points used in the validation are appropriate.

A partial validation has been undertaken for the Lockyer Creek flood models by reviewing the hydrologic model peak flow rates to a downstream gauge location (Glenore Grove). Additional assessment is potentially required to fully confirm the validation of the model, including the use of more gauge data for FFA assessment.

7.4.5 Impacts and Impact Mitigation

Whether the model adequately accounts for the impacts of the reference design and whether those impacts are capable of appropriate local mitigation that either removes the impacts or reduces the impact to landholders in the area.

The presented model impacts appear to conform to the flood impact objectives. However, due to calibration issues and the issues associated with the interaction of flow between local and regional catchments, the presented impacts may need to be altered.

7.4.6 Fit for Purpose

Whether the model is fit for purpose, taking into account the above and any public comments for comments from external stakeholders in relation to the flood model that arises from the public exhibition of the draft Environmental Impact Statement (EIS) for the relevant Inland Rail Project.

The report has been prepared prior to public exhibition and so therefore is not able to include commentary regarding whether the model is fit for purpose based on comments from external stakeholders.

The review has indicated that the model is potentially fit for purpose for the EIS process and to inform the reference design and the mitigation of impacts, subject to:

- the provision of additional documentation to the Panel; and
- adequate response to the issues listed in Table 10.

The necessary additional documentation and sensitivity modelling is detailed in Section 7.5.

7.4.7 Best Practice

Whether the reference design for the proposed structure meets industry standards for railway structures in a floodplain and if so, whether the reference design is in accordance with best practice.

The review has indicated that the reference design meets industry standards and best practice, subject to:

- the provision of additional documentation to the Panel; and
- adequate response to the issues listed in Table 10.

The necessary additional documentation and responses is detailed in Section 7.5. It is noted that the modelling completed in relation to the reference design will need to be modified as part of further design.

7.5 Summary of Findings

Table 9 presents a commentary in relation to the focus areas for the panel that were identified in the *Terms of Reference for an Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland* (Queensland Department of Transport and Main Roads, June 2020).

The review identified a number of areas where additional work is required, either as part of further design stages or to provide additional documentation to the Panel. The items identified in the review are summarised in Table 10.

To facilitate the resolution of the identified issues, each issue has been assigned a level of importance, as described below.

- **Low Importance**

  Additional work is required that will not significantly affect the EIS process. The work can be completed as part of further design (prior to the use of models for detailed design) and the requirement to complete the work can be included as a condition of approval.

- **Medium Importance**

  Clarification or confirmation is sought in relation to an aspect of the supplied reports and models. Depending on the response to the issue by ARTC, the issue can be addressed via conditions of approval if required (i.e. it is deemed to be of low importance) and prior to the use of models for detailed design or via sensitivity testing (i.e. it is deemed to be of high importance as a result of the response).

- **High Importance**

  Sensitivity testing is recommended to determine the significance of the issue to the interpretation of Inland-Rail related flood impacts and for documentation and modelling regarding the results of the sensitivity testing to be supplied to the Panel to confirm whether the issue can be dealt with (if necessary) by conditions of approval (i.e. the item is deemed to be of low importance on the basis of the sensitivity assessment) and prior to the use of models for detailed design or whether the issue affects the interpretation of results.

- **Very High Importance**

  An issue of significance that warrants the revision of the documentation provided to the Panel to include either the documentation of additional justification regarding a conclusion drawn or amended flood modelling. Such issues will need to be addressed prior to the models being used for detailed design.

Figure 25 presents a flow chart indicating the process by which it is proposed to resolve each issue relative to its assigned level of importance. The colour-coding used in the figure was applied to Table 10 to allow the relative importance of each issue to be readily identified.

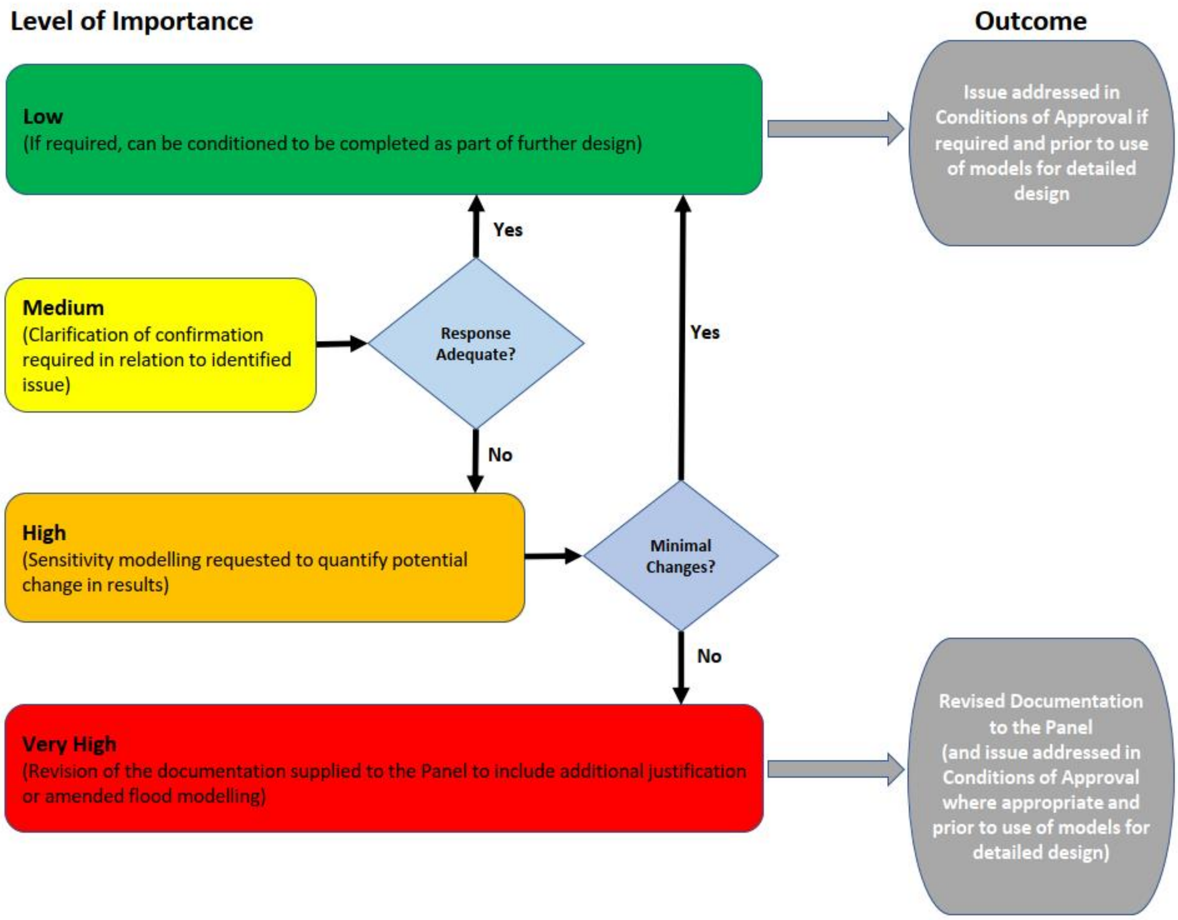

Figure 25: Flow Chart for Resolution of Identified Issues

Table 9: Review of Focus Issues

Focus Issue	Satisfied?	Comment
Extent		
Applicability and appropriateness for the relevant design stage (e.g. reference/detailed etc.)	AIR[1]	Further information is required before the extent of modelling can be deemed appropriate for the reference and design stages. There are areas of the extent where the interaction between local and regional catchments may not have been appropriately modelled.
Appropriateness of tool/s selected for flood modelling	Yes	The hydrologic and hydraulic models are appropriate.
Confirmation that key design criteria are considered reasonable and appropriate compared with typical similar linear infrastructure projects	Yes	The key design criteria are reasonable and appropriate.
Assumptions		
Appropriateness of model arrangements and input parameters	No	Additional documentation and sensitivity modelling are required to confirm that model arrangements and input parameters are appropriate.
Appropriateness of model calibration process	AIR[1]	The model calibration process is generally appropriate. However, there are significant differences in level based on the provided data. Furthermore, the inconsistent parameter approach between the joint calibration model and the design event model undermines the validity of the model calibration. Further justification is required with the potential requirement of sensitivity/additional calibration modelling.
Appropriate application of input data (including addressing data gaps)	AIR[1]	Subject to the provision of additional documentation and sensitivity modelling, input data is generally appropriately applied.
Assumptions around land-use (crops etc.)	AIR[1]	Acceptable assumptions have been made in regard to land-use. However, there is limited documentation surrounding the use of both default Manning's values and the use of depth varying Manning's roughness.
Appropriateness of blockage/debris assumptions	Yes	Sensitivity testing showed that immunity and impact are generally insensitive to blockage and debris assumptions.
Appropriateness of future events application, e.g. climate change	Yes	The future events application is appropriate, subject to ISCA requirements.
Appropriateness of assumed soil conditions	Yes	Assumed soil conditions are reasonable for the current level of investigation.
Application		
Appropriate sensitivity analysis to various items e.g. flow inputs, coefficients	AIR[1]	Additional sensitivity assessment is required in relation to several items.
Appropriateness of change indicators	AIR[1]	Change indicators are generally appropriate, although a more quantitative approach to changes in velocity and duration of inundation would be of benefit for the interpretation of results.
Appropriateness of structure and embankment representation (depending on the stage of the design)	AIR[1]	Several aspects of the structure implementation may require revision.
Flood frequency analysis	AIR[1]	There is limited documentation regarding the FFA undertaken for the area and there are discrepancies between the TUFLOW estimated peak flow rates and the FFA. Further justification is required to address flow underestimation and show FFA analysis for additional gauges within the catchment (as the report indicates multiple FFAs were undertaken for the area).
Interpretation		
Achievement of Design Objectives	AIR[1]	While the impacts are quantified, the impacts are based on flows that may be underestimated in comparison to FFA. Further justification for the calibration and peak flow rate assessment is required. Additionally, the interaction between local and regional catchments may not be adequately addressed which may result in model result changes, impacting the adherence to flood impact objectives.
Appropriateness of relevant sensitivity analysis	Yes	The sensitivity assessment completed with respect to blockage and climate change are appropriate.

[1] AIR stands for Additional Information Required (as summarised in Table 10) in order to confirm that the focus issue is satisfied.

Focus Issue	Satisfied?	Comment
Confirm Inland Rail-related flood impacts, if any, are comprehensively quantified and interpreted to their local property context	AIR[1]	While the impacts are quantified, the impacts are based on flows that may be underestimated in comparison to FFA. Further justification for the calibration and peak flow rate assessment is required. Additionally, the interaction between local and regional catchments may not be adequately addressed which may result in model result changes, impacting the adherence to flood impact objectives.
Appropriateness of the alignment, with regard the related flood impacts, within the current EIS Study Corridor	AIR[1]	While the impacts are quantified and currently meet the flood impact objectives, there are inconsistencies between the local and regional modelling which indicate that the modelling may not be appropriate to assess the flood impacts at the alignment. As such, additional information is required.
Consider whether reasonable and practical steps have been taken to mitigate flood impacts, if any, outside of the project boundary	AIR[1]	Insufficient information has been provided to the Panel in relation to the efficacy of the adopted mitigation measures and the justification for additional mitigation not being required and or practicable.
Additional information that would be required to be addressed in the Detailed Design phase of the program	Yes	It will be necessary to complete additional sensitivity analyses and to refine the models in the detailed design phase.

Table 10: Summary of Identified Issues

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
Extent						
L1	Interaction between local and regional catchments does not seem to be appropriately captured within the models.	3.5	Flood characteristics of local and regional catchments differs greatly.	The assessment does not appear to effectively represent the interaction of flow between local and regional catchments. Furthermore, the inconsistency between flood extents and levels exceeds what would normally be expected between the two independent approaches. This indicates that flooding may be misrepresented in these areas.	Very High	This issue is occurring in populated areas such as Gatton and Laidely. Further documentation and potential sensitivity modelling to ensure flood impact objectives are met is required with respect to the incorporation and assessment of flood interaction between the local and regional models.
Assumptions						
L2	The BRCFS model has been used with minimal alterations to account for local features.	2.3	The model has not been revised to consider the presence of the rail alignment or optimised to best represent flooding in the Lockyer Creek catchment.	Not correctly accounting for flow upstream and downstream of the cross-drainage can result in the over or under-estimation of discharge at a drainage structure.	Low	Further sub-division of sub-catchments and adjustment of catchment boundaries to reflect areas upstream and downstream of the alignment is necessary in later stages of the project. This may influence the modelled hydraulic behaviour as well as the interaction with the proposed design but is unlikely to cause significant changes due to the catchment area upstream of the alignment (should only cause a minor impact to flow).
L3	The joint hydrologic/hydraulic model uses different hydrologic parameters to the hydrologic design model.	2.4, 4	This implies the hydrologic model and the hydraulic model, using the same setup, do not provide consistent results. As a joint calibration approach is used to validate both models, the need to vary the hydrologic design parameters between the two models to achieve reasonable flow rates (compared to the FFA) raises questions on the validity of the joint calibration approach.	This approach undermines the calibration process and overall applicability of its purpose. A failure to obtain consistent parameters between models indicates that either one model or both models are potentially incorrectly setup, which may affect the results presented.	High	Confidence in a consistent modelling approach is important for both the design team and the greater public. Sensitivity modelling and further documentation is required to address this issue.
L4	The ARF does not appear to have been adjusted to assess different locations of interest throughout the alignment. While the use of a single ARF may be appropriate, the provided information does not justify its use in this manner.	2.5	The correct application of the ARF value (in accordance with ARR) ensures the project approach conforms to industry standard and guidance.	The use of a single gauge location (downstream of the alignment) for the calculation of the applied ARF may result in an underestimation of flow rates and affects the design of hydraulic structures and potential impacts.	Medium	Although incorrect application of the ARF may not cause significant change to the modelling results, the lack of correct application does not conform to industry standards and may affect both the design of culverts/bridges and impact outcomes of the project.
L5	Limited discussion regarding hydrologic model loss parameters and their impact on design flows.	2.5, 4	Limited loss variation was made from ARR Data Hub loss values and it is unclear if spatial variation was considered in the approach. This should be included in the reporting because the Lockyer Creek URBS model covers an area of approximately 3000 km^2	There appears to be a reasonable fit for the URBS peak flows to the Glenore Gauge FFA. However, this after modification to the beta factor in the design model and recognising that no other comparisons at other gauge locations have been provided.	High	This issue is linked to item L3 where both items and limited documentation indicates that limited changes were made (L2) to ensure that the design flow estimates provided agreement with recorded data.
L6	The topographic setup is deemed acceptable for the purposes of the assessment undertaken. However, future stages of the project should utilise the latest available LiDAR data which includes, but is not limited to, the Lockyer Valley LGA LiDAR dataset flow in 2018.	3.3	Future stages of the assessment should use the most up-to-date available data	The use of the latest available topographic data may improve model validity in areas	Low	At the inception of this stage of Inland Rail the data was not available. As such, it is recommended that this be sought for future project stages and does not affect the EIS assessment stage.

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
L7	Several issues with the model calibration.	3.5, 4	The model parameter values are based on the BRCFS model calibration. The BRCFS model did not focus on the Lockyer Valley area, noting in the study that local creek flooding may dominate in this area. Additional issues with the calibration include limited FFA documentation and verification, poor flow correlation at Glenore Grove gauge (TUFLOW compared to observed), poor correlation with historic gauge levels and poor correlation with recorded flood levels (especially between Helidon and Grantham)	The joint calibration informs the hydrologic and hydraulic parameters adopted in the modelling approach. The poor calibration fit undermines the design event modelling results and subsequently the flood assessment of the rail alignment.	Very High	Confidence in the calibration approach provides confidence in the design event modelling. Currently, further documentation regarding the calibration modelling and validation of design event flows is required to provide confidence in the modelling. This may also require further sensitivity assessment of both the calibration modelling and design event modelling.
Application						
L8	Justification for flood level impacts and changes to time of submergence.	5.4, 5.5, 5.9	Isolated increases above nominated flood impacts are proposed. One impact at a sensitive receptor is noted.	If an increase is deemed to be excessive then the design will need to be modified.	High	Although some justification has been provided, additional justification is required in relation to flood level increases and changes in ToS. In particular the impact to one residential sensitive receptor (1032), requires further justification.
L9	Increase in level at Gatton and Forest Hill area for extreme events	5.9	The embankment directs more water to the south of the alignment, resulting in greater increases in level than would otherwise occur.	May need to consider alternate drainage configuration if change in flood risk for extreme events is fount to be too great.	High	Embankment redirects flow south towards Gatton and Forest Hill. It is necessary to ensure that the resulting change in flood risk is acceptable.
L10	Potential for scour to occur given generally poor soil conditions.	5.8	Although the design to date results in relatively low velocities, the nature of the soils in the area could result in the proposed drainage causing significant geomorphological impacts.	Depending on the nature of the soils and flow conditions in the vicinity of each crossing, it may be necessary to alter the drainage design.	Medium	The velocity and potential for the resulting scour (due to the poor soil conditions) needs to be reviewed and accounted for in the detailed design.
L11	The adopted critical durations and Rank-6 temporal patterns do not always match what the Panel determined to be the critical duration or Rank-6 temporal pattern.	2.5	The selection of storm durations and temporal patterns has a direct effect on reported flood levels and velocities, and it can have impacts on reported afflux results.	The reported immunity, afflux or other results may not be entirely correct.	Medium	Clarification should be provided around the critical duration and temporal pattern selection to justify occasional use of durations and temporal patterns that are not critical or rank-6, respectively.
L12	Issues surrounding the application of hydraulic roughness.	3.4	Limited documentation surrounding the use of both default Manning's values and the use of depth varying Manning's roughness. Furthermore, hydraulic roughness has not been updated to incorporate the rail alignment.	Unlikely to cause significant changes to results but may cause minor changes.	Low	Unlikely to cause significant change to current reported levels but should be corrected in future project stages
L13	There are a number of 1D/2D connection issues that exist between structures and channels within the model.	3.5	The connection issues, as detailed in Section 3.5, result in: over-connection of structures, artificial lowering of cell elevations, artificial blockages at the confluence of waterways and duplication of storage areas.	The issues were identified after a preliminary review and further investigation into the extent of the issue is required. It is unlikely that the issues have widespread impact on the model results. However, if occurring in close proximity to the alignment it may cause changes to modelled impacts.	Medium	Review, assessment of proximity to the alignment and sensitivity testing is required to ensure that the associated issues do not impact the flood impact objectives.
L14	The flood frequency analysis was only performed at one stream gauge, despite several other stream gauges having data available.	4	A single FFA may not represent the design event hydrology of the catchment well.	Without calculating the FFA at all stream gauges of sufficient record, there is lower certainty in the validity of design storm event results.	High	The adopted gauge does have a long stream record, but its accuracy is limited by the rating curve. Assessing multiple gauges reduces the risk.

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
L15	Varied and inconsistent approaches adopted to apply inflows within the hydraulic model	3.5	2D source area inflows are not applied in a consistent manner (e.g. not at catchment centroid) and 1D inflow region extents span over several catchments (not consistent with catchment delineation). Furthermore, it appears that several of the subcatchment inflows are “double routed”, meaning inflow routing is accounted for in both the hydrologic and the hydraulic model which is likely attributing to the use of a lower beta value. It also appears that there has been an attempt to address this in the TUFLOW boundary condition database.	Inconsistent application of inflow may impact the assessment of both the comparison to validation methods (such as FFA) as well as impacts to the rail alignment. A justified, consistent approach would provide rigor to the assessment.	High	Justification regarding inflow locations, particularly the 2D source area inflows and the extents of the 1D inflow regions is required. This issue may be linked to the use a varied beta value used in the hydrologic design model (compared to the joint calibration model).
L16	Differing source area inflows used between historic and design models	3.5	The 2D source area inflow locations are also slightly different between the calibration model and the design storm event models (existing case and design case).	This difference may undermine the joint calibration approach used to define the design model	Medium	Further justification is required to address why these changes occurred and sensitivity modelling may indicate if this difference causes changes within the model.
L17	Downstream boundary extent and application issues	3.5	There is significant ponding at the downstream boundary (both the 1D and 2D boundary locations) in extreme event modelling.	Although unlikely to impact results at the alignment. It may cause minor changes. Furthermore, presenting these results to the public may undermine landholders confidence in the model.	Low	It is unlikely this is impacting results at the alignment (due to the distance downstream) but should be addressed in future project stages.
L18	Applied minimum nodal storage area of 200 m^2 by default.	3.6	An applied minimum nodal storage area of 200 m has been adopted by default. Furthermore, several nodes have additional nodal area applied.	This is regarded as a high value and may be generating artificial storage in the model.	Medium	Further justification or sensitivity modelling is required to ensure that the adopted approach is not generating artificial storage which is impacting the model results.
L19	Missing hydraulic structures in existing model.	3.7	A preliminary review has identified some missing hydraulic structures within the model extent.	The absence of these structures in the model may be causing artificial blockage in some areas. However, it is unlikely that this will have significant impact on results (once included) to events, such as the 1% AEP, and may only influence frequent events.	Low	It is recommended that an assessment of missing existing structures is undertaken in future project stages to ensure water is not being artificially blocked within the model (which may impact the results of frequent events).
L20	Existing and design structure flow instabilities present in modelling.	3.7, 3.8.1	Preliminary review by the panel have identified both existing and design (proposed) structures caused flow instabilities in the model.	This has the potential to impact results in the immediate vicinity of these structures. However, it is noted that the number of structures this occurs in is low and therefore may be only causing isolated differences.	Medium	Identification and correction of culverts presenting instability should be undertaken. Furthermore, once this has occurred sensitivity assessment should be undertaken to ensure that these issues did not cause significant changes to the EIS results. If significant changes are noted, a reassessment of flood impact objectives may be required.
L21	Bridge losses are identical at all bridges.	3.7.2	Bridge loss inaccuracies could result in reported changes in water level (and other flood impact objectives) being too low or too high.	The design may not properly mitigate flood impacts at all locations.	Medium	Clarification should be provided regarding the use of identical bridge losses and why losses, particularly at key structures, were not calculated using Austroads or a similar method.

Appendix 1 Model Review Summary Tables

Table 11: Hydrological Model Review Summary

Item No.	Description	Checked?	Additional Information
Hydrologic Model Setup			
1h	Model Software	Yes	Section 2.1
2h	All Model files provided and can results be reproduced	Yes	Section 2
3h	Catchment extent	Yes	Section 1.2, 2.3
4h	Sub-catchment delineation	Yes	Section 2.3
5h	Model catchment areas	Yes	Section 2.3
6h	Catchment Parameters *(e.g. slope, roughness etc.)*	Yes	Section 2.4
7h	Adopted Parameters - *routing*	Yes	Section 2.4
8h	Adopted Parameters - *losses*	Yes	Section 2.4
9h	Adopted Parameters - *runoff coefficient*	Yes	Section 2.4
Design Representation			
1d	Sub-catchment changes to represent design	Yes	Section 2.3 (no changes made to developed condition model)
2d	Model parameter changes to represent design	Yes	Section 2.4 (no changes made to developed condition model)
Flood Frequency Analysis			
1f	Gauge records available	Yes	Section 2.2
2f	Gauge record length suitable for FFA	Yes	Not confirmed/stated as adequate in review
3f	Compare design flow estimates to FFA	Yes	Section 4.5
4f	Annual Maximum Series	No	Information not provided in Technical Report
5f	Number of years input to FFA calculation	Yes	Not confirmed/stated as adequate in review
6f	Historical events	Yes	Section 4.2
7f	Censoring and filters	Yes	Not confirmed directly in report but implied

Item No.	Description	Checked?	Additional Information
8f	Probability distribution	Yes	Not confirmed directly in report but implied
9f	Low flow filtering	N/A	
Calibration			
1c	Model Calibration/Validation	Yes	Section 4
2c	Calibration data	Yes	Section 2.2, 4
3c	Calibration events and magnitude	Yes	Section 4
4c	Review rating curves	Yes	Section 4
ARR 2016/2019			
1a	Design flow estimates sufficient	Yes	Section 4.5
2a	Use of ARR 2016/2019	Yes	Section 2
3a	Critical duration	Yes	Section 2.5
4a	Mean temporal pattern selection	Yes	Section 2.5
5a	IFD rainfall data	Yes	Checked but not stated in text
6a	Temporal pattern zone	Yes	Section 2.5
7a	Areal varied patterns	Yes	Checked but not stated in text
8a	Areal reduction factors	Yes	Section 2.5
9a	Design rainfall losses - Calibration events	Yes	Section 2.5
10a	Design rainfall losses - ARR data hub	Yes	Section 2.5
Alternative Validation Method			
1am	Alternative validation method used FFA/RFFE	Yes	Section 4
2am	Design flow comparison to FFA/RFFE	Yes	Section 4.5
3am	Is the RFFE appropriate for the catchment	N/A	N/A

Table 12: Hydraulic Model Review Summary

Item No.	Description	Checked	Additional Information
	Hydraulic Model Setup		
1h	Model Software	Yes	Section 3.1
2h	All Model files provided and can results be reproduced	Yes	
3h	Model extent	Yes	Section 3
4h	Model setup	Yes	Section 3
5h	Model boundaries	Yes	Section 3.5
	Control		
1c	TUFLOW run log	No	Not provided
2c	TUFLOW Version	Yes	Section 3.1
3c	Solver	Yes	Section 3.1
4c	Timestep	N/A	Adaptive
5c	Materials/roughness definition	Yes	Section 3.4
6c	TUFLOW Materials File	Yes	Section 3.4
7c	Direct Rainfall - Losses	N/A	Lumped inflows adopted
	Calibration		
1c	Model Calibration/Validation	Yes	Section 4
2c	Calibration data	Yes	Section 4
3c	Calibration events and magnitude	Yes	Section 4
	Events and Scenarios		
1e	Events and Scenarios	Yes	Not confirmed directly in report but implied
	1% AEP	Yes	Section 5.3
	Climate change	Yes	Section 5.10.2
	Blockage	Yes	Section 5.10.1
	Extreme events	Yes	Section 5.3
	Other sensitivity assessments	Yes	Section 5.10.1
2e	Start and end times	Yes	No issues identified
3e	Initial conditions	Yes	None used and not required

Item No.	Description	Checked	Additional Information
4e	Event text	Yes	No issues identified
5e	Scenarios and variables	Yes	No issues identified
	Boundary Conditions		
1b	Inflow location	Yes	Section 3.5
2b	Inflow values	Yes	Section 3.5
3b	Boundaries	Yes	Section 3.5
4b	Direct rainfall volume check	NA	Lumped inflows adopted
5b	1D connection type	Yes	Section 3.5
6b	1D connections	Yes	Section 3.5
7b	Channel connections	Yes	Section 3.5
8b	Active cells	Yes	Section 3.5
	Geometry		
1g	Cell orientation	Yes	Checked but not stated in text
2g	2D active cells	Yes	Section 3.5
3g	Model extent	Yes	Section 3.5
4g	Material check	Yes	Section 3.4
5g	Material check (Design scenario)	Yes	Section 3.4
6g	Elevation raster check	Yes	Section 3.3
7g	Bridge representation	Yes	Section 3.8.2
8g	Breaklines	Yes	Section 3.3
9g	Topographic modifications	Yes	Section 3.3
	1D Network – Existing		
1e	1D input check	Yes	Section 3.8.1
2e	Cover check	Yes	Checked but not stated in text
3e	1D continuity	Yes	Checked but not stated in text
4e	1D locations & sizing	Yes	Section 3.8.1
5e	1D losses	Yes	Checked but not stated in text
6e	1D blockage	Yes	Section 3.8.1
7e	1D connection type	Yes	Section 3.8.1

Item No.	Description	Checked	Additional Information
8e	1d connection grid cell check	Yes	Section 3.8.1
9e	1d network invert levels & outlet check	Yes	Section 3.8.1
10e	Channel selection	Yes	Section 3.6
11e	No. cross-sections	Yes	Section 3.6
12e	Channel representation	Yes	Section 3.6
13e	Channel input values	Yes	Section 3.6
14e	1D IWL	Yes	Checked but not stated in text
Design Representation			
1d	1D locations & sizing	Yes	Section 3.8
2d	1D input check	Yes	Section 3.8
3d	Cover check	Yes	Checked but not stated in text
4d	1D continuity	Yes	Checked but not stated in text
5d	1D blockage	Yes	Section 3.8
6d	1D connection type	Yes	Section 3.8
7d	1d connection grid cell check	Yes	Section 3.5
8d	1d network invert levels & outlet	Yes	Section 3.5
9d	Bridge representation	Yes	Section 3.8.2
10d	Topographic modifications	Yes	Section 3.3
11d	Design criteria flood level impacts	Yes	Section 5.3
12d	Design criteria duration of flooding impacts	Yes	Section 5.3
13d	Design criteria hazard category impacts	No	Not assessed by FFJV in detail
14d	Design criteria velocity and flow direction impacts	Yes	Section 5.3
Results			
1r	Can results be replicated	Yes	No issues identified
3r	Review negative depths	Yes	None identified
4r	Review timestep outputs for HPC	Yes	Section 5.2

Item No.	Description	Checked	Additional Information
5r	Check raster outputs for irregularities	Yes	Checked but not stated in text
6r	Check .csv outputs for culverts	Yes	Checked but not stated in text

Appendix B Western Creek Model Review

Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland

Appendix B: Western Creek Models Review - Draft Report on Review of Helidon to Calvert Section

May 11, 2021

Contents

Tables

Figures

1 Introduction

1.1 Overview

This report presents the findings of the review by the Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland of the flood modelling of Western Creek catchment by the Future Freight Joint Venture (FFJV) in support of the draft Environmental Impact Statement (EIS) and Feasibility Design Report (FDR) for the Helidon to Calvert (H2C) section of the Inland Rail Project.

A summary of the issues identified in the review is provided in Section 7.5. A summary of the model review items can be found in Appendix 1.

The following FFJV reports were included in this review:

- Inland Rail Helidon to Calvert, Chapter 13 Surface Water and Hydrology, Revision 0.1, 18 March. (Future Freight Joint Venture, March 2020)
- Inland Rail Helidon to Calvert, Appendix M – Hydrology and Flooding Technical Report, 09 February. (Future Freight Joint Venture, February 2021)
- Helidon to Calvert Feasibility Design Report, Section 8 Drainage, Volume 1, Revision 0, 25 February. (Future Freight Joint Venture, February 2020)

In addition to the above, the following Technical Notes were also considered:

- Ipswich Rivers and FFJV Flood Study – Impacts Comparison (Future Freight Joint Venture, 15 April 2020)
- H2C Value Engineering – Structures – Flood Requirements (Future Freight Joint Venture, 25 October 2019)
- Waters Road – Potential options to reduce impacts noted by Ipswich City Council (Future Freight Joint Venture, 6 February 2020)

Chapter 13 of the draft EIS and Appendix M (the Technical Report) of the draft EIS relate to the modelling of regional flooding in Western Creek. The FDR provides information in relation to local catchment flooding not currently included in the draft EIS in full.

ARTC supplied the URBS hydrologic and TUFLOW hydraulic models that accompanied the Hydrology and Flooding Technical Report. These models were included in the review.

The TUFLOW hydraulic models and the 12d models containing the ILSAX calculations that accompanied the FDR, which were used to assess catchments less than 100 km^2 in size, were not part of this review.

1.2 Catchment Extent and Proposed Drainage

The Western Creek catchment is located within the overall Bremer River catchment. Figure 1 shows the Bremer River catchment to Walloon together with the boundary of the Western Creek catchment. The figure also includes the Inland Rail alignment (shown in purple) and some of the rainfall and stream gauges in the vicinity.

Figure 2 shows the drainage structures adopted for the embankment within the extent of the Western Creek catchment. With reference to the figure, the drainage proposed with respect to regional flooding includes five bridges (shown in grey in Figure 2), thirty rail culverts and four road culverts (all shown in green in Figure 2) on the main alignment.

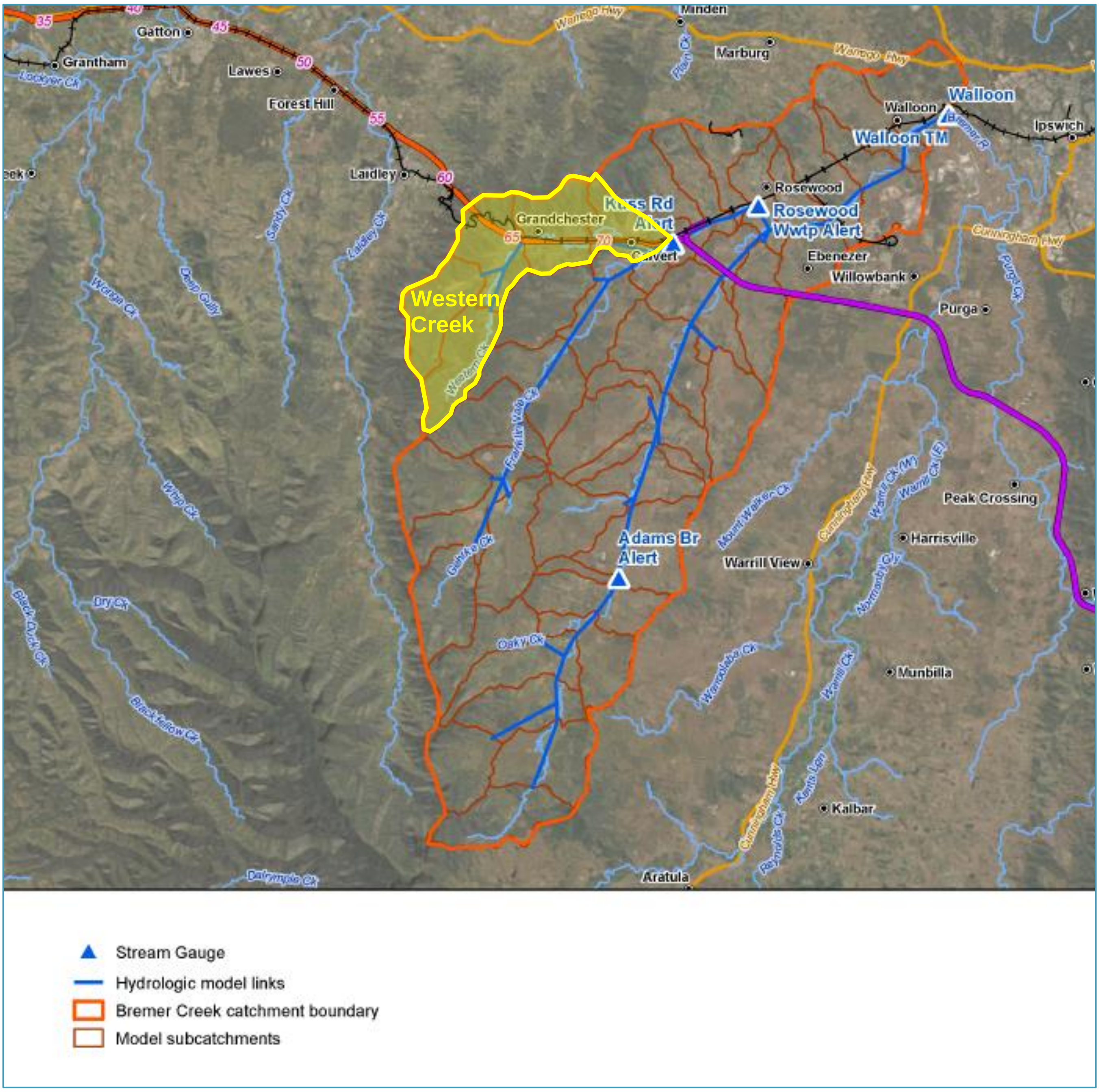

Figure 1: Bremer River (including Western Creek) Catchment Extent (Figure B-1B FFJV Technical Report)

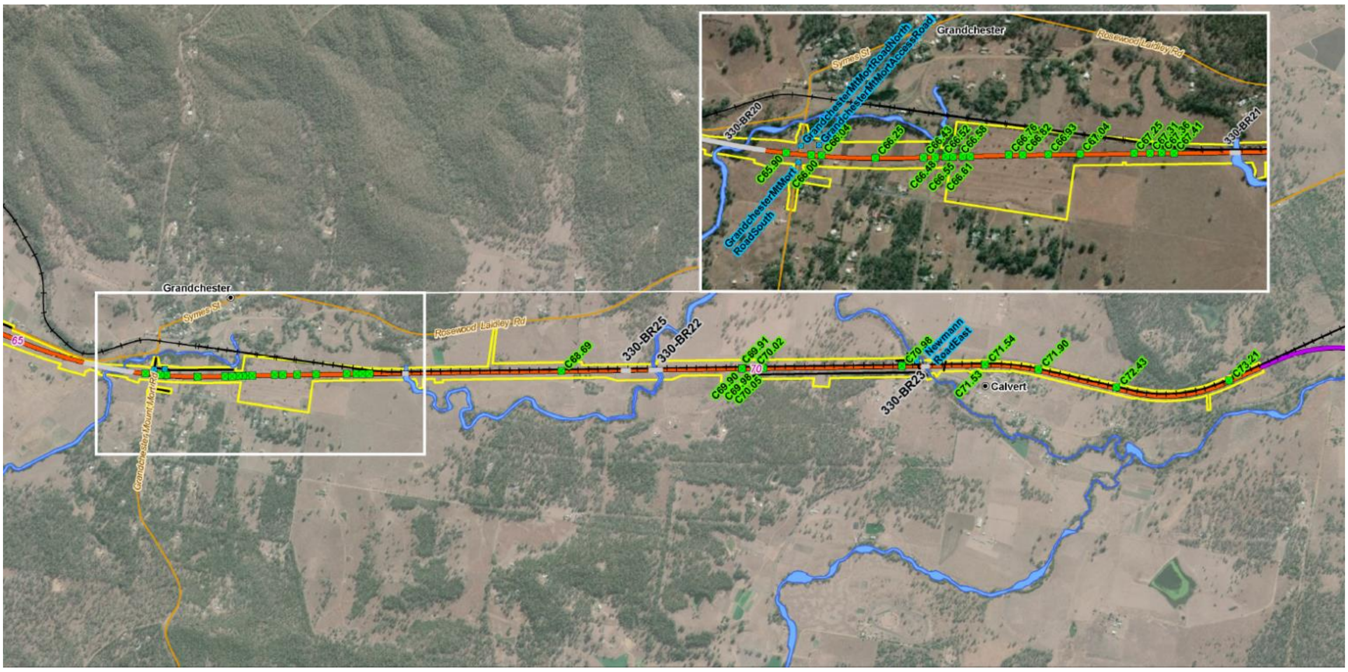

Figure 2: Regional Drainage Structures (Figure B-1D FFJV Technical Report)

Section 13.9.2.3 of the EIS also states that due to the proximity of the Project alignment to the existing QR rail line and the flood immunity requirements for the Project, refinement of the existing drainage structures under the QR rail line was required. In this location it was required to extend eight existing QR rail line banks of culverts and add four (note the EIS states three) new banks of culverts under both the Project alignment and the QR rail line. Based on Table 13.43 of the EIS, the culverts to be extended are C68.69, C69.91, C70.05, C70.98, C71.54, C71.90, C72.43 and C73.21 while the new culverts are C69.90, C69.98, C70.02 are C71.53.

1.3 Methodology

1.3.1 Overall

Overall, the methodology for the modelling of regional flooding (see Section 2 of the Technical Report and Section 13.5.2.3 of Chapter 13) was considered acceptable by the Panel. The adopted methodology is summarised below:

1. Determine and consider existing flood studies.
2. Consult with relevant parties to obtain flood data and to discuss model behaviour and impacts.
3. Develop and calibrate hydrologic and hydraulic models of the catchment.
4. Determine design inflows for design events (20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and Probable Maximum Flood) based on the 2016 version of Australian Rainfall and Runoff (ARR).
5. Use hydrologic and hydraulic models to calculate flood levels, flows, velocities and inundation times for the existing catchment conditions.
6. Add the proposed Inland Rail design and determine appropriate mitigation measures. These measures were primarily drainage structures.
7. Consider the sensitivity of the model to climate change and blockage.
8. Identify residual impacts and undertake engagement with the community and relevant stakeholders.

Although the overall methodology was considered appropriate, there were several concerns about:

- The application of the methodology.
- The sizing of drainage structures.
- The assessment of the impacts.
- The level of detail provided in the Technical Report to justify assumptions made in the modelling.
- The conclusions drawn in the report (and subsequently repeated in Chapter 1 of the draft EIS), because they were lacking details of how they were derived.

Finally, in general, not including local catchments within the regional model has the potential to be of concern. Refer to Section 2.3 for discussion of local catchments within the Western Creek catchment extents.

1.3.2 Community Consultation

It is understood that ARTC, in conjunction with FFJV, have undertaken consultation with all affected landowners as contained in *Appendix C – Stakeholder Engagement and Community Consultation Report* of the draft EIS. It is assumed that this consultation included a discussion of site-specific impacts for minor and major catchments with reference to the flood impact objectives.

1.4 Previous Studies

The modelling of the Bremer River catchment which includes Western Creek is largely based on the work undertaken for the Brisbane River Catchment Flood Study (BRCFS). As the BRCFS was comprehensive and subject to detailed peer review, this approach is considered to be generally reasonable.

However, as the focus of the BRCFS investigation was on areas downstream of the proposed embankment it is necessary to ensure that the modelling is sufficiently detailed to represent conditions at the railway and to accurately calculate likely impacts.

It is also noted that the Ipswich City Council commissioned a joint hydraulic/ hydrologic study of the entire Bremer River catchment that was completed in 2020.

As part of the Detailed Design stage, FFJV advised that the hydrologic and hydraulic modelling for Bremer River (including Western Creek) will be reviewed and updated to consider the current Ipswich City Council hydrologic and hydraulic modelling completed in early 2020.

In addition to these studies, flood modelling of Western Creek was competed by consultants Engeny on behalf of Ipswich City Council (the Engeny Report).

- Western Creek Flood Mapping Study, Volume 1- Report, Revision 2, July 2014.
- Western Creek Flood Mapping Study, Volume 2- Appendices, Revision 2, July 2014.

The modelling included the development of a RAFTS hydrologic model and TUFLOW hydraulic model of the catchment including calibration to the 2011 event. Although the consideration of design events was completed based on ARR1987 rather than ARR2016, the calibration, flood frequency assessment and the design flows derived by the study are of relevance.

It is noted that the Technical Report only refers to a summary report for the 2014 Western Creek study as being available (refer Section 5.1.2.3 of the Technical Report). Consequently, the results presented in the two volumes of the report may not have been available for the investigation. If this is the case, it is recommended that the report be made available to ARTC.

1.5 Scope of the Review

This review assessed the regional flooding model of the H2C section within the Western Creek catchment. Specifically, the Bremer River URBS model and the Bremer River TUFLOW model.

To support the local catchment modelling reported in the FDR, two TUFLOW models were developed to model drainage requirements. One model was used to consider the culverts required at C62.87, C63.08, C63.20, C63.59 and C64.78, and the bridge required at Ch 64.385 km. The other model was used to consider the culverts required at C70.53 and C72.24. In both cases, flows for the models were derived using 12d ILSAX. These models overlap the regional Bremer River TUFLOW model that is the subject of this review.

As a consequence of this overlap, structures within the regional model extent may have been sized using the local model. This report reviews the Western Creek models independently of the other models, though it does still check the sizes of all structures within its extent that may have been sized in the other models.

The modelling presented in the Technical Report with respect to Western Creek was completed using the hydrologic and hydraulic models developed to investigate the Bremer River for the C2K section of Inland Rail. A significant portion of the reporting provided with respect to modelling of Western Creek in the Technical Report matches the reporting prepared for the Bremer River in the C2K Technical Report.

The outcome of the Panel review of the modelling presented in the C2K Technical Report with respect to the Bremer River is documented in Appendix A (Bremer River Models Review – Draft Report on Review of Calvert to Kagaru Section) of the Draft Report on Review of Calvert to Kagaru Section (Version 3, February 2021).

To avoid repetition of the previous review, this review focusses on those issues particularly relevant to the Western Creek catchment. The review assumes that the issues relevant to the Bremer River model as a whole (and therefore the representation of Western Creek) will be addressed.

2 Hydrologic Model Review

2.1 Overview

The hydrologic modelling for Bremer River including Western Creek was undertaken using URBS. The same URBS model was used for the assessment of the Calvert to Kagaru (C2K) section of the rail alignment that traversed the Bremer River catchment. The Panel has undertaken a detailed review of the Bremer River catchment for the C2K portion of the Inland Rail as reported in *Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland Appendix A: Bremer River Models Review – Draft Report on Review of Calvert to Kagaru Section, January 2021*.

Given the same hydrologic model is used for the respective Western Creek and Bremer River assessments, the majority of the comments and recommended actions detailed in the Bremer River review are also applicable to the Western Creek assessment. Rather than repeating the issues in detail verbatim as part of this review for Western Creek, resolution of the Bremer River model issues will subsequently resolve the majority of issues associated with Western Creek. This assessment subsequently only highlights specific issues relevant to the Western Creek portion of the alignment.

The URBS model used for the assessment was based on the model developed for the Brisbane River Catchment Flood Study. While the investigation was very detailed and subject to comprehensive review and scrutiny, it focused on the middle and lower reaches of the Brisbane River and the largest tributaries (i.e. Upper Brisbane, Stanley, Lockyer, Bremer, Warrill and Purga). The applicability of the model to areas further upstream within a particular catchment such as Western Creek needs to be considered in greater detail; for example, it needs to be confirmed that unsuitable parameters at a sub-catchment level are not balanced by the parameters adopted for routing.

The local drainage catchment flows for the minor catchments were generated in accordance with the 2016 version of Australian Rainfall and Runoff (ARR 2016) using ILSAX within the 12D Drainage Network Editor. 12D Drainage is generally considered to be a suitable tool for local drainage analysis.

2.2 Data

2.2.1 Stream Gauge Data

The modeling presented in the Technical Report with respect to Western Creek relied on the same stream gauges as those considered for the Bremer River in the C2K modelling, with the main focus of the calibration being the Walloon gauge:

- Adams Bridge (flow comparison);
- Kuss Road (comparison between hydrologic and hydraulic model agreement);
- Rosewood WWTP (comparison of gauged levels to calculated levels from hydraulic model); and
- Walloon (comparison of gauged flows to hydrologic and hydraulic models).

The 2011 calibration completed by Engeny included the consideration of the recorded stage hydrograph at the Grandchester Alert station. Given the location of the gauge within the study area, the recorded data would have been of benefit for assessing the quality of model calibration.

2.2.2 Rainfall Data

The design flood events were assessed using design rainfall intensity frequency duration (IFD) data and temporal patterns in accordance with the latest *Australian Rainfall and Runoff* methodology.

While the rainfall data reflects the currently available data, as discussed in Section 2.4.3 of the C2K Technical Report on the Bremer River there is a concern that the data results in the underestimation of design rainfall intensities.

2.3 Catchment Delineation

The sub-catchment delineation adopted for the Western Creek portion of the Bremer River catchment is the same as that used for the Brisbane River Catchment Flood Study as shown in Figure 3 which also includes location of the rail alignment. No refinement of the sub-catchment extents was undertaken considering the location of the rail alignment. The same sub-catchments were used for the consideration of existing and developed conditions.

While the catchment delineation is generally acceptable with respect to the derivation of flows at stream gauges, it is not tailored to the alignment of the railway within the Western Creek catchment.

- ***Sub-catchments 4, 28 and 33***

  The alignment traverses sub-catchments 4, 28 and 33 approximately through the middle of each sub-catchment. While the local drainage catchment assessment detailed in the FDR that covers mainly sub-catchment 33 further spits this sub-catchment, it is recommended that refinement is also required for the regional assessment.

  For detailed design, it is considered necessary to divide these sub-catchments to reflect the areas either side of the alignment reflect conditions in the vicinity of the railway.

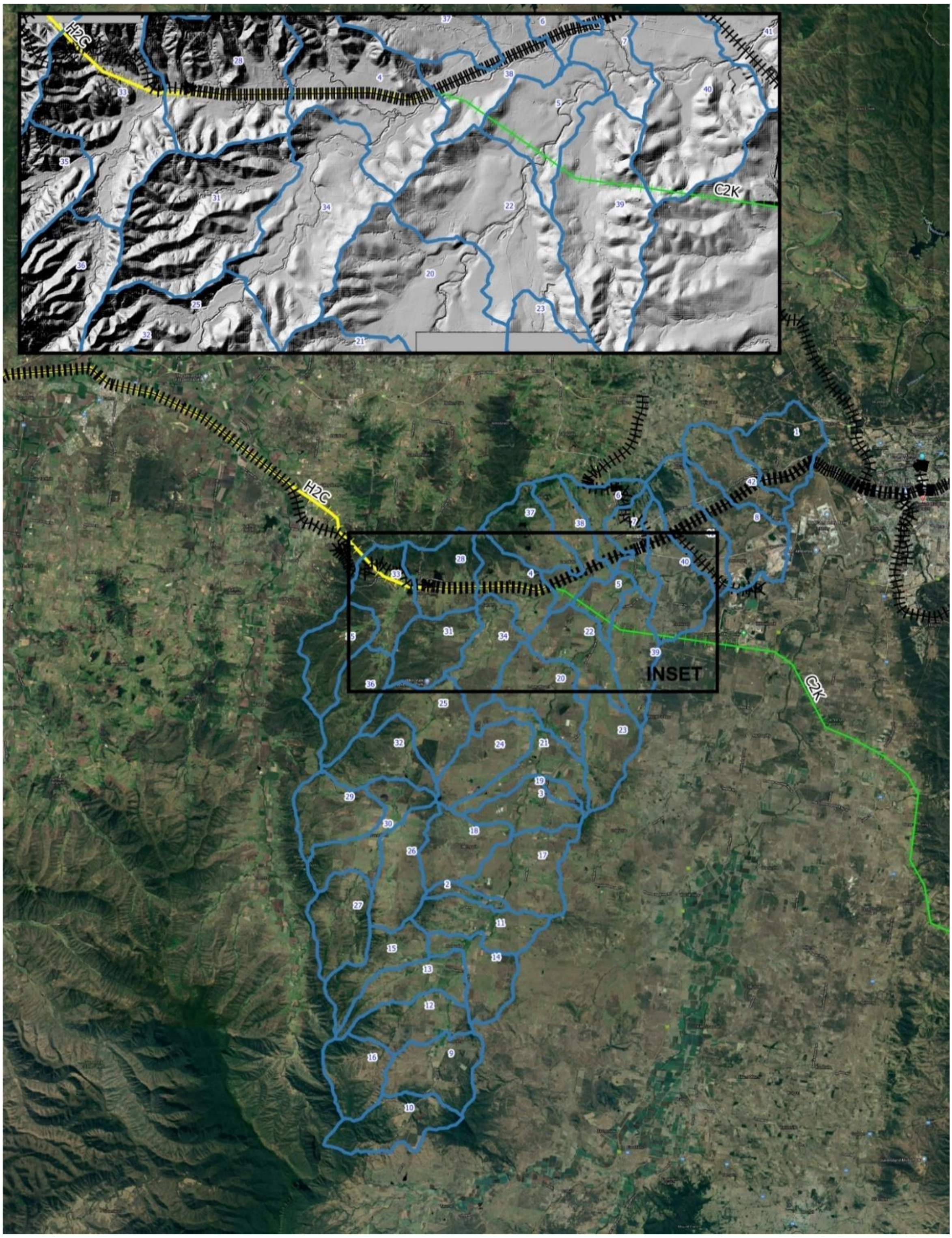

Figure 3: Bremer River Catchment in Western Creek Delineation

2.4 Model Parameters

URBS relies on a number of key parameters to represent runoff and storage within each sub-catchment.

Following calibration, the adopted URBS parameters were:

- Alpha 0.79;
- Beta 2.8;
- m 0.8 (non-linear catchment routing – standard value);
- n 0.85 (non-linear channel routing).

These values are considered within the reasonable range expected of each parameter and are similar to the values nominated in the *Ipswich Rivers Flood Study Update, Model Development and Calibration* (Revision 1, July 2018).

Despite this, the Technical Report notes the following:

For each of the tributary hydrologic sub-models, the calibration process focussed on achieving a good match of the flow hydrograph at the primary calibration gauge site …, typically at or near the downstream end of the catchment. The calibration parameters are therefore not necessarily optimised for individual tributaries or areas in the upper catchments.

While the Technical Report acknowledges that the calibration parameters may not be suitable for the calculation of flows to the rail alignment location, there has been no effort to address this in the assessment, with the overriding assumption that the extensive calibration process undertaken for the BRCFS is deemed suitable for this assessment. Given the H2C section within the Western Catchment is located approximately 20 km upstream of the Walloon gauge, the ability to apply parameters derived for areas downstream of the area of interest needs to be confirmed.

Validation/comparison of design flows to the rail alignment crossings within the Western Creek to alternate methods such as the Rational Method and/or Regional Flood Frequency Estimation method is recommended to ensure flows are not being underestimated with the use of regional parameters that may be more applicable to a location well downstream of the area of interest. Further, the previous Engeny study (refer Section 1.4) provides a point of comparison in terms of model flows.

2.5 Design Discharges

2.5.1 Temporal Patterns

The temporal patterns recommended for use in ARR2016 (which match those nominated in ARR2019) vary according to the catchment area being considered. Point temporal patterns are defined for catchments less than 75 km^2 in area, with areal temporal patterns provided for a range of catchment areas including 100 km^2, 200 km^2 and 500 km^2.

The catchment area draining to the main crossings of the railway vary. The total catchment area conveyed to the outlet of Sub-catchment 33 is in the order of 50 km^2. For the Western Creek where the H2C alignment meets the C2K section, the catchment area is approximately 225 km^2. The catchment area increases to over 600 km^2 at the Walloon gauge.

Based on a review of the supplied hydrologic model, it is considered that a single set of temporal patterns (the set for patterns for an area of 500 km^2) were adopted for the investigation.

It is recommended that for detailed design, a greater range of the temporal patterns be considered and that for the current review the model be used to assess the likely change in flow associated with the use of alternate temporal patterns in order that the potential change in flow, flood level and impact can be considered.

2.5.2 Derivation of Design Storms

Focal points were used to extract appropriate Areal Reduction Factors (ARFs) to be applied to the point of interest. As the catchment area increases, the ARF decreases to reflect the greater variation in rainfall as catchment area increases.

The resultant rainfall applied across the catchment assessed can therefore vary considerably as a result of where the focal point is taken and the total catchment area contributing to this point. The assessment for the Western Creek/ Bremer River section of the alignment adopted the Walloon gauge as the focal point for determining the design event rainfall and flows applied to the catchment. While this approach allows calculated flows for design events to be compared to those recorded and estimated at the gauge, the use of a focal point further upstream (i.e. at the railway within Western Creek) would result in higher flows.

Based on work completed by the Panel, selecting a focal point at the alignment could potentially increase the design flows by 4 percent or more. While the increase in flow is small, as it is considered that the selection of a focal point well downstream of the H2C section of railway within the Western Creek catchment is not appropriate.

Section 8.2.1 of the Technical Report details the methodology associated with the derivation of design storms. The modelling included modelling the ten temporal patterns associated with each duration between 30 minutes and 168 hours for the full range of events considered.

Based on the median flow obtained for each duration, the critical storm duration at the Walloon gauge and Ch 65.69 km (Western Creek and associated floodplain breakout and tributaries at Grandchester) and Ch 73.21 km (Western Creek and associated floodplain breakout and tributaries at Calvert/connection to C2K Project) was determined for the range of AEP events (Table 8.6 of the Technical Report). This approach is considered to be reasonable with respect to the main crossings within Western Creek.

Further, as noted in the Panel review of the Bremer River for the C2K section, the design flow rates are considered to be underestimated based on other available data.

3 Existing Case Hydraulic Model Review

3.1 Overview

The hydraulic modelling for Bremer River including Western Creek was undertaken using the 1D/2D (one-dimensional/ two-dimensional) hydrodynamic modelling package TUFLOW incorporating the latest Heavily Parallelised Compute (HPC) solver. The same TUFLOW model was used for the assessment of the Calvert to Kagaru (C2K) section of the rail alignment that traversed the Bremer River catchment.

Given the same hydraulic model is used for the respective Western Creek and Bremer River assessments, the majority of the comments and recommended actions detailed in the Panel’s Bremer River review referenced in Section 2.1 are also applicable to the Western Creek assessment. As for the hydrologic review, this assessment of the hydraulic model subsequently only highlights specific issues relevant to the Western Creek portion of the alignment.

Assessment of local drainage provisions for Minor Catchments (considered to be less than $10km^2$), was undertaken using the 12D Drainage functions (Network Editor and Dynamic Culvert), with subsequent TUFLOW modelling to determine flood level impacts (Section 8.3.2 of the FDR). 12D Drainage is generally considered to be a suitable tool for assessing less complex flow patterns where there is limited interaction between neighbouring catchments.

Further discussion with respect to the interaction between the regional and local models is provided in subsequent sections below.

3.2 Boundary Conditions

3.2.1 Upstream Boundaries

Inflows to the TUFLOW model have been applied as source area (SA) polygons which apply the total flows from the upstream catchments to the terrain. The Western Creek/ Bremer River model includes inflows that in some cases are well downstream of the model boundary.

Figure 4 indicates the location of the boundary inflows TOT033 (representing the total flow including sub-catchment 33) and TOT034 (representing the total inflow including sub-catchment 34).

In the case of inflow TOT033, the topography is relatively steep and the application of the inflow within the hydraulic model extent only results in a relatively small extent of backwater upstream. Further, the inflow is located sufficiently upstream of the railway. The schematisation of TOT033 is therefore considered to be acceptable.

However, in the case of TOT034 the topography is relatively flat such that the lumped flows spread upstream.

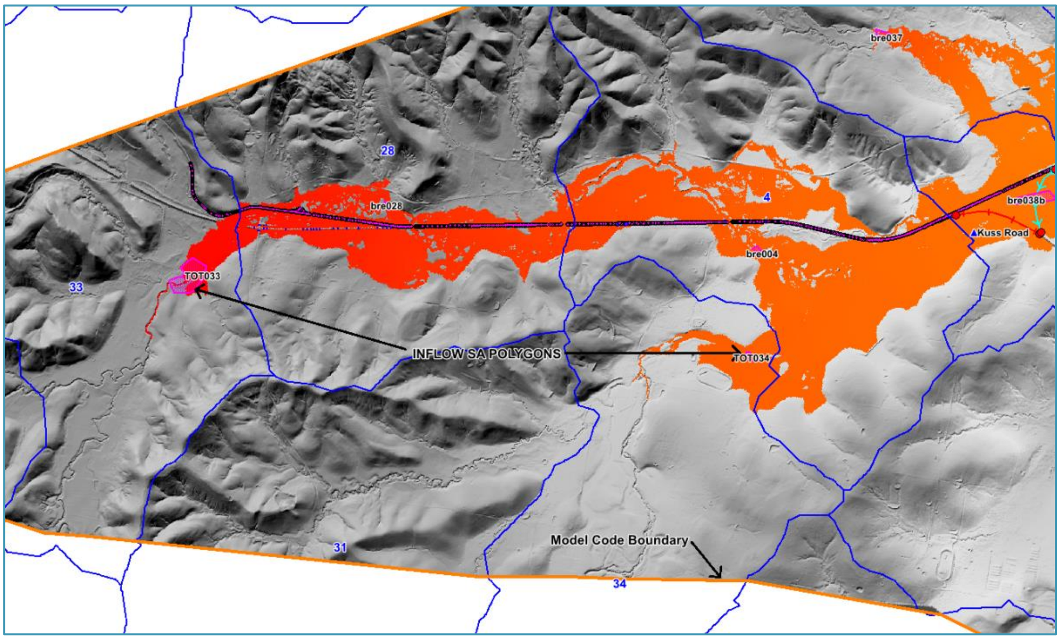

Figure 4: Upstream Model Boundary and Upstream Inflows

In addition to the flood storage provided by these backwater areas, the inundation mapping produced by the model is suspect, as it reflects the lower flood level applicable at the point of inflow rather than the higher flood level likely to be applicable further upstream. In the case of the area upstream of the TOT034 inflow, Figure B-7F of the Technical Report indicates that five flood sensitive receptors are located in the affected area. The flood level at these receptors for a given event will be higher than that suggested by the Technical Report.

However, as the receptors in question are located a considerable distance from the alignment and any associated flood level impact, it is expected that any revision to the model will not produce an impact at the receptors that requires a subsequent revision of the proposed drainage.

Despite this, it is necessary to adjust the model to ensure that the flood storage in the area is not overestimated and that realistic levels and flood immunity are nominated for the sensitive receptors.

3.2.2 Sub-catchment Inflows

Inflow hydrographs for the local sub-catchments are applied as source area (SA) polygons which for the Western Creek catchment were applied at the centroid. However, for the balance of sub-catchments within the Bremer River model, local inflows were located predominantly at the upstream extent of each sub-catchment. The inflows applied are the URBS local catchment hydrographs which are representative of the flows to the centroid of the sub-catchment and thus an additional routing length has been modelled for those inflows located at the upstream extents.

This is not normally a significant issue if applied consistently throughout the model as timing effects should balance out. However, in this case it is noted that the model adopts specific model parameters for sub-catchments within the hydraulic model extent to avoid double routing of flow. For this to be appropriate, a consistent approach should have been used throughout the model.

As noted in Section 2.3, the alignment crosses a number of sub-catchments. As shown in Figure 4, this results in the inconsistent application of inflows to the model.

In the case of sub-catchment 28, the runoff for the entire sub-catchment is conservatively applied upstream of the railway. For sub-catchment 4, the inflow point is downstream of the railway, meaning that the flow to be conveyed across the alignment will be underestimated.

It is recommended that for detailed design the sub-catchment delineation is revised to reflect the alignment in order that all the area upstream of the railway is appropriately catered for.

3.3 Modelling of Structures

The majority of existing railway bridges within the Western Creek catchment have been modelled using estimated levels and parameters due to lack of detailed information. Detailed survey of all structures is required for the next phase of the assessment to ensure accurate data is used.

3.4 Model Stability

The model was found to be generally stable. Within the Western Creek catchment, a bank of existing culverts beneath the existing railway line (72 x 1.2 m x 0.9 m rectangular culverts, TUFLOW ID: Rail2 as shown in Figure 5) has connection issues resulting in unstable flow through the culverts (refer Figure 6). These culverts, in addition to further checks on all other 1D structures as required, needs to be rectified as part of further design to ensure they do not artificially impact on the rail design.

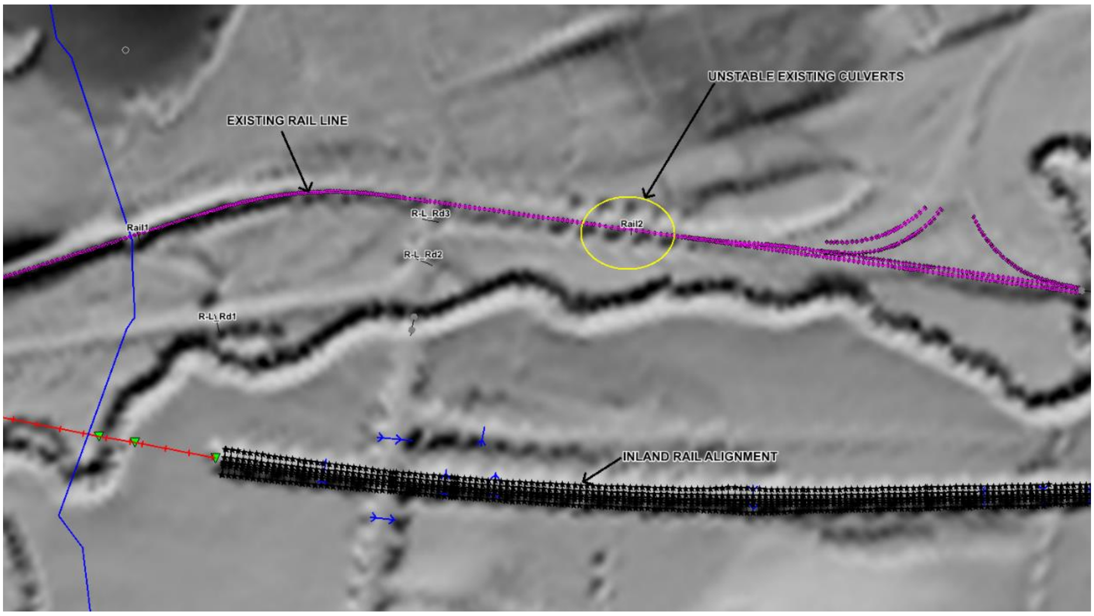

Figure 5: Location of Culvert with Model Instabilities

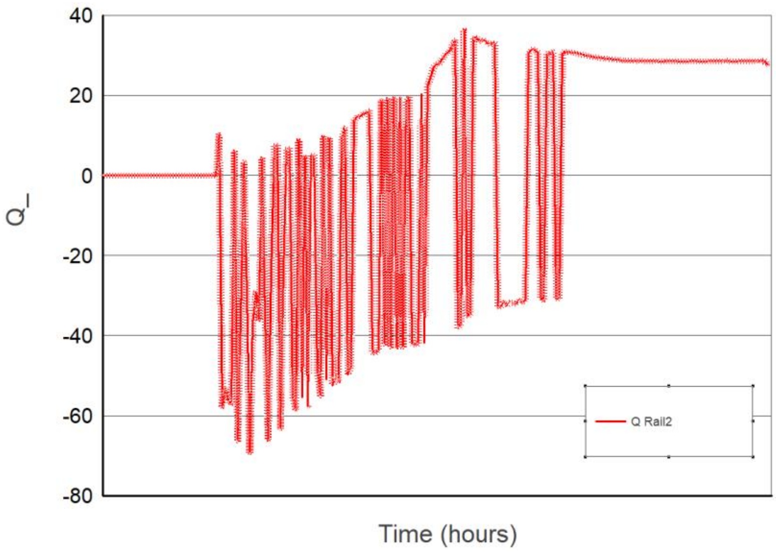

Figure 6: Unstable Culvert Representation

3.5 Local Catchment Modelling

The approach adopted with respect to the modelling of local catchments (refer Section 3.1) would appear to be reasonable.

In this case, the eleven local catchments identified for the Western Creek range in size from 1 to 291 hectares in size. For such areas, the methodology is considered to be acceptable. It is noted, however, that some local flows have been applied in close proximity to the proposed alignment, not allowing the spread zone for the source area to be hydraulically removed.

Whilst this would be suitable for flood sizes that remain in bank, this might not be appropriate for the 1 in 2,000 AEP flood results tabled but not mapped for local catchments.

The application of inflows to the model will require attention as part of further design.

4 Calibration

4.1 Acceptability of Calibration

A detailed discussion of the suitability of the calibration of the Bremer River including Western Creek models is included in the Panel review of the Bremer River catchment for the Calvert to Kagaru section of the Inland Rail. The outcome of the detailed review of the calibration is summarized below.

Subject to the following, it is considered that the calibration of the Bremer River model overall is acceptable for the purposes of the draft EIS:

- Confirmation that the application of rainfall and pluviograph data is appropriate for the catchment under consideration;
- Validation of the model using another event (the 2017 event is suggested); and
- Confirmation of the acceptability of the 2011 flood level data relative to adopted ground level data.

Additional matters of relevance to Western Creek are detailed below.

It can be highlighted that while the calibration of the 2011 event within Western Creek appears to be relatively good at Calvert, ±100mm, at Grandchester the levels are significantly and consistency lower by up to approximately 500mm as shown in Figure 7 and Figure 8.

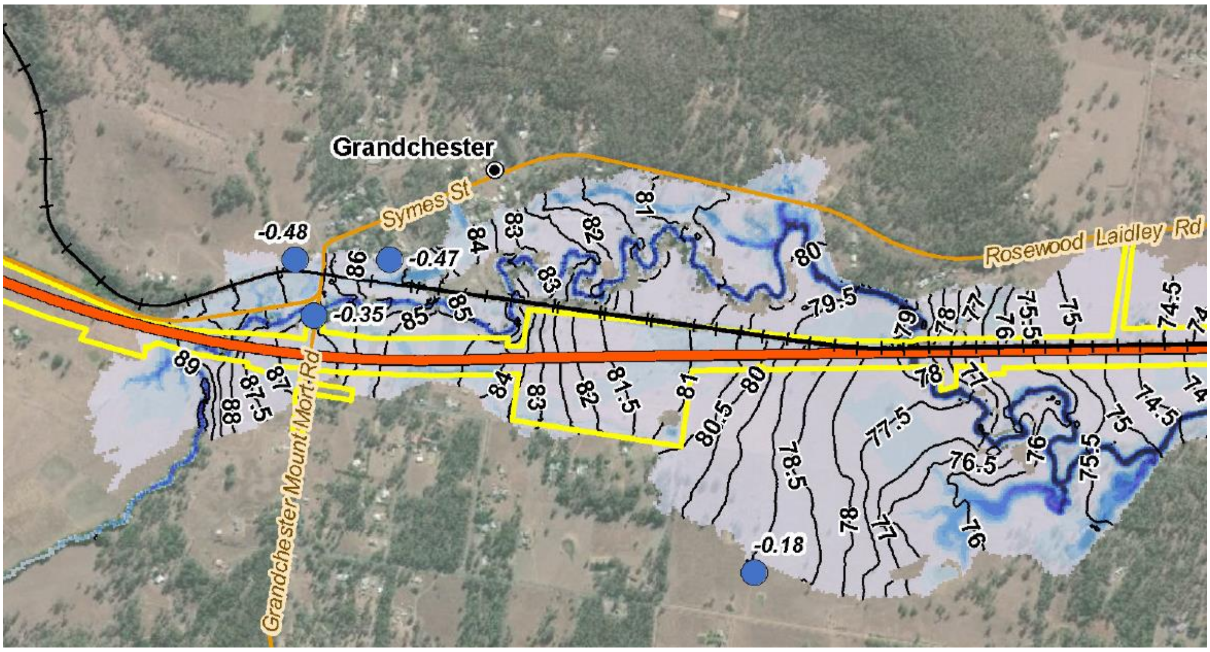

Figure 7: 2011 Calibration for Western Creek (Figure B2-D of Technical Report)

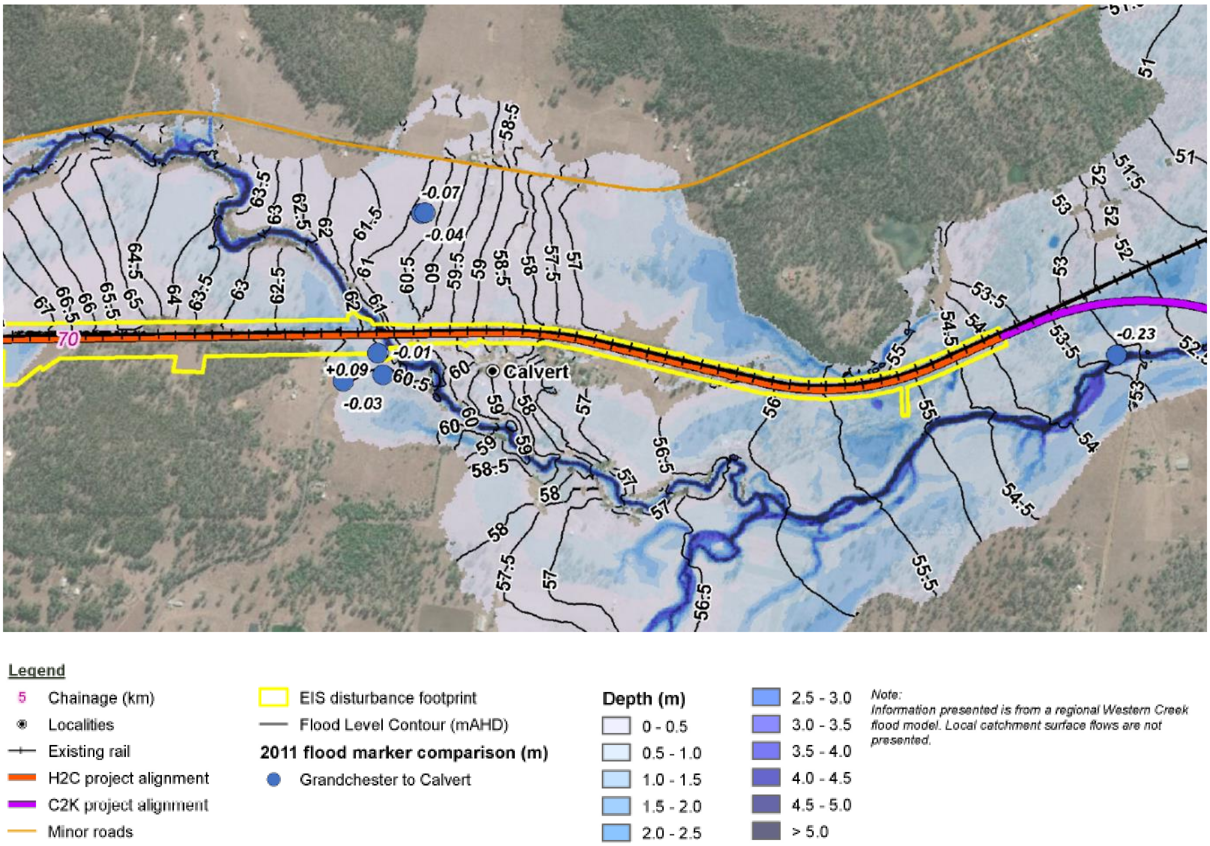

Figure 8: 2011 Calibration for Western Creek (Figure B2-D of Technical Report)

In comparison, the calibration presented in the Engeny report (refer Section 1.4) for the 2011 event appears to achieve a closer agreement to recorded values. Further, the calibration of Engeny also considered the recorded stage hydrograph at the Grandchester Alert station.

Given the location of the station within the Western Creek catchment, the consideration of the agreement between the hydraulic model and the levels recorded at the Grandchester Alert station gauge (assuming that a rating curve is not available for the station) for the 2011 event is necessary to confirm that the calibration for the 2011 event is reasonable. Similarly, the reasons for the poor calibration in the vicinity of Grandchester (particularly given the agreement presented in the Engeny report) need to be considered.

4.2 Local Catchments

Validation of flows was undertaken by comparison to the Rational Method. Given the size of the local catchments, this approach is appropriate. No validation of levels was undertaken.

Section 8.2.3 of the FDR notes that the agreement to the Rational Method for the Western Creek local catchments was within a tolerance of -6 to 7 percent, which the Panel considers to be acceptable.

5 Proposed Design - Regional Modelling

5.1 General

The proposed design and its impacts are discussed in Section 13.9.2.3 of the draft EIS and Section 9.3 of the Technical Report. It is recommended that the level of detail in the Technical Report be increased to provide greater information regarding the impact of the proposed design and the justification for adopting the nominated drainage structures given the associated impacts.

5.2 Embankment Height

Apart from the need to connect to the existing rail line, most of the embankment has been set well above the calculated 1% AEP flood level to satisfy vertical alignment requirements (for example, local road clearances). The embankment has a freeboard in excess of one metre (Section 9.3.2.2 of the Technical Report) and in many areas an even greater freeboard (Table 9.23 of the Technical Report).

In comparison, the design criterion for the embankment is to achieve 300 mm freeboard with respect to the 1% AEP event. The design consequently has the capacity to include a reasonable increase in peak flow (as recommended in the Panel's review of the Bremer River section of C2K) without raising the level of the embankment.

With respect to the potential for overtopping during extreme events such as the PMF, Section 9.3.2.1 of the Technical Report indicates only a small depth of overtopping of less than 0.4 m as shown in Table 1.

Table 1: Rail Overtopping Details During Extreme Events (Table 9.22 from Technical Report)

Table 9.22 Western Creek – Rail overtopping details during extreme events

Approximate chainages (km)	1 in 2,000 AEP event overtopping depth (m)[1]	1 in 10,000 AEP event overtopping depth (m)[1]	PMF event overtopping depth (m)[1]
65.90 to 66.00	-	-	0.15
67.35 to 67.60	-	-	0.10
Area around Ch 70.00[2]	-	-	0.37

Table notes:

1 Depths vary over the length of the Project alignment that overtops. The length of rail that overtops increases with event rarity.
2 At this location the QR West Moreton System rail corridor TOR has less than 1% AEP immunity and overtops in the Existing Case.

5.3 Flood Level Impacts and Sensitive Receptors

5.3.1 Flood Level Impacts

Table 2 lists the locations where the calculated increases in flood level exceed the nominated flood impact objectives (refer main report) between Grandchester and Calvert.

Table 2: Flood Level Impacts (Table 13.45 from draft EIS)

Chainage (km)/ Location	Design criteria for 1% AEP event	Change in peak water level (mm)	Comment
Ch 65.88 km Agricultural land	≤200 mm (localised increases of up to 400 mm)	+370	This localised area experiences an increase in peak water levels of up to 370 mm due to the raised level crossing. This reduces to less than 200 mm within 30 m of the toe of the road embankment.
Ch 66.12 to Ch 66.50 km Agricultural land	≤200 mm (localised increases of up to 400 mm)	+285	In this locality, the there is an access road to Mt Grandchester-Mt Mort Road for local residents. This low level road currently has limited drainage and leads to localised increases in peak water levels near the Project alignment.
Ch 67.30 km QR rail line	≤100 mm	+330	This change in peak water level is within the Project disturbance footprint and caused by shallow sheet flow being trapped behind the proposed embankment.
Ch 69.44 to Ch 69.92 km Agricultural land	≤200 mm (localised increases of up to 400 mm)	+390	This increase of 390 mm extends up to 480 m from the existing culvert under the QR rail line upstream towards bridge 330-BR22. The cause of this change in peak water levels is that overtopping of the QR rail line is prevented. The proposed Project alignment and associated drainage structures were selected to balance peak flows during frequent events and additional storage requirements for the 1% AEP event.

Table 9.25 of the Technical Report also includes additional locations near Calvert as shown in Table 3.

Table 3: Afflux at flood sensitive receptors during the 1% AEP event (Table 9.25 from Technical Report)

Location	Afflux (mm)	Comment
Road and rural area (Ch 71.00 km)	440	Land appears to be rural and not used for high-value agricultural farming based on provided aerial imagery. Afflux on Newmann Road south of the Project alignment is caused by Western Creek breakout flow ponding against the road embankment. Afflux is 340 mm in exceedance of the 100 mm guiding design criteria for roads. However, the ground level of the road diversion has increased by approximately 500 mm as compared to the previous road levels (range: 250 mm to 1,200 mm). This results in a reduction of time of inundation whilst maintaining previous immunity levels for frequent events. Afflux on rural land between Western Creek and this location is highly localised (within 10 m of the road embankment – in the Right of Way of the road). Impacts at this location could be reduced with local road culverts during detailed design.

The impacts nominated in the above tables are based on design flow rates that are considered to be potentially too low (refer Section 2.5.2). The use of higher flows could result in increased impacts for a given drainage configuration.

The April 2020 Technical Note that considers the latest Ipswich Rivers study results, calculated the impact associated with the use of increased flows in the FFJV model for the Bremer River catchment including Western Creek, suggesting an increase in absolute flood level for the 1% AEP event of about 70 mm (Table 10 of the Technical Note).

On the east abutment of the Western Creek Bridge to the QR West Moreton Junction (Ch 1.30 km), the Technical Note indicated that there was limited change in afflux between the unfactored and factored flow cases.

As the identified impacts would appear to affect a relatively limited rural area and not affect sensitive receptors (refer below), an increase in level is potentially not unreasonable. However, while the draft EIS and Technical Report provide some explanation and justification in relation to the acceptability of the increase in level, further justification is required in relation to the selection of drainage structures and the acceptability of the associated increase in level in cases where an increase extends over a considerable area.

Further, the October 2019 Technical Note presents the results of a value engineering process which included (Section 2 of the Technical Note):

- Treating only flooding at habitable dwellings as a constraint, with higher tolerances adopted for other types of flood sensitive receptors; and
- Increase the peak water level impact up to the 400 mm limit (noting that the Flood Impact Objectives nominate an increase of less than 200 mm with “localized areas up to 400 mm”.

The above relaxations would allow the size of drainage structures to be reduced.

The Technical Note indicates that it will be necessary to engage with stakeholders and the community in relation to any changes in design. Further, there is no indication that reduced drainage structures will be adopted for further design.

Given the size of the project, the completion of value engineering exercises is to be expected. However, it highlights the need for the increases in level nominated in the Technical Report to be appropriately justified and for any revision to drainage design in the future to be similarly justified, including consultation with stakeholders and the community.

5.3.2 Sensitive Receptors

Figure 9 indicates the location of sensitive receptors (houses etc.) identified by the FFJV within the Western Creek catchment that are potentially impacted by the railway. Sensitive receptors are considered in greater detail by the FFJV when the afflux is greater than 10 mm for the event under consideration. Based on the figure below and Appendix D of the Technical Report, only two sensitive receptor locations, 1345 and 1346, have an impact greater than 10mm.

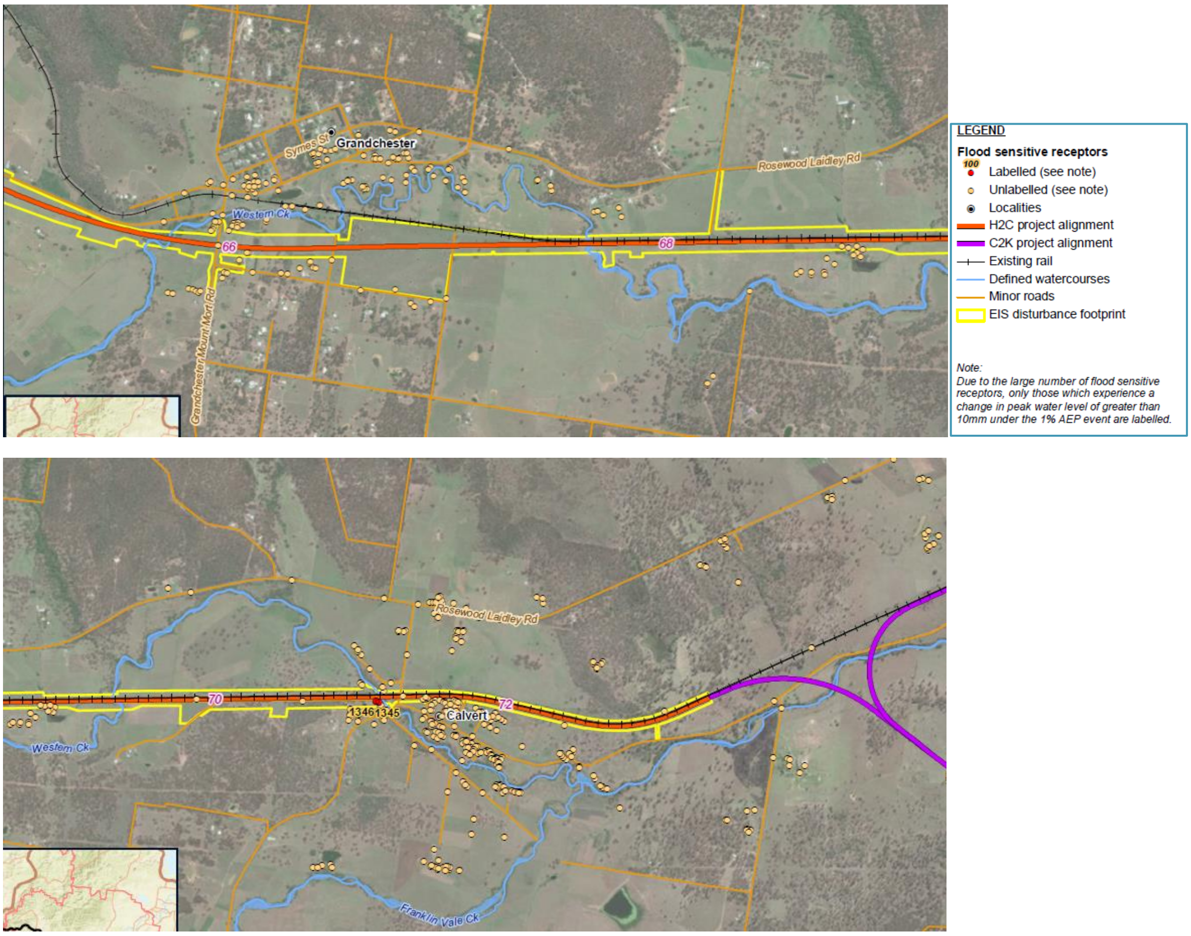

Figure 9: Sensitive Receptors (Figures 13.8d and 13.8e of draft EIS)

Table 4 lists the sensitive receptors affected by events up to the 1% AEP event including climate change. As the figures accompanying the Technical Report only identify two of the sensitive receptors (1345 and 1346), it is not possible to locate the other sensitive receptors noted in the table.

Table 4: Sensitive Receptors - 1% AEP Event with Climate Change (Appendix D of Technical Report)

Identified flood sensitive receptor No	Identified flood sensitive receptor type	Catchment	20% AEP (mm)	10% AEP (mm)	5% AEP (mm)	2% AEP (mm)	1% AEP (mm)	1% AEP with Climate Change (mm)	1% AEP with 0% Culvert Blockage (mm)	1% AEP with 50% Culvert Blockage (mm)	1% AEP with 20% Bridge Blockage (mm)
1169	Residential dwelling	Bremer	-	-	-	0	2	74	2	47	-4
1171	Sheds and rural free	Bremer	-	-	-	0	1	75	2	53	-23
1304	Sheds and rural free	Bremer	-	0	2	0	0	10	0	0	0
1313	Sheds and rural free	Bremer	-	-	-	-	-	21	-	-	-
1317	Sheds and rural free	Bremer	-	-	-	-	-	78	-	-	-
1340	Residential dwelling	Bremer	-	-	-26	-32	3	20	-1	15	9
1341	Residential dwelling	Bremer	-	-	-	-	0	20	0	1	2
1342	Sheds and rural free	Bremer	-	-	-38	-39	3	19	-2	15	9
1345	Sheds and rural free	Bremer	-	-	-	422	441	434	441	440	421
1346	Residential dwelling	Bremer	-	-	-	-	315	325	316	314	292
1347	Water tank	Bremer	-	-	-	-	-	195	-	-	-
1548	Paved road	Bremer	-	-	-	-	-	26	-	-	-
1588	Unpaved road	Bremer	-	-	4	1	0	27	0	-1	13
1610	Paved road	Bremer	0	0	1	4	7	14	8	8	7
1611	Bridge	Bremer	3	0	1	4	7	14	7	7	7
1786	Unpaved road	Bremer	3	4	3	5	8	14	5	27	8

With reference to the above table, increases in level of 441 mm and 315 mm are reported at receptors 1345 and 1346 respectively for the 1% AEP event. No justification is provided for this increase in level. Further, the adoption of higher design flows could result in an increase at a sensitive receptor that is in excess of the design objective (for example receptor 1169).

It is recommended that sensitivity testing be undertaken to confirm whether the nominated drainage structures are sufficient to minimize impacts given the flood impact objectives based on increased flows and the adjustment of the flood model as recommended within the Panels' review of the Bremer River section for H2C.

Further, while there is no strict criterion for the consideration of flood level impacts for extreme events (refer Section 5.7), it is recommended that impacts for extreme events be tabulated for the next phase of assessments.

For example, the impact maps between Grandchester and Calvert for the PMF event are shown below in Figure 10. Impacts at some sensitive receptors could be in excess of 0.5 m.

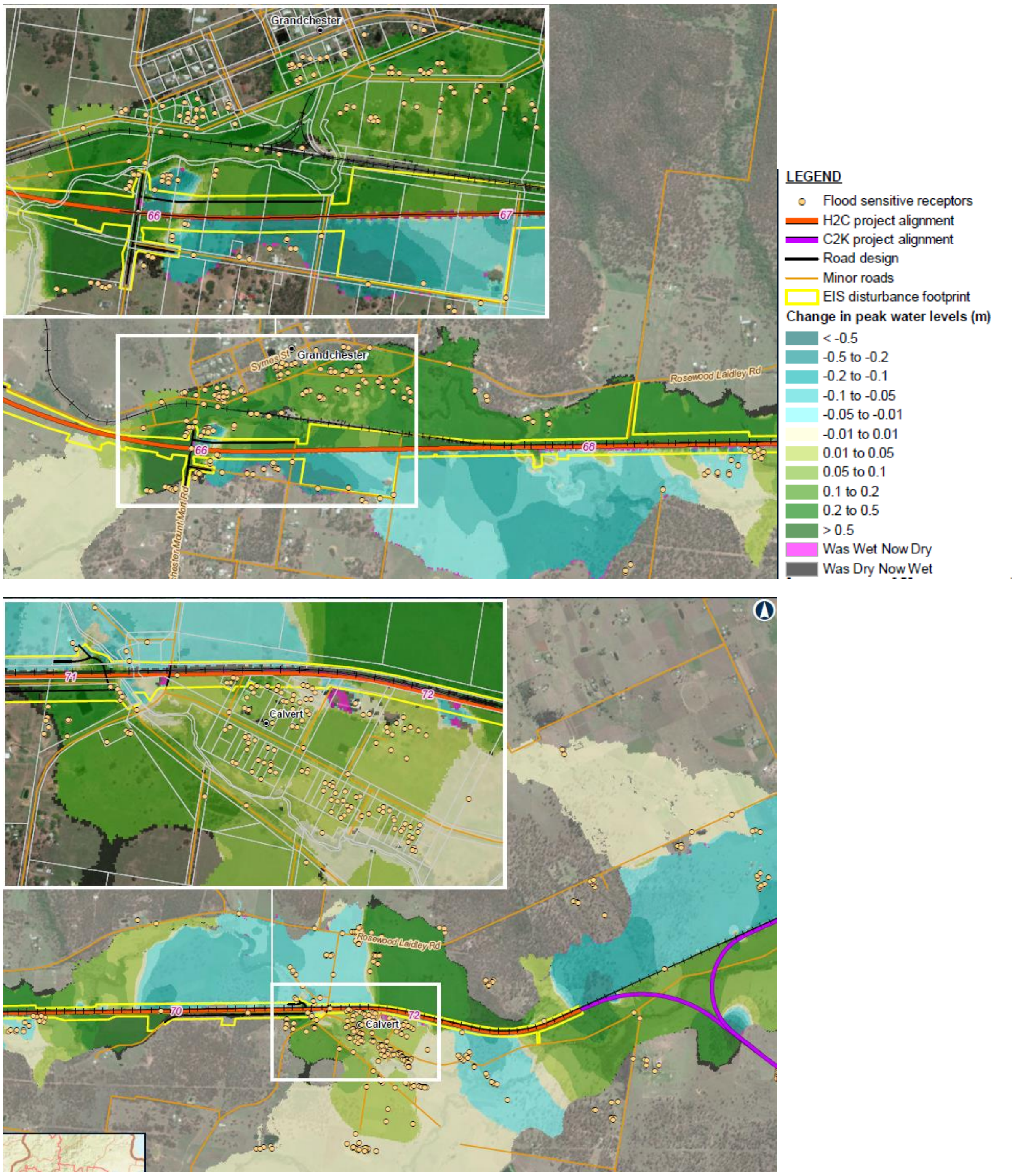

Figure 10: Change in Water Level for PMF Event at Sensitive Receptors (Figures 13.26a and 13.26b of draft EIS)

The tables/maps do not list the relevant floor level (or at least ground level if no survey data is available) at each receptor. This makes the assessment of any increase in level difficult as the proximity of flood waters to the floor of a structure and the depth of water over the floor are key criteria for the consideration of impacts. It is recommended that floor/ground level information be surveyed and added to the tables as part of further design in order for the change in flood level at each receptor to be assessed. It is noted that the Engeny report contains some surveyed floor level information.

5.4 Duration of Flooding and Time of Submergence

Table 5 presents the calculated increase in the time of submergence for the 1% AEP event for locations where changes in peak water levels lie outside the flood impact objectives. No tabulated impacts on the Annual Average Time of Submergence (AAToS) were provided and should be included in future phases to allow for a comprehensive review of potential impacts on submergence times.

Table 5: Change in Time of Submergence 1% AEP Event Only (Table 13.46 of draft EIS)

Chainage (km)/ Location	Existing Case ToS (hrs)	Developed Case ToS (hrs)	Comment
Ch 65.88 km Agricultural land	61.6	28.0	This reduction in ToS is due to the upgrade of the culverts under Grandchester-Mount Mort Road which increases low flow drainage capacity.
Ch 66.12 to Ch 66.50 km Agricultural land	51.6	69.0	In this locality, there is an access road to Mt Grandchester-Mt Mort Road for local residents. This low level road currently has limited drainage and leads to localised increases in ToS of up to 17.5 hrs.
Ch 67.30 km QR Rail Line	26.0	50.5	This increase in ToS is within the Project disturbance footprint and caused by shallow sheet flow being trapped behind the Project embankment.
Ch 69.44 and Ch 69.92 km Agricultural land (Upstream of Project alignment)	21.2	17.6	In the Existing Case the QR rail line overtops to the east of this location. This reduction in ToS is due to upgrading the culverts under the QR rail line which eliminates overtopping and addresses downstream impacts.
Ch 70.00 km Agricultural land (Downstream of Project alignment)	15.7	14.0	In the Existing Case the QR rail line overtops at this location. This reduction in ToS is due to upgrading the culverts under the QR rail line which eliminates overtopping and addresses downstream impacts.

The report notes that the changes to submergence times are not expected to significantly affect any sensitive receptors or infrastructure with the main localised increase of up to 17.5 hours at the low-lying road between Ch 66.12 and Ch 66.50 with it expected to be resolved at a local catchment scale with road drainage. Further details regarding this access road and whether it provides the only means of access during flood events is requested to allow an informed view on the potential impacts of this extended ToS.

It is also considered necessary to confirm that the change in time of submergence will not affect the viability of any crops. From this perspective, it is also necessary to consider the change in time of submergence for more frequent events as it is the more frequent events that have the potential to impact on crops or grazing land.

Similarly, it is necessary to consider whether the use of higher flows in the model will significantly affect the duration of inundation.

As there are a number of locations that experience a reasonable increase in the ToS, it is requested that additional information be provided justifying the increase, and that ToS information be provided in relation to other sensitive receptors where there is an increase in ToS.

5.5 Roads

Insufficient information is provided in relation to the impact (in terms of flood level impacts, ToS and AATOS) of the alignment on road immunity and flooding.

The Technical Report nominates an increase in level at Newmann Road but does not provide sufficient justification for the increase.

There is also a concern in relation to Waters Road. The road runs through both the eastern end of the H2C corridor and the western end of the C2K corridor. Table 9.4 of the C2K Technical Report noted an increase of 80 mm along Waters Road between Kuss Road and Lane Road.

Table 13.19 of Chapter 13 of the draft EIS for H2C notes that the Waters Road is overtopped to a depth of 0.25 m in the 1% AEP event. As depths less than 0.3 m are potentially trafficable, an increase in depth of 80 mm would be of significance.

The February 2020 Technical Note provides a description and considers options for eliminating the increase in level at Waters Road, noting Council’s concern that the road acts as an emergency escape route. The Technical Note indicates that significant works would be required to remove the increase in level and presents a range of options that could be considered further.

It is recommended that additional consideration be given to the increase at Waters Road and available options for its mitigation. Further details regarding this access road and whether it provides the only means of access during flood events is requested to allow an informed view on the potential impacts including any extension to the ToS. Additionally, current ToS has only been assessed at locations where the increase in water level of 100mm to 200mm occurs.

It is recommended that all locations where ToS is increased by more than 20% should be reported to ensure that roadways submerged by floodwaters (not just at locations where an increase greater than 100 mm occurs) are captured.

5.6 Flow Velocities

For the adopted design flows, velocities at each crossing are generally less than 2 m/s. While such velocities would appear to be manageable (in particular in cases where large bridge spans are proposed), given the nature of the soils in the rail corridor, it is necessary to consider the potential for erosion and whether larger or amended drainage structures are required. It is also noted that higher outlet velocities at Ch 69.90 and Ch 69.91 of 5.3 m/s in the 1% AEP event, and at Ch 70.98 of 3.1 m/s will require more stringent erosion protection measures. Provision of larger culverts to reduce velocities in these locations is preferred in lieu of increased scour protection measures.

The report considers the potential for scour in terms of flow velocities. Bed shear stress and stream power, which typically informs the changes to the geomorphology of the waterways, should also be referred to provide further details as to the potential impacts of the proposed works. Velocity is the pseudo parameter generally relied upon where these outputs have not been generated.

For example, one of the bridge crossings has a design flow velocity of 2.1 m/s. While this is lower than the adopted tolerance of 2.5 m/s, it would be beneficial to know the shear stress associated with the velocity and the change in velocity/shear stress from the current situation.

The velocity and shear stress of flow in the vicinity of proposed culverts will be of interest as there will be less ability to deal with erosion at these locations compared to the bridges where the significant proposed width provides a degree of flexibility.

In addition, climate change induced rainfall intensity increases, and the use of increased flows will result in higher velocities than those presented with respect to the 1% AEP event as calculated by the FFJV.

It will be necessary to ensure as part of detailed design that the potential for scour including climate change and increased flows is addressed, with the adoption of larger drainage structures if necessary.

Overall, the acceptability of flow conditions will require a site by site consideration of the velocity and associated shear stress/ stream power relative to the soil conditions at the point the velocity occurs. Given the erodibility of the soils in the area, it will be necessary to pay close attention to the management of flow velocity as part of detailed design.

Further discussion is provided in the Geomorphologic Report in Appendix C of the overall H2C Technical Review.

5.7 Extreme Events

The draft EIS and Technical Report present the results of modelling completed with respect to events greater than the 1% AEP design event, namely the 1 in 2,000 AEP, 1 in 10,000 AEP and Probable Maximum Flood events.

For such events, flood impact objectives are not readily applicable. The focus of the review of extreme events is to ensure that the flooding behavior does not change significantly as a result of the development and result in an increased flood risk.

In this case, the increase in flood level in the vicinity of Grandchester is of significance as the embankment directs more flow to the north of the railway (refer Figure 10). The Panel recommends that in areas where the alignment is close to population centres, such as towns, the impact in extreme events (for example the 1 in 2,000 AEP) should not significantly increase for both flood levels and the number of affected properties. A target objective of less than 200 mm increase in flood levels would achieve this objective. Furthermore, the design should ensure that there is no significant increase in flood hazard to the community.

5.8 Design Criteria Outcomes and Associated Impacts

5.8.1 Sensitivity Tests

Given the natural nature of the catchment, any planning changes to future land uses is unlikely to change the impervious fraction significantly across the upstream catchment to an extent that would result in noticeable impacts on the design event flows. As a consequence, the lack of a sensitivity assessment by FFJV against future land use is reasonable.

Blockage potential of the proposed bridges and culverts has been assessed in accordance with the ARR2016 guidelines. The guidelines recommend that the potential for blockage needs to consider the upstream catchment's available debris type, dimensions, availability, transportability, structure interaction and random chance. However, it has not been documented in the draft EIS how the blockage percentages were actually determined.

The assessment ultimately adopted zero blockage for the multi-span bridges proposed and 25% for culverts with a minimum diameter/width of 1.2 m.

For these values to be correct, the debris potential would need to be "Low". It is likely that the catchment characteristics would result in a Low designation and therefore the blockage values adopted are considered appropriate.

Sensitivity scenarios have also considered zero and 50% blockages which are suitable for the assessment.

In addition, a bridge blockage sensitivity scenario was also modelled (Section 9.3.4.1 of the Technical Report). For bridges represented in 1D channels this was determined by doubling bridge obstruction (e.g. caused by piers) and determining the associated form loss/bend loss. For bridges represented in the 2D domain a 20 per cent blockage factor was adopted. Confirmation that this bridge blockage scenario has been applied across all bridges throughout the Project is required.

5.8.2 Climate Change

The impacts of climate change have been assessed in accordance with the ARR2016 guidelines for the 1% AEP design event. The selected representative concentration pathway of 8.5 has been adopted to the 2090 horizon.

As an RCP of 8.5 is the most conservative and *Australian Rainfall and Runoff* only provides recommendations up to 2090, the climate change assessment parameters are considered appropriate for this assessment.

The resultant increases in flood level do not compromise the minimum freeboard of 300 mm required under the design criteria for the 1% AEP event (excluding climate change) except at Ch 69.90 km where the residual freeboard is 280 mm.

6 Proposed Design - Local Catchments

The review of the proposed local drainage documented in the model was limited to a review of the results presented in the FDR and summarised in Section 9.4 and Appendix E of the Technical Report.

The flood level impacts presented in Table 3 of Appendix F3 in the FDR (also Appendix E of the updated Technical Report), indicate that the proposed culverts and bridges will result in an increase in level for the 1% AEP event of 250 mm, 120 mm and 190mm for 330-BR19, C64.78 and C70.53 respectively. Impacts at C63.08 and C63.20 of 60 mm and 50mm also result. The table also indicates that the change in time of inundation for the 1% AEP event is a maximum of 0.86 hours for C68.20 with all other crossings being less.

The impacts detailed above are relatively localised and dissipate over a short distance. Some local catchment impacts do extend onto rural properties that have been identified the “sensitive receptors” (in this case Dams in Table 54 of the FDR). While it is unlikely that these increases will result in actionable damage, consultation with affected land owners is still recommended.

The flood level increases and changes in inundation time are considered to be both minimal and acceptable given the affected area.

Similarly, the flow velocity/shear stress associated with the discharge from the culverts should be manageable during detailed design by the provision of suitable scour protection measures.

The associated impacts of the alignment on local flooding as reported in Table 54 of the FDR are generally less than 10-30mm for houses, sheds and roads with the larger impacts of up to 140mm occurring rural farm dams. All impacts are within the stated impact objectives, however confirmation of community acceptance of these impacts is still expected to be required.

Table 54 of the FDR also identifies increases in level of between 20 mm and 50 mm at a number of roads. Additional justification is required in relation to the acceptability of an increase at roads (or structures enlarged to remove the increase).

The drainage structures included in the local catchment modelling include a bridge (330-BR19 at Ch 64.39 km) with a span of 159 m, While it is of concern that a major structure is included as a local catchment drainage feature, the bridge drains a relatively small area (compared to the size of the bridge) of 2.9 km^2. Although it needs to be confirmed, it is expected that the size of the bridge is dependent on factors other than the flow being conveyed.

7 Conclusion

7.1 Overview

A review was completed with respect to the regional models and reporting prepared in relation to the Western Creek catchment for the Helidon to Calvert section of the Inland Rail project. The overall review also included the FDR (excluding models) prepared for the local catchments within the Western Creek catchment.

A summary of the model review is provided in Appendix 1. Section 7.5 provides a summary of the key findings and identified issued.

7.2 Major Crossings

The hydrologic and hydraulic modelling for Bremer River including Western Creek was used for the assessment of the C2K section of the rail alignment that traversed the Bremer River catchment. The Panel has undertaken a detailed review of the Bremer River catchment for the C2K portion of the Inland Rail as reported in *Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland Appendix A: Bremer River Models Review – Draft Report on Review of Calvert to Kagaru Section, January 2021*.

Given the same models were used unchanged for the respective Western Creek and Bremer River assessments, the majority of the comments and recommended actions detailed in the Bremer River review are also applicable to the Western Creek assessment. Rather than repeating the issues in detail verbatim as part of this review for Western Creek, resolution of the Bremer River model issues will subsequently resolve the majority of issues associated with Western Creek. This assessment subsequently only highlights specific issues relevant to the Western Creek portion of the alignment.

Although the following section provides an overview of the findings of both this Western Creek and the Bremer River reviews and recommendations with regard to required additional work, the key finding of the reviews was in relation to the flow rates associated with design events. Due to the expected underestimation of rainfall intensities within the wider Bremer River catchment, it is considered that the resultant flows presented in the draft EIS are underestimated. The April 2020 FFJV Technical Note provides a degree of quantification of the impact potentially associated with the use of higher flows.

This is of concern in terms of the interpretation of Inland Rail-related flood impacts as the adoption of higher flows in subsequent design stages will result in greater impacts (in terms of level, extent and duration of submergence and flow velocities) if the currently proposed drainage structures were to be retained or the need to adopt larger drainage structures to provide impacts similar to those currently nominated.

Section 7.5 presents a summary of the key findings and identified issues.

7.3 Minor Crossings

Minor crossings are presented within the hydraulic model but assessed via a local drainage model. These have been included for large flood events where flow from several of the waterways may cause inundation of the structures. However, the provided flood extents in both the FDR report and Technical Report (detailing local and regional models) show that the models are not independent, and the approach may not be appropriate.

7.4 Advice and Recommendations

Based on the review of the Bremer River including Western Creek model, the following advice and recommendations are made in accordance with the *Terms of Reference for an Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland* (Final, June 2020).

7.4.1 Relevant Guidelines

Whether the development of the models and their application accords with the relevant requirements of national and state guidelines/manuals (guidelines) for flood estimation and design of structures in flood prone environments.

While the models have been generally developed and applied in accordance with relevant guidelines and manuals, the review identified a number of issues in relation to the development and application of the models that could affect the interpretation of the Inland Rail-related flood impacts. The issues, and the proposed methods for their resolution, are summarised in Section 7.5.

7.4.2 Floodplain Extent

Whether the extent of the floodplain covered by the flood model is appropriate, and if not recommendations as to what additional extent would be appropriate

The overall extent of the floodplain covered by the flood model is appropriate. Consideration could be given to merging the local catchment flood model of the area to the west of Grandchester detailed in the FDR with the overall model as part of detailed design.

7.4.3 Calibration

Whether the method, and extent of calibration of the model accords with guidelines and industry standards for calibration.

While the method and extent of calibration is expected to be adequate, insufficient information has been provided to fully confirm accordance with industry standards. The additional information required with respect to the calibration is described in Section 7.5.

7.4.4 Validation

Whether the method for validation of the model accords with guidelines and industry standards and whether the assumptions used underpin the validation process, and the data points used in the validation are appropriate

While the validation of the models generally accord with guidelines and industry standards (noting the limited data available for validation), additional information is potentially required (subject to the response to the items raised in the Panel's Review of the Bremer River catchment for the C2K section of the alignment) to fully confirm the validation of the models and with regard to the flows adopted in the models. The additional information potentially required with respect to the validation is described in Section 7.5.

7.4.5 Impacts and Impact Mitigation

Whether the model adequately accounts for the impacts of the reference design and whether those impacts are capable of appropriate local mitigation that either removes the impacts or reduces the impact to landholders in the area

There is a concern that the flow rates adopted, particularly for the design 1% AEP event, are underestimated in the draft EIS. The use of underestimated flows will result in the underestimation of impacts on flood level.

To consider the impacts associated with higher flows in the draft EIS, it is necessary to interrogate the impact plots presented with respect to larger events to estimate the impact associated with larger events. The April 2020 Technical Note provides some quantification of the likely impacts associated with the use of higher flows. It is recommended that additional consideration be given to the flows appropriate for the catchment, with modelling and mapping undertaken based on the resultant adopted flows to provide a more reliable quantification of impacts, in particular for the design 1% AEP event (refer Section 7.5). This will allow impacts to be appropriately identified.

At a number of locations, impacts in excess of those nominated in the Flood Impact Objectives are obtained. The impacts could potentially be mitigated if necessary by the adoption of larger drainage structures.

However, it is also anticipated that an impact in excess of the objectives can be tolerated given the current land use of affected areas. Additional documentation should be supplied to the Panel to justify the impact and the reason that it is not practicable to adopt additional mitigation measures to reduce the identified impact. Further, the potential impact at a number of sensitive receptors needs to be confirmed.

7.4.6 Fit for Purpose

Whether the model is fit for purpose, taking into account the above and any public comments for comments from external stakeholders in relation to the flood model that arises from the public exhibition of the draft Environmental Impact Statement (EIS) for the relevant Inland Rail Project

The report has been prepared prior to public exhibition and so therefore is not able to include commentary regarding whether the model is fit for purpose based on comments from external stakeholders.

The review has indicated that the model is potentially fit for purpose for the draft EIS process, subject to:

- the provision of additional documentation to the Panel;
- adequate response to the issues listed in Table 7; and
- the consideration of the additional impact associated with the use of higher flow rates.

The necessary additional documentation and sensitivity modelling is detailed in Section 7.5.

7.4.7 Best Practice

Whether the reference design for the proposed structure meets industry standards for railway structures in a floodplain and if so, whether the reference design is in accordance with best practice.

The review has indicated that the reference design meets industry standards and best practice, subject to:

- the provision of additional documentation to the Panel;
- adequate response to the issues listed in Table 7; and
- the consideration of the additional impact associated with the use of higher flow rates.

The necessary additional documentation and sensitivity modelling is detailed in Section 7.5. It is noted that the modelling completed in relation to the reference design will need to be modified early in the detailed design phase.

7.5 Summary of Findings

Table 6 presents a commentary in relation to the focus areas for the panel identified in the *Terms of Reference for an Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland* (Final, June 2020).

The review identified a number of areas where additional work is required, either as part of further design stages or to provide additional documentation to the Panel. The items identified in the review are summarised in Table 7.

It should be noted that only those issues specific to the Western Creek catchment have been presented in this review. Reference should be made to the Panel's review of the Bremer River catchment for the C2K section of the project for the full issues identified to be addressed for the wider catchment models used in both assessments.

To assist the interpretation of the table, if a similar issue has been raised as a result of the Bremer River model review for C2K, the relevant issue number from the Bremer River review has been added to the table.

To facilitate the resolution of the identified issues, each issue has been assigned a level of importance, as described below.

- ***Low Importance***

  Additional work is required that will not significantly affect the EIS process. The work can be completed as part of further design (prior to the use of models for detailed design) and the requirement to complete the work can be included as a condition of approval.

- ***Medium Importance***

  Clarification or confirmation is sought in relation to an aspect of the supplied reports and models. Depending on the response to the issue by ARTC, the issue can be addressed via conditions of approval if required (i.e. it is deemed to be of low importance) and prior to the use of models for detailed design or via sensitivity testing (i.e. it is deemed to be of high importance as a result of the response).

- ***High Importance***

  Sensitivity testing is recommended to determine the significance of the issue to the interpretation of Inland-Rail related flood impacts and for documentation and modelling regarding the results of the sensitivity testing to be supplied to the Panel to confirm whether the issue can be dealt with (if necessary) by conditions of approval (i.e. the item is deemed to be of low importance on the basis of the sensitivity assessment) and prior to the use of models for detailed design or whether the issue affects the interpretation of results.

- ***Very High Importance***

  An issue of significance that warrants the revision of the documentation provided to the Panel to include either the documentation of additional justification regarding a conclusion drawn or amended flood modelling. Such issues will need to be addressed prior to the models being used for detailed design.

Figure 11 presents a flow chart indicating the process by which it is proposed to resolve each issue relative to its assigned level of importance. The colour-coding used in the figure was applied to Table 7 to allow the relative importance of each issue to be readily identified.

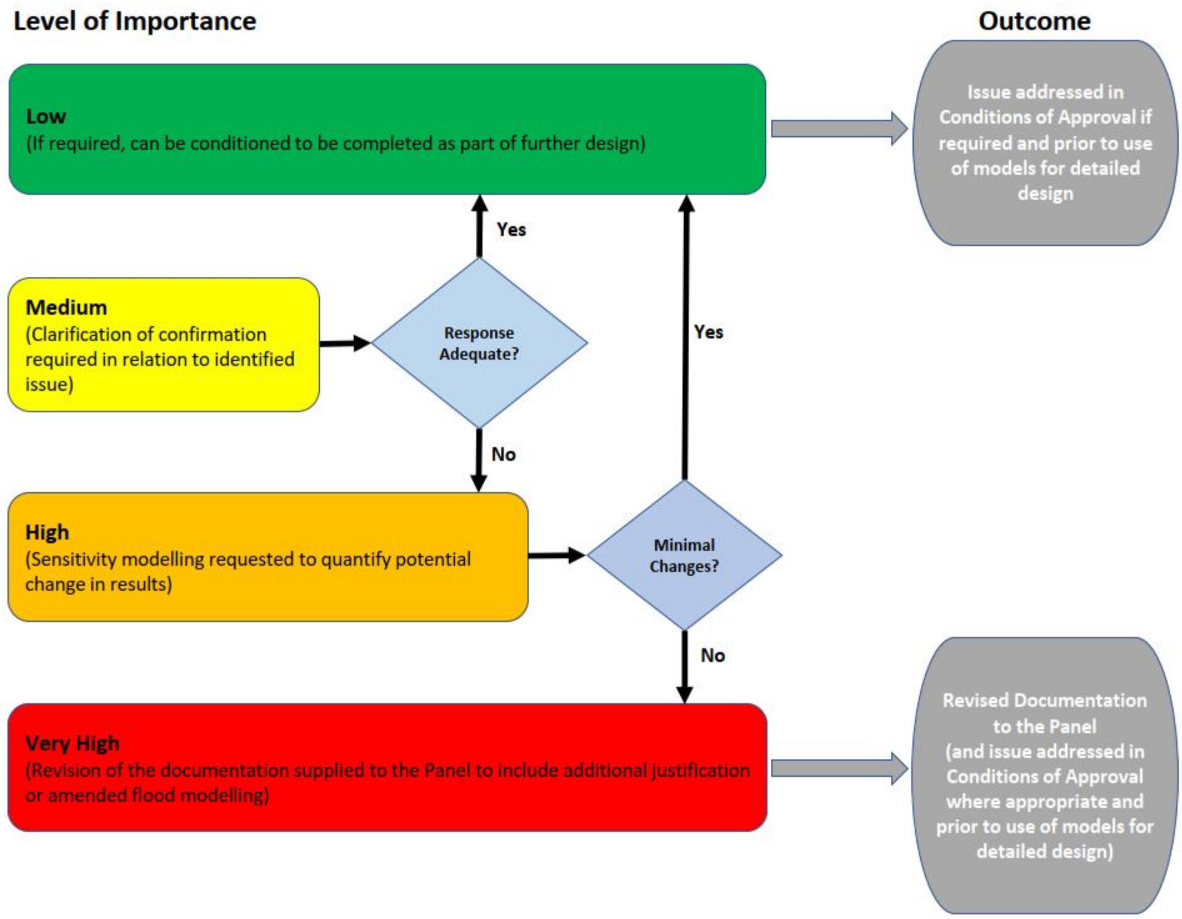

Figure 11: Flow Chart for Resolution of Identified Issues

Table 6: Review of Focus Issues

Focus Issue	Satisfied?	Comment
Extent		
Applicability and appropriateness for the relevant design stage (e.g. reference/detailed etc.)	Yes	The extent of modelling is appropriate for the reference and design stages.
Appropriateness of tool/s selected for flood modelling	Yes	The hydrologic and hydraulic models are appropriate.
Confirmation that key design criteria are considered reasonable and appropriate compared with typical similar linear infrastructure projects	Yes	The key design criteria are considered to be reasonable and appropriate.
Assumptions		
Appropriateness of model arrangements and input parameters	AIR[1]	Additional documentation and sensitivity modelling is required to confirm that model arrangements and input parameters are appropriate.
Appropriateness of model calibration process	AIR[1]	The model calibration process is generally appropriate, subject to confirmation with additional documentation and potentially additional modelling.
Appropriate application of input data (including addressing data gaps)	AIR[1]	Subject to the provision of additional documentation and sensitivity modelling, input data is generally appropriately applied. The main issue identified in the review is the appropriateness of the available design rainfall data.
Assumptions around land-use (crops etc.)	AIR[1]	Acceptable assumptions have been made in regard to land-use (subject to sensitivity testing identified with respect to application).
Appropriateness of blockage/debris assumptions	Yes	The blockage and debris assumptions are appropriate.
Appropriateness of future events application, e.g. climate change	Yes	The application as a sensitivity only is appropriate, subject to the potential revision of design rainfall intensities available for the area and subject to ISCA requirements.
Appropriateness of assumed soil conditions	Yes	Assumed soil conditions are reasonable for the current level of investigation.

Focus Issue	Satisfied?	Comment
Application		
Appropriate sensitivity analysis to various items e.g. flow inputs, coefficients	AIR[1]	Additional sensitivity assessment is required in relation to level of vegetation and bridge loss coefficients as part of further design. Additional sensitivity assessment is recommended as part of the consideration of the modelling completed to date.
Appropriateness of change indicators	AIR[1]	Change indicators are generally appropriate, although a more quantitative approach to changes in velocity and duration of inundation would be of benefit for the interpretation of results
Appropriateness of structure and embankment representation (depending on the stage of the design)	Yes	Structures and embankments have been appropriately represented.
Flood frequency analysis	No	The flood frequency analysis and associated work indicates that the flow rates derived for design storm events (in particular the design 1% AEP event) are underestimated. The higher flows presented in the April 2020 Technical Note provide some quantification of the potential incremental impact associated with the use of higher flows.
Interpretation		
Achievement of Design Criteria	AIR[1]	The Design Criteria have been generally achieved, apart from the available rainfall intensity information which is considered to result in the underestimation of peak flow rates for design storms (in particular the design 1% AEP event). This will not affect the level of the embankment which is set well above the relevant design level and only relates to the sizing of hydraulic structures.
Appropriateness of relevant sensitivity analysis	Yes	The sensitivity assessment completed with respect to blockage and climate change are appropriate.
Confirm Inland Rail-related flood impacts, if any, are comprehensively quantified and interpreted to their local property context	AIR[1]	While impacts are quantified, the impacts are based on flows that are considered to be underestimated. To identify impacts associated with higher flows, it is necessary to estimate impacts based on the impacts identified for larger events. This leads to potential uncertainty in the consideration of the relative importance of the impacts presented with respect to the railway compared to the severity of the event being considered. The April 2020 Technical Note provides some quantification of the potential incremental impact associated with the use of higher flows.
Appropriateness of the alignment, with regard the related flood impacts, within the current EIS Study Corridor	Yes	The alignment is considered to be appropriate for the current EIS study corridor.

Focus Issue	Satisfied?	Comment
Consider whether reasonable and practical steps have been taken to mitigate flood impacts, if any, outside of the project boundary	AIR[1]	Insufficient information has been provided to the Panel in relation to the efficacy of the adopted mitigation measures and the justification for additional mitigation not being required and/ or practicable.
Additional information that would be required to be addressed in the Detailed Design phase of the program	Yes	It will be necessary to complete additional sensitivity analyses and to refine the models in the detailed design phase. It is also considered that it will be necessary to consider higher flow rates in the detailed design phase which may affect the sizing of hydraulic structures and associated scour protection.

Note: [1]AIR stands for Additional Information Required (as summarised in Table 7) in order to confirm issue satisfied.

Table 7: Summary of Identified Issues

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
			Assumptions			
WC1 (B1)	Additional information is available for 2011 calibration.	2.2.1, 2.4, 4.1	Need to ensure calibration is robust and model suggests lower levels than recorded at Grandchester	Need to use a model that represents conditions as closely as possible to allow calculation of impacts.	High	Calibration data available for Grandchester Alert station and previous study of Western Creek produced improved calibration. Can use regional methods to confirm flow within sub-catchments.
WC2 (B4)	Sub-catchment extents not based on railway alignment, with alignment passing through sub-catchments.	2.3, 3.2.2	Need to quantify the runoff that occurs upstream and downstream of the alignment in order that flow paths are represented and the flow to be conveyed by drainage structures is correct.	Not correctly accounting for flow upstream and downstream of the culvert can result in the over or under-estimation of discharge at a drainage structure depending on the point of application of the inflow for a sub-catchment.	Low	For detailed design, further sub-division of sub-catchments and adjustment of catchment boundaries to reflect areas upstream and downstream of the alignment is necessary.

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
WC3 (B5)	Inflow for main flow path (TOT034) located too far within model and too close to the railway.	3.2.1	Conditions upstream of the alignment preferred to be accurately modelled in order that flow paths are correctly represented and levels at sensitive receptors correctly calculated.	Levels upstream of inflow point TOT034 are incorrect, modelling results in additional floodplain storage, and conditions upstream of model inflow point are not appropriately represented.	Low	Current modelling could result in incorrect representation of flow paths but is far enough upstream of sensitive receptors to not have a significant impact.
WC4 (B9)	Focal point for the calculation of design rainfalls located at stream gauge (well downstream) rather than also at railway.	2.5.2	The selection of a focal point at the railway will increase design flows.	Further reduction of flows due to the selected focal point will result in the underestimation of drainage structure requirements or impacts.	High	Concern regarding BOM IFD data resulting in low design rainfall estimates and use of factor for larger catchment could exacerbate this issue.
WC5 (B11)	Applicability of areal temporal pattern set applicable to the gauge (500 km^2) compared to the set applicable to the two main crossings (200 km^2) and the point temporal patterns applicable to catchments less than 75km^2 in area.	2.5.1	Temporal patterns affect the peak flow at each crossing point.	The adoption of temporal patterns applicable to larger catchments to smaller catchments could affect flows and therefore the sizing of drainage structures and impacts.	High	The use of alternate temporal patterns could affect peak flows and the timing of peaks at the crossing points, in turn affecting the design of drainage structures and impacts. If it is determined that the use of alternate temporal patterns produces a minimal impact, then the consideration of a wider range of patterns can be left to further design.

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
WC6 (B17)	Model stability	3.4	Instabilities can affect peak conditions and impacts.	In the worst case, flows can be misrepresented together with impacts. However, given the location of the instability and its isolated nature, the impact is expected to be negligible.	Low	To note need to remove instability as part of modelling for detailed design.
Application						
WC7 (B22)	Justification for flood level impacts and changes to time of submergence.	5.3.1, 0, 5.4, 5.5, 6	An increase in level in excess of that nominated is proposed. Impacts at sensitive receptors.	If an increase is deemed to be excessive, then the design will need to be modified.	Very High	Although some justification has been provided, additional justification is required in relation to flood level increases and changes in ToS. In particular impacts at sensitive receptors, taking into account increased flows, is required.
WC8	Increase in level in Grandchester area for extreme events	5.7	The embankment directs more water to the north of the embankment, resulting in greater increases in level than would otherwise occur	May need to consider alternate drainage configuration if change in flood risk for extreme events is found to be too great.	High	Embankment redirects flow to north towards Grandchester. It is necessary to ensure that the result change in flood risk is acceptable.
WC9 (B25)	Potential for scour to occur given generally poor soil conditions.	5.6	Although the design to date results in relatively low velocities, the nature of the soils in the area could result in the proposed drainage resulting in significant geomorphological impacts.	Depending on the nature of the soils and flow conditions in the vicinity of each crossing, it may be necessary to alter the drainage design.	High	The April 2020 Technical Note indicates that flood levels will increase upstream of crossings as a result of the adoption of higher flows. The increased flood levels will produce higher flow velocities through the crossings. The increase in velocity and the potential for the increase to result in scour (and potentially the need to enlarge drainage structures) needs to be reviewed and accounted for in detailed design.

Appendix 1 Model Review Summary Tables

Table 8: Hydrological Model Review Summary

Item No.	Description	Checked?	Additional Information
Hydrologic Model Setup			
1h	Model Software	Yes	Refer to Bremer River Review
2h	All Model files provided and can results be reproduced	Yes	Refer to Bremer River Review
3h	Catchment extent	Yes	Refer to Bremer River Review
4h	Sub-catchment delineation	Yes	Section 2.3
5h	Model catchment areas	Yes	Section 2.3
6h	Catchment Parameters *(e.g. slope, roughness etc.)*	Yes	Refer to Bremer River Review
7h	Adopted Parameters - *routing*	Yes	Refer to Bremer River Review
8h	Adopted Parameters - *losses*	Yes	Refer to Bremer River Review
9h	Adopted Parameters - *runoff coefficient*	N/A	FDR notes that Rational Method used to confirm local catchment flows
Design Representation			
1d	Sub-catchment changes to represent design	Yes	Section 2.3 (they have not changed anything in post-dev case)
2d	Model parameter changes to represent design	Yes	Refer to Bremer River Review (no changes in hydrology for post-dev case)
Flood Frequency Analysis			
1f	Gauge records available	Yes	Refer to Bremer River Review
2f	Gauge record length suitable for FFA	Yes	Refer to Bremer River Review
3f	Compare design flow estimates to FFA	Yes	Refer to Bremer River Review
4f	Annual Maximum Series	No	Refer to Bremer River Review
5f	Number of years input to FFA calculation	Yes	Refer to Bremer River Review.
6f	Historical events	Yes	Refer to Bremer River Review
7f	Censoring and filters	Yes	Refer to Bremer River Review
8f	Probability distribution	Yes	Refer to Bremer River Review
9f	Low flow filtering	N/A	
Calibration			
1c	Model Calibration/Validation	Yes	Refer to Bremer River Review

Item No.	Description	Checked?	Additional Information
2c	Calibration data	Yes	Refer to Bremer River Review
3c	Calibration events and magnitude	Yes	Refer to Bremer River Review
4c	Review rating curves	Yes	Refer to Bremer River Review
ARR 2016/2019			
1a	Design flow estimates sufficient	No	Consider flow estimates too low- Refer to Bremer River Review
2a	Use of ARR 2016/2019	Yes	Refer to Bremer River Review
3a	Critical duration	Yes	Refer to Bremer River Review
4a	Mean temporal pattern selection	Yes	Median TP selected not mean. Refer to Bremer River Review
5a	IFD rainfall data	Yes	Refer to Bremer River Review
6a	Temporal pattern zone	Yes	Refer to Bremer River Review
7a	Areal varied patterns	Yes	Refer to Bremer River Review
8a	Areal reduction factors	Yes	Section 2.5.2 but concerned they are at gauge and not railway
9a	Design rainfall losses - Calibration events	Yes	Refer to Bremer River Review
10a	Design rainfall losses - ARR data hub	Yes	Refer to Bremer River Review
Alternative Validation Method			
1am	Alternative validation method used FFA/RFFE	Yes	Refer to Bremer River Review
2am	Design flow comparison to FFA/RFFE	Yes	Refer to Bremer River Review
3am	Is the RFFE appropriate for the catchment	NA	Refer to Bremer River Review

Table 9: Hydraulic Model Review Summary

Item No.	Description	Checked?	Additional Information
Hydraulic Model Setup			
1h	Model Software	Yes	Refer to Bremer River Review
2h	All Model files provided and can results be reproduced	Yes	
3h	Model extent	Yes	Refer to Bremer River Review
4h	Model setup	Yes	Refer to Bremer River Review
5h	Model boundaries	Yes	Refer to Bremer River Review
Control			
1c	TUFLOW run log	No	
2c	TUFLOW Version	Yes	
3c	Solver	Yes	Refer to Bremer River Review
4c	Timestep	N/A	HPC version used
5c	Materials/roughness definition	Yes	
6c	TUFLOW Materials File	Yes	
7c	Direct Rainfall - Losses	NA	
Calibration			
1c	Model Calibration/Validation	Yes	
2c	Calibration data	Yes	
3c	Calibration events and magnitude	Yes	Refer to Bremer River Review
Events and Scenarios			
1e	Events and Scenarios	Yes	Refer to Bremer River Review
	1% AEP	Yes	Note consider flow too low. Refer to Bremer River Review
	Climate change	Yes	Refer to Bremer River Review
	Blockage	Yes	Refer to Bremer River Review
	Extreme events	Yes	Refer to Bremer River Review
	Other sensitivity assessments	No	
2e	Start and end times	No	
3e	Initial conditions	Yes	Not detailed
4e	Event text	Yes	
5e	Scenarios and variables	NA	

Item No.	Description	Checked?	Additional Information
Boundary Conditions			
1b	Inflow location	Yes	3.2.2
2b	Inflow values	Yes	Not detailed
3b	Boundaries	Yes	3.2.1
4b	Direct rainfall volume check	NA	
5b	1D connection type	Yes	Not detailed
6b	1D connections	Yes	Not detailed
7b	Channel connections	NA	
8b	Active cells	NA	
Geometry			
1g	Cell orientation	No	Not relevant
2g	2D active cells	Yes	
3g	Model extent	Yes	
4g	Material check	Yes	Refer to Bremer River Review
5g	Material check (Design scenario)	Yes	No change from existing
6g	Elevation raster check	Yes	
7g	Bridge representation	Yes	Refer to Bremer River Review
8g	Breaklines	Yes	
9g	Topographic modifications	Yes	Section 5.2
1D Network – Existing			
1e	1D input check	Yes	Implied not detailed
2e	Cover check	No	
3e	1D continuity	Yes	Spot checks. Implied not detailed
4e	1D locations & sizing	Yes	
5e	1D losses	Yes	
6e	1D blockage	Yes	
7e	1D connection type	Yes	
8e	1d connection grid cell check	Yes	
9e	1d network invert levels & outlet check	Yes	
10e	Channel selection	NA	
11e	No. cross-sections	NA	

Item No.	Description	Checked?	Additional Information
12e	Channel representation	NA	
13e	Channel input values	NA	
14e	1D IWL	NA	
Design Representation			
1d	1D locations & sizing	Yes	
2d	1D input check	Yes	
3d	Cover check	Yes	
4d	1D continuity	Yes	
5d	1D blockage	Yes	
6d	1D connection type	Yes	
7d	1d connection grid cell check	Yes	
8d	1d network invert levels & outlet	Yes	
9d	Bridge representation	Yes	Refer to Bremer River Review
10d	Topographic modifications	Yes	
11d	Design criteria flood level impacts	Yes	
12d	Design criteria duration of flooding impacts	No	
13d	Design criteria hazard category impacts	Yes	Not detailed
14d	Design criteria velocity and flow direction impacts	Yes	Not detailed
Results			
1r	Can results be replicated	Yes	Not detailed
3r	Review negative depths	Yes	Not detailed. One bank of existing culverts was unstable in Western Creek (72 x 1.2 x 0.9 RCBCs “Rail2” in H2C package)
4r	Review timestep outputs for HPC	No	
5r	Check raster outputs for irregularities	Yes	
6r	Check .csv outputs for culverts	Yes	

Appendix C Geomorphology Review

Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland

Appendix C: Geomorphology Assessment - Draft Report on Review of Helidon to Calvert Section

May 26, 2021

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1 Introduction

This report presents the findings of the review by the Independent International Panel of Experts for Flood Studies of Inland Rail in Queensland of the geomorphology assessments completed by the Future Freight Joint Venture (FFJV) in support of the draft Environmental Impact Statement (EIS) and Feasibility Design Report (FDR) for the Helidon to Calvert (H2C) section of the Inland Rail Project.

The Coordinator-General's (OCG) Final Terms of Reference (TOR) is limited in its requirements to assess geomorphological impact. However, Item 11.54 of Water resources asks for "Identification and mapping of soils that would require particular management due to wetness, erosivity, depth, acidity, salinity, contamination or other relevant features in the project description".

A review of Chapter 13 Surface Water and Hydrology and Appendix M Hydrology and Flooding Technical Report of the draft EIS documents prepared for the H2C section of the Inland Rail has been undertaken to determine the level of consideration given to address this requirement i.e. "the level of interference with watercourses and floodplain areas".

Such an assessment involves the consideration of fluvial geomorphic processes and considers the environmental impacts to floodplain, channel, sediment transport and waterway health.

An overview of the level of detail on such processes included in the draft EIS, an assessment of the knowledge gaps, consideration of the potential unknown impacts associated with those knowledge gaps, and a high-level assessment of the work required to fill those gaps is provided in the following sections.

Appendix L – Surface Water Quality Technical Report touches briefly on channel morphology in Section 2.4 by the need for five waterway diversions. Section 2.4 also mentions proposed high-level mitigation measures:

> *"In addition to the mitigation measures identified above and as part of the detailed design phase, when finalised positions of infrastructure elements (e.g. abutments/piers etc) are known and detailed soil studies are complete, geomorphological assessment of identified risk locations will be undertaken."*

Chapter 8 Land Resources (which covers topography, geology, soils and soil conservation works) does not reference geomorphology.

2 Geomorphology

2.1 Overview

Consideration of fluvial geomorphic processes within, upstream and downstream of a waterway crossing prior to design is considered best practice within the industry (Queensland Department of Transport and Main Roads, 2019). This gives better control when preparing detailed design and construction specifications, and ultimately reduces risk and cost.

A geomorphic assessment of the channel and floodplain characteristics, particularly when combined with hydraulic modelling results of the existing and developed case, allows for an appreciation of the natural dynamism of fluvial environments and can prevent catastrophic damage to roads, waterways crossings and infrastructure. This should be conducted prior to a detailed design phase to give a greater understanding of the limitations and potential risks associated with a particular crossing.

The draft EIS as it stands, largely ignores fluvial geomorphic processes. The presented assertions, risk assessment items and proposed mitigation measures (which are almost all highly generalised and/or deferred to detailed design) appear to be based on the assumption that the channels located at the waterway crossings will remain where they are and at the same dimensions for the duration of the crossing design life.

It is only where the channel is located at laterally and vertically bedrock-controlled valley settings is this assumption 100% correct. Many of the mitigation measures listed in the draft EIS that relate to impacts on riverine health lack sufficient detail to provide confidence in a reduction in risk associated with geomorphic processes.

2.2 Waterway Crossings

Lateral migration of channels in SEQ is generally slow; however, the variety of river types and conditions across SEQ is vast. Rivers vary significantly based on, for example, climate, vegetation, catchment size, geology, valley slope and anthropogenic pressures. Almost all waterways along the alignment are likely to be undergoing bed deepening at varying rates, a process that leads to steepening of the banks, subsequent bank collapse and channel widening. Importantly, almost all the waterways which are intersected by the Inland Rail alignment are dynamic and actively changing either episodically (related to high flow events) and/or gradually (changing under base flow conditions). The draft EIS does not characterise or consider such changes in the assessment of waterway crossings.

Hard structures in waterways, such as culverts and weirs are problematic in most fluvial settings (particularly in vertosol soil environments) due to the dynamism of these waterways. These structures will stay in one place whereas the channel may, move laterally, deepen, or widen. Due to the variability in river types and condition along the alignment there is no universal solution to any given issue at a crossing. Rivers are dynamic, and they respond to various pressures through complex processes.

Simple adoption of box or pipe culvert designs on a waterway based solely on flow conveyance (without a waterway assessment) is not best practice and potentially leads to various issues including impacts to waterway health in addition to potential failure of the culvert structure, through undermining or outflanking.

There has been limited assessment of upstream and downstream channel conditions and processes to gain an understanding of the likely rate or trajectory of channel change at proposed crossing locations. Chapter 11.6.8 of the EIS notes river health and the potential impact of structures will be assessed during the detailed design phase. However, there has been limited consideration of the likely river health and stability impacts imposed by bridge and culvert crossings within the EIS phase, which are likely to extend further (upstream and downstream) than the draft EIS disturbance footprint.

2.3 Minor Waterways

Many waterways have been classified as minor waterways as they have catchment areas of less than 10 km^2. However, some of these require relatively large drainage structures with:

- Pipe culverts of up to 30 pipes that are up to 2.4 m in diameter (23 pipe culverts classified as minor waterway crossings).
- Box culverts of up to 9 sections (17 box culverts classified as minor waterway crossings).
- Bridges with spans of up to 445 m (5 bridges classified as minor waterway crossings).

Such structures are likely to result in impacts to river health and have a high likelihood of failure if not designed with an understanding of the nature of upstream and downstream fluvial processes (and known failure mechanisms associated with waterway crossings). Particularly, as instream structures such as culverts will generally have a higher impact on hydraulic processes, waterway health and channel stability when compared to bridges. Various other factors also need to be considered, including catchment slope, local rainfall characteristics, channel size and sediment transport processes.

Hard structures that have had no site-specific consideration to gauge their suitability are likely to impose limits on sediment transport and/or increase scour. This will lead to high ongoing monitoring and maintenance costs.

2.4 Black Vertosol Soils

Black vertosol soils are prevalent within the study area (sometimes referred to as black earths or cracking clays; Vanderstaay A. G., 2000a and Vanderstaay A. G., 2000b). In general, these soils can extend to between 1 and 4 meters deep and have very little resistance to erosion through flowing water or immersion. These soils are readily observed in the bank profile along many waterways in this area. These highly erodible vertosol sediments generally make up the surface layer of some valley fills.

Vertosol soils must be considered in detail through any design process for the following reasons:

- These sediments, combined with the concentration of flow in the channel, have led to significant incision in this area.
- Exposed vertosol bank sediments, especially but not only when combined with incision are a significant problem in this area and lead to bank collapse and channel widening.

- Concentrated overland flow has led to large floodplain gullies throughout the Lockyer Valley. As with the bank collapse and channel widening, this is an escalated problem in this area due to the easily erodible nature of the vertosol bank sediments.
- Hard structures such as concrete or rock are known issues in these soils.

Although this is a known problem, very little is known about remediation in these soils and many trials have failed. There are no stream management guidelines that currently address waterway management in vertosol soil landscapes. However, numerous studies into erosion and waterway stability in vertosol environments were undertaken in the 1980's, most notably Sallaway (1985) and Truong (1983) both commissioned by the then Queensland Department of Primary Industries.

Truong (1983) investigated "waterway" instability in several regions across Queensland including North Queensland, Capricornia, Burnett, Near North Coast, Near South West, Moreton and the Darling Downs. All regions were found to experience severe gullying into the floodplain and, in most cases, this was attributed to a lack of vegetation, difficulties in vegetation establishment, and/or poor maintenance.

Sallaway (1985) focused on the central highlands. He found that perched and constructed waterways do very poorly and attributed this to the disturbance of the soil. Sallaway (1985) recognised that many of the waterways are in a state of dynamic equilibrium and states the following regarding the stabilisation of waterways in these landscapes:

> *"without a detail understanding of the geomorphology of these catchments, and a detailed survey of the geometry of each individual catchment a guaranteed stable design could not be given".*

Sallaway (1985) cites Schumm (1977) and discusses catchment/waterway system stability in terms of threshold exceedance and complex response. These thresholds are dependent on slope, sediment supply and flow conditions and the sensitivity of the floodplain during large-scale rainfall events (Schumm, 1973; Lewin and Macklin, 2003).

In addition to the documentation from the Queensland Department of Primary Industries studies, Transport and Main Roads have published a series of documents which incorporate best practice guidelines for drainage structures, pavement types and erosion control for expansive soil environments. It is recommended that guidance from these documents be incorporated as appropriate into future stages of the project.

2.5 The Big Flood

The Australian Research Council commissioned an investigation to understand flooding in the Lockyer Valley following widespread flooding in January 2011. The study was called "The Big Flood – Will it Happen Again?" (Australian Research Council, 2016) and used a combination of high-resolution LiDAR, aerial imagery, sediment sampling using drill rigs, tree ring sampling, paleoflood reconstructions based on slack water deposits and river evolution modelling (REM).

The study found that the 2011 flood caused large amounts of sediment to be moved from both the hillslopes and the channel with erosion from within the Lockyer Creek channel. It also found that *"the thin (< 1m), less cohesive floodplain sediments of the upper tributaries of Tenthill Creek and Laidley Creek were more easily eroded and were significant sediment sources during the event".*

2.6 Potential Impacts

A lack of understanding of the likely rate or trajectory of channel change at crossing locations will come at a high cost, both to environmental values and the operator (through maintenance and operational disruption). The potential ramifications of omitting "minor" catchments from the draft EIS and not considering these processes prior to detailed design for all waterway crossings include, but are not limited to:

- Environmental Impacts:
  - Floodplain or channel scour leading to widespread channel change or avulsion, resulting in destruction of riparian vegetation, decreased aquatic habitat and increased sediment load.
  - Initiation or exacerbation of bed deepening process resulting in environmental impacts such as bank collapse, channel widening, destruction of riparian vegetation, decreased aquatic habitat and increased sediment load.
  - Disconnection of fish passage (both upstream and downstream), not only associated with the physical barrier of pipe culverts but, in some instances, the resulting sediment influx which may result in reduced aquatic habitat.
- Risks to infrastructure requiring high maintenance costs.
  - Bridge spans not sufficient to account for channel movement, leading to bridge abutments being vulnerable to erosion due to channel migration or avulsion. May also lead to very high maintenance costs.
  - Inappropriately designed waterway crossings (pipe culverts) leading to scour, undercutting, and out outflanking leading to environmental impacts such as destruction of riparian vegetation, decreased aquatic habitat and increased sediment load. May also lead to very high maintenance costs.

3 Conclusions

The TOR for the draft EIS did not require a geomorphic assessment. Therefore, the omission of this assessment from the draft EIS is accepted. Chapter 11.6.8 of the EIS notes river health and the potential impact of structures will be assessed during the detailed design phase. However, it appears that the current EIS design lacks critical consideration of the environmental impact to waterways and does not provide confidence that risks to the environment can be mitigated. To properly understand the risks and impacts to environmental values associated with riverine processes, a geomorphic condition assessment should be carried out across all intersected waterways. Only then can an informed decision be made regarding the options for mitigation of that risk.

This can be undertaken, in the first instance, at a reasonably high level. For example, the implications for channel change resulting from the proposed design can be based on a desktop assessment by an appropriately qualified and experienced fluvial geomorphologist. This process can be used to flag high risks associated with various waterways. However, prior to detailed design these high-risk sites should be assessed in detail to provide guidance on design considerations to mitigate environmental impacts and to reduce the likelihood of failure (and therefore maintenance costs).

Instream structures such as culverts will generally have a much higher impact on hydraulic processes, waterway health and channel stability when compared to other design options like bridges. Proper consideration of geomorphic processes at these structures may indicate the necessity to change the proposed design to achieve an acceptable design outcome. Therefore, the omission of a geomorphic condition assessment from the design process represents an underrepresentation of the potential for environmental impacts and ongoing monitoring and maintenance costs.

4 Recommendations

The review identified a number of areas where additional work is required, either as part of further design stages or to provide additional documentation to the Panel. The items identified in the review are summarised in Table 1.

To facilitate the resolution of the identified issues, each issue has been assigned a level of importance, as described below.

- ***Low Importance***

  Additional work is required that will not significantly affect the draft EIS process. The work can be completed as part of further design (prior to the use of models for detailed design) and the requirement to complete the work can be included as a condition of approval.

- ***Medium Importance***

  Clarification or confirmation is sought in relation to an aspect of the supplied reports and models. Depending on the response to the issue by FFJV, the issue can be addressed via conditions of approval if required (i.e. it is deemed to be of low importance) and prior to the use of models for detailed design or via sensitivity testing (i.e. it is deemed to be of high importance as a result of the response).

- ***High Importance***

  Sensitivity testing is recommended to determine the significance of the issue to the interpretation of Inland-Rail related flood impacts and for documentation and modelling regarding the results of the sensitivity testing to be supplied to the Panel to confirm whether the issue can be dealt with (if necessary) by conditions of approval (i.e. the item is deemed to be of low importance on the basis of the sensitivity assessment) and prior to the use of models for detailed design or whether the issue affects the interpretation of results.

- ***Very High Importance***

  An issue of significance that warrants the revision of the documentation provided to the panel to include either the documentation of additional justification regarding a conclusion drawn or amended flood modelling. Such issues will need to be addressed prior to the models being used for detailed design.

Figure 1 presents a flow chart indicating the process by which it is proposed to resolve each issue relative to its assigned level of importance. The colour-coding used in the figure was applied to Table 1 to allow the relative importance of each issue to be readily identified.

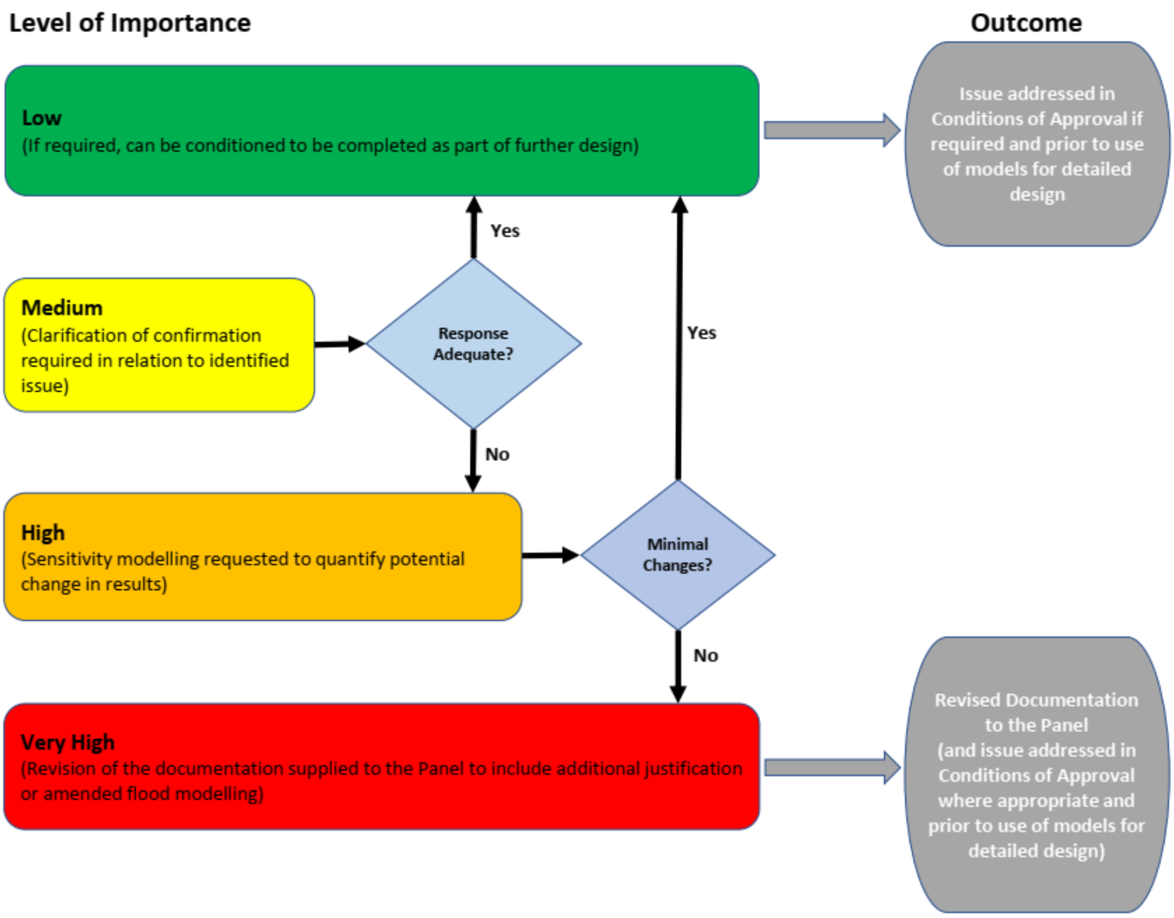

Figure 1: Flow Chart for Resolution of Identified Issues

Table 1: Summary of Identified Issues

Item No.	Item/Issue	Reference Section	Relevance to Assessment	Impact on Design	Level of Importance	Reason for Adopted Level of Importance
G1	No assessment of upstream or downstream channel condition and processes to gain an understanding of the likely rate or trajectory of channel change	2.1, 2.2, 2.4	Required to be able to identify risk and quantify impact of proposed rail alignment and structures on waterways	Not accounting for changes in waterway location and condition over the life of the project.	Low	A geomorphic condition assessment completed by an appropriately qualified and experienced fluvial geomorphologist is not definitively documented. Leaving this assessment until detailed design may result in sub-optimal design solutions, the need for redesign, as well as the potential for environmental impacts and high ongoing monitoring and maintenance costs.
G2	Impacts of minor waterway crossings not assessed	2.3	Cumulative impact of minor waterway crossings not considered as a result of the omission	Not accounting for changes in waterway location and condition over the life of the project.	Low	Instream structures such as culverts will generally have a much higher impact on hydraulic processes, waterway health and channel stability when compared to bridges.

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