

CHAPTER 14

Flooding and Geomorphology

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

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14. Flooding and Geomorphology

14.1 Scope of chapter

The purpose of this chapter is to provide a description of the hydrology and geomorphology impact assessment for the Inland Rail—Border to Gowrie Project (the Project) and address the 'Flood Management' section of the Terms of Reference (ToR) inclusive of ToR items 11.64 to 11.69. Appendix A2: Terms of Reference Cross-reference Table provides a cross reference for each ToR against the relevant sections in the revised draft Environmental Impact Statement (EIS).

The updated assessment has been prepared in response to the following:

- ▶ Submissions received from stakeholders in relation to the public notification of the draft EIS
- ▶ Further consultation with impacted landowners
- ▶ Changes to the reference design and construction methodologies since the draft EIS was completed
- ▶ The additional information and clarification requests from the Coordinator-General
- ▶ The outcomes of the review undertaken by the Independent International Panel for Flood Studies of Inland Rail in Queensland (the Expert Flood Panel).

For hydrology and flooding, this chapter includes a detailed hydraulic assessment establishing the existing flooding regime (the Existing Case), followed by consideration of the proposed works and refinement of the drainage structures to minimise impacts to manageable levels. The existing environment is described, and an assessment is made of the potential impacts of the Project. Potential short and long-term impacts on local and regional flooding behaviour, the community and the environment have been assessed based on a review of the Project's pre-construction, early works and construction works, and commissioning and operation stages. The results of the impact assessment and recommended mitigation measures have been outlined.

For geomorphology, this chapter includes a detailed description of the existing fluvial geomorphic landforms and processes upstream and downstream of the watercourses/waterways and floodplains proposed to be crossed by the Project. Potential impacts during the pre-construction, early works and construction works and commissioning and operations stages of the Project were analysed in a series of risk assessments to inform mitigation and management measures required to maintain Existing Case geomorphological processes where practical or minimise change to allow processes to continue to function into the future. Geomorphic mitigation and management measures are discussed.

Since the draft EIS, the Project's reference design has been revised in response to engagement with key stakeholders (including landowners, communities, councils and technical authorities), with further assessments and review of design optimisation opportunities conducted to incorporate efficiencies and impact reduction to the environment and community.

The Project and its revised reference design includes 1,193 reinforced concrete box culverts, 2,134 reinforced concrete pipe culverts and a series of viaducts/bridge structures spanning a total of 11 kilometres (km) of watercourses and floodplains.

The key components and features of the Project and its revised reference design relevant to flooding and geomorphology are described in the following:

- ▶ Chapter 5: Project Description
- ▶ Appendix B1: Design Drawings
- ▶ Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Appendix B).

Full details of the hydrology and flooding assessment are provided in Appendix T1: Hydrology and Flooding Technical Report—Volume 1.

Flood maps were prepared to visualise and communicate anticipated flood impacts for the range of modelled flood events. The 20% and 1% annual exceedance probability (AEP) flood maps are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2. In addition, an interactive **Online Digital Platform**¹ hosts the full suite of flood maps for all modelled AEP events.

Full details of the geomorphology assessment are provided in Appendix H: Geomorphology Report.

¹ anz.planengage.com/inlandrail-border-to-gowrie

14.2 Regulatory environment

The policies, standards and guidelines relevant to the Project with respect to flooding and geomorphology are presented in Table 14-1.

TABLE 14-1 POLICIES, STANDARDS AND GUIDELINES RELEVANT TO THIS ASSESSMENT

Policy, standard or guideline	Relevance to the Project
<i>Australian Rainfall and Runoff: A Guide to Flood Estimation</i> (ARR 2019) (Ball et al., 2019)	This national guideline document, data and software suite is used for the estimation of design flood characteristics in Australia. The 2019 edition is published and supported by the Australian Government and is an update to the <i>Australian Rainfall and Runoff</i> 2016. ARR 2019 is pivotal to the safety and sustainability of Australian infrastructure, communities and the environment. It is an important component in the provision of reliable and robust estimates of flood risk. Consistent use of ARR 2019 ensures that development does not occur in high-risk areas and that infrastructure is appropriately designed. ARR 2019, being the current version of this guideline during the formative stages of the Inland Rail Program and this Project, was adopted as a guiding document for flooding aspects of this assessment to ensure consistency in assessment across the Inland Rail Program.
<i>Water - EIS information guideline</i> (Department of Environment and Science (DES), 2022g)	This guideline provides advice to proponents in relation to water resources and associated environmental values when preparing an EIS. The guideline covers flooding, subsidence and alterations to overland flow, and has been used to guide the methodology of this assessment.
<i>Australian Standard (AS)7637:2014: Hydrology and Hydraulics</i> (Rail Industry Safety and Standards Board, 2014)	This standard describes the hydrological and hydraulic requirements (e.g. functions, performance, design constraints and risk attributes) for the design and assessment of railway infrastructure in relation to all forms of drainage and flood-prone areas. It provides general hydraulic and mitigation requirements including where feasible, to maintain the existing flow regime onto adjoining public or private property. It also provides guidance on erosion and sedimentation mitigation for cross-drainage infrastructure.
<i>Guide to Road Design Part 5: Drainage—General and Hydrology Considerations</i> , Edition 3.2 (Austroads, 2021)	This guide provides information on the elements that need to be considered in the design of a drainage system. Guidance is provided on the safety aspects of stormwater flows, environmental considerations and water-sensitive treatments within a drainage system. Drainage considerations are outlined, covering the determination of the flood immunity, freeboard to be used for the design, types of structures, and operational and maintenance requirements. The hydrologic assessment provides guidance on rainfall intensities, run-off coefficients and determining the design discharges. Design processes and formulae necessary to design effective drainage systems and infrastructure are included. It is supported by appendices containing design charts and worked examples. This guide outlines good practice in relation to drainage design that will apply in most situations, rather than specifying mandatory practice. This guide also describes the types of open channels, culvert and floodways, and provides design procedures and guidance on best practice for the detailed design of these components.
<i>Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways</i> , Edition 1.1 (Austroads, 2013)	This guide describes the types of open channels, culverts and floodways and provides design procedures, and outlines guidance on best practice for the detailed design of these components.
<i>Evaluating Scour at Bridges</i> , Fifth edition (United States Department of Transport—Federal Highway Administration (US Department of Transport), 2012a)	This manual is part of a set of hydraulic engineering circulars issued by the Federal Highway Administration to provide guidance for bridge scour and stream stability analyses. This document provides guidelines for the following: ▶ Designing new and replacement bridges to resist scour ▶ Evaluating existing bridges for vulnerability to scour ▶ Inspecting bridges for scour ▶ Improving the state-of-practice of estimating scour at bridges.
<i>Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular No. 14</i> , Third Edition (US Department of Transport, 2006)	This manual is part of a set of hydraulic engineering circulars issued by the Federal Highway Administration to provide design procedures for energy dissipator designs for highway applications.

Policy, standard or guideline	Relevance to the Project
<i>Guide to Bridge Technology Part 8: Hydraulic Design of Watercourse Structures, Chapter 5 Bridge Scour.</i> Editions 2 and 2.1 (Austroads 2018, 2019)	This document provides guidance on bridge scour characteristics, inputs such as Manning's 'n' values, methods for estimating scour, scour countermeasures and scour related to construction.
<i>Stream Stability at Highway Structures</i> , 4 th Edition (US Department of Transportation, 2012b)	This manual includes an approach to a qualitative geomorphic analysis (level 1 analysis) for bridge failure, noting that the steps identified are generally applicable to most stream stability problems. The approach has generally been applied to this assessment, adapted for Project channel types and to meet Project objectives.
<i>Bridge Scour Manual: Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour</i> (Department of Transport and Main Roads (DTMR), 2019e)	This manual sets out a multi-disciplinary approach to the estimation of the depth and extent of scour required for design of waterway bridges. It is a guide to those involved in the planning, design, operation and maintenance of bridges spanning waterways. This manual represents the policy of the DTMR with respect to the planning, design, operation and maintenance of scour in bridges. This manual includes references for channel typologies to be used in Queensland, considerations for initial assessment of scour, geomorphic inputs required for detailed scour assessment, and when scour risk for bridges can be considered low. Channel typologies: ▶ References channel typologies to be used in Queensland after Saynor et al. (2008). There has been a progression in stream typology understanding through Erskine et al, (2005), Saynor et al. (2008), and most recently, Erskine et al (2017). The same authors have been involved in all these studies, and this Project follows the 2017 version. Geomorphic factors: ▶ Geomorphic factors influencing bridge scour adapted from Melville and Coleman (2000) are listed. While a useful list, the methodology is for input into detailed design for bridge scour at watercourses with well-defined channels and is not directly relevant to the channel types in the Project area or EIS objectives. Therefore, the baseline assessment has included consideration of the geomorphic factors listed that are relevant for Project area channel types, the majority of which are poorly defined, with an adapted methodology to meet Project objectives. Considerations for scour assessment: ▶ Considerations for initial assessment of scour, geomorphic inputs required for detailed scour assessment. Methods for estimating scour at later Project stages and design of scour countermeasures are also included.
<i>TUFLOW Classic/ HPC User Manual</i> , Build 2018-03-AD (TUFLOW, 2018)	This manual sets out the user instructions for the application of TUFLOW to develop 1D/2D hydraulic models to simulate flooding behaviour. TUFLOW is used widely within industry to complete 1D and 2D computations of floods, tides and urban stormwater network hydraulics.
<i>Floodplain management for erosion control and high productivity on the Darling Downs</i> (Department of Primary Industries, (1988)	This guide describes the management practices that have been developed to control erosion and maintain high productivity on the floodplains of the Darling Downs and surrounding brigalow areas.
<i>Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia</i> (Australian Institute for Disaster Resilience, 2017a)	This handbook provides advice on management of flooding within the floodplains and catchments of waterways due to catchment flooding from prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains, tropical cyclones) and provides a framework for the management of flood risk.
<i>Road Planning and Design Manual: Supplement to Austroads Guide to Road Design, Part 5: Drainage – General and Hydrology Considerations</i> , (Department of Transport and Main Roads, 2021)	This manual represents the policy of the Department of Transport and Main Roads with respect to the planning, design, operation and maintenance of road drainage infrastructure and floodway crossings.

Policy, standard or guideline	Relevance to the Project
<i>Soil conservation guidelines for Queensland</i> (Department of Science, Information Technology and Innovation, 2015)	These guidelines provide practical information and tools for application in soil conservation. The guidelines provide coverage of many land management aspects of relevance to the study area, impact assessment area and the Project, including the management of land on floodplains. <i>Chapter 9: Waterways</i> (Carey et al., 2015) is focused on design and stabilisation of natural and artificial waterways to reduce erosion for soil conservation. Geomorphic processes other than erosion, such as the continuation of sediment transport, are not considered. This includes references to key contributing catchments characteristics, including soil type, slope, land use and vegetation cover. <i>Chapter 13: Gully erosion and its control</i> (Carey et al., 2015) provides practical information, tools and guidelines on assessment and mitigation measures for gully channel types in Queensland.
<i>AS/NZ ISO 31000:2009 Risk management: principles and Guidelines</i> (Standards Australia and Standards New Zealand, 2009)	This approach is used for impact assessment.
<i>Gully and Stream Bank Toolbox, A technical guide for gully and stream bank erosion control programs in Great Barrier Reef catchments</i> (Wilkinson et al, 2022)	This technical guide provides guidance on assessment and mitigation measures to reduce erosion, including for gully channel types.
<i>Australian Disaster Resilience Guideline 7-3 Flood Hazard</i> (Australian Institute for Disaster Resilience, 2017b)	This technical guideline expands information on flood hazard provided in Chapter 5 of <i>Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia</i> (2017a), to provide a basis for quantifying the variations in flood hazard and technical guideline for flood emergency response classification of the floodplain.
<i>AS 5100.1:2017, Bridge design: Part 1: Scope and general principles</i> (Standards Australia, 2017b)	This set of principles outline the Ultimate Limit State (ULS) and Serviceability Limit State events for the design of State-controlled roads, including bridges. The Serviceability Limit State is 1% AEP, and the ULS is 0.05% AEP.
<i>Design criteria for Bridge and other Structures</i> , (DTMR, 2018a)	This document provides design criteria for ULS and scour protection of piers as detailed below: ▶ ULS design criteria for Queensland takes precedence: 0.05% AEP or overtopping event if less than 0.05% AEP, whichever is critical in terms of flood forces. ▶ Design of bridge piers shall not rely on scour protection. Scour protection should not be installed around new bridge piers.

14.3 Key Project impact assessment terminology

The key Project assessment terminology used within this document are defined below:

- ▶ The Project: refers to the Inland Rail—Border to Gowrie Project, the subject of this revised draft EIS. The Project is a 217.48 km section of new dedicated single track, open access freight railway between the New South Wales (NSW)/Queensland (QLD) border and Gowrie, in Queensland. The Project is described in detail in Chapter 5: Project Description.
- ▶ The Project footprint: is the area required to accommodate all permanent and temporary components of the Project, being:
 - ▶ Permanent footprint: is the area required to accommodate permanent infrastructure associated with the Project, including rail, road and other miscellaneous infrastructure. Rail infrastructure includes rail tracks, crossing loops, turnouts, earthworks, bridges, drainage, level crossings, grade separations, rail maintenance access roads, signalling and fencing. Road-related works resulting from the Project encompasses new and upgraded roads, realignments and diversions, intersection improvements and closures.
 - ▶ Temporary footprint: is the area required to accommodate construction activities, for the duration of the Project construction stage, and facilities of a temporary nature and duration to support the Project. The temporary footprint is generally wider than the permanent footprint to allow for the construction of Project elements including fencing, drainage features, including erosion and sediment control measures, temporary stockpiling of soil and cleared vegetation, and to allow necessary construction access and turnaround provisions. Temporary Project facilities include laydowns, site office areas, non-resident workforce accommodation, a material distribution centre, concrete batch plants and borrow pits.

- ▶ The Project alignment: refers to the position given to the centreline of the Project railway track on the ground.
- ▶ The Project's revised reference design: was developed in response to engagement with key stakeholders, assessment of field verified survey data and review of design optimisation opportunities. The revised reference design is described in Chapter 5: Project Description and Appendix B1: Design Drawings, and with respect to flooding infrastructure, the Cross Drainage Register in Appendix T1: Flooding and Hydrology Technical Report–Volume 1 (Appendix B). The Project's revised reference design will continue to be further refined post-EIS, during the detailed design stage. During the detailed design stage, the general principle is that design changes either improve the safety or performance of the Project, improve environmental outcomes, or incorporate value engineering opportunities. The Australian Rail Track Corporation (ARTC) is responsible for integrating any EIS conditions into the detailed design.
- ▶ The study area: covers the catchment areas that drain towards and downstream of the Project footprint. These catchments have been modelled as part of the hydrology and flooding assessment to estimate flood flows and studied to define the regional geomorphic landscapes and their distribution along the Project footprint.
- ▶ The impact assessment area: refers to the area covered by the regional and local catchment hydraulic models shown in Figure 14-3.
- ▶ Pre-construction, early works and construction works in the context of this chapter refers to:
 - ▶ site preparation for construction
 - ▶ establishment of access roads/tracks
 - ▶ vegetation clearing and other ground disturbance activities that will be required to comply with relevant legislative requirements, approval conditions, guidelines and plans
 - ▶ additional surveys and geotechnical investigations to inform construction works
 - ▶ relocation or protection of Queensland Rail (QR) assets that were not required to be undertaken in advance as part of enabling works
 - ▶ utility/service interfaces that were not required to be undertaken well in advance as part of enabling works
 - ▶ modification of biosecurity fencing
 - ▶ installation of boundary fencing
 - ▶ establishment of site offices and initial laydown areas including Whetstone Material Distribution Centre (MDC)
 - ▶ establishment of non-resident workforce accommodation
 - ▶ site set out and pegging within the Project footprint, where not completed in pre-construction activities and early works
 - ▶ establishment of laydown areas and compounds, including vehicle inspection/workshops, washdown facilities and temporary fencing, where not completed in pre-construction activities and early works
 - ▶ clearing—using dozers, chainsaws, excavators, trucks and similar equipment, where not completed in pre-construction activities and early works
 - ▶ establishment of erosion and sediment controls as per the approved Erosion and Sediment Control Plan, where not completed in pre-construction activities and early works
 - ▶ rail corridor works, including track works turnouts and crossing loops
 - ▶ road and road-rail interface works
 - ▶ road realignments, grade separations and upgrades works
 - ▶ rail maintenance access roads
 - ▶ bridge construction
 - ▶ fencing
 - ▶ fauna habitat connectivity measures (e.g. fencing, crossing structures in accordance with detailed design specifications and Appendix N: Draft Fauna Management Plan)
 - ▶ signalling and communications
 - ▶ laydown, stockpile, and storage areas, that are not for enabling works and where not completed in pre-construction activities and early works
 - ▶ ballast—supply, delivery and installation
 - ▶ concrete sleepers—supply, delivery and installation
 - ▶ utilities and services to support/service the Project (that are not for enabling works)
 - ▶ bulk earthworks—major cut-to-fill operations include the winning of suitable construction material from sections of cut along the Project alignment or from borrow pits external to the site
 - ▶ permanent and temporary drainage controls, including culverts and longitudinal drainage
 - ▶ clean-up, landscaping, site restoration and rehabilitation, and any other activities necessary to complete such works
 - ▶ demobilisation of construction sites and activities.

For the purposes of the impact assessment, mitigations and risk assessment, the construction stage is assumed to include early works and pre-construction activities.

- ▶ Commissioning and operations in the context of this chapter refers to:
 - ▶ testing and commissioning (i.e. checking) of the rail line and communication/signalling systems
 - ▶ bridge and culvert inspections and maintenance
 - ▶ sleeper replacement
 - ▶ rail replacement, welding and grinding
 - ▶ ballast replacement and cleaning
 - ▶ track tamping and reconditioning
 - ▶ vegetation management
 - ▶ signalling systems and equipment testing and maintenance
 - ▶ transportation of equipment, materials and workforce
 - ▶ other asset management in accordance with ARTC technical maintenance.

For the purposes of the impact assessment, mitigations and risk assessment, the operations stage is assumed to include commissioning.

- ▶ Regional flooding: happens when widespread, prolonged rain falls over a large river or large creek catchment. As the river/creek channel reaches capacity, excess water flows over its banks causing flooding. Regional flooding downstream can occur hours or days after the rainfall has finished. In a regional system river or large creek flooding may coincide or exacerbate flooding in adjacent small creeks and tributaries due to backwater effects.
- ▶ Local catchment flooding: can include small creek flooding, overland flow flooding or a combination of both. Small creek flooding happens when intense rain falls over a minor small creek catchment and is often referred to as flash-flooding due to the rapid catchment response time. Run-off from houses and streets also contributes to creek flooding. The combination of heavy rainfall, run-off and the existing water in the creek causes creek levels to rise. Overland flow is run-off that travels over the land during heavy rainfall events. Overland flow can be unpredictable because it is affected by localised rainfall and urban features such as stormwater pipes, roads, fences, walls and other structures. The actual depth and impact of overland flow varies depending on local conditions, but it generally occurs quickly.
- ▶ The Existing Case: is the baseline scenario (i.e. before the Project is built).
- ▶ The Developed Case: is the post-development scenario (i.e. once the Project has been built) and is also considered as the initial case within the terms of the impact assessment and risk assessment. The Developed Case design is described in Chapter 5: Project Description and Appendix B1: Design Drawings, and with respect to flooding infrastructure, the Cross Drainage Register in Appendix T1: Flooding and Hydrology Technical Report–Volume 1 (Appendix B).

Flood sensitive receptors: are infrastructure items within the impact assessment area that may be vulnerable to changes in flooding behaviour (e.g. dwellings, schools, hospitals, roads). Flood sensitive receptors are discussed in Section 14.7.6.

- ▶ The hydrologic and flooding investigation has adopted the latest approach to design flood terminology as detailed in ARR 2019. Accordingly, design events are quoted in terms of AEP, with the adopted terminology for the simulated design events shown in bold in Table 14-2.

TABLE 14-2 FLOOD EVENT NOMENCLATURE

Exceedances per year (EY)	Annual exceedance probability (% AEP) ¹	AEP (1 in x years)	Average recurrence interval
0.22	20	5	4.48
0.11	10	10	9.49
0.05	5	20	20
0.02	2	50	50
0.01	1	100	100
0.0005	0.05	2,000	2,000
0.0001	0.01	10,000	10,000
-	-	PMF²	-

Table notes:

1. As an example, in general terms, a 1% AEP event means that there is a 1% chance of a flood event of that magnitude occurring in any given year
2. PMF –The term 'probable maximum flood' refers to the largest flood that could conceivably be expected to occur at a particular location, usually estimated from probable maximum precipitation

- ▶ In the context of hydrology and flooding:
 - ▶ Waterways are defined under the *Fisheries Act 1994* (Qld) and include a river, creek, stream, watercourse or inlet of the sea. The definition includes freshwater and tidal waters, both permanent and ephemeral waterways, and includes drainage features. It also includes channels along which fish are expected to move if they connect isolated water bodies to defined waterways during times of flow; however, it does not include isolated waterbodies where no connectivity is available. The revised reference design includes full-width crossings of 19 major waterways (stream order ≥ 3) and 81 minor waterways (stream order < 3).
 - ▶ Watercourses are defined under the *Water Act 2000* (Qld) as a river, creek or other stream, which includes a stream in the form of an anabranch or a tributary where water flows either permanently or intermittently, regardless of flow frequency; however, a watercourse does not include any section of a feature that has a tidal influence or is upstream or downstream from a defined limit between potential estuarine and fresh water. Therefore, by definition, all watercourses are waterways but not all waterways are watercourses.
- ▶ In the context of geomorphology:
 - ▶ The term watercourse, used for the fluvial geomorphic assessment only, refers to any natural fluvial geomorphic drainage feature, including grassy swales, stream channels or rivers, and is not a reference to 'watercourse' as defined in the *Water Act 2000* (Qld).
- ▶ Erosive Threshold Velocity (ETV): means the velocity at which water movement has the potential to create scour or erosion.
- ▶ Bankfull discharge: is the flow at which water fills a channel without overtopping the banks and is typically the discharge where the most geomorphic 'work' is done. It is also referred to as the 'channel forming discharge'. While large floods are more dramatic, they do not tend to accomplish as much total work in the geomorphic environment as the bankfull discharge event as water spreads out and flows slowly over the adjacent floodplain. The bankfull event for this assessment has been taken as the 20% AEP flood event. Based on the Existing Case flood modelling, this event is close to bankfull for most watercourses, as the majority of the flow is contained within the channel. The Condamine River and several other named watercourses experience partial floodplain flow during a 20% AEP flood event, indicating that its bankfull event is more frequent.
- ▶ Contributing catchments: are the catchments upstream of the Project that direct flow across the Project alignment. Catchment variables (e.g. area, slope and soil/rock cover) upstream of the Project alignment provide information on the flows and sediment (e.g. fluvial geomorphology) that must be allowed to cross the Project alignment in order to maintain current geomorphic processes and landforms.
- ▶ Strahler stream order: describes the hierarchy of a stream system from the top of the catchment to the bottom of a catchment. A first order stream has no other streams flowing into it; when two first order streams meet, the channel becomes a second order stream, two second order streams joining become a third order stream and so on.
- ▶ Many small unnamed watercourses cross the Project alignment. Nomenclature of these watercourses and their contributing catchments in the geomorphology assessment is based on which sub-catchment they are located in, followed by a number:
 - ▶ MR Macintyre River
 - ▶ MB Macintyre Brook
 - ▶ C CK Canning Creek
 - ▶ SC South Condamine (Back Creek)
 - ▶ NC North Condamine
 - ▶ OC Oakey Creek.

Catchments less than 10 hectares (ha) have 's' for small after the sub-catchment identification letters (e.g. MBs, OCs) with Canning Creek shortened to CCs. Back Creek drains the southwest Condamine River valley side slopes and drains into the Condamine River downstream of the Project alignment. There is another Back Creek in the study area, a tributary of Canning Creek on the Macintyre Brook catchment. This is referred to as 'Back Creek 2'.
- ▶ Flood basins: can develop between channels of an anastomosing river, such as the Condamine River, where channels have natural levees. Flood basins are 'saucer-like' alluvial islands between the natural channels and levees where the land directly adjacent to the channel is higher than the land in the central part of the basin. Flood flows can be deeper and faster in the central basin areas. A river basin is a portion of land that is drained by a river and its tributaries.

14.4 Independent International Panel of Experts for Flood Studies in Queensland

In June 2020, the Australian Government established an Independent International Panel of Experts for Flood Studies (the Expert Flood Panel) to provide advice to the Australian Government and the Queensland Government on the flood modelling and designs developed by ARTC for Inland Rail in Queensland, and to provide assurance to the public that the flood models and reference designs developed by ARTC meet national guidelines and industry best practice.

As an advisory body to government, the Expert Flood Panel was independent of ARTC in respect of the development, public consultation, and approvals for the Inland Rail EIS process.

The Expert Flood Panel undertook a comprehensive review of all of the hydrologic and hydraulic modelling, supporting technical information and reporting prepared by ARTC and its consultants. The Expert Flood Panel prepared draft reports for each of the key catchments crossed by the Project alignment being Macintyre River, Macintyre Brook, Cremascos Road, Bybera Road, Pariagara Creek, Cattle Creek, Native Dog Creek, Bringalily Creek, Nicol Creek, Back Creek, Condamine River, Westbrook and Dry Creek, and Gowrie Creek.

In each report the Expert Flood Panel documented a series of comments, and rated their risk level, in an issues management register. ARTC, and its consultants, worked closely with the Expert Flood Panel to provide additional technical information and/or undertaking sensitivity testing to address the concerns of the Expert Flood Panel. The Expert Flood Panel provided their final report to the Queensland and Australian Governments on 6 September 2022 and it was released publicly on 7 October 2022. The final report can be viewed on the Department of Transport and Main Roads website at tmr.qld.gov.au.

The final report presented the outcomes of the Expert Flood Panel's review of the flood models and reference designs developed by ARTC for each of the Queensland projects, including the Border to Gowrie Project. It brings together and addresses the findings of the panel's initial draft reports for each Project section. The panel recognised the substantial work undertaken by ARTC to identify existing flooding characteristics and to assess and mitigate potential impacts associated with Inland Rail.

The Expert Flood Panel found ARTC's modelling framework to be in accordance with both national guidelines and current industry best practice. Significant infrastructure projects, like Inland Rail, are accomplished through an iterative process and the panel acknowledged that it is normal practice for iterative improvements and changes to occur through the various project design and approval stages. As such, the panel identified a number of issues in the issues management register where ARTC has agreed to provide additional information in the respective revised draft EIS or address the issue during the subsequent design stages of the Project.

In respect to the panel's Terms of Reference, the Expert Flood Panel found the models developed and used by ARTC are 'fit for purpose', meaning suitable for an EIS, and subsequently detailed design, once the recommended actions have been adopted by ARTC.

The Queensland Government and Australian Government accepted the Expert Flood Panel's final report findings and recommendations. ARTC and the Department of Transport and Main Roads have agreed on a process to ensure each of the recommendations is implemented, including appointment of flood experts (former Expert Flood Panel members) to review and certify when each recommendation and issues management register item has been satisfied, in accordance with the timeframes specified in the final report for each Queensland Project.

The development of flood impact objectives (FIOs) for the Project (see Section 14.6.3.3) was undertaken in consultation with the Expert Flood Panel. The FIOs are quantifiable flooding metrics aimed at identifying locations where the Project has the potential to cause a change in baseline flood characteristics that may result in adverse impacts.

A detailed summary of the Project-related issues and ARTC's responses are presented in the issues management register in the final Expert Flood Panel Report (Appendix B). The Issues management register has been replicated in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix A) with the location where each comment has been addressed and response documented in the revised draft EIS identified.

14.5 Stakeholder engagement

Community and stakeholder consultation focused on hydrology, flooding and geomorphology has been undertaken at key milestones since the early Project design development stages. Details regarding the stakeholder and community sessions undertaken for flooding and geomorphology are documented in Appendix E: Consultation Report, and the consultation process to inform the flooding and geomorphology assessment is described below.

During 2018/19, the consultation process included:

- ▶ Data collection, including historic flood markers, photographs, videos and anecdotal accounts
- ▶ Information gathering with regards to erosive soils, geomorphic processes and existing scour and erosion issues
- ▶ Feedback on hydrologic and hydraulic modelling calibration and validation modelling results
- ▶ Periodic updates to the community via newsletters and community sessions
- ▶ Updates on flood modelling progress at Community Consultative Committee meetings
- ▶ Phone calls and emails to individual landowners
- ▶ Feedback on design flood modelling results—community feedback on preliminary design solutions has been used to make several design modifications (e.g. more culverts and larger bridges)
- ▶ One-on-one consultation with landowners affected by potential changes in flooding behaviour. Feedback from landowners has been incorporated into the development of the revised reference design and the revised draft EIS, where relevant.

Community information and engagement sessions were held between 2018 and 2020 throughout the design development stage, to gain insight from key landowners on observed flooding behaviour, which was used to inform the flood model calibration, using recorded historical flood events. Many meetings were conducted with landowners, on a one-to-one basis, within the floodplains upstream and downstream of the proposed rail crossing to gather further anecdotal flood data and version information, which was used to improve the model validation process, and to inform updates and improvements to the reference design.

Information collected during the earlier consultation sessions was used to inform the development of the flood models and provide validation of the performance of each regional floodplain model.

One-on-one meetings held with impacted landowners discussed the potential changes in flooding regimes associated with the proposed Project alignment including:

- ▶ Confirmation of modelled Existing Case flood depths, velocity, time of inundation, hazard and flow behaviour
- ▶ Predicted changes in peak water levels, velocity, time of inundation, hazard and flow behaviour
- ▶ Potential impacts to lots, roads and flood sensitive receptors; including houses, sheds, silos and other assets such as pump stations
- ▶ Potential mitigation options.

Stakeholder engagement meetings that were conducted to discuss potential flood impacts on State and local government-controlled assets included meetings with DTMR, Goondiwindi Regional Council (GRC), Toowoomba Regional Council (TRC) and the Department of Resources.

In 2020, the Expert Flood Panel was appointed by the Australian Government to complete a comprehensive review of the hydrology and flooding assessment undertaken by ARTC for the Inland Rail projects in Queensland (Section 14.3). The FIOs were developed as part of the Expert Flood Panel review process. Where it is not practicable or feasible to achieve the FIOs at flood sensitive receptors and/or the nominated land uses, acceptable impacts and/or appropriate mitigation measures will be determined on a case-by-case basis.

An assessment has been carried out to determine flood impact objective exceedances on roads, lots and flood sensitive receptors. The outcomes of this assessment are included in the revised draft EIS, including potential mitigation measures that will be employed during detailed design to eliminate or reduce flood impact objective exceedances.

Further consultation with potentially impacted landowners was undertaken in October 2022. This engagement campaign included almost 100 private landowners identified as having potential flood impact objective exceedances because of the Project. One-on-one meetings were offered to these landowners with hydrology specialists and ARTC stakeholder engagement team members.

Meetings were held in Toowoomba, Pittsworth, Millmerran, Inglewood and Yelarbon between 4 October 2022 and 3 November 2022, and covered the following topics:

- ▶ Project update and timing
- ▶ Flooding, hydrology and geomorphology information to be covered in the revised draft EIS
- ▶ Updated flood modelling results as endorsed by the Expert Flood Panel
 - ▶ the meetings were also used to validate the updated flood modelling information against landowner experience
- ▶ Outline of what the FIOs are, including:
 - ▶ how it is applied and exceedances calculated
 - ▶ what it means if there is an exceedance
- ▶ Property (lot)-specific impacts:
 - ▶ an interactive geographic information system (GIS) platform was used to show modelling results and impacted areas
- ▶ Possible mitigation measures, including discussions regarding:
 - ▶ how the areas affected by exceedances are currently used (e.g. cropping/grazing)
 - ▶ whether there is any sensitive infrastructure in the area that may experience exceedances
 - ▶ how the area is used operationally (e.g. equipment movements/property access)
 - ▶ whether there are any existing scour and erosion issues or geomorphic observations of note on the property
- ▶ Consultation material was prepared and presented during the one-on-one sessions, including a fact sheet to outline the revised reference design, explain what FIOs are and how ARTC plan to address flood impact objective exceedances as part of detailed design. The consultation material included some examples of typical mitigation measures, and modelling results showing examples of 'before' mitigation and 'after' mitigation scenarios. More information regarding proposed mitigation measures and their effectiveness, is provided in Section 14.9.1.4, with examples of mitigation measures presented in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 22.4.1).
- ▶ Examples of mitigation measures presented to impacted landowners included:
 - ▶ spaced out culvert cells to further spread flows
 - ▶ varying culvert invert levels to balance flow conveyance and manage the time of inundation-related flood impact objective exceedances
 - ▶ additional culvert cells, or larger culvert sizes
 - ▶ erosion and scour protection at culvert outlets
 - ▶ energy dissipaters to reduce outlet velocities.

Feedback received from the one-on-one meetings have been fed into the revised draft EIS and will be confirmed in detailed design. Examples of the types of feedback received from landowners include:

- ▶ Modification to culvert locations to accommodate local catchment flow paths, as observed by landowners
- ▶ More accurate representation of local runoff flow paths in the flood models during detailed design
- ▶ Insights into drainage (and flood protection) works planned by landowners, and requests for Inland Rail design modifications to ensure that cross-drainage flows are reported to a specific location, from where the landowner could pick it up into their new drainage system
- ▶ Preferences for box culverts over pipes in certain locations, and requests for additional cells without flood flow paths for access/stock crossing purposes
- ▶ In most instances, landowners were not concerned about changes to the time of inundation-related flood impact objective exceedances, especially where it occurs in areas such as bushland or grazing.

In addition to the one-on-one meetings, ARTC has also provided updates to Australian Government, Queensland Government and local government representatives. A briefing to the Inner/Southern Darling Downs Community Consultative Committees was held in November 2022 to update the community on multiple technical assessments, including hydrology and flooding.

ARTC will continue to consult and work collaboratively with landowners and other stakeholders regarding the Project, potential flooding and geomorphic impacts, design outcomes, and proposed construction staging in relation to hydrological profiles to ensure that impacts are understood and appropriately mitigated. During the detailed design process, the Project will undergo an independent verification process to ensure the FIOs have been applied appropriately, and appropriate mitigation and management controls are in place to minimise risks to people, property, infrastructure and the environment.

14.6 Methodology

The flooding and geomorphology impact assessment was undertaken in accordance with the following standardised outline methodology:

- ▶ Define the existing (baseline) environment and flood sensitive receptors
- ▶ Assess and describe impacts for the pre-construction, early works and construction works stage, and commissioning and operations stage of the Project
- ▶ Identify and describe the avoidance and mitigation measures, including those already included in the revised reference design
- ▶ Assess and describe the remaining residual impacts remaining after the inclusion of the proposed mitigation measures
- ▶ Summarise the impact assessment, includes initial and residual risk for the pre-construction, early works and construction works stage and the commissioning and operations stage of the Project.

The flooding and geomorphology assessment methodology has incorporated the requirements of the Expert Flood Panel and addresses the additional information requests by the Coordinator-General and the draft EIS submissions.

14.6.1 Overlap between geomorphology and flooding

The geomorphological assessment and the hydrology and flooding assessment overlap and have distinct differences. In broad terms:

- ▶ The fluvial geomorphological assessment describes the landforms and processes occurring within watercourses and geomorphic floodplains both naturally and in response to historic change (e.g. catchment changes, floodplains works) as well as identifying potential impacts of the Project on the fluvial systems.
- ▶ The hydrology and flooding assessment describes in detail the hydraulic conditions (e.g. flow, speed, and depth) over the length of the alignment for specific flood events and informs both structure design and flood mitigation works to be undertaken.

While the hydraulic models are fundamental design and assessment tools, they have no ability to model changes to the physical process of watercourses (e.g. erosion/deposition) in response to construction activities during the events modelled. Similarly, they are not used to assess potential changes associated with periods of low flow.

To assess the potential physical change in watercourses as a result of the Project, it is necessary to undertake both geomorphological assessments, and flooding and hydrology assessments.

More specifically, the geomorphology assessment is focused on fluvial geomorphic landforms, specifically assessment of geomorphic floodplains, channels, and watercourses.

All flow, including overland flow pathways on hill slopes, was assessed as part of the flooding and hydrology assessment, and any exceedances were noted, and mitigation options identified, within Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18).

The detailed step-by-step methodologies followed for the flooding and geomorphology impact assessments are discussed in Section 14.6.3 and Section 14.6.4.

14.6.2 Impact assessment

Both flooding and geomorphology undertook a qualitative risk assessment following the methodology included in Chapter 4: Assessment Methodology to identify and assess potential Project-related risks. In summary, this included:

- ▶ An initial case risk to assess the potential impacts with the application of the revised reference design mitigation measures in place
- ▶ Identifying and implementing additional mitigation measures
- ▶ A residual risk assessment to reassess impacts including additional mitigation measures.

14.6.3 Flooding methodology

14.6.3.1 Flood sensitive receptors

Flood sensitive receptors were identified from aerial and satellite imagery and validated, where possible, during site visits. Flood sensitive receptors include dwellings, sheds, commercial properties/lots (e.g. petrol stations and shops), silos, hospitals, roads, rail lines, and airports.

A total of 1,329 flood sensitive receptors were identified within the impact assessment area and assessed as part of the flood impact assessment. Flood sensitive receptors are discussed and mapped in Section 14.7.6.

14.6.3.2 Hydraulic design criteria

Table 14-3 outlines the hydraulic design criteria that have guided the Project's revised reference design to minimise flooding and geomorphic impacts. Detailed hydrologic and hydraulic modelling has been undertaken to meet these design criteria with a series of iterations undertaken to incorporate design refinement. The resulting design outcomes relative to these design criteria have been incorporated into the revised reference design and are detailed in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (see sections 5.5.2, 6.5.2, 7.5.2, 8.5.2, 9.5.2, 10.5.2, 11.5.2, 12.5.2, 13.5.2, 14.5.3, 15.5.2, 16.5.2, 17.5.2 and 18.6.2), Appendix B1: Design Drawings and the Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B).

TABLE 14-3 PROJECT HYDRAULIC DESIGN CRITERIA

Performance criteria	Requirement
Flood immunity	Rail line–1% AEP flood immunity to formation level.
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design to be undertaken based on ARR 2019 and State and local government guidelines. ARR 2019 climate change guidelines are to be applied with an increase in rainfall intensity to be considered. No sea-level change considerations are required due to the location outside tidal zone. ARR 2019 blockage assessment guidelines are to be applied.
Scour protection of structures	All bridges and culverts should be designed to reduce the risk of scour with events up to 1% AEP event considered. Mitigation to be achieved through providing appropriate scour protection or energy dissipation or by changing the drainage structure design.
Structural design	1 in 2,000 AEP event to be modelled for bridge-design purposes.
Extreme events	Damage resulting from overtopping to be minimised.
Flood flow distribution	Locate structures to maintain efficient conveyance and spread of floodwaters.
Sensitivity testing	Consider climate change and blockage in accordance with ARR 2019. Understand risks posed and Project design sensitivity to climate change and blockage of structures.

14.6.3.3 Flood impact objectives

The nominated FIOs as presented in Table 14-4 have been developed in consultation with the Expert Flood Panel to provide guidance as to the point at which a more detailed consideration of impact potential is required when they are exceeded. The Project will target achieving the FIOs for events up to and including the 1% AEP (without climate change) for land, receptors, and/or infrastructure that is potentially impacted by the Project within the commissioning and operations stage.

Where it is not practicable or feasible to achieve the FIOs at flood sensitive receptors and/or the nominated land uses, acceptable impacts and/or appropriate mitigation measures will be determined on a case-by-case basis, including through consultation with stakeholders and landowners.

The designated FIOs are design and operationally focused and not considered appropriate for the pre-construction, early works and construction works stages. Further details on the approach to the construction works stage can be found in Section 14.9.1.

TABLE 14-4 FLOOD IMPACT OBJECTIVES (DETAILED DESIGN, COMMISSIONING AND OPERATIONS)

Parameter	Objectives
Change in peak water levels afflux ¹	Existing habitable² and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops) and sensitive infrastructure³ Yards or gardens of residential or commercial/ industrial properties/lots (excluding habitable² dwellings/ buildings) Existing non-habitable structures (e.g. agricultural sheds, pump-houses) Existing local roads currently in use Existing rail lines State controlled roads Agricultural and grazing land/forest areas and other non-agricultural land ≤ 10 millimetres (mm)⁴ ≤ 50 mm⁵ ≤ 100 mm^{4,6} 10 to 100 mm⁷ 10 to 20 mm⁷ ≤ 200⁸ mm with localised⁹ areas up to 400 mm Changes in peak water levels are to be assessed against the FIOs. Changes in peak water levels can have varying impacts on different infrastructure/land. The FIOs 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. For peak water levels assessed at any structure, the change in peak water level is measured relative to the existing floor level.
Change in duration of inundation ^{1,4}	Identify changes to time of inundation by determining time of submergence in existing and developed¹⁰ cases. Assess impacts against the following objectives for habitable floors²: ▶ Where existing flood inundation is less than 1 hour—up to 1 hour duration of inundation ▶ Where existing flood inundation of 1 hour or more occurs—up to a 5 per cent increase in duration of inundation. For impacted roads/rail, the duration of inundation can increase by up to 10 per cent, subject to the determination of the time of submergence and consideration of impacts on accessibility/egress during flood events in consultation with the relevant authority. Assess impacts against the following objectives for all other land uses: ▶ Where existing flood inundation is less than 1 hour—up to 1 hour duration of inundation ▶ Where existing flood inundation of 1 hour or more occurs—up to a 10 per cent increase in duration of inundation. The duration performance targets do not apply to newly flooded land where compliant with afflux criteria (see general notes below).
Flood flow distribution ¹	Aim to minimise changes in natural flow patterns and minimise changes to flood-flow distribution across floodplain areas. This includes the objective of maintaining drainage paths that are conveying runoff from adjoining terrain, minor watercourses, and gullies, to avoid ponding of water and/or excessive duration of inundation. Identify any changes and justify acceptability of changes by assessing the risk with a focus on land use and flood sensitive receptors. The identification of changes to flow distribution is to include the consideration of a range of floods, from small (frequent) events for conditions throughout the event, to large and extreme (infrequent) events. This exercise will be undertaken to identify (and where deemed necessary, mitigate) any increased risk to flood sensitive receptors associated with flow distribution changes.
Velocities ¹	Maintain existing velocities where practical or minimise increases in velocities. Identify changes to velocities and impacts on external properties/lots. The ETV for natural ground surfaces should be established from a site-specific assessment by a suitably qualified specialist, and in consideration of engineering guidelines. For sealed surfaces, this same approach could be applied, or through reference to suitable guidelines/specifications. Assess against the following performance objectives: ▶ Sealed surfaces (or surfaces otherwise protected against erosion): ▶ for existing velocities equal to or greater than 1 metre per second (m/s) (or the defined ETV), the increase in velocity is limited to 20 per cent ▶ for existing velocities (or velocities associated with new flow paths) less than 1 m/s, the maximum design velocity is 1.2 m/s (or the defined ETV) ▶ Natural ground surfaces including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas: ▶ for existing velocities equal to or greater than 0.5 m/s (or the defined ETV), the increase in velocity is limited to 10 per cent (or within an acceptable range as determined by geomorphological assessment) ▶ for existing velocities (or velocities associated with new flow paths) less than 0.5 m/s (or the defined ETV), the maximum design velocity is 0.5 m/s (or the defined ETV).

Parameter	Objectives
Hazard (velocity x depth product) ¹	Assess against the following objectives: Roads/rail, urban and commercial areas, dwellings: ▶ A 10 per cent increase in velocity x depth product. Other land: ▶ A 20 per cent increase in velocity x depth product. In both cases where the velocity x depth product is below 0.15 square metres per second (m²/s) in the Developed⁶ Case, no percentage change performance targets apply.
Extreme event risk management	Consider risks posed to neighbouring properties/lots and emergency access/egress for events larger than the 1% AEP event to minimise unexpected or unacceptable impacts. At sites with existing sensitive infrastructure³, uses involving vulnerable people and/or any critical road network that was designed to be immune to flooding in any extreme event, the objective for increase in peak water level under the 0.2% AEP (1 in 500) is 10 mm¹¹. At existing habitable² dwellings and/or commercial and industrial buildings/premises under the 0.05% (1 in 2000) AEP event, a maximum increase in peak water level of 250 mm applies.
Sensitivity testing	Consider risks posed by climate change and blockage in accordance with ARR (2019). Undertake assessment of impacts associated with Project alignment for both scenarios.

Table notes:

1. These FIOs apply for events up to and including the 1% AEP event and relate to land outside the rail corridor (as well as roads and level crossings that lie within/traverse the rail corridor). Where transport corridors are shared or lie immediately adjacent to the Inland Rail corridor, relevant FIOs apply as outlined in Table 14-4 (i.e. for existing rail, State Controlled roads and local roads).
2. Habitable floors include all lawfully occupied dwellings regardless of land use zoning.
3. Sensitive infrastructure means infrastructure that is an essential service required to operate during emergency events, including water treatment facilities, telecommunications substations and electrical substations.
4. Data permitting and based on a review of calibration outcomes, where negative calibration bias is identified, a suitable tolerance (commensurate with the bias) will be added to the design flood levels to assess afflux and duration acceptability against the nominated flood impact objective threshold.
5. This flood impact objective reduces to ≤20 mm for developed lots that are less than 1,000 square metres (m²) in area.
6. The current usage of non-habitable structures will be reviewed as design progresses and additional detail becomes available (e.g. animal shelter versus horticultural packing facility). This could influence the application of one of the other FIOs, which may be more suited to the specific usage of the structure.
7. Consultation will be undertaken with the relevant asset owner based on the application of the appropriate FIOs. This consultation will present all changes (>10 mm) across the road or rail network to identify specific roads or sections of rail that require local and/or route specific considerations. In flood sensitive locations this may entail a lower afflux threshold being adopted.
8. Where the Project alignment crosses the Condamine River and Lockyer Creek floodplains, this objective reduces to 100 mm (with localised⁹ areas up to 200 mm), in light of the combination of floodplain sensitivity, inundation duration, and land use (intensive horticulture).
9. 'Localised' is defined as the lesser of <1.0 ha or 5 per cent of an individual lot.
10. Developed scenario implies fully constructed/operational rail line and associated works.
11. The 0.2% AEP (1 in 500) event is only required to be assessed where adherence to the flood impact objective cannot be inferred from the 1% AEP and 1 in 2000 AEP event results.

General notes:

- ▶ Justification must be provided in the selection of a governing flood impact objective where two or more competing FIOs may apply—in the absence of such justification the most limiting of the applicable FIOs will apply.
- ▶ The ETV means the velocity at which water movement has the potential to create scour or erosion. For natural surfaces, the erosive threshold of the soil/ground cover/vegetative conditions will be established from an assessment by a suitably qualified specialist. In the absence of such assessment being undertaken an ETV of 0.5 m/s will be assumed.
- ▶ The effects of any increased lateral spread of floodwaters (i.e. associated with permissible afflux) beyond 1 ha or 5 per cent of the affected lot area should be considered on merit, taking into account affected receptors and land-usage (e.g. flood depth and flood duration).
- ▶ The term 'Road' relates to the operational road surface.
- ▶ Within the rail corridor erosion protection measures will be installed, as required. This is with a view to managing the risk of scour propagating beyond the rail corridor boundary.
- ▶ Consultation will be undertaken using the full suite of flood impact information, including afflux, velocity, duration and hazard. In locations where the afflux or velocity FIOs are exceeded, the change in flood hazard will be communicated to the landowner with respect to the combined flood hazard classifications as defined in ARR 2019 and the velocity x depth product.

14.6.3.4 Flooding impact assessment—detailed methodology

Pre-construction, early works and construction works

Pre-construction, early works and construction works are all temporary in nature and will be in various forms as the Project progresses to being fully constructed. As such, flood impacts will be highly influenced by any planned construction staging, planned embankment raises and cuts, and temporary drainage works. At this stage of planning for the Project, detailed construction phasing is not available and will be developed as contractors are onboarded to the Project and commence constructability reviews. As such, the following methodology has been employed for the assessment of impacts from temporary project facilities within the temporary footprint:

- ▶ Assessment of flood risk via a Flood Risk Assessment (FRA) utilising Existing Case results including Whetstone MDC, the Turallin facility, and the Yelarbon and Inglewood non-resident workforce accommodation sites.
- ▶ A screening of temporary project facilities, including concrete batching plants, fuel depots, laydown and stockpile areas against the 1% AEP flood risk mapping was carried out to determine the works and activities that are likely to occur within areas at risk of flooding.

Construction works within the temporary disturbance footprint will be guided by FRA as part of the Construction Environmental Management Plan (CEMP). The FRA approach is discussed in Section 14.9 and will be documented via a Flood Risk Management Plan (FRMP). Erosion and sediment control will be developed as a component of the CEMP and endorsed by the Environmental Monitor prior to construction works commencing. The CEMP and its relevant Plans including erosion and sediment control plans will be prepared in accordance with statutory and Project requirements to minimise the risk of adverse flood impacts through mitigation determined via an FRA, where required.

Commissioning and operations

The hydrology and flooding assessment has adopted a quantitative approach to the impact assessment using the FIOs set out in Table 14-4 and has involved the following activities:

- ▶ Collation and review of available background information including existing hydrologic and hydraulic models, survey, rainfall and streamflow data, calibration information and anecdotal flood related data. This review established which datasets were suitable to use for the Project's reference design.
- ▶ Determination of critical flooding mechanisms for waterways and drainage paths in vicinity of the Project temporary and permanent footprint (i.e. regional flooding versus local catchment flooding).
- ▶ Determination of high-risk waterways and overland flow paths, that the Project alignment crosses, considering the:
 - ▶ catchment sizes, resulting flood flows and velocities
 - ▶ land use in the vicinity of the Project
 - ▶ extent and depth of flood inundation
 - ▶ duration of flood events and catchment response time
 - ▶ soil types and geomorphologic conditions of the waterways and surrounding land
 - ▶ proximity to and nature of flood sensitive receptors (e.g. houses, sheds and roads)
- ▶ Development of tailored hydrologic and hydraulic models for key waterways and overland flow paths. Individual modelling approaches, including justification for the selection of each approach are outlined in the individual modelling sections within Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Sections 5 to 18).
- ▶ Validation of the hydrologic and hydraulic models against recorded data for historical flood events, including more recent 2021 events.
- ▶ Community and stakeholder engagement to validate model performance and gain acceptance of modelling and calibration outcomes. Anecdotal flood event information such as flood photography, recorded flood markers and personal observations from landowners were sourced to validate the calibration of the hydrologic and hydraulic models.
- ▶ Update of hydrologic models to include ARR 2019 design events. ARR 2019, is the current version of this guideline during the formative stages of Inland Rail Program and this Project, was adopted as a guiding document for flooding aspects of this assessment to ensure consistency in assessment across the Inland Rail Program.
- ▶ Simulation of ARR 2019 design events for the Existing Case and comparison to previous studies to confirm drainage paths, waterways, and associated floodplain areas, and establish the existing flood regime in the vicinity of the Project.
- ▶ Inclusion of Project alignment and drainage structures for the Developed Case in the hydraulic models and simulation of ARR 2019 design events including the 20%, 10%, 5%, 2%, 1% AEP events, extreme events including the 1 in 2,000 and 1 in 10,000 AEP events and the Probable Maximum Flood (PMF).
- ▶ Tropical cyclone-induced rainfall events are captured in the ARR 2019 data hub, and historic rainfall and stream gauge data used in the hydrologic assessments.
- ▶ Assessment of commissioning and operational stage potential impacts of the Project using the suite of design flood events including consideration of change in flood levels, flow distributions, velocities, hazard and inundation periods. The impact assessment considered full design event model simulations (i.e. the full flood hydrograph) as the maximum impact may not occur at the peak of the flood. For example, the maximum velocity impact may occur when downstream water levels are lower. Existing Case and Developed Case results were therefore compared based on the maximum result of the model simulation, for every design event to determine maximum impacts.
- ▶ Determination of initial mitigation measures to manage potential impacts in future project stages including refinement of location and dimensions of drainage structures.

- ▶ Sensitivity analysis on the design for factors including climate change and blockage risk:
 - ▶ A blockage factor of 25 per cent was applied to all proposed culverts in the revised reference design based on guidelines set out in ARR 2019. The adopted blockage factor for the proposed bridges was between 5 per cent and 10 per cent based on the waterway area blockage due to bridge piers. The sensitivity of the flood impact assessment was tested using two additional blockage scenarios, namely 0 per cent and 50 per cent.
 - ▶ The potential impacts of climate change on areas at risk of flooding were assessed for the 1% AEP design event to determine the sensitivity of the Project to the potential long-term changes in climate. The assessment was undertaken in accordance with ARR 2019.

The hydrology and hydraulic impact assessment provided key inputs to the Project's revised reference design where the Project is located within the modelled flood extents. Key dependencies for the Project's revised reference design include:

- ▶ Modelling of the Existing Case 1% AEP event to ascertain existing conditions and inform the flood immunity for the Project alignment and to size drainage structures
- ▶ Modelling of 1 in 2,000 AEP event to provide inputs for bridge design and wider resilience assessment
- ▶ Modelling of rare flood events (e.g. 1 in 10,000 AEP and PMF events) to assist in consideration of overtopping risk
- ▶ Modelling of smaller, more frequent events, to ensure the design performance is assessed and refined against these more regular events
- ▶ Modelling the full range of flood events to quantify potential impacts and inform mitigation measures
- ▶ Input to drainage design including scour protection design—water levels, flows and velocities from this assessment have been used to inform the design of scour protection
- ▶ Input to structure selection and design for culverts and bridges.

Comprehensive details of the hydrologic and hydraulic modelling undertaken are provided in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Sections 5 to 18).

14.6.4 Geomorphology methodology

14.6.4.1 Assessment of baseline conditions

The existing baseline geomorphic environment and fluvial processes are described following a cascading methodology that works from broad scale regional review to site-specific assessments. Below is a summary of the methodology (see Appendix H: Geomorphology Report Section 2.2 for further details):

- ▶ The baseline includes classification of watercourse and floodplain landforms, assessment of processes and sensitivity to change.
- ▶ The existing channel and floodplain landscapes traversed by the Project alignment are subject to extensive modification by agricultural activities and that these activities and other future modifications to the landscape by landowners beyond the rail corridor are likely to change water flows and stream conditions, particularly sedimentation that are outside of the Project's influence and control.
- ▶ Field inspections were undertaken at representative sites to ground truth the baseline assessment. Site observations of existing geomorphic processes, such as locations and extents of erosion and deposition provide the best information on Existing Case conditions and potential future impacts.
- ▶ Identification and classification of watercourses:
 - ▶ Existing watercourse data sets, aerial imagery, topographic and hydraulic data were reviewed to identify all potential watercourse crossings.
 - ▶ Geomorphic factors for watercourse and sub-reach classification were assessed based on aerial imagery and field inspection. Channel typology follows recommendations in the *Bridge Scour Manual, Queensland* (DTMR, 2019g). The factors assessed were adapted for Project footprint channel types and Project objectives from *Bridge Scour Manual, Queensland* (DTMR, 2019e) and *Stream Stability at Highway Structures*, (US Department of Transport, 2012), additional factors considered good practise were also collected.
 - ▶ High-level assessment of Project watercourse types was undertaken. These are linked to process zone and geomorphic baseline conditions and provides a relative context for all watercourses that cross the Project alignment irrespective of catchment.

- ▶ Assessment of watercourse processes:
 - ▶ There is a strong link between channel typology and processes. The channel type is the physical manifestation of the fluvial processes acting on the watercourse, including water flow, sediment transport, deposition and erosion, for example the channel type gully has active gully erosion.
 - ▶ Evidence for geomorphic processes, including aggregation and erosion were assessed from aerial imagery and field inspections at representative sties.
 - ▶ Assessment of channel type and channel planform change was undertaken by review of historic aerial imagery as well as available historic maps and documents. This was only identified in the Condamine area.
- ▶ Assessment of watercourse sensitivity to change, also termed stream stability/instability in *Stream Stability at Highway Structures* (US Department of Transport, 2012):
 - ▶ A sensitivity to change criteria for Project watercourses has been developed incorporating consideration of the main components of stream stability included in the *Stream Stability at Highway Structures* (US Department of Transport, 2012) for qualitative geomorphic assessment (i.e. overall stability, lateral stability and vertical stability).
 - ▶ The criteria use historic change in planform including channel width and channel type, together with current processes, soil erodibility rating, contributing catchment characteristics and human interventions to assess for overall, lateral and vertical sensitivity to change. Over time, vertical change in channel beds results in changes to channel width and planform. Identification and classification of floodplains: delineation of geomorphic floodplains in the Project footprint.
 - ▶ Description of floodplain characteristics, including width, elevation, soils, vegetation cover, Strahler order of main watercourse and landforms based on aerial imagery review and field inspection.
 - ▶ Classification of floodplain types after Nanson and Croke (1992), which includes consideration of floodplain landforms and processes, stream power and sediment types.
- ▶ Assessment of floodplain processes:
 - ▶ Description of floodplain processes by floodplain type.
 - ▶ Description of any site-specific floodplain processes observed from aerial imagery review and field inspection, including human induced change.
- ▶ Assessment of floodplain sensitivity to change:
 - ▶ A sensitivity to change criteria for Project floodplains has been developed similar to the criteria developed for Project watercourses.
 - ▶ The criteria use historic change in landforms, together with current processes, soil erodibility rating, contributing catchment characteristics and human interventions to assess for sensitivity to change.

14.6.4.2 Assessment of potential impacts

This stage identified potential impacts for watercourses and floodplains within the temporary footprint for the pre-construction works, early works and construction works stages, and by individual watercourse and floodplain for the commissioning and operations stages. The potential consequences of the impacts were assessed under the risk assessment. Below is a summary of the methodology (see Appendix H: Geomorphology Report Section 2.3 for further details):

- ▶ Commissioning and operations stage potential impacts were assessed for all watercourses included in the sub-reach assessment and all geomorphic floodplains. Watercourses not included in the sub-reach assessment have so little evidence of active fluvial geomorphology that they typically have no channel form where they cross the Project alignment and were assessed under hydrology and flooding against the FIOs. Any exceedances were noted, and mitigation options identified, within Appendix T1: Hydrology and Flooding Technical Report–Volume 1. The mitigations were reviewed by a geomorphologist.
- ▶ Criteria to assess for commissioning and operations stage potential impacts were identified (Table 14-5 and Table 14-6). A design flow velocity change of within 10 per cent of the existing case is considered unlikely to result in potential impacts due to the Project, as this change falls within the range of natural flow variability. This also aligns with flood impact objective targets for flow velocity of within 10 per cent of existing case for natural surfaces.
- ▶ Where the criteria are met, the potential for an impact to occur is assessed taking into consideration mitigation in the revised reference design, geomorphic processes at the site and the amount, type and location of potential change. Meeting the criteria to assess for potential change does not mean that impacts may occur. Consequence levels are applied to the potential impact as part of the risk assessment.

- ▶ Commissioning and operations stage potential impacts were assessed based on the following:
 - ▶ Assessment of the potential impacts of the revised reference design infrastructure type/location/orientation, for example:
 - The location of embankments or bridge abutments relative to channels may lead to flow constriction or channel encroachment potential impacting channel type and planform. This may occur even when flow characteristics such as velocity and stream power remain similar to the Existing Case.
 - Location and orientation of culverts to flow. The proposed culverts may not be optimally located or aligned to the Existing Case conditions and may result in the potential for flow to be discharged out of the channel or focused against a channel bank.
 - ▶ Manual hydraulic data extraction to assess potential changes in flow characteristics between the Existing Case and Developed Case, in particular flow velocity and stream power.
 - Where hydraulic jumps may occur due to design structures, the potential impact on flow characteristics are included in the design stage hydraulic models.
 - As the baseline field inspections occurred not long after an estimated 20% AEP event in the Condamine River, potential impacts could be calibrated with 20% AEP Existing Case flows in this area.
 - ▶ Criteria relating to potential flow velocity change were aligned with FIOs in that design flow velocities within 10% of the Existing Case were considered within natural variability and were not a change from existing.

TABLE 14-5 CRITERIA TO ASSESS FOR POTENTIAL CHANGE TO WATERCOURSES

Geomorphic process	Criteria to assess for potential change above Existing Case conditions
Erosion	Design flow velocities >10% of the Existing Case flow velocities.
Deposition	Design flow velocities <10% of the Existing Case flow velocities.
Planform change	Design flow not aligned to natural landform (e.g. design cross-drainage causes flow to occur against the edge of or outside of an existing channel). Rail embankment/bridge abutments within 5 metres (m) of a channel.
Channel type change	Rail embankment/bridge abutments within 5 m of a channel. Change from distributed flow, non-channelised valley floor or wash slope channel types, to point source flow where the design flow velocities are >10% than the existing. Changes from distributed to point source flow may initiate erosion and the development of rilling/gullying when there is increased design flow.

TABLE 14-6 CRITERIA TO ASSESS FOR POTENTIAL CHANGE TO FLOODPLAINS

Geomorphic process	Criteria to assess for potential change above Existing Case conditions
Erosion	Design flow velocities >10% of the Existing Case flow velocities. Design flow not aligned to flood channel (e.g. design cross-drainage causes flow to occur against the edge of or outside of an existing flood channel).
Deposition	Design flow velocities <10% of the Existing Case flow velocities.
Reduced disconnection	Project alignment sidles along a floodplain and cuts off flow.

14.6.4.3 Risk assessment

Below is a summary of the risk assessment methodology undertaken with further details provided in Appendix H: Geomorphology Report (see sections 2.4 and 2.5):

- ▶ A qualitative risk assessment has been undertaken following the methodology included in Chapter 4: Assessment Methodology to identify and assess potential Project related impacts. In summary this included:
 - ▶ an initial case risk to assess the potential impacts with the application of the revised reference design mitigation measures in place
 - ▶ identifying and implementing additional mitigation measures
 - ▶ a residual risk assessment to reassess impacts including additional mitigation measures.

- ▶ An assessment of impacts on catchment-wide processes including sediment budget and other related potential impacts was undertaken based on the outcomes of the individual watercourse and floodplain assessment.
- ▶ Likelihood assessment:
 - ▶ There is a relationship between flow frequency, the landform inundated and severity of flow events (Table 14-7). The risk assessment framework includes some very frequent likelihoods, with associated low or no rainfall/flow, some of which are not relevant for fluvial geomorphology. A review was undertaken to identify appropriate likelihoods to include in the risk assessment based on the hydrological setting, Existing Case hydraulic data and Project fluvial geomorphic landforms and found that:
 - Channel bankfull conditions occur around likelihood 'possible' (taken as the 20% AEP event). Bankfull is considered the channel forming discharge, and potential impacts to channels were assessed for this likelihood.
 - Floodplain impacts begin to occur from likelihood 'possible' (when some floodplain inundation may occur locally) and less frequent events. Full floodplain flow does not occur until likelihood 'rare', therefore floodplain impacts were assessed as 'rare' likelihood using the 1% AEP hydraulic data.
- ▶ Consequence assessment:
 - ▶ Descriptions of potential consequences to the geomorphic environment, based on the environmental consequence descriptions from Chapter 4: Assessment Methodology, was included to aid in the risk assessment (Table 14-8).
 - ▶ The consequence was assessed based on the potential impacts identified and the sensitivity to change of the individual watercourses and floodplains.
 - ▶ Sensitivity to change does not directly relate to consequence. A site with an Existing Case (i.e. pre-Project) high sensitivity to change, such as a gully, can be subject to a low-risk of adverse change through appropriate infrastructure design. These sites would still have a high sensitivity to change during operation of the Project, but the Project would have a low-risk of contributing to the occurrence of erosion. Conversely, a site with low sensitivity to change can be subject to high-risk of adverse change through inappropriate infrastructure design. Hence, the design approach is the critical factor in achieving the desired outcome and reducing the potential impacts of the Project on natural systems.
- ▶ Detailed assessments of potential changes at Existing Case high-risk sites were undertaken to better understand the geomorphic processes at these sites and inform additional mitigations. The initial risk was not updated for these sites based on the detailed assessment. The detailed assessments included the following:
 - ▶ Descriptions and photos with scale of bed and bank material, including any armouring, if present, evidence of sediment transport (e.g. erosion and/or deposition), channel geometry and characteristics, location and type of any bank failures, vegetation including woody debris and estimates of Manning's 'n' using the table in Appendix A of *Guide to Bridge Technology Part 8: Hydraulic Design of Watercourse Structures, Chapter 5 Bridge Scour* (Austroads 2019a).
 - ▶ Collection of representative samples for laboratory testing, including particle size distribution, Atterberg Limits and erodibility testing.
 - ▶ Assessment of site ETVs in a combined approach including theoretic ETVs assessed from laboratory testing together with field observations.
 - ▶ Updated assessment of the fluvial geomorphic landforms and processes based on field work.
 - ▶ Identification of site-specific additional mitigation measures to be included in the assessment of residual risk.
- ▶ The following additional detailed assessment will be completed as part of the geomorphology assessment methodology prior to final EIS approvals:
 - ▶ Supplementary testing using direct methods (e.g. flume testing), additional assessment and subsequent ETV determination based on revised results is currently underway at a number of potentially high-risk sites including on floodplains and overland flow paths.
 - ▶ Relevant mitigations including those relating to erosion treatment options within, and external to, the corridor will be reviewed and revised as necessary based on the updated analysis.

TABLE 14-7 GEOMORPHIC COMMENTARY ON LIKELIHOOD

Likelihood	Description	Frequency of occurrence	Flow modelling data	Typical flow distribution by landform
Almost certain	Is expected to occur in most circumstances	Once per month if flow is occurring.	No modelling data. No geomorphic events.	Within channel flow only, flow only occurs in snow channels at this frequency.
Likely	Will probably occur in most circumstances	Between once a month and once a year if flow is occurring.	No modelling data.	Within channel flow only, flow only occurs in snow channels at this frequency.
Possible	Might occur at some time	Between once a year and once in 5 years.	Flow modelling data available for a once in 5year (20% AEP) event.	Within channel with some localised floodplain flow. Within channel consequences will peak at bankfull conditions, estimated to be approximately a once in 5 year event. Unlikely to have full floodplain engagement.
Unlikely	Could occur at some time	Between once in 5 years and once in 20 years.	Flow modelling data available.	Within channel and floodplain flow.
Rare	May occur in exceptional circumstances	Once in more than 20 years.	Flow modelling data available.	Within channel and floodplain flow.

TABLE 14-8 GEOMORPHIC COMMENTARY ON CONSEQUENCE

Consequence	Description	Geomorphology commentary
Not significant	Contained environmental damage—fully recoverable, no cost or ARTC action required	Geomorphic consequences that are already occurring in the environment. Estimated at approximately <10 per cent change in flow characteristics for all soil types. This buffer covers natural variability and potential error in models and soil mapping resolution.
Minor	Isolated environmental damage—minimal ARTC remediation required	Direct consequences: ▶ Minor erosion or deposition at isolated culvert/bridge sites. ▶ Examples may include immediate post construction (first 5 years) effects that need minimal remediation to address, minor design updates to culvert wingwalls and aprons may be required. Indirect/cumulative effects: ▶ Not significant as direct effects are isolated and minor.
Moderate	Localised/clustered environmental damage—requiring remediation	Direct consequences: ▶ Minor to moderate erosion or deposition at clusters of sites. ▶ Examples may include scour holes on the order of 5 m² and 0.5 m below the bed and several metres of along bank erosion, <0.5 m bank retreat, deposition downstream with minor infilling of existing pools. Indirect/cumulative effects: ▶ Indirect consequences starting to become apparent.
Major	Considerable environmental damage—requiring remediation	Direct consequences: ▶ Major erosion or deposition at an isolated culvert/bridge site or cluster of sites. ▶ Examples may include scour holes on the order of 25 m² and 1 m below the bed or tens of metres of along bank erosion, <1m bank retreat, deposition downstream with major infilling of existing pools. Indirect/cumulative effects: ▶ Indirect consequences may include new channels forming on the floodplain due to avulsion, bed aggradation, downstream adjustment of channel.

Consequence	Description	Geomorphology commentary
Extreme	Widespread long-term or permanent environmental damage—remediation required	Direct consequences: ▶ Extreme erosion or deposition at an isolated culvert/bridge site or cluster of sites. ▶ Examples may include scour holes on the order of 100 m² and 2 m below the bed and several tens of metres of along bank erosion, <5 m bank retreat, avulsion forming a new channel, deposition downstream with major infilling of existing pools and possibly channels increasing future avulsion potential. Indirect/cumulative effects: ▶ Indirect consequences may include new channels forming on the floodplain due to avulsion, bed aggradation, downstream adjustment of channel.

14.6.5 Erosive threshold velocity assessment approach

A preliminary ETV assessment was undertaken to inform the scour and erosion protection strategy for the Project. The ETV values for soil types encountered by the Project were determined and are provided in Appendix T1: Flooding and Hydrology Technical Report–Volume 1 (Appendix D). These ETVs are not suitable to be applied to Project watercourses, but are applicable to new drainage features or design culverts that do not discharge to watercourses. Table 8 in Appendix D of Appendix T1: Hydrology and Flooding Technical Report–Volume 1 presents estimated ETV values for bare soil and 50, 70 and 100 per cent vegetation cover scenarios by soil groups and erodibility classes. The ETV values along the Project for a 50 per cent vegetation cover scenario are estimated at between 0.9 and 1.2 m/s.

An impact assessment was undertaken against the FIOs using the Existing Case and initial case hydraulic modelling results to define velocity exceedances on properties/lots external to the Project permanent footprint. A representative and conservative average bare soil ETV value of 0.5 m/s was adopted for the purposes of this impact assessment.

Sealed and unsealed surfaces likely to be impacted by a velocity flood impact objective exceedance (measured against a target of 0.5 m/s) are identified and reported in Section 14.8, with modelling details presented in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (see sections 5.5.3, 6.5.3, 7.5.3, 8.5.3, 9.5.3, 10.5.3, 11.5.3, 12.5.3, 13.5.3, 14.5.4, 15.5.3, 16.5.3, 17.5.3, 18.6.3).

In addition to the initial scour protection requirements identified, the areas immediately downstream of the culvert outlets that may experience flood impact objective velocity exceedances were also identified, and additional scour protection has been allowed for within the revised reference design. The Project's proposed scour protection downstream of culverts is summarised in the Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B).

The geomorphology risk assessment comprises assessing and minimising the potential for change to the fluvial geomorphic environment due to the Project, allowing Existing Case geomorphological processes to continue to function into the future. This aligns with the flood impact objective of 'maintaining existing velocities where practical or minimise increases in velocities' (Table 14-4).

Erosion threshold velocities are not typically used in fluvial geomorphic assessment, particularly for channels, as the natural environment is complex and dynamic. The ETVs are based on bed material samples and do not consider vegetation, slope, sinuosity, soil dispersity, armouring, volume of erosion, flow duration or geomorphic processes at the site and do not necessarily equate to the erosive potential. Areas of high flow velocity do not necessarily correspond to areas of erosion on the ground. The ETVs also do not consider existing sediment transport regimes, this is particularly important for channels with large bedloads that require a certain flow velocity to function. Reducing the flow velocities below the velocities required to transport a channel's bedload can cause deposition and may lead to blocked culverts and potentially avulsion. Design flow velocities should be sufficient to maintain existing sediment transport regimes. Site observations of existing geomorphic processes, such as locations and extents of erosion and deposition, provide the best information on potential future impacts and site erosion potential.

Regional-level ETVs for soils such as those in Table 9.1 in the *Soil conservation guidelines for Queensland* (Chapter 9, Department of Science, Information Technology and Innovation, 2015a) have not been used in this assessment as they do not reflect the Existing Case fluvial conditions for the following reasons:

- ▶ Fluvial systems are dynamic and natural fluvial processes include some erosion.
- ▶ Regional level ETVs are not representative of the erosive potential of a site.

- ▶ As per Appendix T1: Flooding and Hydrology Technical report—Volume 1 (Appendix D), it is acknowledged that: ‘Historic hydrological studies have measured maximum velocities in Project watercourses that greatly exceed the provided ETVs. Due to the complex nature of these systems and little research being available for allowable velocities within Queensland’s drainage lines it is recommended that the ETVs are not applied to Project watercourses.’
- ▶ The ETVs for bare soil are lower than the Existing Case 20% AEP flow velocities at 87 per cent of Project watercourses. These thresholds do not reflect field observations of geomorphologically stable channels.
- ▶ Imposing bare earth ETVs will reduce flow velocity from the Existing Case and will impact the sediment transport capacity of Project watercourses negatively and prevent natural fluvial geomorphic processes from occurring.
- ▶ A reduction in the ability of a watercourse to transport sediment can lead to channel bed aggradation, change in channel and landform type, including avulsion,) and reduced/loss of transport of woody debris. Woody debris has significant ecological importance as it has a role in carbon budgets and nutrient cycling, is a source of energy for aquatic ecosystems, provides habitat for terrestrial and aquatic organisms, and the presence of woody debris on gully floors can also reduce erosion.
- ▶ See Appendix H: Geomorphology Report for further detail on the ETV methodology used for this assessment.

A detailed geomorphic assessment has been undertaken for initial case high-risk sites, as reported in Appendix H: Geomorphology Report (Appendix L). As part of this detailed assessment, ‘combined’ ETVs were established for some sites. These combined ETVs comprise a combination of theoretical ETV assessment, based on laboratory testing, with site geomorphic observations. See Appendix H: Geomorphology Report (Section 2.5.3.1) for further details on this method.

14.7 Existing environment

14.7.1 Climate

The Köppen climate classification system indicates that the study area falls within the Cfa—Humid Subtropical Climate region, which is characterised by hot and humid summers, and mild winters. A review of Bureau of Meteorology (BoM) climate data of relevance to surface water conditions within the study area was undertaken to validate this classification and to establish an appreciation of location-specific conditions. This climatic data was sourced from several representative BoM monitoring stations within the study area, as identified in Table 14-9.

Table 14-9 summarises the recorded rainfall data for six BoM weather stations within the study area. The data shows that the region receives its heaviest rainfall in summer, with the highest recorded single rainfall event occurring in January 2010, with 433.6 mm. During the winter months, the area predominantly receives low-to-no rainfall (BoM, 2019a).

TABLE 14-9 WEATHER STATIONS WITHIN THE STUDY AREA AND ASSOCIATED RAINFALL DATA

Station number	Name	Locality and approximate linear distance from the Project alignment	Operation date	Annual rainfall average (mm)	Month of highest rainfall/ amount (mm)	Month of lowest rainfall/ amount (mm)
041391	Woodspring	Woodspring (~5)	1954 to 2022	631.6	Dec (91.1)	Jun (29.1)
041047	Inglewood Post Office	Inglewood (~2)	1883 to 2022	652.7	Jan (83.8)	Aug (32.4)
41069	Millmerran Post Office	Millmerran (~2)	1900 to 2014	662.6	Jan (88.8)	Aug (30.9)
041110	Turallin	Turallin (~10)	1909 to 2015	648.5	Jan (91.1)	Sep (31.5)
41314	Brookstead Post Office	Brookstead (<1)	1958 to 2022	643.3	Dec (101.7)	Jun (28.2)
41082	Pittsworth	Pittsworth (~1)	1886 to 2022	692.9	Dec (97.8)	Aug (30.3)
041529	Toowoomba Airport	Toowoomba (~8)	1996 to 2022	709.0	Feb (111.3)	Apr (26.7)
041560 ¹	Goondiwindi Airport	Goondiwindi	2020 to 2022	943.8	Nov (228.0)	Sep (3.6)

Source: BoM (2022)

Table note:

1. Goondiwindi Airport weather station has only recorded 18 months of data to June 2022.

Other key climatic characteristics of the study area are as follows:

- ▶ Annual rainfall across the Border Rivers basin decreases along an east–west gradient from over 1,000 mm in the eastern ranges around the Great Dividing Range to around 500 mm in the west (BoM, 2019a).
- ▶ The Condamine River basin is characterised by high annual rainfall of around 600 mm to 800 mm in the upper reaches in the east and low annual rainfall of around 300 mm to 500 mm in the lower reaches on the floodplains of the Darling Downs in the west (BoM, 2019b).
- ▶ Tropical cyclones can impact on the study area, especially the headwaters of the Condamine River basin. The most recent tropical cyclone to have impacted the study area was the resulting sub-tropical system from tropical cyclone Seth in 2022, which produced extreme rainfall in Southern Queensland.
- ▶ Long-term average rainfall varies from around 950 mm/year in the northeastern part of the study area, in Toowoomba, to around 660 mm/year in the southwestern part, in Inglewood (BoM, 2019a).
- ▶ Rates of evaporation are generally higher in the summer months, where the mean average evaporation rate was 7.7 mm compared to the winter months, where the mean evaporation rate was 3.2 mm.
- ▶ Mean maximum monthly temperatures typically range from 26.9°C in the summer to 11.5°C in the winter (BoM, 2019a).

14.7.2 Catchment overview

The Project is located across two river basin areas, the Condamine River and the Border Rivers (Figure 14-1). The Project alignment extends through the Border Rivers basin from the NSW/QLD border to approximately 15 km southwest of Millmerran at Chainage (Ch) 117.0 km. From this point, the Project alignment is located in the Condamine River basin until its northern end point at Ch 208.2 km. Agriculture is the dominant land use in both basins, specifically irrigated cropping, dryland cropping and open grazing. For further detail regarding land use, see Chapter 8: Land Use and Tenure.

The study area features two distinct areas of high elevation along flat-to-undulating terrain, as the Project alignment passes through the floodplains of the Border Rivers and Condamine River basins (BoM, 2017a). The Project's lowest point of elevation occurs at the southern end of the Project alignment at the Macintyre River, with an approximate elevation of 227 m. From this point, elevation along the Project alignment generally increases steadily in a northward direction towards Mount Domville and Commodore Peak, south of Millmerran.

The Project alignment elevation reaches 482 m at Ch 122.2 km as it passes through the Clontarf and Millmerran area before dropping into the Condamine River floodplain—a shallow topographical parabola between Millmerran and Yarranlea, with a low point of 377 m. From Yarranlea, the Project alignment increases in elevation until Ch 179.8 km near Southbrook, where a maximum elevation of 595 m is reached. From this high point, elevation of the Project alignment decreases to an end point, at Ch 208.2 km, of 458 m.

The Border Rivers basin covers approximately 23,800 square kilometres (km²) and, in combination with the Moonie River basin, comprises approximately 12 per cent of the Queensland portion of the Murray–Darling basin (DES, 2019a). This basin resides predominantly in Queensland with a portion extending into NSW.

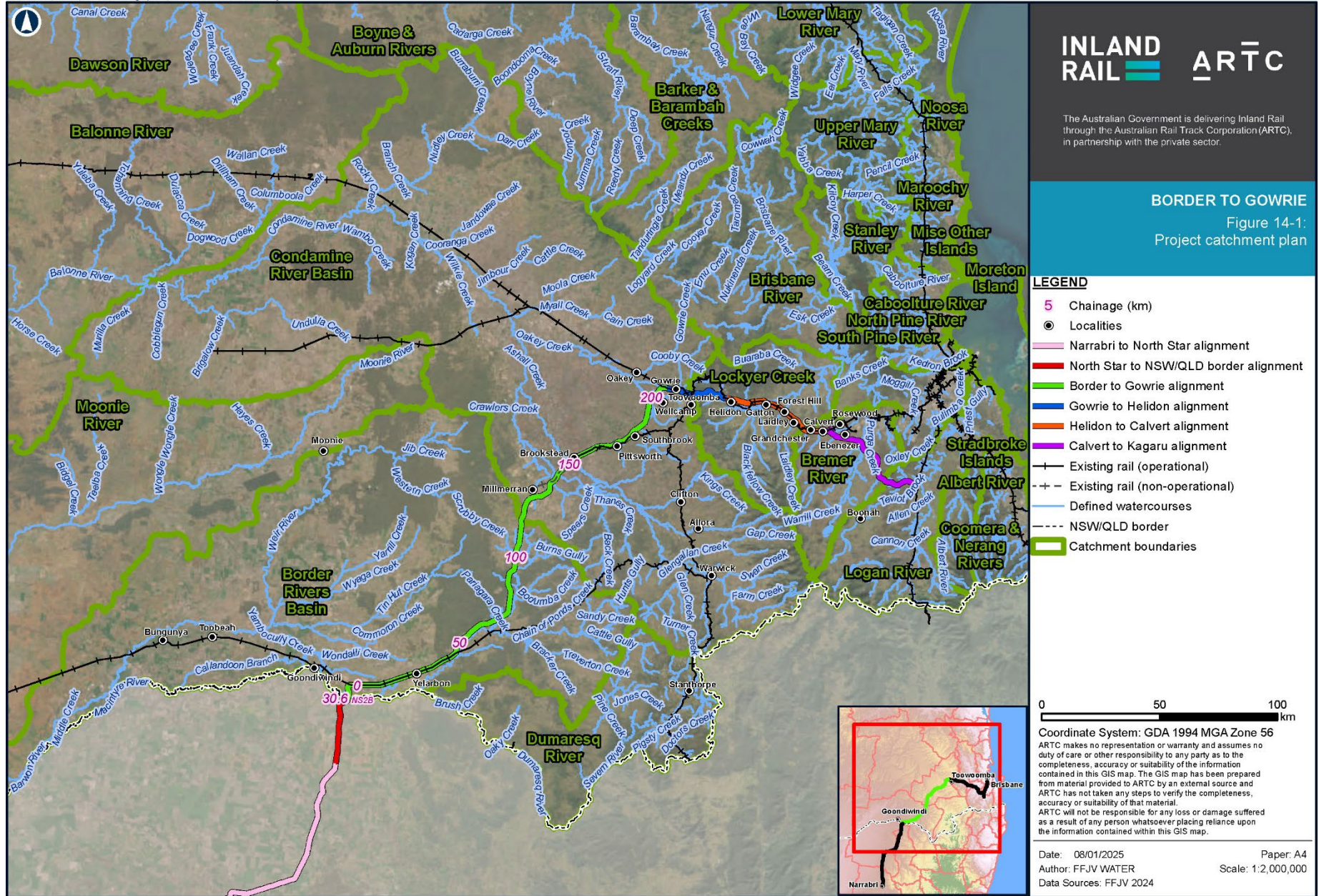
The Border Rivers are a network of perennial streams that rise in the western slopes of the Great Dividing Range on the Granite Belt and New England Tablelands and together form the headwaters of the Darling River (DES, 2019a). In Queensland, the Macintyre Brook, Severn River, Mole River and Beardy River drain from the Inglewood, Granite Belt, Tenterfield and Deep Water districts, respectively. The confluence of the Severn River and the Mole River becomes the Dumaresq River, which forms part of the border between Queensland and NSW. The Dumaresq River enters the Macintyre River above Goondiwindi and continues to form the border between the two states.

The Macintyre River flows generally west before reaching its confluence with the Weir River, west of Goondiwindi. The Weir River headwaters are located in the Dunmore State Forest, southwest of Cecil Plains. It is fed by a number of tributaries that drain to an area west of Millmerran and Inglewood and north of Goondiwindi. The Weir River generally flows in a southwest direction and combines with the Macintyre River, north of Mungindi, where it becomes the Barwon River (DES, 2019a).

The Condamine River basin covers approximately 25,440 km² and comprises approximately nine per cent of the Queensland Murray–Darling basin (DES, 2019b). The Condamine River basin forms part of the headwaters of the Murray–Darling basin river system that flows through the southern states.

The main channel in this basin begins in the headwaters of the Condamine River, near Warwick. This is within the Main Range National Park. The Condamine River flows north-west until around Brigalow, where the river turns west and crosses into the Maranoa and Balonne River basin. It then becomes the Balonne River between the town of Condamine and Surat and eventually discharges into the NSW intersecting streams. Tributaries of the Condamine River include Emu Creek, Glengallan Creek, Hodgson Creek, Oakey Creek, Wilkie Creek and Charleys Creek.

The major water storages in the Queensland Border River basin are Glenlyon Dam (capacity 254 gegalitres) and Coolmunda Dam (capacity 69 gegalitres), which are approximately 68 km and 10 km from the Project footprint, respectively. The major water storage in the Condamine River basin is Leslie Dam, with a capacity of 106 gegalitres, which is located approximately 72 km east of the Project footprint. Additionally, smaller water storages are present for the management of supplemented and non-supplemented (e.g. regulated or natural) flow for irrigation, stock and domestic uses throughout the catchment (DES, 2019a & 2019b).



14.7.3 Defined watercourses, waterways and waterbodies

14.7.3.1 Watercourses and waterways

The revised reference design includes full-width crossings of 19 major waterways (stream order ≥ 3) and 81 minor waterways (stream order < 3).

There are 18 defined watercourses within the study area, as listed below, and shown on Figure 14-2. Where the watercourse is intersected by, or parallel to the Project alignment, the approximate chainage is given:

- ▶ Macintyre River—intersected at the NSW/QLD border at NS2B Ch 30.6 km (NS2B)
- ▶ Macintyre Brook
- ▶ Canning Creek
- ▶ Pariagara Creek—at Ch 67.3 km
- ▶ Cattle Creek—at Ch 88.2 km
- ▶ Bringalily Creek—at Ch 100.6 km
- ▶ Nicol Creek—at Ch 104.4 km
- ▶ Back Creek unnamed tributary—at Ch 126.9 km
- ▶ Back Creek—Ch 128.0 km
- ▶ Grasstree Creek – at Ch 139.9 km
- ▶ Condamine River (Main Branch)—at Ch 144.2 km
- ▶ Condamine River (North Branch)—at Ch 149.9 km
- ▶ Umbiram Creek unnamed tributary—at Ch 184.8 km
- ▶ Half Mile Gully—Ch 190.0 km
- ▶ One Mile Gully—Ch 193.1 km
- ▶ Westbrook Creek—at Ch 198.5 km
- ▶ Dry Creek—at Ch 199.3 km
- ▶ Gowrie Creek.

Defined watercourses within the study area have been identified in reference to Department of Regional Development, Manufacturing and Water's *Water identification map—watercourses—Queensland*(2022). Further classification of waterways within the study area is discussed in Chapter 13: Surface Water.

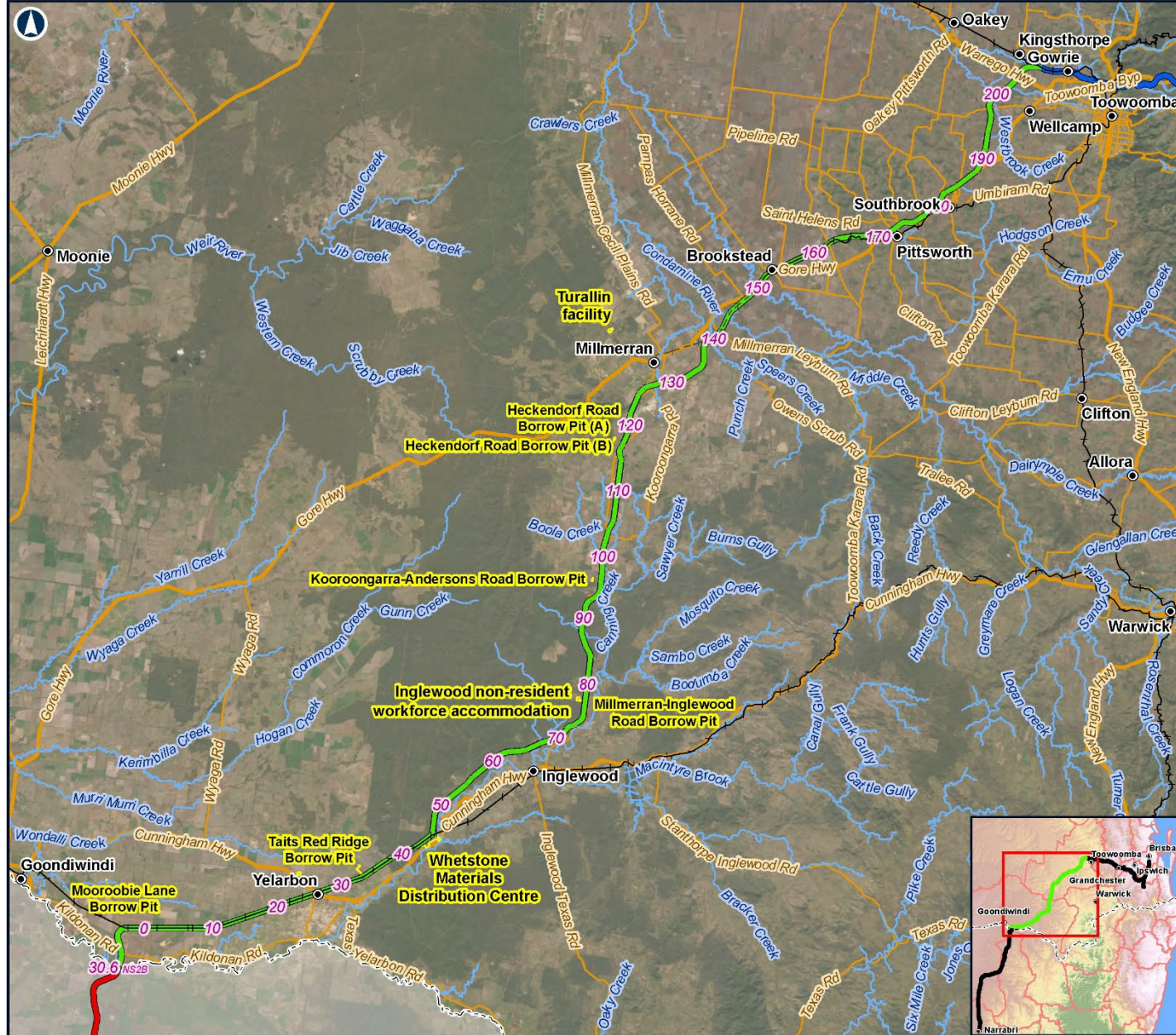
14.7.3.2 Water bodies

Various dams, weirs and artificial water bodies are located in the vicinity of the Project and are discussed in Chapter 13: Surface Water.

Waterways for waterway barrier works

Waterways for waterway barrier works are regulated under the *Fisheries Act 1994* (Qld) and the *Planning Act 2016* (Qld) when barriers to fish movement, including partial barriers, are installed across waterways. Barrier works include construction, raising, replacement and some maintenance works on structures such as culverts, crossings, bed-level and low-level crossings, weirs and dams, both permanent and temporary. In addition to affecting connectivity for aquatic fauna, water-quality risk to species is considered with waterway barrier works due to the potential impact it may have on water passage.

Waterways for waterway barrier works that are intersected by the Project alignment are discussed in Chapter 13: Surface Water.



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BORDER TO GOWRIE

Figure 14-2:
Defined watercourses associated
with the Project

LEGEND

-  Chainage (km)
-  Localities
-  North Star to NSW/QLD border alignment
-  Border to Gowrie alignment
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Existing rail (non-operational)
-  Major roads
-  Minor roads
-  Defined watercourses
-  NSW/QLD border
- Impact assessment area**
-  Project footprint

0 20 40 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV 2024

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14.7.4 Existing flooding regime

Flooding in the study area occurs through two mechanisms, or a combination of both mechanisms, being:

- ▶ Rainfall over the upstream waterway catchment areas
- ▶ Backwater from downstream major systems. For example, in the vicinity of the Project, Pariagara Creek is affected by flooding that occurs in the Macintyre Brook system, and Bringalily Creek is affected by backwater from Canning Creek.

Hydrologic and hydraulic models have been developed to enable the existing flooding regime within the study area to be assessed and for potential impacts of the Project to be identified. Available data and previous studies were collected and reviewed to support the development and calibration of hydrologic and hydraulic models for the Project. The hydrologic and hydraulic models developed for the waterways that the Project alignment crosses are summarised in Table 14-10. The extent of each of the regional hydraulic models are presented in Figure 14-3. Refer to Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Figure 3.3) for local drainage hydraulic model extents.

TABLE 14-10 PROJECT HYDROLOGIC AND HYDRAULIC MODEL SUMMARY

Location	Hydrologic model package used	Hydraulic model package used
Gowrie Creek	RAFTS ¹	TUFLOW ²
Westbrook Creek	RAFTS	TUFLOW
Condamine River	URBS ³	TUFLOW
Back Creek	URBS	TUFLOW
Nicol Creek	URBS	TUFLOW
Bringalily Creek	URBS	TUFLOW
Native Dog Creek	URBS	TUFLOW
Cattle Creek	URBS	TUFLOW
Pariagara Creek	URBS	TUFLOW
Macintyre Brook–Yelarbon to Inglewood	URBS	TUFLOW
Macintyre Brook at Bybera Road ⁵	URBS	TUFLOW
Macintyre Brook at Cremascos Road ⁵	URBS	TUFLOW
Macintyre River	URBS	TUFLOW
Local drainage catchments across alignment	12D Drainage Network Editor ⁴	TUFLOW

Table notes:

1. Commercial hydrologic modelling software package

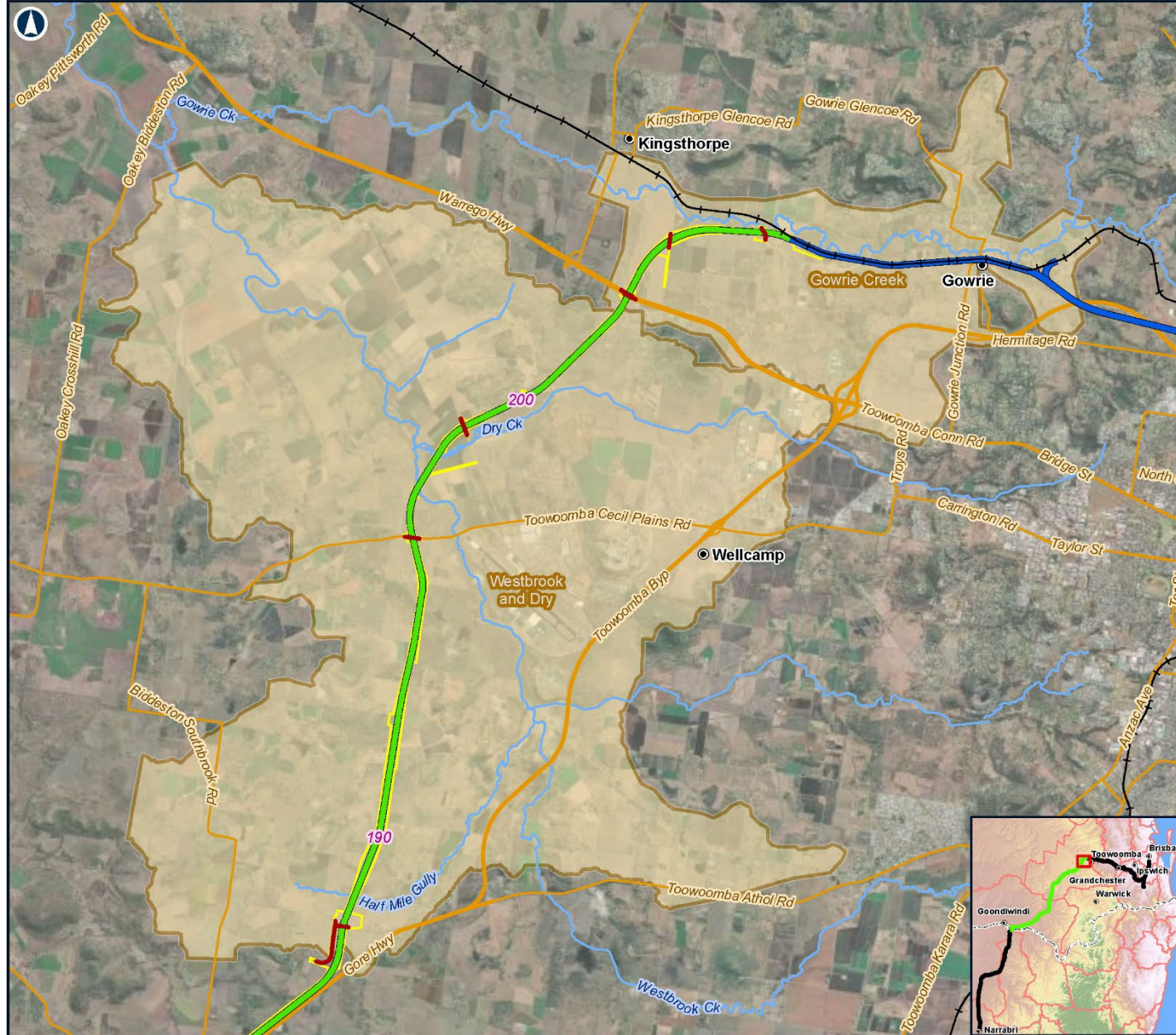
2. Commercial hydraulic modelling software package

3. Commercial hydrologic modelling software package ('Unified River Basin Simulator')

4. Commercial terrain modelling, surveying and civil engineering software package including water engineer

5. The Bybera Road and Cremascos Road models are small and localised. Results at these locations are reported under the Macintyre Brook (Yelarbon to Inglewood) sections of this chapter.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-3a:
Extents of Project regional hydraulic models
Gowrie, Westbrook and Dry Creeks

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment (the Project)
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Regional hydraulic model extents
-  Impact assessment area
-  Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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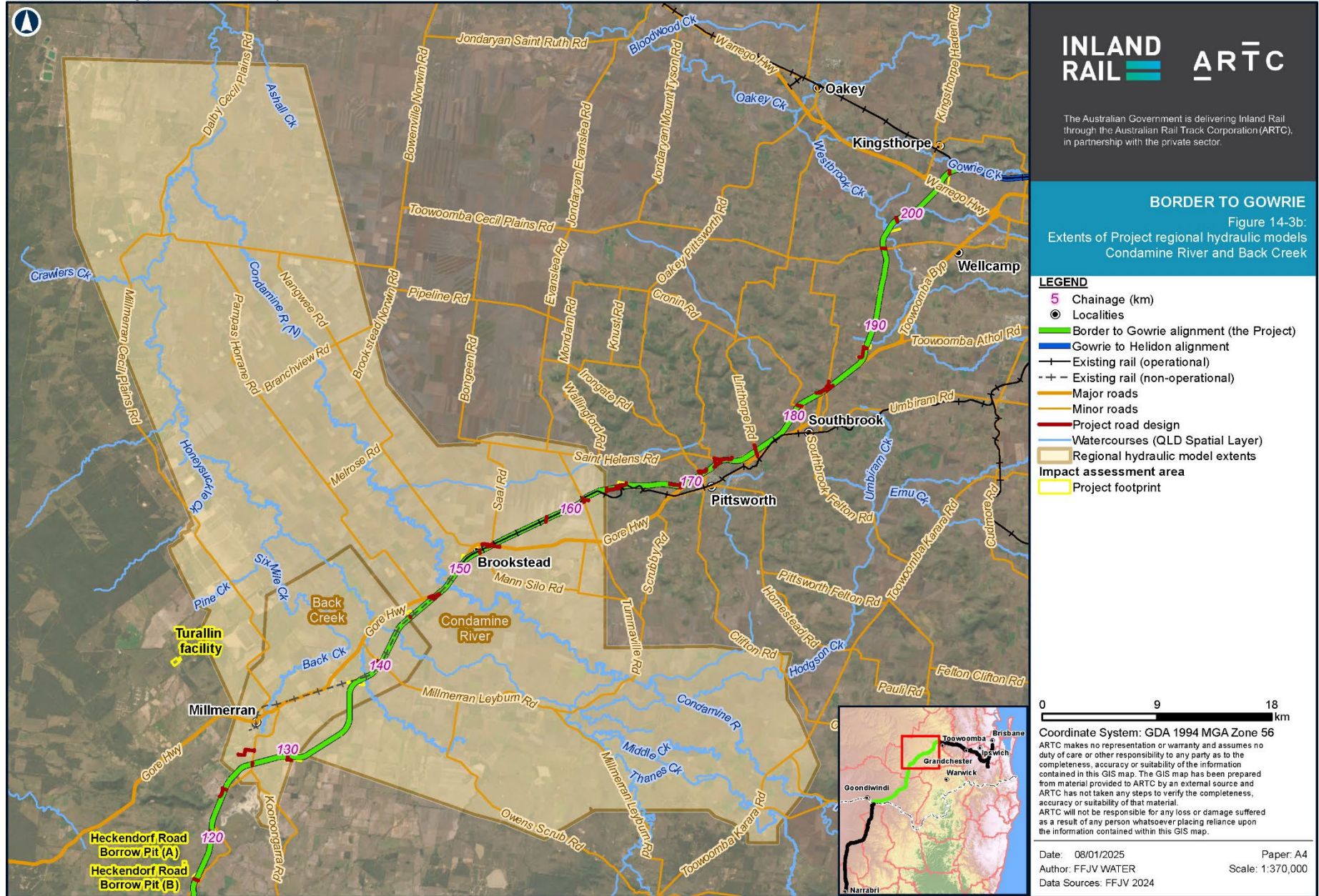
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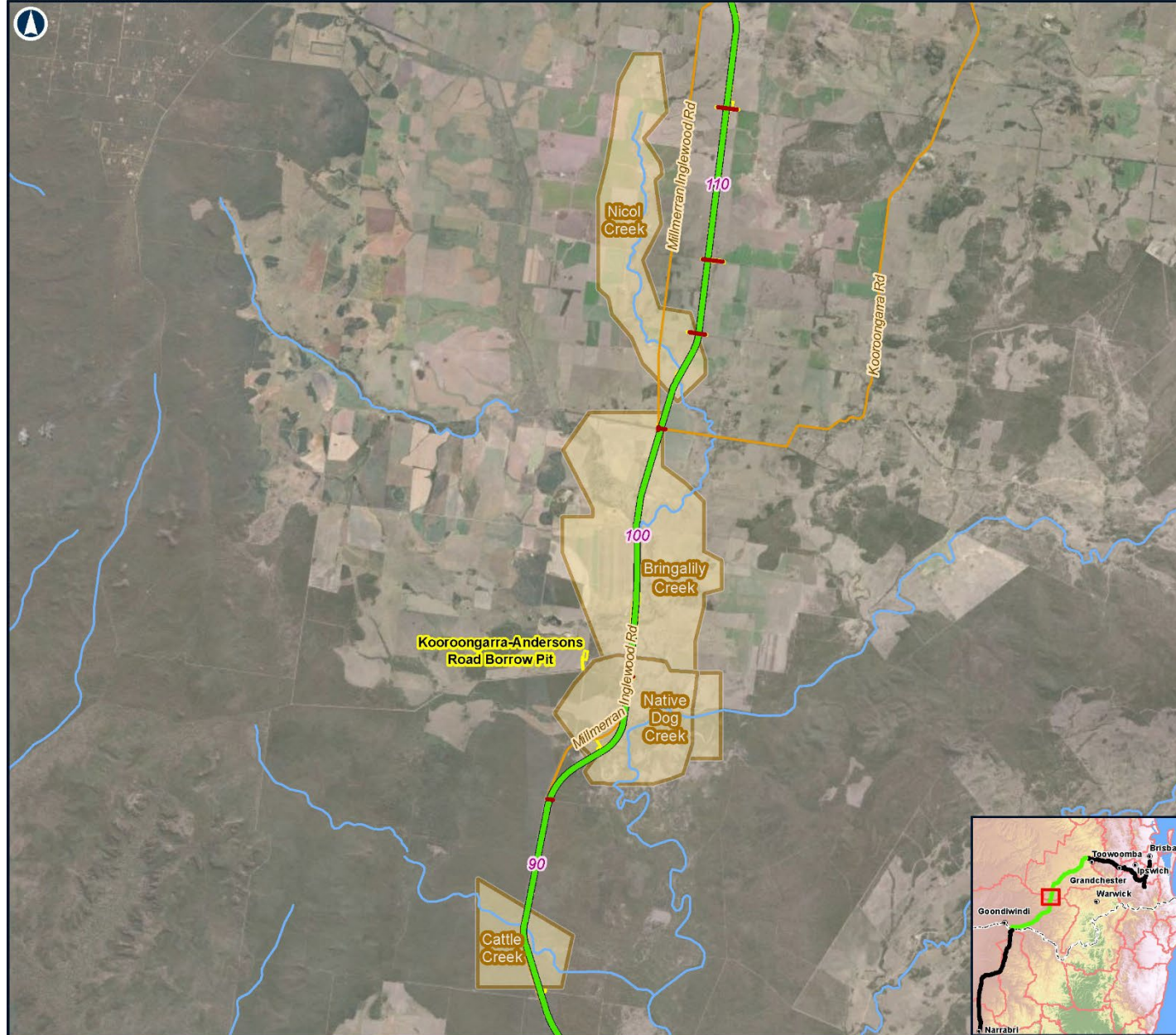
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BORDER TO GOWRIE

Figure 14-3c:
Extents of Project regional hydraulic models
Nicol, Bringalily, Native Dog and Cattle Creeks

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment (the Project)
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Regional hydraulic model extents
- Impact assessment area**
-  Project footprint

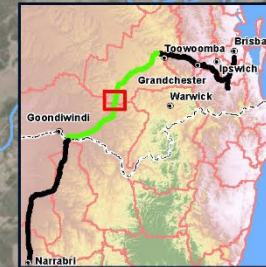
0 3.5 7 km

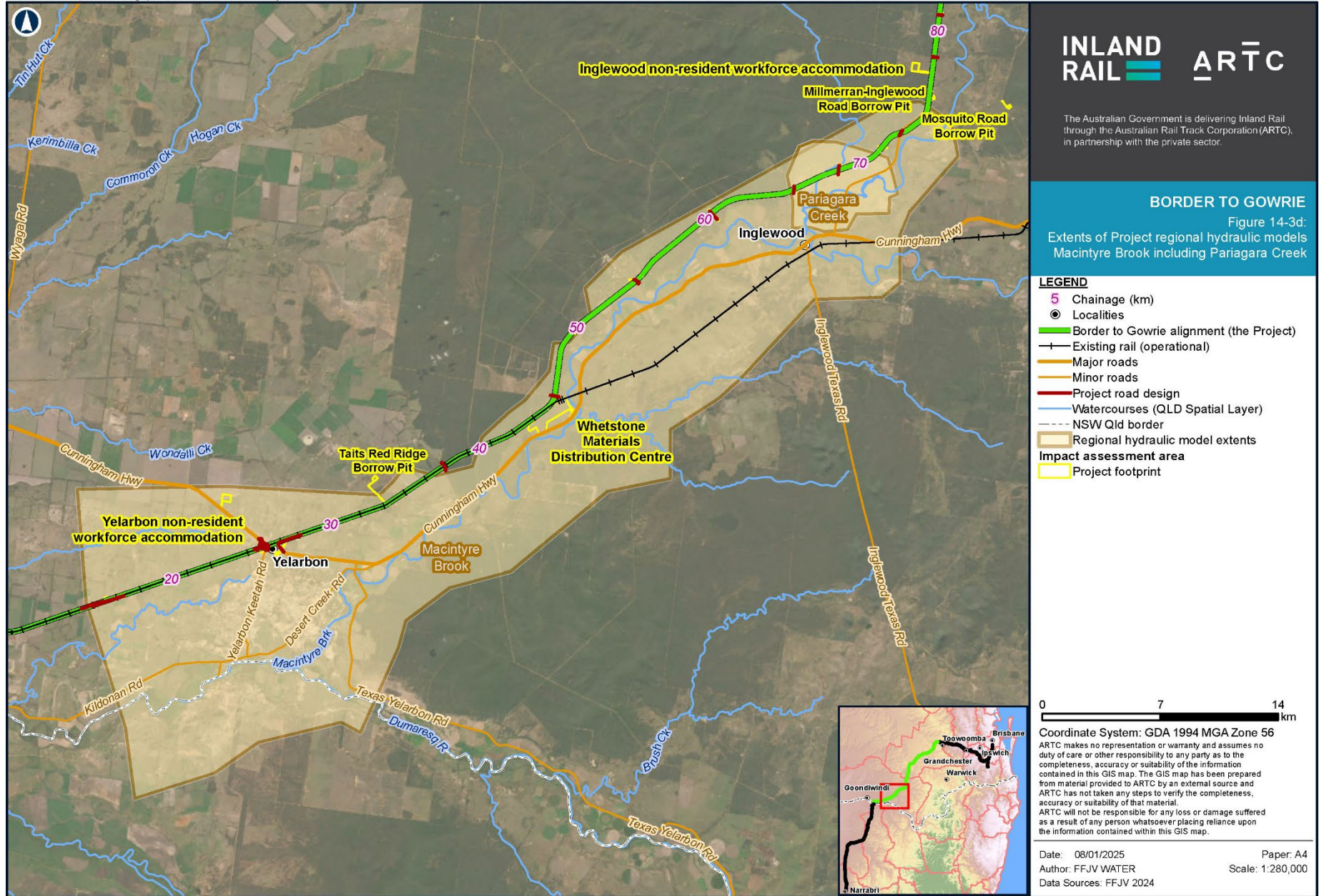
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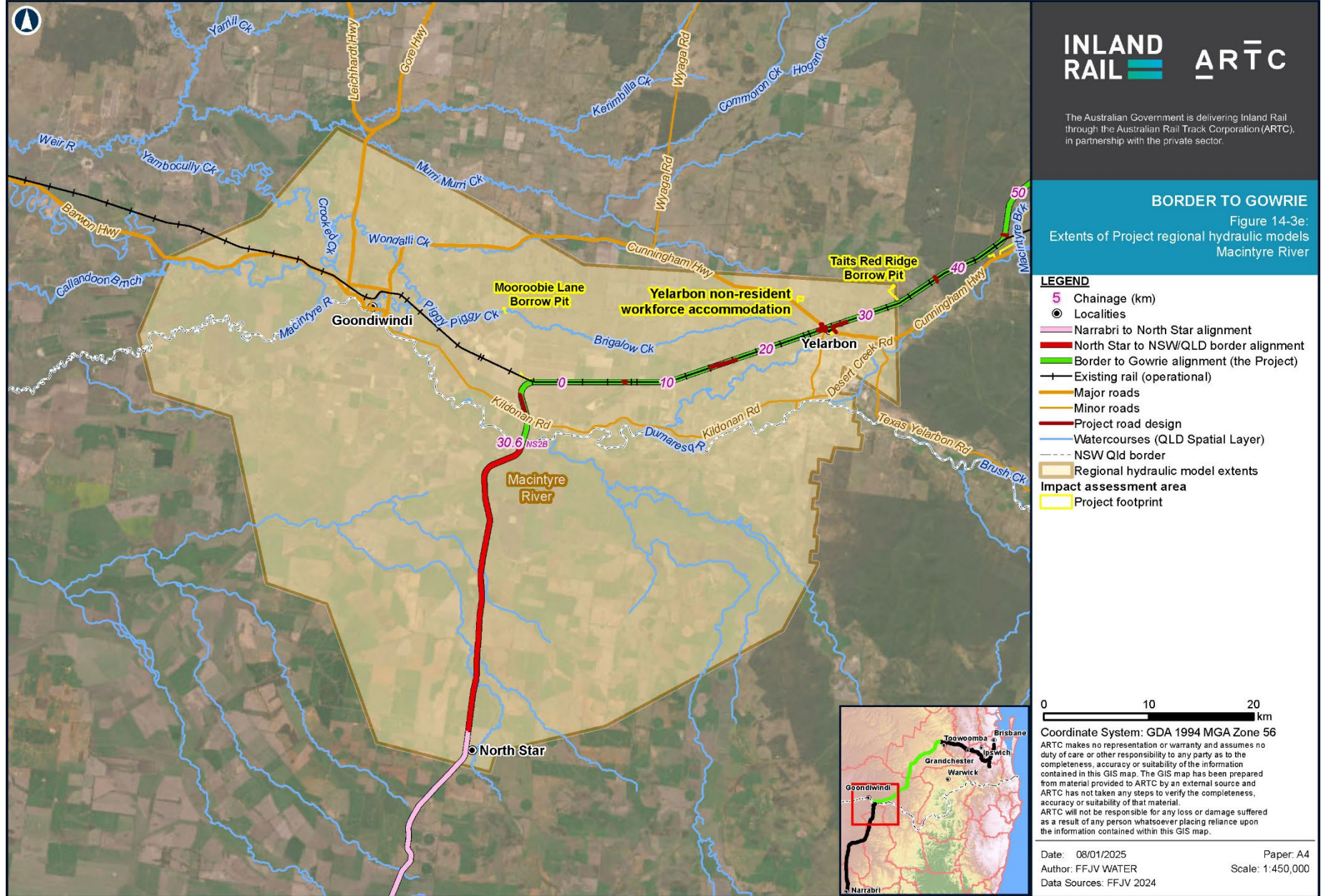
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Data Sources: FFJV 2024

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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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14.7.4.1 Calibration to historical flood events

Available background information was sourced to support validation of the hydrologic models and calibration of the hydraulic models. This background information included existing models, streamflow data and available anecdotal flood data. This data was sourced from a wide range of sources and stakeholders, including:

- ▶ BoM
- ▶ TRC and GRC
- ▶ DTMR
- ▶ Sunwater
- ▶ Landowners and other affected stakeholders.

Where possible, modelling of each waterway catchment was calibrated against historical events, with results matched to recorded data from available and suitable stream gauges, community feedback and anecdotal flood data. The Macintyre River was calibrated to the 1976, 1996 and 2011 historical flood events; Macintyre Brook was calibrated to the 1976 event; the Condamine River to the 1991 and 2010 events; and Gowrie Creek to the 2010, 2011 and 2013 events.

These historical events were selected to represent a range of event magnitudes and flood durations. Acceptable calibration of hydrologic and hydraulic models was achieved for these catchments and the models were considered suitable for assessment of the Project. To further strengthen modelling, several other events were used to validate the models including the December 2021 event in the Condamine River and Macintyre Brook floodplains.

Further details regarding the calibration of the models are available in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (see sections 5.2.2, 7.2.3, 8.2.4, 9.2.2.2, 10.2.5, 11.2.11, 12.2.4, 13.2.4, 14.3.7, 15.2.5, 16.2.5 and 17.3.6). The magnitude of each of the historical events has been estimated at each of the major stream gauges in the relevant waterway catchments. The estimated AEP of each event is outlined in Table 14-11, Table 14-12 and Table 14-13.

TABLE 14-11 ESTIMATED AEP OF HISTORICAL EVENTS: GOWRIE CREEK

Stream gauge	Estimated historical event AEP (%)			
	December 2010 ¹	January 2011 ¹	January 2013 ¹	February 2013 ¹
Cranley	~9%	~1%	~26%	26%

Table notes:

~ Approximate equivalent AEP

1. Events used for model calibration purposes

TABLE 14-12 ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS: CONDAMINE RIVER

Stream gauge	Estimated historical event AEP (%)					
	1956	1976	1991 ¹	2010 ¹	2013 ²	2021 ²
Warwick	No data	~0.6%	~19.6%	~2.6%	~3.7%	~10.4%
Talgai	No data	No data	~26.0%	~8.9%	~2.1%	~13.5%
Tummalville	No data	~1.0%	~25.1%	~13.0%	~19.9%	~15.4%
Cecil Weir	~3.7%	~2.2%	~23.3%	~0.8%	~12.1%	~15.2%

Table notes:

~ Approximate equivalent AEP

1. Events used for model calibration

2. Events used for model validation

TABLE 14-13 ESTIMATED AEP OF HISTORICAL EVENTS: MACINTYRE BROOK AND MACINTYRE RIVER

Stream gauge	Estimated historical event AEP (%) ¹			
	1976 ²	1996 ²	2011 ²	2021
Boggabilla	~0.4 to 0.2%	~1.6 to 2%	~1.1 to 1.2%	~2.6 to 3.6%
Booba Sands	~2 to 0.7%	~7.7 to 5.3%	~10 to 7.7%	~3.8 to 1.8%
Inglewood	~2 to 2.6%	~10 to 10%	~11.1 to 11.1%	~4.8 to 5%
Bonshaw	~1.6 to 1.1%	~14.3 to 14.3%	~0.8 to 0.5%	~4.5 to 3.8%
Roseneath	~1.2 to 1.6%	~11.1 to 11.1%	~1.2 to 1.5%	~4.5 to 5%
Holdfast	~0.5 to 1.2%	~4.3 to 11.1%	~4% to 10%	~14.3 to 25%
Ashford	~0.4 to 1.4%	~2.4 to 7.7%	~10 to 25%	~11.1 to 25%
Coolatai	~1.2 to 0.2%	~5.9 to 2.4%	~66.7 to 66.7%	~33.3 to 25%

Table notes:

~ Approximate equivalent AEP

1. Two values provided, the first is a comparison against reconciled Design Event Approach flows and second value is a comparison to Flood Frequency Analysis flows

2. Events used for model calibration purposes

The hydrologic models for the remaining catchments (i.e. Westbrook and Dry Creeks, Back Creek, Nicol Creek, Bringalily Creek, Native Dog Creek, Pariagara Creek and Cattle Creek) were not calibrated due to unavailability of observed gauge data; however, the flood discharges obtained from hydrologic models were compared to those derived using other flood estimation methods such as DTMR's Quantile Regression Technique, ARR 2019's Regional Flood Frequency Estimation and scaling of donor catchment Flood Frequency Analysis flows.

14.7.4.2 Existing Case hydrology and flooding modelling results

Modelling of the Existing Case has been undertaken to provide a base case against which the introduction of the Project infrastructure and associated drainage structures can be assessed. Details of the existing flood regime on each floodplain in the vicinity of the Project are discussed below.

Gowrie Creek

The Project alignment does not cross Gowrie Creek, and predominantly avoids the 1% AEP inundation extents, before connecting into the Gowrie to Helidon section of Inland Rail at Draper Road.

Under the 1% AEP event, around the Leeson Road/Draper Road junction, the peak depth of water is approximately 4 m to 5 m in the Gowrie Creek channel, and up to around 1 m to 2 m on the floodplain at the Project alignment. The floodplain inundation under the 1% AEP event varies between 200 m and 500 m wide. Several small, unnamed flow paths draining the area to the north of the Warrego Highway cross the Project alignment.

The 1% AEP event overtops the existing West Moreton System in several sections. Table 14-14 presents a summary of overtopping depths for the existing QR rail line and key roads near the Project under a range of design events. The 1% AEP event peak water levels are presented in Figure 14-4a.

TABLE 14-14 GOWRIE CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

Infrastructure	Location	Approximate overtopping depth (m)					
		1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Chamberlain Road	End of road near Gowrie Creek	1.73	0.78	0.45	0.41	0.38	0.35
Kingsthorpe–Tilgonda Road	Near Gowrie Creek (~650 m west of Lessons Road)	2.63	1.57	1.41	1.00	0.67	0.36
Leeson Road	Gowrie Creek Crossing	2.80	2.03	1.89	1.64	1.34	0.97
Existing QR West Moreton Line	~950 m west of Gowrie Creek/QR West Moreton Line	0.51	0.39	0.30	0.05	Dry	Dry
Warrego Highway	Approximately 1,100 m east of Kingsthorpe Haden Road Intersection	0.19	0.11	0.07	0.04	0.01	Dry

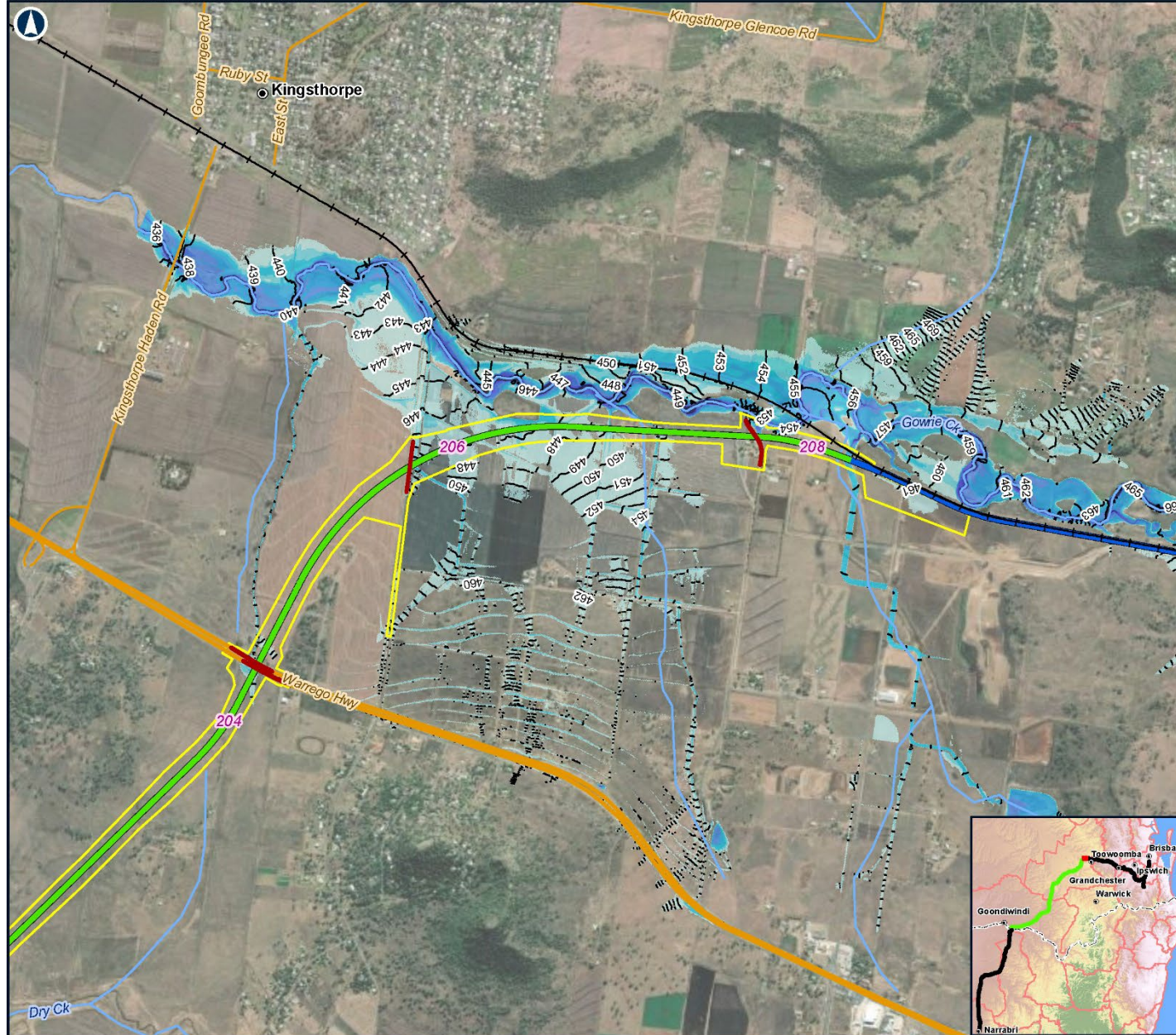
Peak 1% AEP velocities within the Gowrie Creek channel are high, in the order of 3 to 5 m/s. On the floodplain, velocities are generally in the order of 0.5 to 1.5 m/s as shown in Figure 14-4b.

Peak 1% AEP hazard (i.e. velocity-depth product) within the Gowrie Creek channel are extremely high and exceed 20 m²/s. Lower hazard zones are noted along the Project footprint, with the velocity-depth product ranging from 0.1 to 1 m²/s, and 1.4 m²/s at the proposed Charlton drain crossing as shown in Figure 14-4c.

Peak 1% AEP time of inundation within the Gowrie Creek channel are generally in the order of 11 to 14 hours. On the floodplain, time of inundation is generally in the order of 4 to 12 hours as shown in Figure 14-4d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-4a:
Existing Case - 1% AEP Peak water levels
Gowrie Creek

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  1m water surface contour (mAHD)

Estimated water depth (m)

- | | |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| | > 5.0 m color swatch" data-bbox="798 627 818 642"/> |

Impact assessment area

-  Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025

Author: FFJV WATER

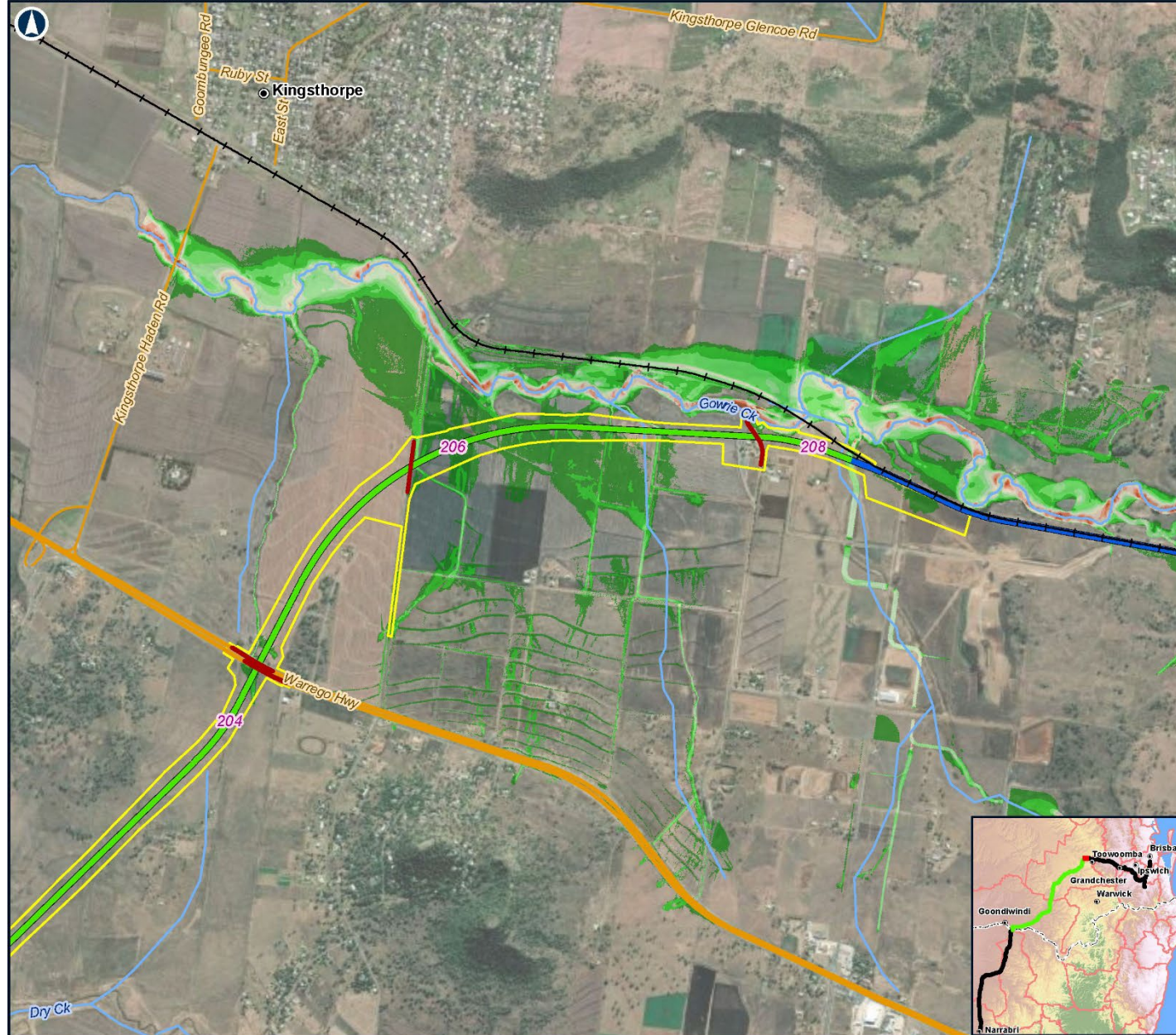
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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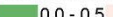
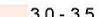
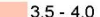
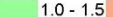
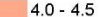
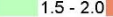
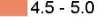
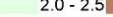
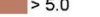
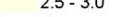
BORDER TO GOWRIE

Figure 14-4b:
Existing Case - 1% AEP Peak velocities
Gowrie Creek

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated velocity

- | | |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | |

Impact assessment area

-  Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025

Author: FFJV WATER

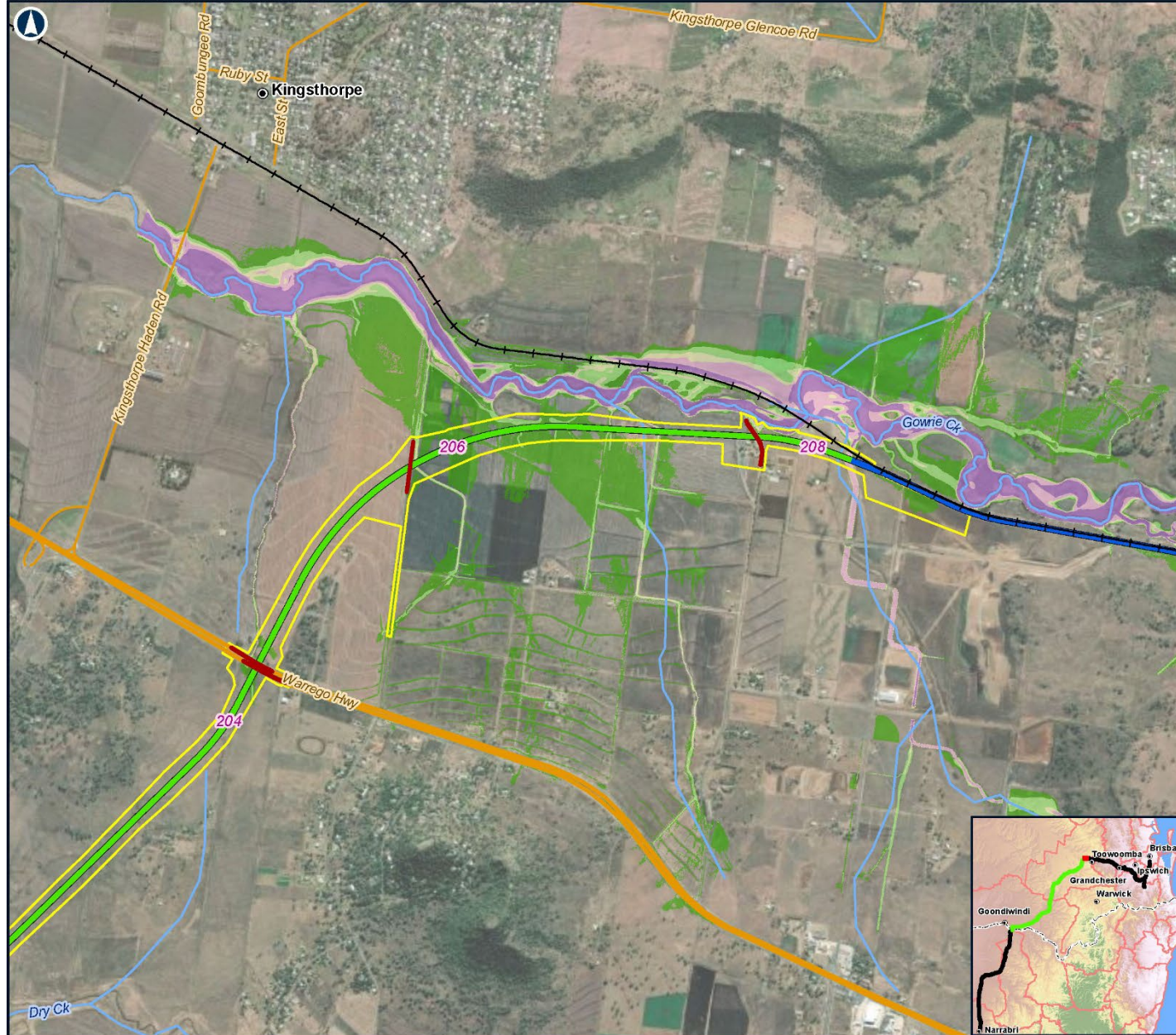
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Map by: JA/DTH Z:\GIS\GIS_310_B2\GIS\Tasks\310-IHY-2022\11212154_Chapter_14_EIS_Figures\310-IHY-2022\11212154_ARTC_F14_Xx_EX_Velocity_v4.mxd Date: 9/01/2025 14:29

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-4c:
Existing Case - 1% AEP Peak hazard
Gowrie Creek

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- Estimated Velocity x Depth product (m^2/s)
 - < 0.15
 - 0.15 - 0.5
 - 0.5 - 1.0
 - 1.0 - 2.0
 - > 2.0
- Impact assessment area
- Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER

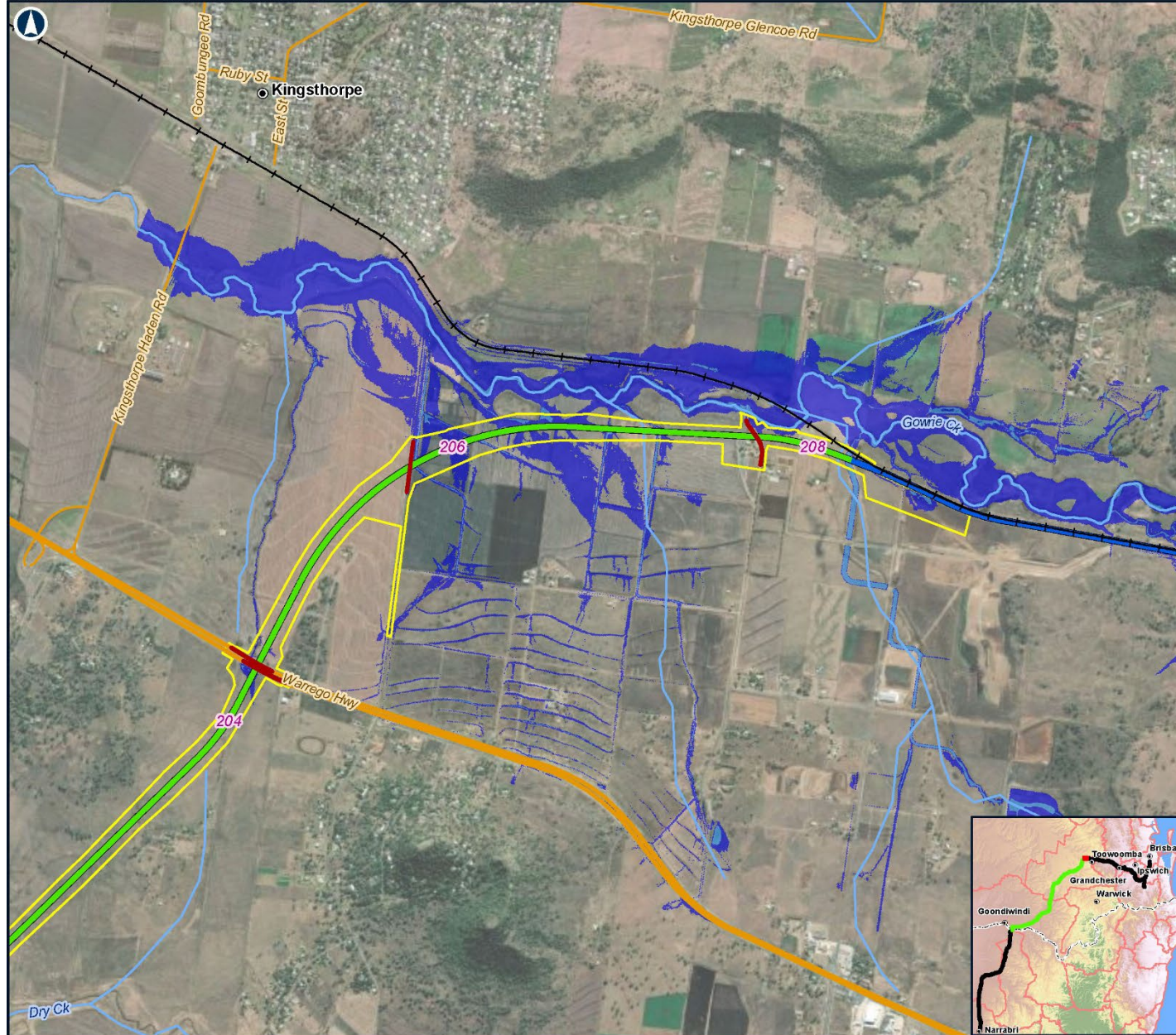
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE Figure 14-4d: Existing Case - 1% AEP Peak time of inundation Gowrie Creek

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated duration of inundation (hours)

- | | |
|---|--|
|  0 - 10 |  60 - 70 |
|  10 - 20 |  70 - 80 |
|  20 - 30 |  80 - 90 |
|  30 - 40 |  90 - 100 |
|  40 - 50 |  > 100 |
|  50 - 60 | |

Impact assessment area

-  Project footprint

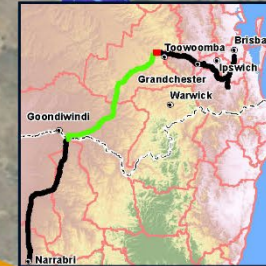
0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025
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Westbrook Creek and Dry Creek

The Project alignment crosses Westbrook Creek and Dry Creek to the west of Toowoomba Wellcamp Airport. The western section of Toowoomba Wellcamp Airport is protected by a flood levee. The Project crossing location of this floodplain is approximately 800 m upstream of the confluence of Westbrook Creek and Dry Creek. The combined 1% AEP event inundated floodplain width at the crossing point of the Project is approximately 1.7 km. At Brimblecombe Road, where the road crosses Dry Creek, the inundated floodplain width is approximately 500 m, and at Toowoomba–Cecil Plains Road, where the road crosses Westbrook Creek, the inundated floodplain width is approximately 800 m.

The Westbrook Creek and Dry Creek floodplains are well defined, with a few minor localised breakouts and small tributary drainage lines. Under the 1% AEP event, around the Project alignment crossing of Westbrook Creek, the peak depth of water is approximately 4.5 m in the channel and up to 3 m deep on the floodplain. At Dry Creek the 1% AEP event water depth in the channel is around 3.5 m deep and up to 1 m deep on the floodplain.

Table 14-15 presents a summary of overtopping depths for key roads near the Project under a range of design events. The 1% AEP event peak water levels are shown in Figure 14-5a.

TABLE 14-15 WESTBROOK CREEK AND DRY CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

Infrastructure	Location	Approximate overtopping depth (m)					
		1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Anderson Road	Downstream of Westbrook Bridge	4.63	3.90	3.62	3.21	2.79	2.30
Brimblecombe Road	Dry Creek crossing	0.98	0.79	0.73	0.63	0.52	0.43
Toowoomba–Cecil Plains Road	Approximately 300 m to the west of Westbrook Creek Crossing	1.1	0.75	0.67	0.60	0.45	0.22

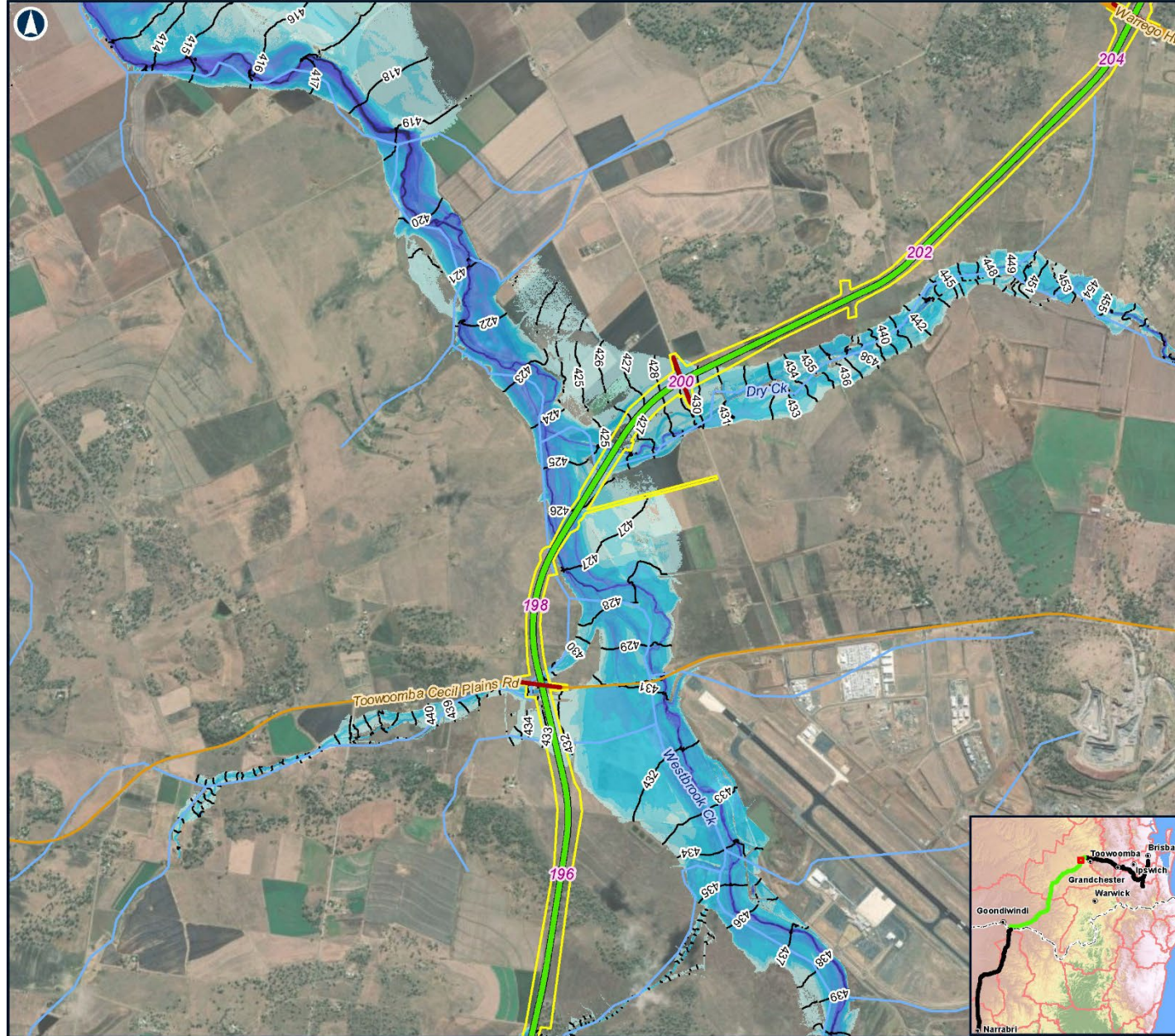
Peak Existing Case velocities for the 1% AEP event in the channels of Westbrook and Dry Creeks at the Project alignment are in the order of 2 to 3 m/s, and on the floodplain, velocities are generally in the order of 1 to 1.5 m/s as shown in Figure 14-5b.

For the Existing Case 1% AEP event, high hazard zones within the floodplain occur within the main channels of Westbrook and Dry Creeks. Estimated peak velocity-depth product values of 10 m²/s and 7.5 m²/s are noted within the respective waterways at the proposed Project crossings. Lower hazard zones are located on the floodplains with velocity-depth product values ranging between 0.1 m²/s to 0.6 m²/s as shown in Figure 14-5c.

Peak Existing Case 1% AEP event time of inundation within the Westbrook and Dry Creeks channel are generally in the order of 8 to 12 hours. On the floodplain, time of inundation is generally in the order of 2 to 4 hours as shown in Figure 14-5d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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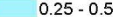
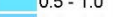
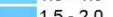
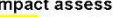
BORDER TO GOWRIE

Figure 14-5a:
Existing Case - 1% AEP Peak water levels
Westbrook & Dry Creeks

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  1m water surface contour (mAHD)

Estimated water depth (m)

- | | |
|--|---|
|  0 - 0.25 |  2.5 - 3.0 |
|  0.25 - 0.5 |  3.0 - 3.5 |
|  0.5 - 1.0 |  3.5 - 4.0 |
|  1.0 - 1.5 |  4.0 - 4.5 |
|  1.5 - 2.0 |  4.5 - 5.0 |
|  2.0 - 2.5 |  > 5.0 |

Impact assessment area

-  Project footprint

0 1 2 km

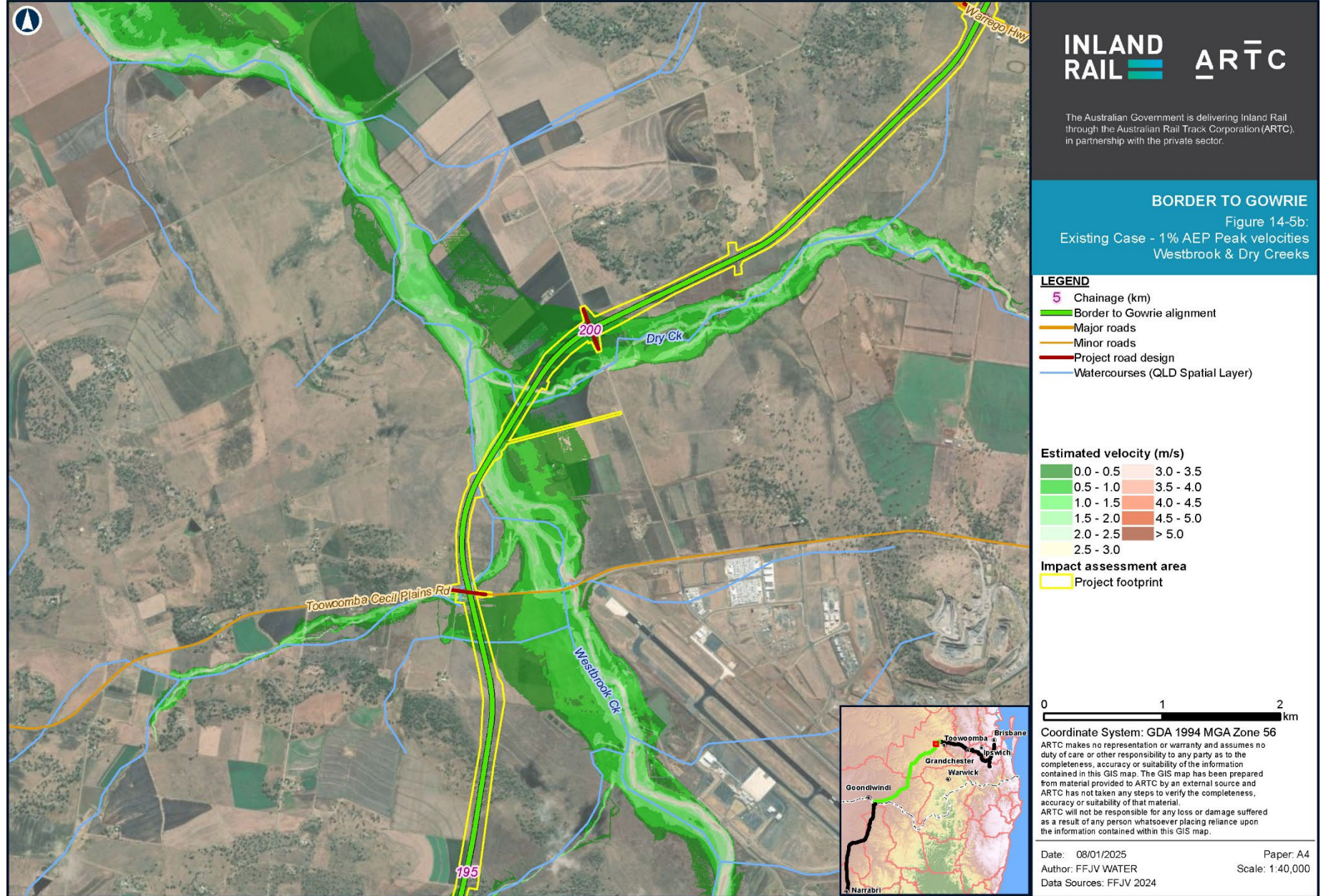
Coordinate System: GDA 1994 MGA Zone 56

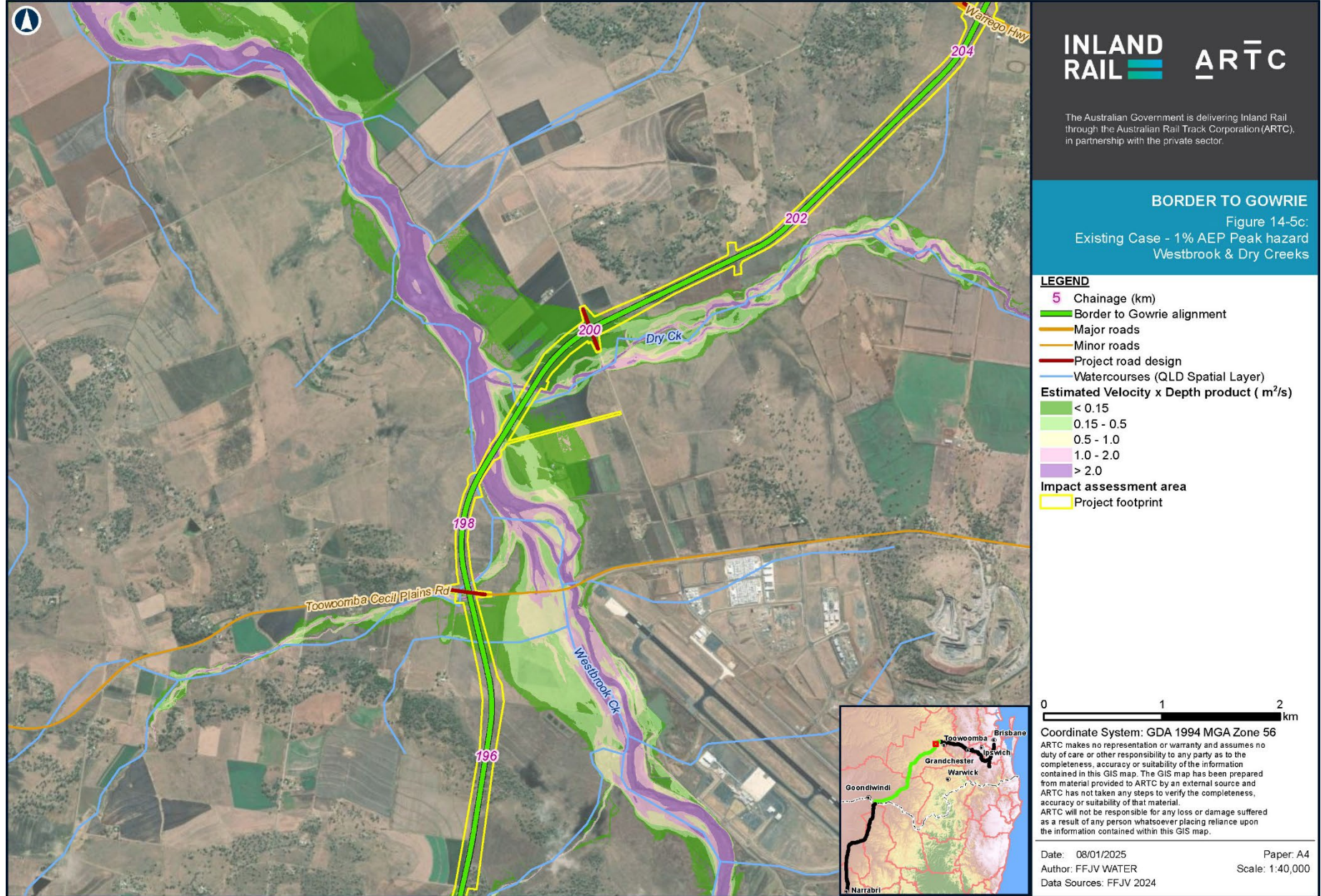
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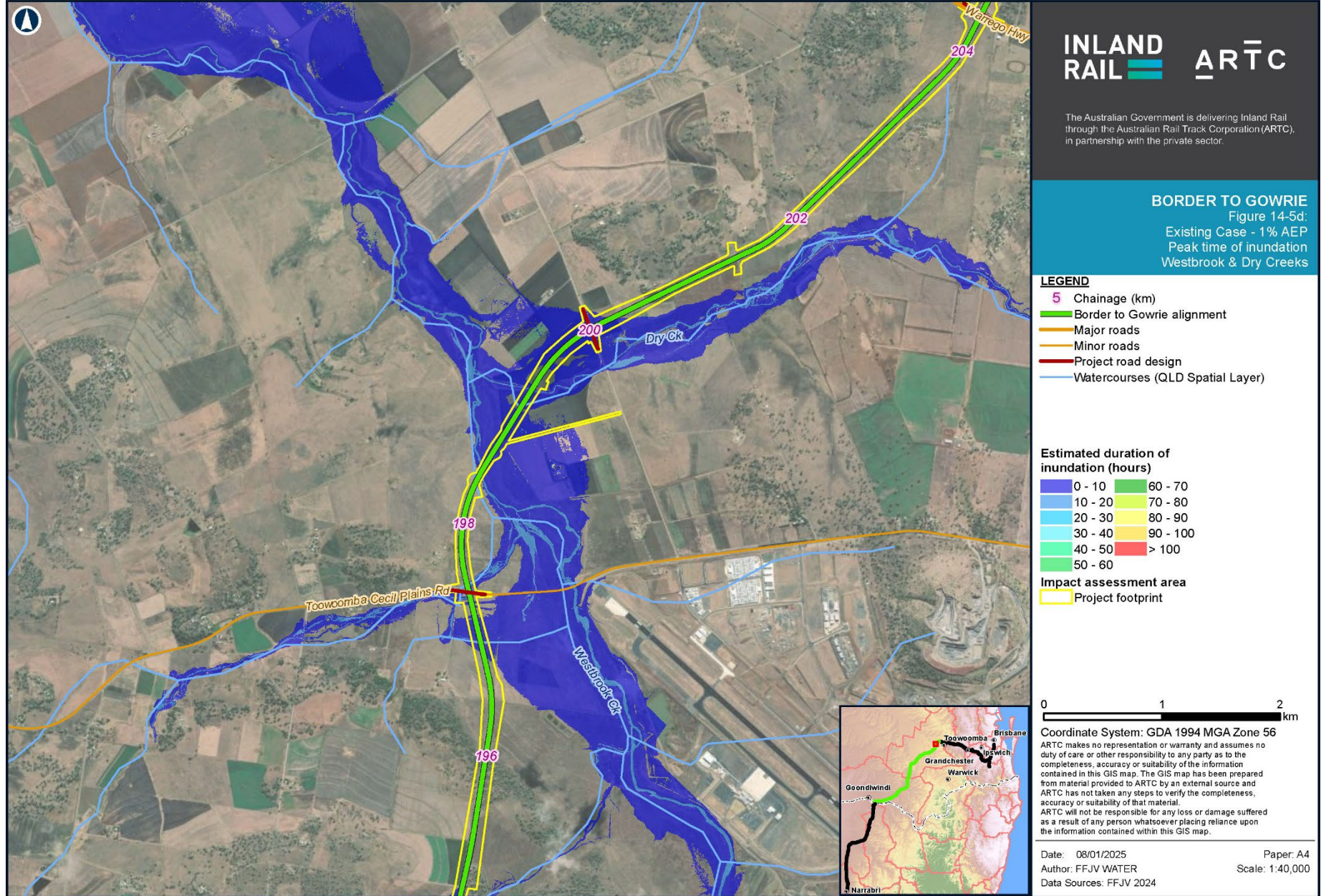
Date: 08/01/2025
Author: FFJV WATER
Data Sources: FFJV 2024

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Condamine River

The Project alignment crosses the Condamine River floodplain between Millmerran and Brookstead. The floodplain is formed by three main river branches, including the Condamine River North Branch, the main Condamine River and a southern branch known as Grasstree Creek.

On the Condamine River floodplain, the terrain is flat and the sinuous creek channels begin to break their banks in a 50% AEP event, and then flow between branches in 20% AEP and larger events. Due to the minimal slope throughout the majority of the floodplain, flooding in this area is typically characterised by slow moving flood waters. The Existing Case 1% AEP event inundated width along the Project alignment between Grasstree Creek and Brookstead is approximately 12.5 km.

Under existing conditions, there are multiple pieces of infrastructure impacted by flooding, including the existing QR rail line, multiple State-controlled roads, and various structures including houses and sheds. The existing State-controlled roads within the floodplain, which includes the Gore Highway, Millmerran Leyburn Road and Pampas-Horrane Road, all have low flood immunity.

Under the 1% AEP event, the Existing Case peak depth of water is approximately 8 m in the Condamine River channel, 2 m in the Condamine River North Branch channel, and approximately 5 m deep in the Grasstree Creek channel.

Table 14-16 presents a summary of overtopping depths for the Millmerran Branch Line and key roads near the Project under a range of design events. The 1% AEP event peak water levels are shown in Figure 14-6a.

TABLE 14-16 CONDAMINE RIVER: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

Infrastructure	Location	Approximate overtopping depth (m)					
		1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Gore Highway	D/S of the proposed Main Branch bridge	2.08	1.37	1.18	0.94	0.70	0.39
Millmerran-Leyburn Road	Immediately U/S of the Project alignment	1.86	1.05	0.84	0.67	0.58	0.47
Pampas-Horrane Road	D/S of Project alignment	1.03	0.38	0.30	0.25	0.12	Dry
Existing QR Rail Line ¹	Adjacent to Main Condamine Crossing	1.95	1.30	1.14	0.93	0.72	0.40
Existing QR Rail Line	Adjacent to North Branch Condamine Crossing	1.06	0.89	0.84	0.69	0.45	0.35
Yandilla Grain Silos	Yandilla, immediately U/S of Project alignment	1.11	0.30	0.10	Dry	Dry	Dry

Table notes:

D/S = Downstream

U/S = Upstream

1. The existing QR Millmerran Branch Line across the Condamine River floodplain will be replaced by the Project rail

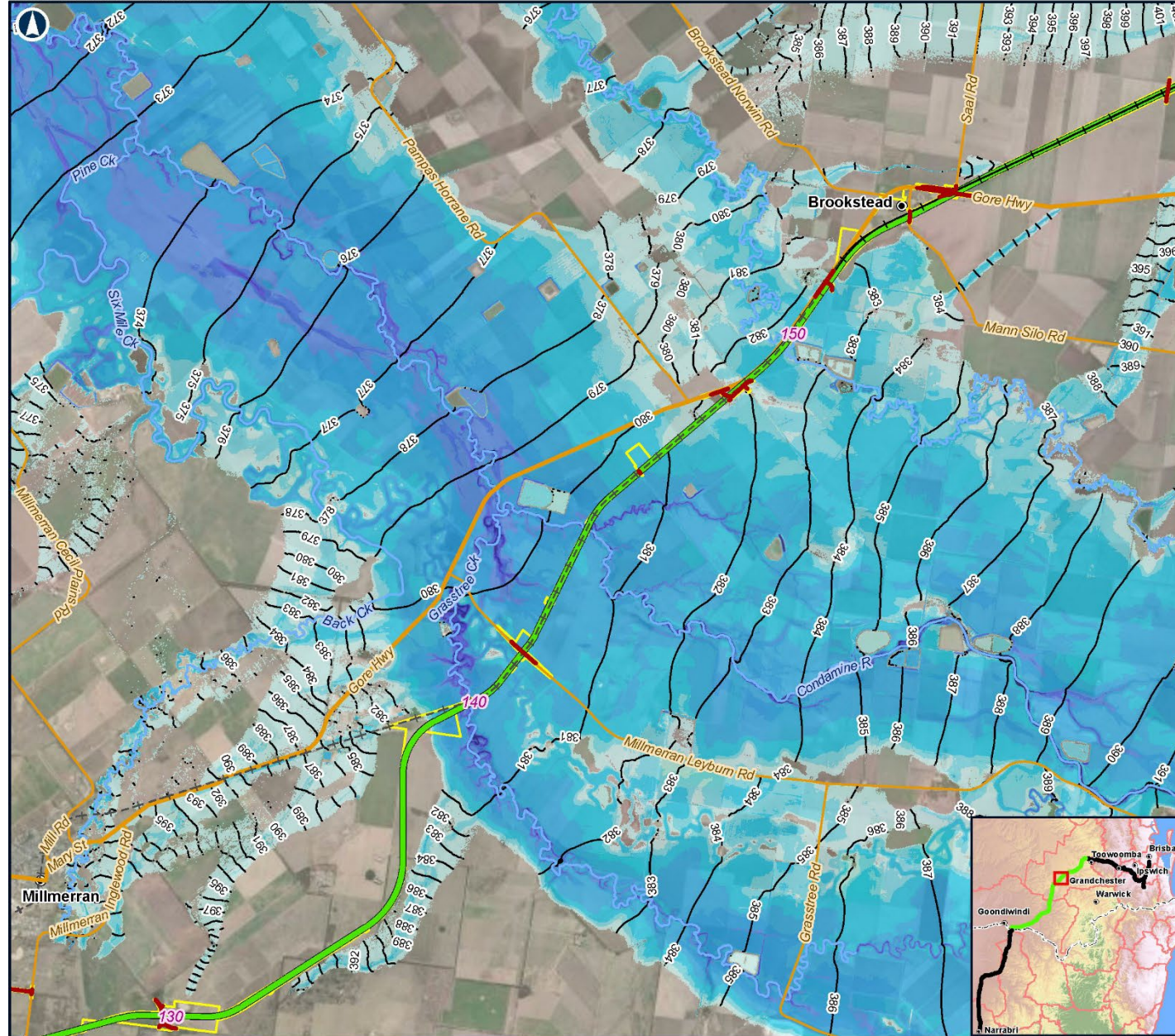
Peak 1% AEP velocities in the Condamine River channel are typically between 1.5 m/s and 2 m/s, around 1 m/s in the Grasstree Creek channel, and less than 1 m/s in the North Branch channel. On the floodplain, velocities are generally in the order of <0.5 m/s as shown in Figure 14-6b.

Peak 1% AEP velocity-depth product within the channels of Condamine River at the Project alignment are in excess of 1 m²/s, with velocity-depth products of between 0.3 m²/s and 1 m²/s across approximately 5 km of the width of the floodplain and 0.3 m²/s across approximately 50 per cent of the width of the floodplain as shown in Figure 14-6c.

Peak 1% AEP time of inundation of the Condamine River floodplain and the Grasstree Creek floodplain are inundated by around 96 to 120 hours (i.e. 4 to 5 days) with floodplain fringes typically inundated by up to 48 hours (i.e. 2 days), as shown on Figure 14-6d. The North Branch floodplain is inundated by around 72 to 96 hours (i.e. 3 to 4 days) with floodplain fringes typically inundated by up to 48 hours (i.e. 2 days).

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-6a:
Existing Case - 1% AEP Peak water levels
Condamine River

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Existing rail (non-operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  1m water surface contour (mAHD)

Estimated water depth (m)

- | | |
|--|---|
|  0 - 0.25 |  2.5 - 3.0 |
|  0.25 - 0.5 |  3.0 - 3.5 |
|  0.5 - 1.0 |  3.5 - 4.0 |
|  1.0 - 1.5 |  4.0 - 4.5 |
|  1.5 - 2.0 |  4.5 - 5.0 |
|  2.0 - 2.5 |  > 5.0 |

Impact assessment area

-  Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025

Author: FFJV WATER

Data Sources: FFJV 2024

Paper: A4

Scale: 1:110,000

Map by: JA/DTH Z:\GIS\GIS_310_B2\GIS\310-IHY-2022\1212154_Chapter_14_EIS_Figures\310-IHY-2022\1212154_ARTC_F14_Xx_EX_Depth_v4.mxd Date: 9/01/2025 14:25

BORDER TO GOWRIE

Figure 14-6b:
Existing Case - 1% AEP Peak velocities
Condamine River

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- +— Existing rail (operational)
- +- Existing rail (non-operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

Estimated velocity (m/s)

- | | |
|-----------|-----------|
| 0.0 - 0.5 | 3.0 - 3.5 |
| 0.5 - 1.0 | 3.5 - 4.0 |
| 1.0 - 1.5 | 4.0 - 4.5 |
| 1.5 - 2.0 | 4.5 - 5.0 |
| 2.0 - 2.5 | > 5.0 |
| 2.5 - 3.0 | |

Impact assessment area

- ☐ Project footprint

Coordinate System: GDA 1994 MGA Zone 56

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Paper: A4

Scale: 1:110,000

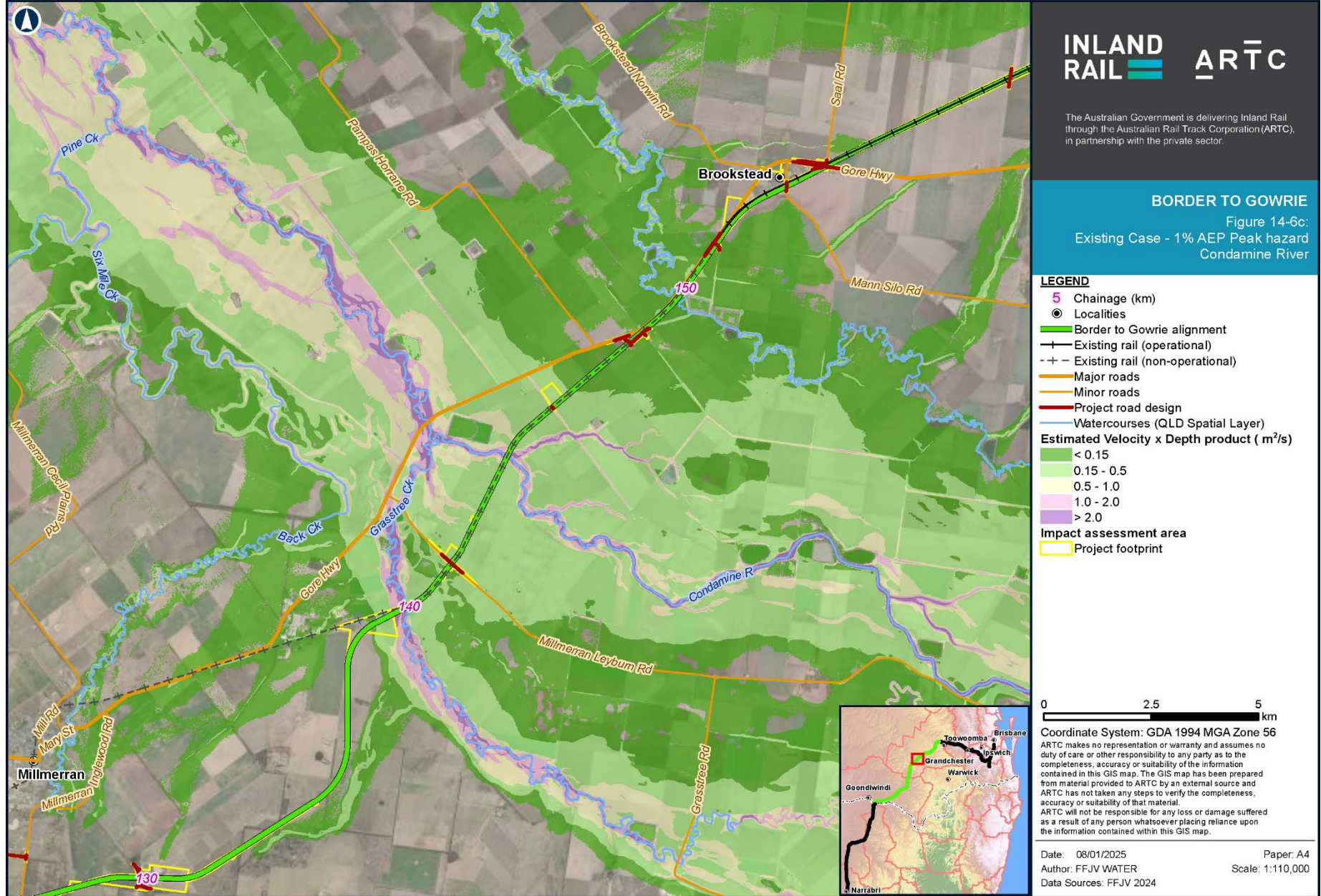


Figure 14-6d:
Existing Case - 1% AEP
Peak time of inundation
Condamine River

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- + Existing rail (operational)
- + - Existing rail (non-operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

0 - 10	60 - 70
10 - 20	70 - 80
20 - 30	80 - 90
30 - 40	90 - 100
40 - 50	> 100
50 - 60	

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Paper: A4
Scale: 1:110,000

Back Creek

The Project alignment crosses Back Creek as well as one of its small tributaries. Back Creek is a narrow and meandering system, that, under the 1% AEP event, has flood depths of up to 5.4 m in its main channel. The flood depths along the Project alignment range from 0.5 m to 1.5 m through the floodplain crossings, with a depth of 4.6 m at the Project crossing of the Back Creek channel. The 1% AEP inundated floodplain varies between 300 m and 2.3 km wide.

Table 14-17 presents a summary of overtopping depths for Millmerran–Inglewood Road and the Gore Highway, under a range of design events. The 1% AEP event peak water levels are shown in Figure 14-7a.

TABLE 14-17 BACK CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

Infrastructure	Location	Approximate overtopping depth (m)					
		1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	Approximately 1,400 m D/S of the Project alignment	1.24	0.98	0.95	0.85	0.71	0.57
Gore Highway	Approximately 3 km D/S of the Project alignment	0.92	0.62	0.57	0.48	1.88	0.30

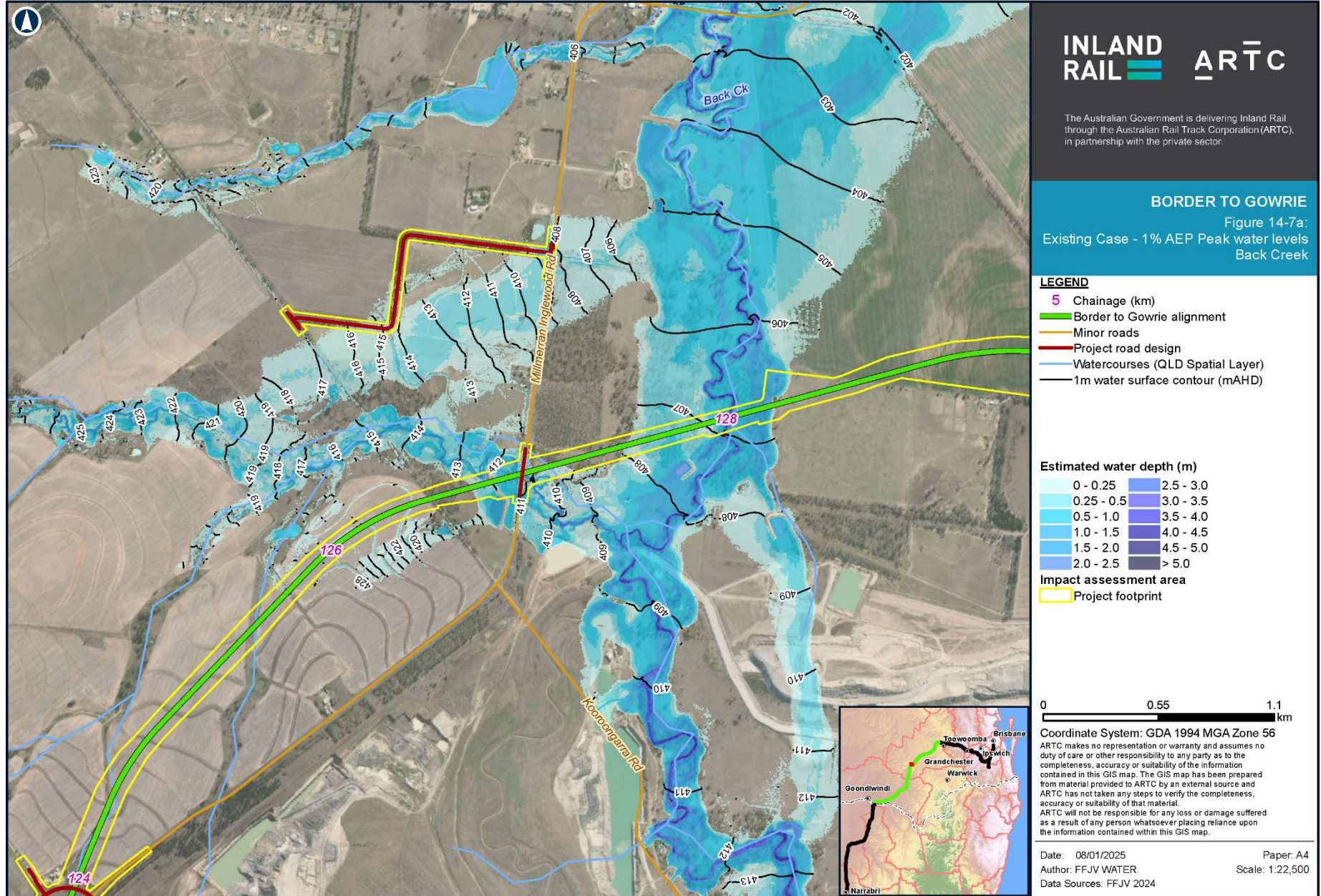
Table note:
D/S = Downstream

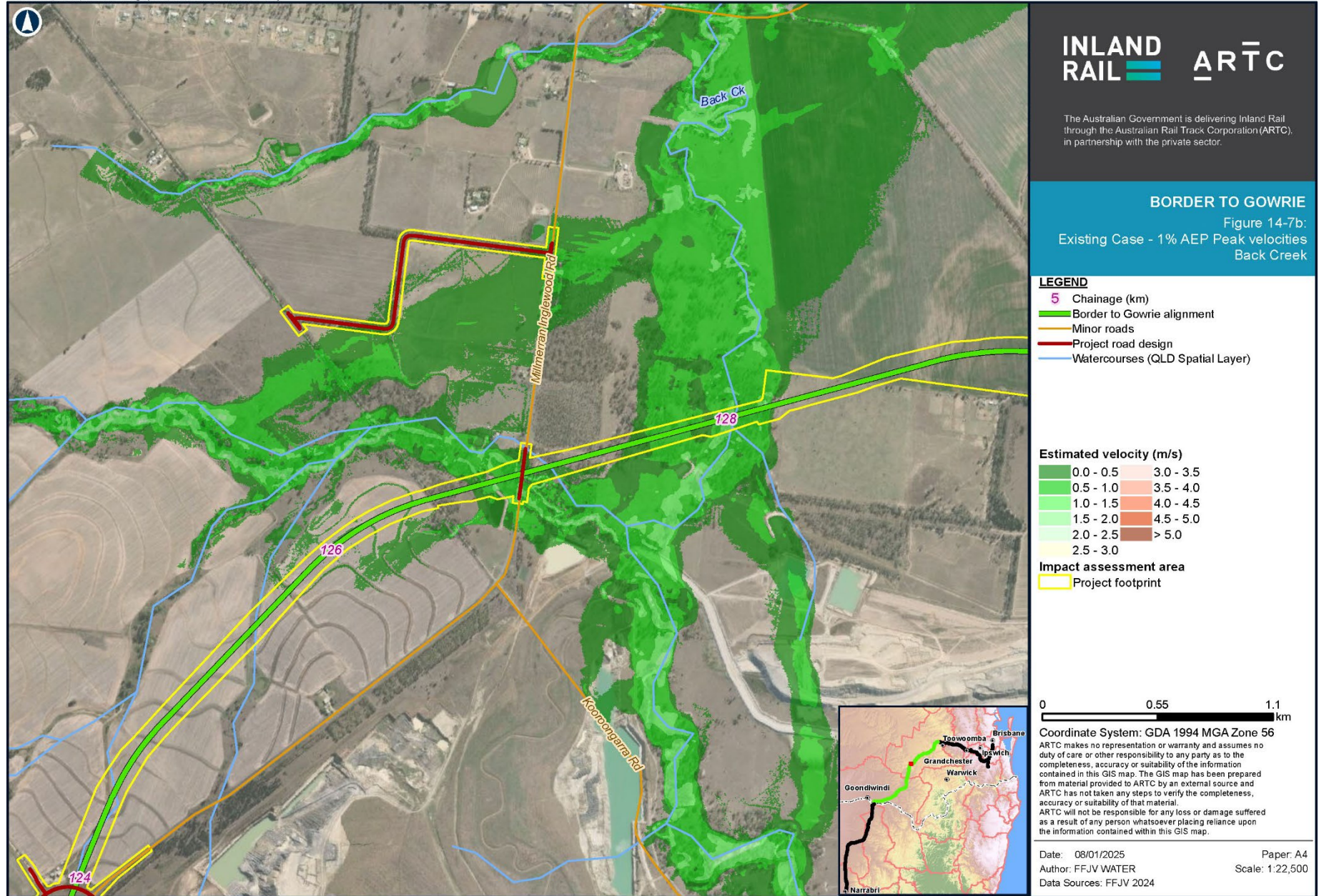
Peak 1% AEP velocities are expected to reach between 1 m/s and 2 m/s in the Back Creek channel. The average velocity across the floodplain is approximately 0.6 m/s. Typical values remain below 0.5 m/s in shallower areas of the floodplain, and from 0.8 m/s to 1 m/s in minor flow channels (e.g. minor channels) as shown in Figure 14-7b.

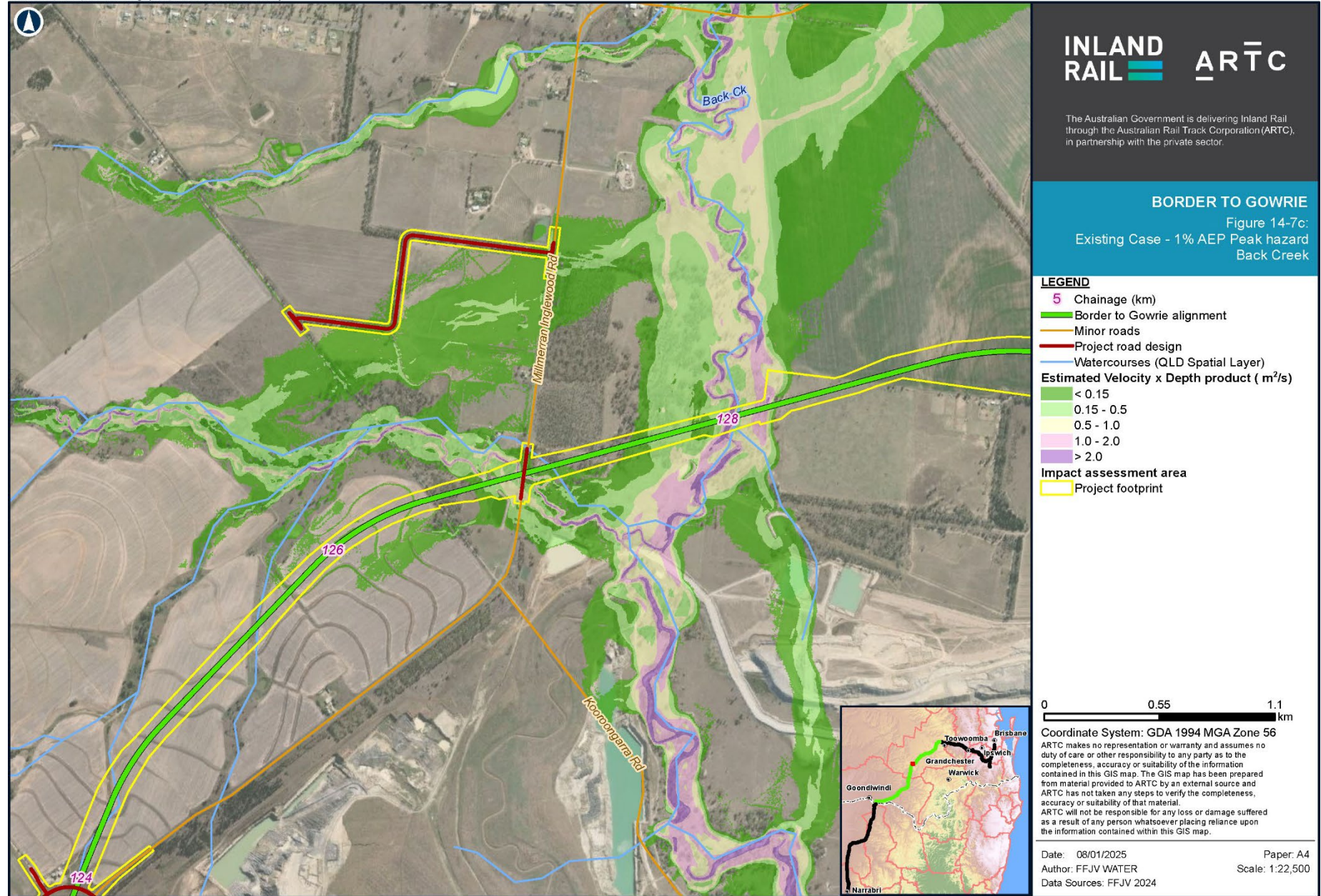
Peak 1% AEP hazard (i.e. velocity-depth product) within the channels of Back Creek at the Project alignment are in excess of 2 m²/s within the main Back Creek channel, and secondary tributaries. Peak hazard values in the vicinity of the Project exceed 4 m²/s. Flood hazard values outside of the main channels are typically less than 0.5 m²/s as shown in Figure 14-7c.

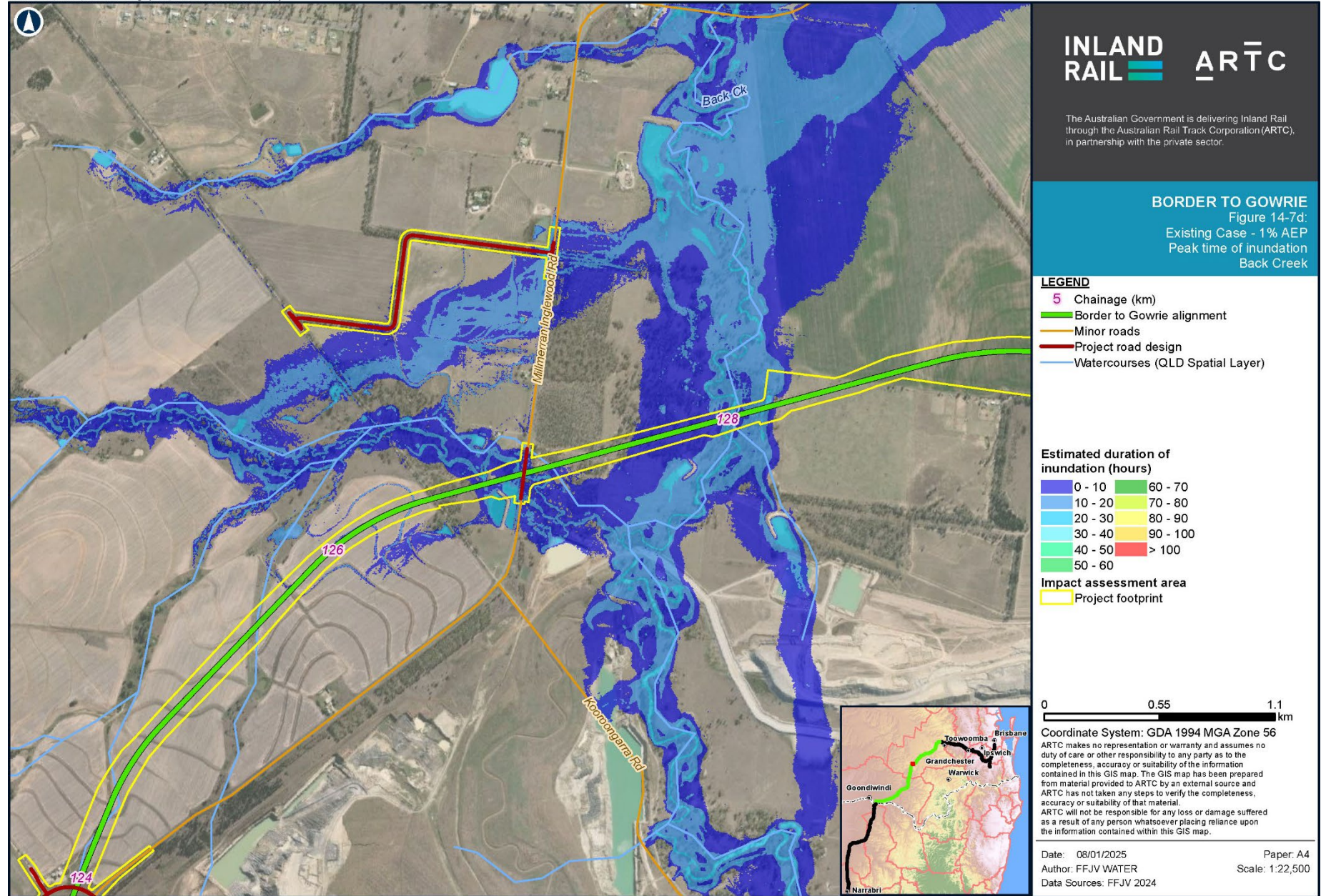
Time of inundation along the floodplain fringes (i.e. low flow areas) are typically inundated for less than 5 hours as shown in Figure 14-7d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.









Nicol Creek

The Project alignment crosses Nicol Creek approximately 350 m east of Millmerran–Inglewood Road. Nicol Creek is a narrow and meandering system with depths in a 1% AEP event of between 2 m and 4 m within the main channel, and between 0.3 m and 1 m in breakout areas. At the Project alignment, the 1% AEP Existing Case flood depths are approximately 1.7 m.

Nicol Creek is a defined creek in terms of channel depths and banks and the flood extents under the 1% AEP event remain in proximity to the creek alignment. The 1% AEP inundated floodplain varies between 50 m and 200 m wide.

Table 14-18 presents a summary of overtopping depths of Millmerran–Inglewood Road, near the Project, under a range of design events. The 1% AEP event peak water levels are shown in Figure 14-8a.

TABLE 14-18 NICOL CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	2.63	2.33	2.16	1.97	1.92	1.46

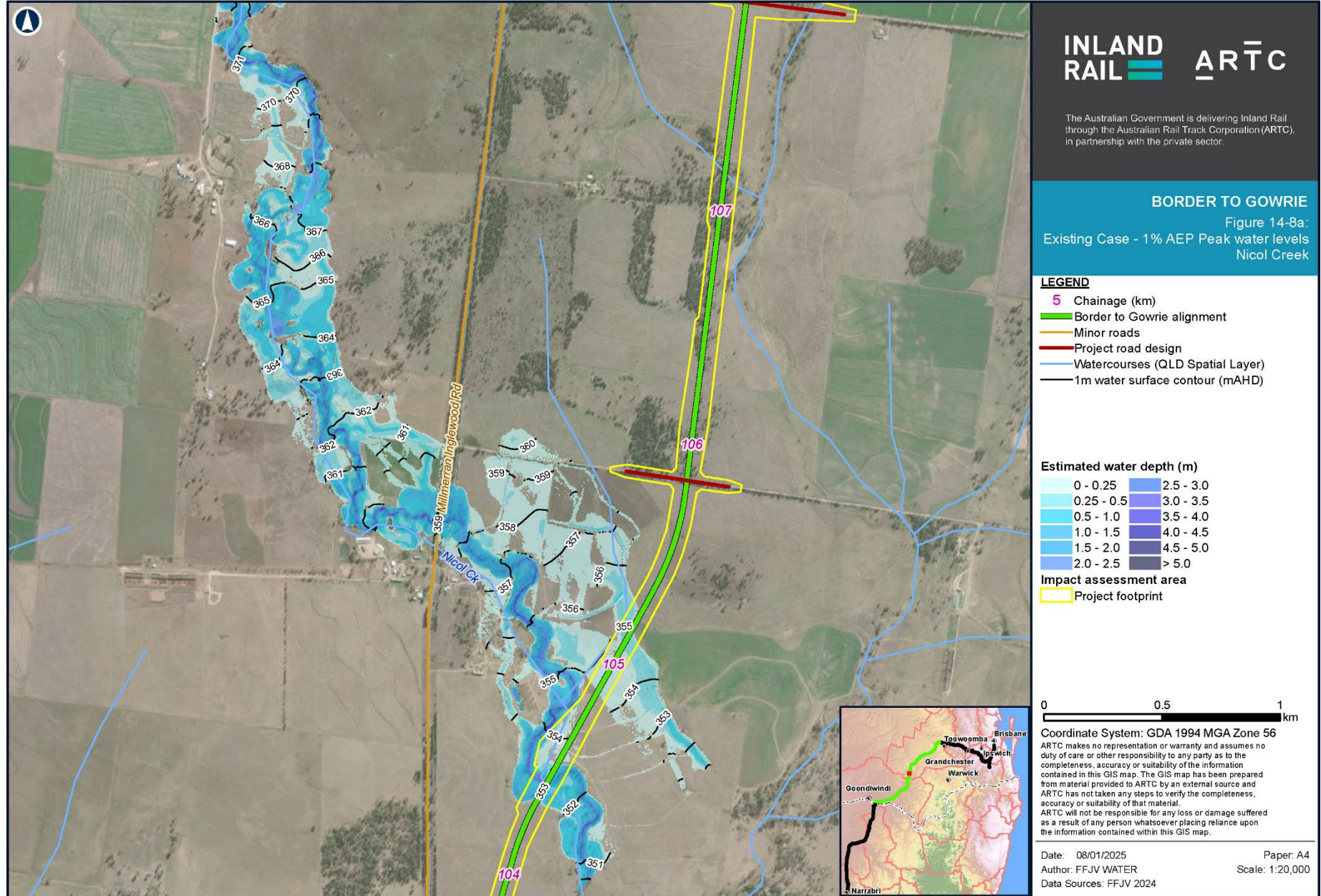
Peak flood velocities are predicted to reach up to 2.8 m/s upstream of the proposed bridge crossing, and within Nicol Creek. For the 1% AEP flood event, flood water breaks out of the main channel downstream of Millmerran–Inglewood Road and enters the broader floodplain. The average velocity across the floodplain is approximately 0.25 m/s as shown in Figure 14-8b.

Peak 1% AEP event hazard (i.e. velocity-depth product) of approximately 6 to 7 m²/s is recorded within Nicol Creek, approximately 200 m upstream of the proposed bridge crossing. Excluding the channelised high flow zones, flow along the floodplain north of Nicol Creek immediately upstream of the Project alignment has average depth-velocity product of less than 0.5 m²/s as shown in Figure 14-8c.

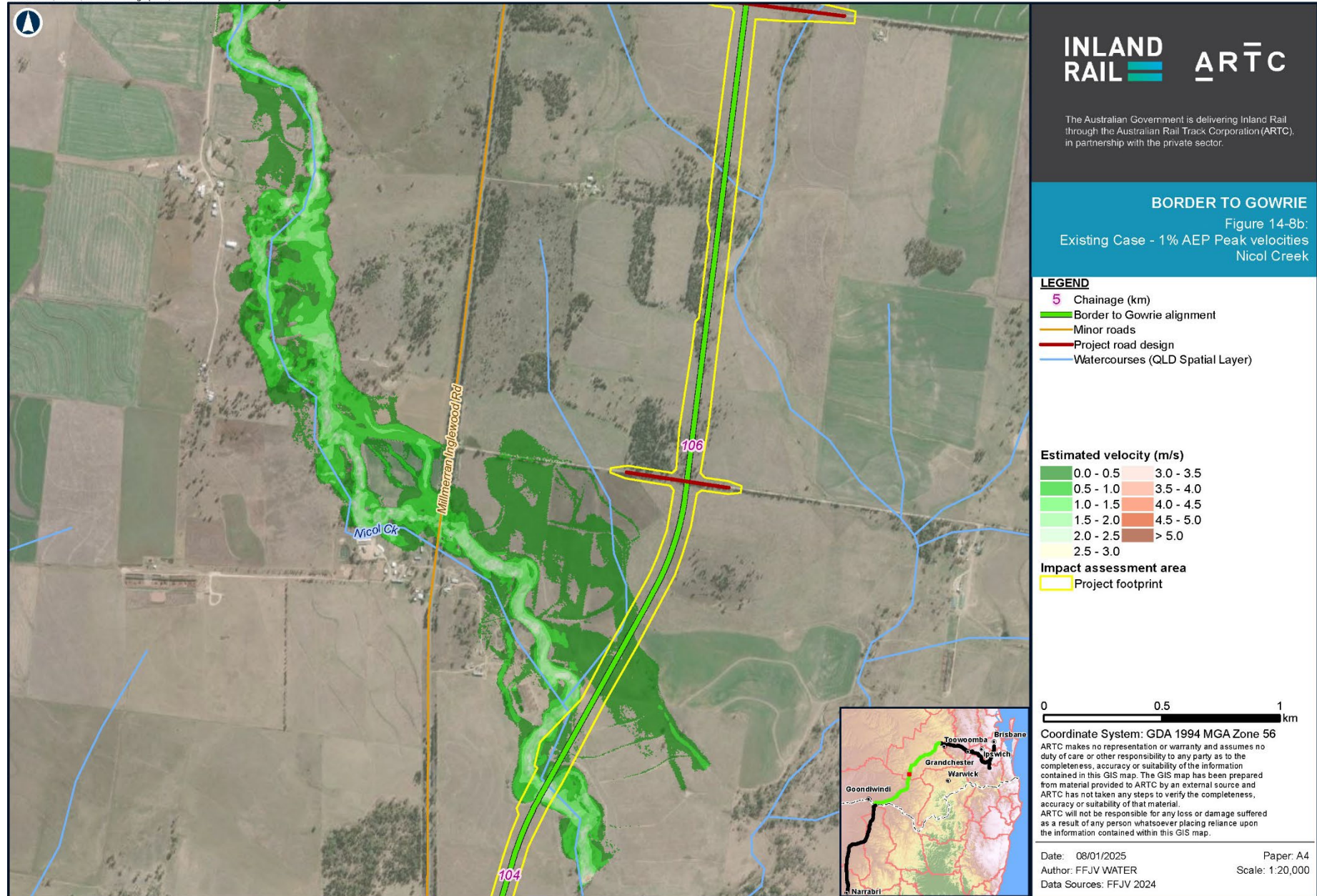
Peak 1% AEP time of inundation within the Nicol Creek channel are generally in the order of 5 to 11 hours. On the floodplain, time of inundation is generally in the order of 5 to 8 hours as shown in Figure 14-8d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

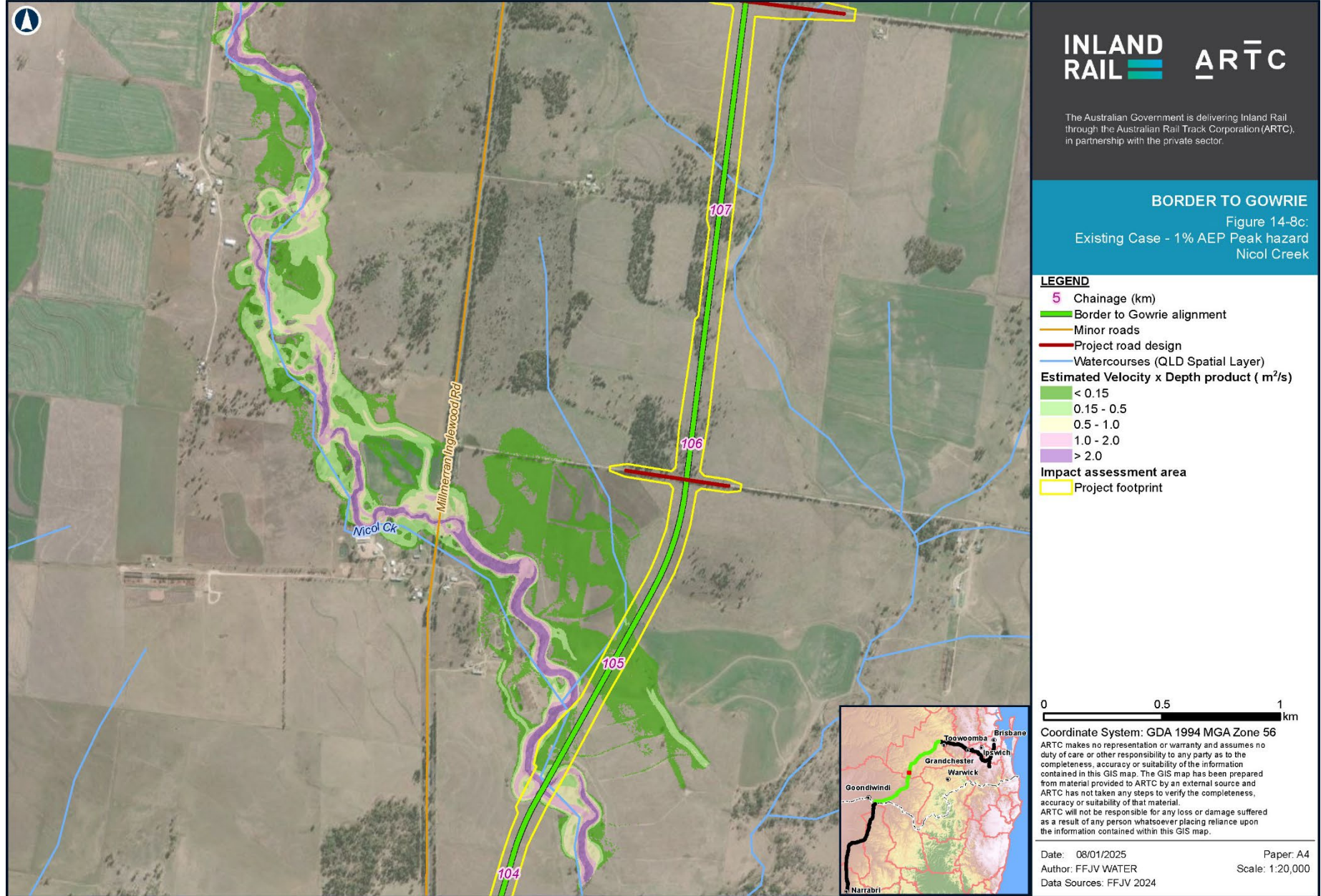


Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



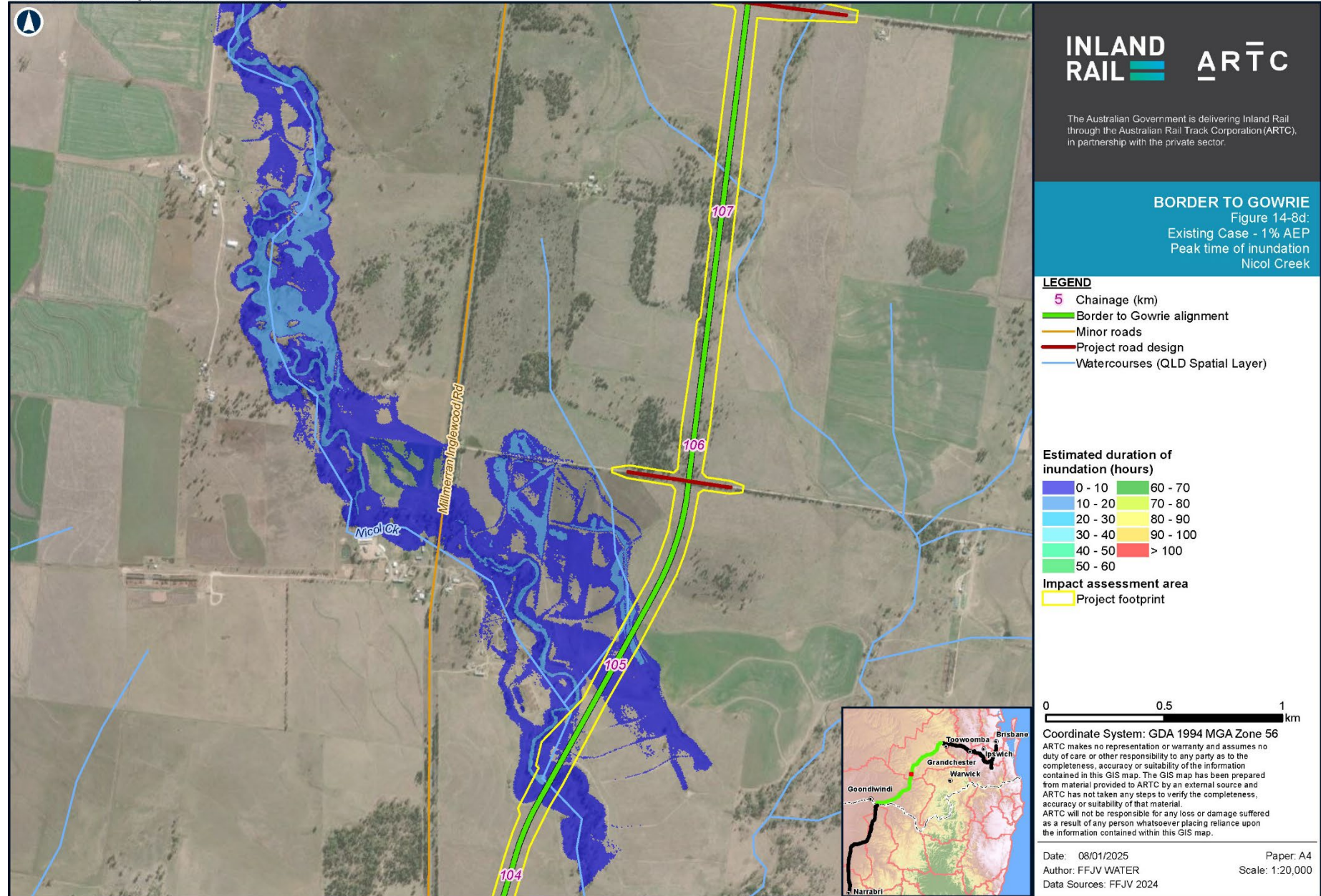
Map by: JA/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-2022\11212154_Chapter_14_EIS_Figures\310-IHY-2022\11212154_ARTC_F14_Xx_EX_Velocity_v4.mxd Date: 9/01/2025 14:29

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Map by: JA/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202211212154_Chapter_14_EIS_Figures\310-IHY-202211212154_ARTC_F14_Xx_EX_PeakHazard_v4.mxd Date: 9/01/2025 14:27

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Map by: JA/DTH Z:\GIS\GIS_310_B2\GISTasks\310-IHY-202211212154_Chapter_14_EIS_Figures\310-IHY-202211212154_ARTC_F14_Xx_EX_PeakInundationTime_v4.mxd Date: 9/01/2025 14:28

Bringalily Creek

Bringalily Creek is a well-defined water course with high sinuosity and is an upstream tributary of Canning Creek. Under the Existing Case 1% AEP event, the flood depth in Bringalily Creek channel is up to approximately 7.5 m. This depth reduces to an average modelled flood depth of around 1 m in other areas of the floodplain. The Bringalily Creek flood inundation extent, under the Existing Case 1% AEP event, varies between 500 m and 1.2 km wide.

Table 14-19 presents a summary of overtopping depths for key roads near the Project under a range of design events. The Existing Case 1% AEP event peak water levels are shown in Figure 14-9a.

TABLE 14-19 BRINGALILY CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

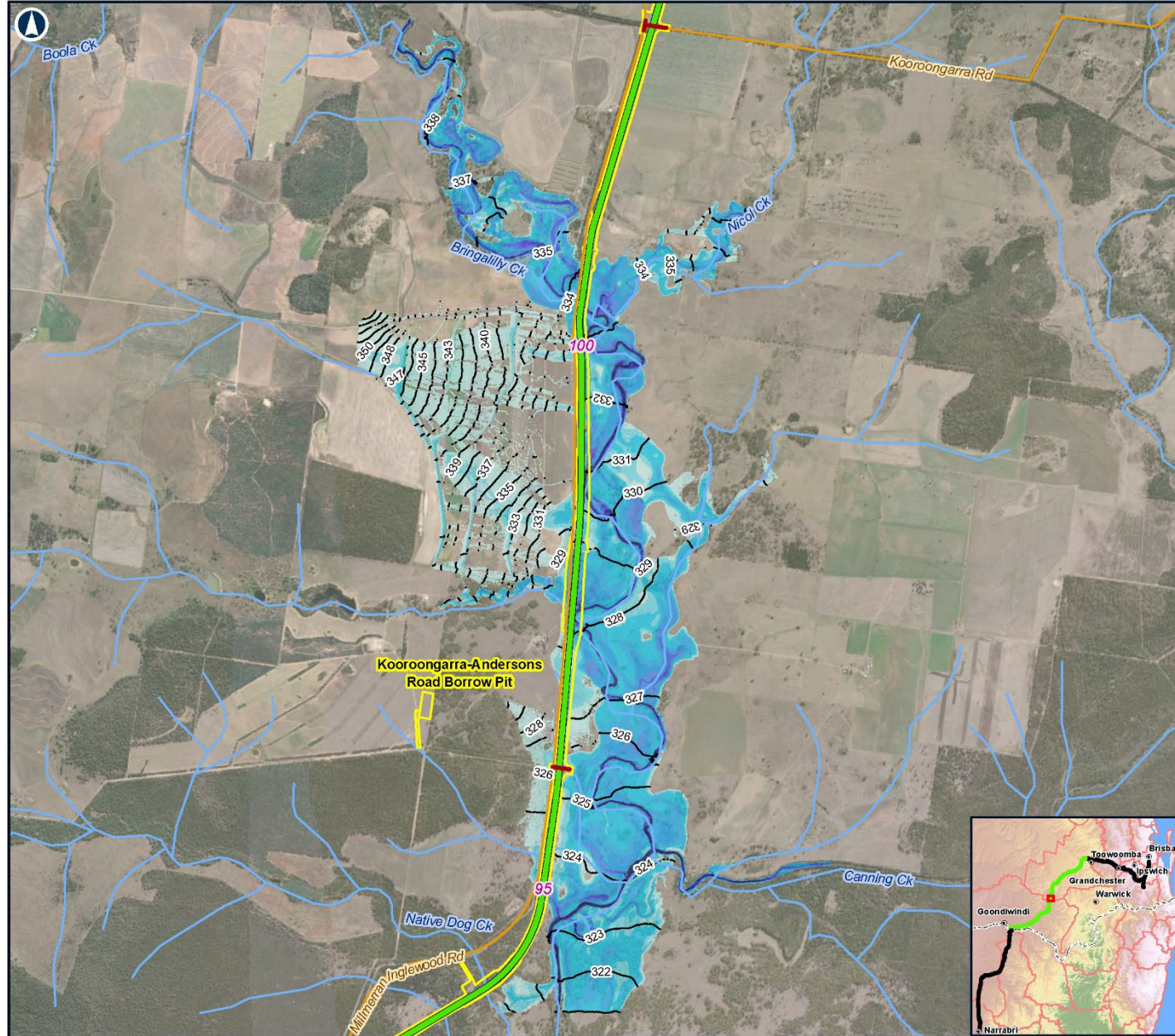
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road (middle)	1.48	0.92	0.81	0.27	0.16	0.11
Millmerran–Inglewood Road (south)	0.14	0.05	0.07	0.04	0.03	0.03
Millmerran–Inglewood Road (north)	1.77	1.24	1.14	0.57	0.27	Dry
Heckles Road	1.20	0.75	0.70	0.54	0.45	0.39
Forestry Road	0.31	0.26	0.34	0.23	0.21	0.20

Peak 1% AEP event flood velocities are predicted to reach 5.0 m/s in localised areas and confined within the main channel with average velocities on the floodplain of approximately 0.6 m/s as shown in Figure 14-9b.

For the 1% AEP event, a velocity-depth product of $>9 \text{ m}^2/\text{s}$ is achieved within the existing bridge crossing. Excluding the channelised high flow zones, sheet flow in the floodplains west of Millmerran-Inglewood Road have an average velocity-depth product of less than $0.5 \text{ m}^2/\text{s}$ as shown in Figure 14-9c.

Results for the 1% AEP event highlights flood water inundating areas upstream of Millmerran-Inglewood Road for periods greater than 10 hours. The profile also highlights ponding areas created by farming activities and existing road infrastructure as shown in Figure 14-9d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.



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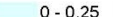
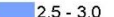
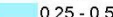
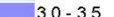
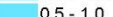
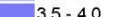
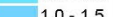
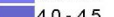
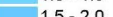
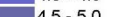
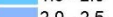
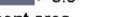
BORDER TO GOWRIE

Figure 14-9a:
Existing Case - 1% AEP Peak water levels
Bringalilly Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  1m water surface contour (mAHD)

Estimated water depth (m)

- | | |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| |  |

Impact assessment area

-  Project footprint

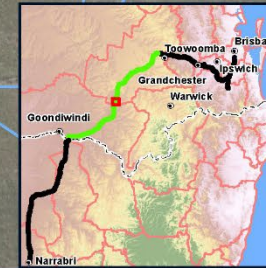
0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

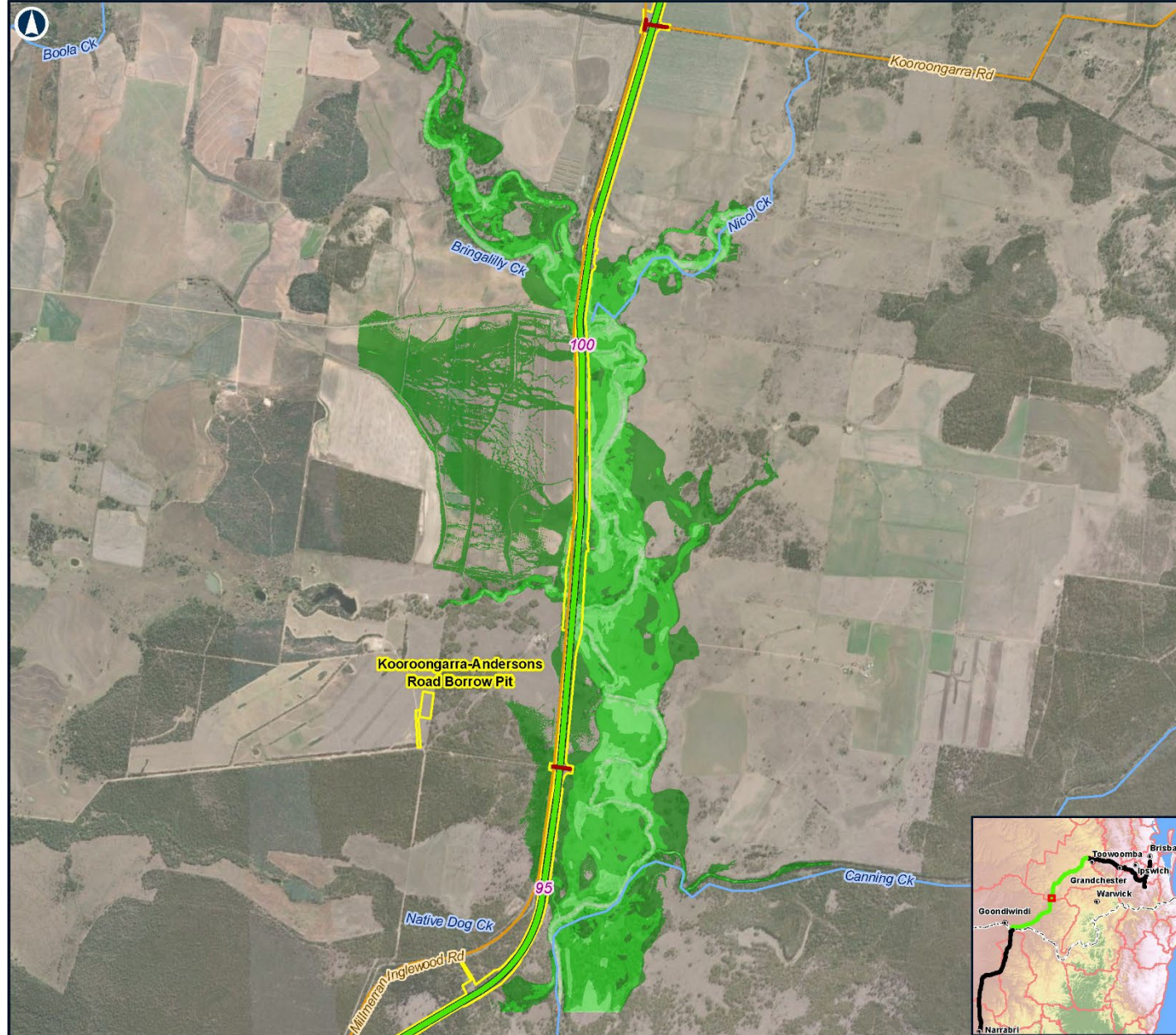
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Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
Scale: 1:50,000



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-9b:
Existing Case - 1% AEP Peak velocities
Bringalily Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated velocity (m/s)

	0.0 - 0.5		3.0 - 3.5
	0.5 - 1.0		3.5 - 4.0
	1.0 - 1.5		4.0 - 4.5
	1.5 - 2.0		4.5 - 5.0
	2.0 - 2.5		> 5.0
	2.5 - 3.0		

Impact assessment area

-  Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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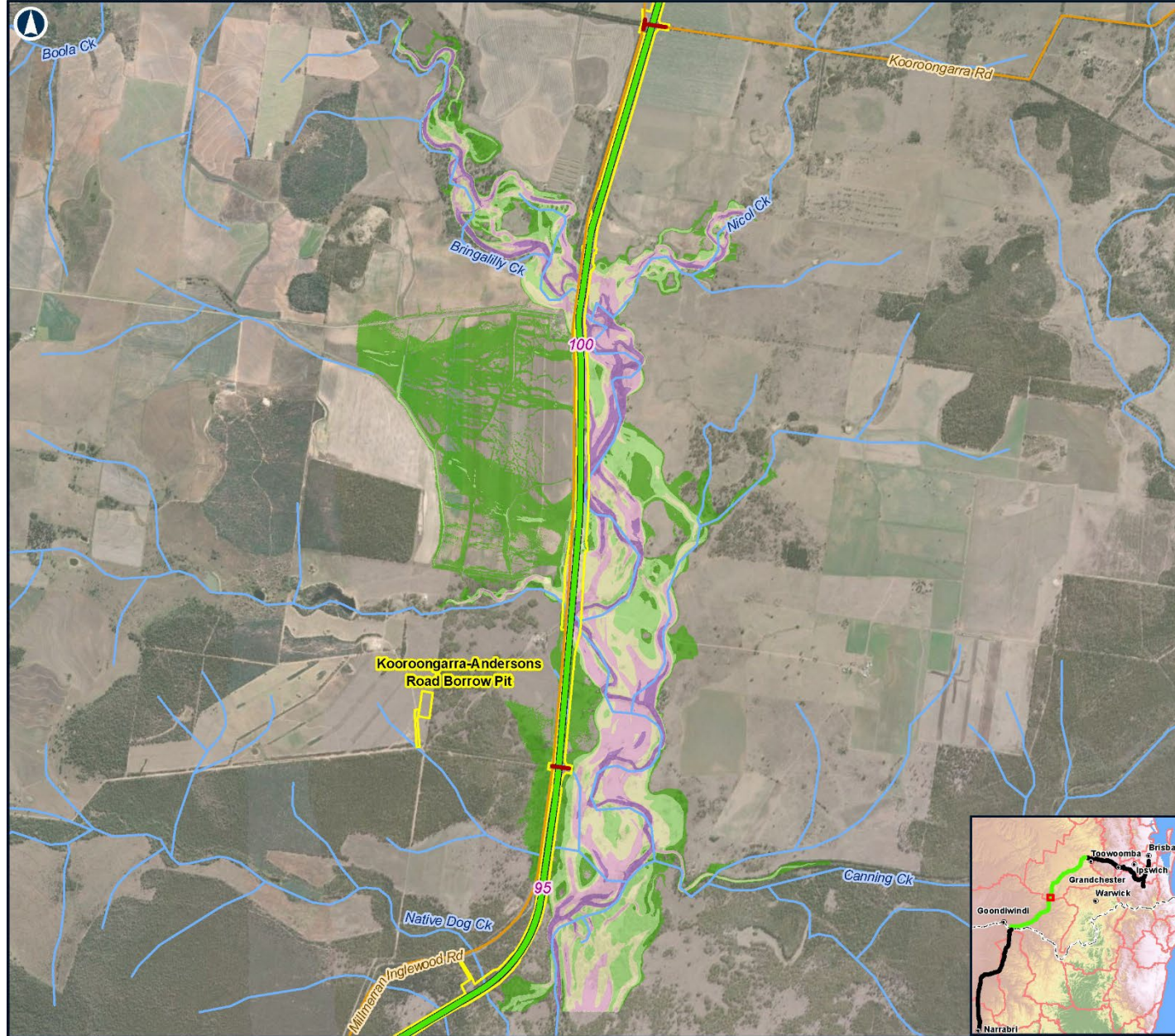
Author: FFJV WATER

Data Sources: FFJV 2024

Paper: A4

Scale: 1:50,000

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BORDER TO GOWRIE

Figure 14-9c:
Existing Case - 1% AEP Peak hazard
Bringalilly Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
- Estimated Velocity x Depth product (m²/s)**
 -  < 0.15
 -  0.15 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  > 2.0
- Impact assessment area**
 -  Project footprint

0 1 2
km

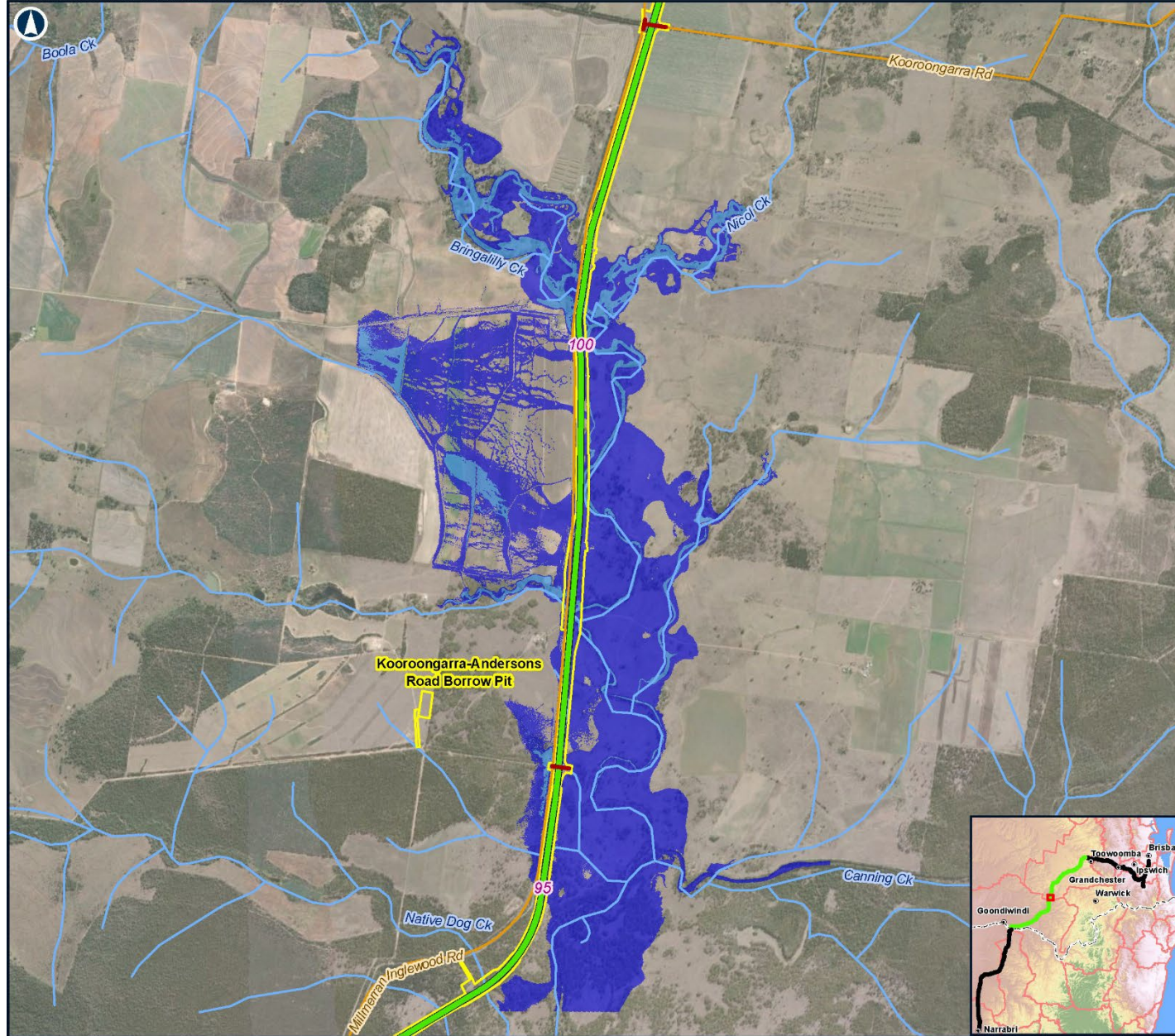
Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025
Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
Scale: 1:50,000

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE Figure 14-9d: Existing Case - 1% AEP Peak time of inundation Bringailly Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated duration of inundation (hours)

- | | |
|---|--|
|  0 - 10 |  60 - 70 |
|  10 - 20 |  70 - 80 |
|  20 - 30 |  80 - 90 |
|  30 - 40 |  90 - 100 |
|  40 - 50 |  > 100 |
|  50 - 60 | |

Impact assessment area

-  Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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Map by: JA/DTH Z:\GIS\GIS_310_B2\GISTasks\310-HY-202211212154_Chapter_14_EIS_Figures\310-HY-202211212154_ARTC_F14_Xx_EX_PeakInundationTime_v4.mxd Date: 9/01/2025 14:28

Native Dog Creek

Native Dog Creek is a well-defined watercourse with well-vegetated overbank areas. Native Dog Creek crosses Millmerran–Inglewood Road and is an upstream tributary of Canning Creek.

Under the 1% AEP event, the flood depth in the Native Dog Creek channel is up to approximately 3.2 m and around 1 m on the floodplain area. The floodplain inundated extent is approximately 580 m wide.

Table 14-20 presents a summary of overtopping depths for Millmerran–Inglewood Road, near the Project, under a range of design events. The 1% AEP flood levels are shown in Figure 14-10a.

TABLE 14-20 NATIVE DOG CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

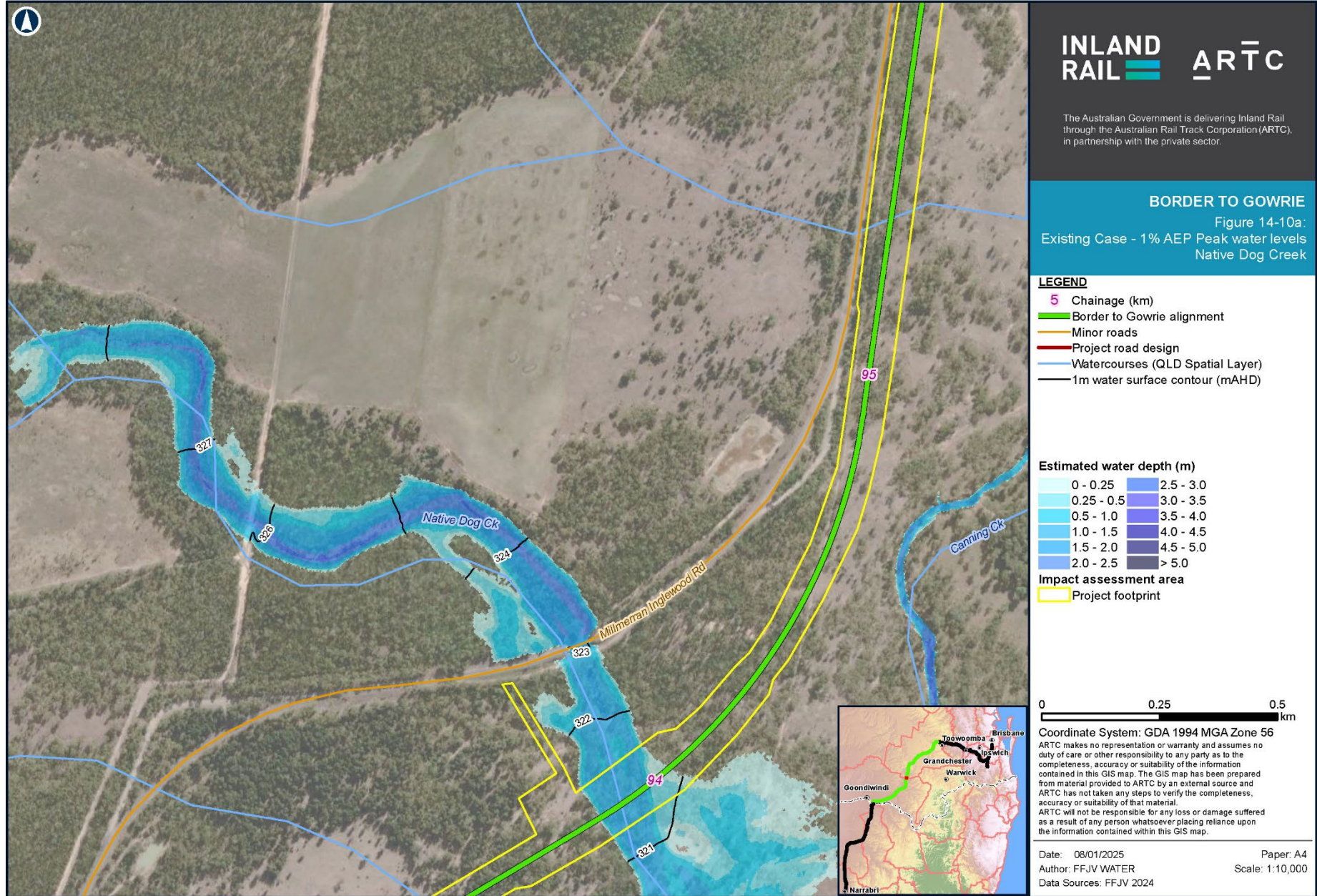
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	2.18	1.68	1.42	1.13	0.98	0.88

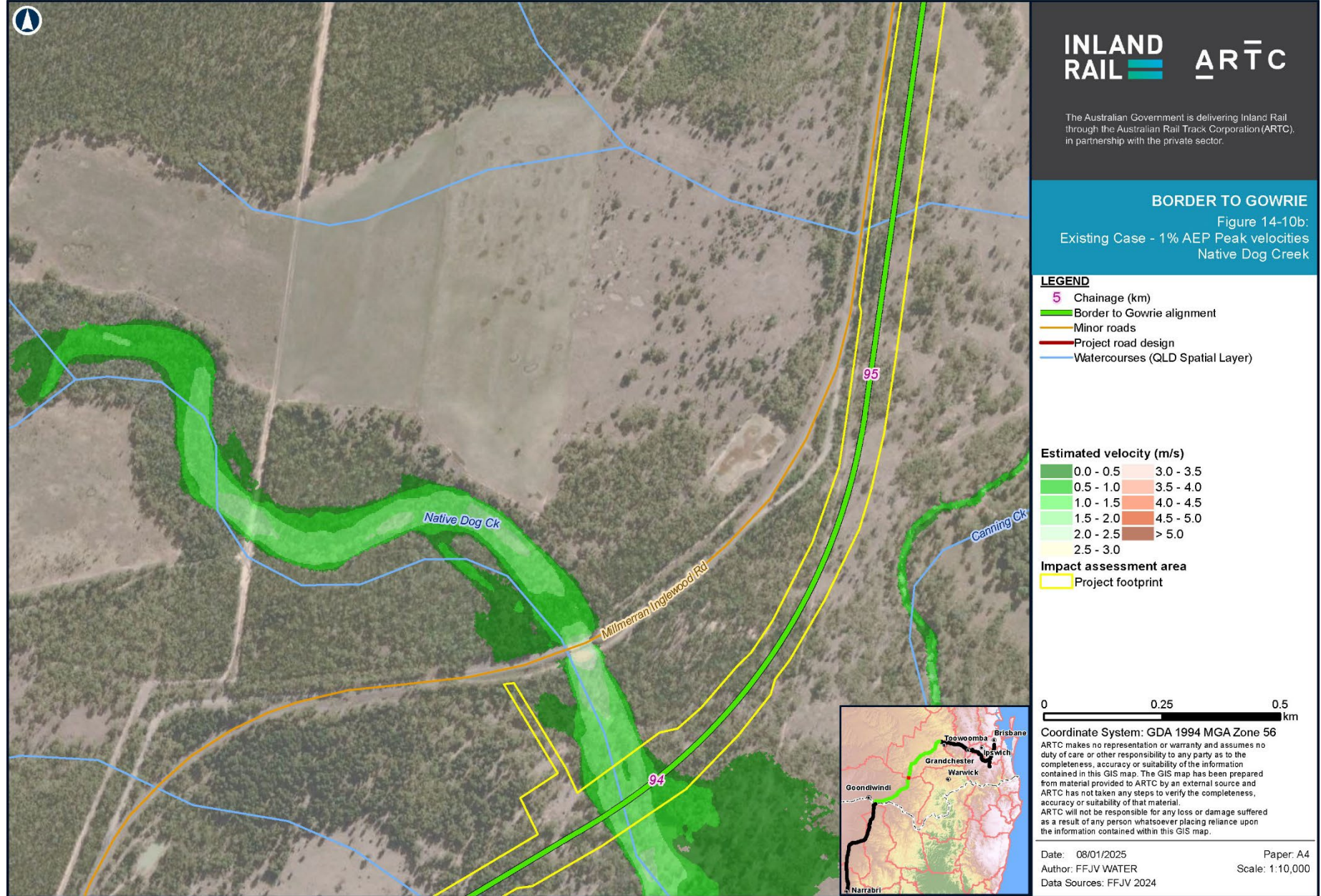
Peak 1% AEP flood velocities are expected to reach up to 3.1 m/s in localised areas, while the average velocity across the floodplain is approximately 0.9 m/s, as shown in Figure 14-10b.

Peak 1% AEP hazard (i.e. velocity-depth product) within the channels of Native Dog Creek at the Project alignment are in the order of 1.5 m²/s to 2.5 m²/s, and on the floodplain velocity-depth product are generally in the order of 0.3 m²/s to 0.7 m²/s as shown in Figure 14-10c.

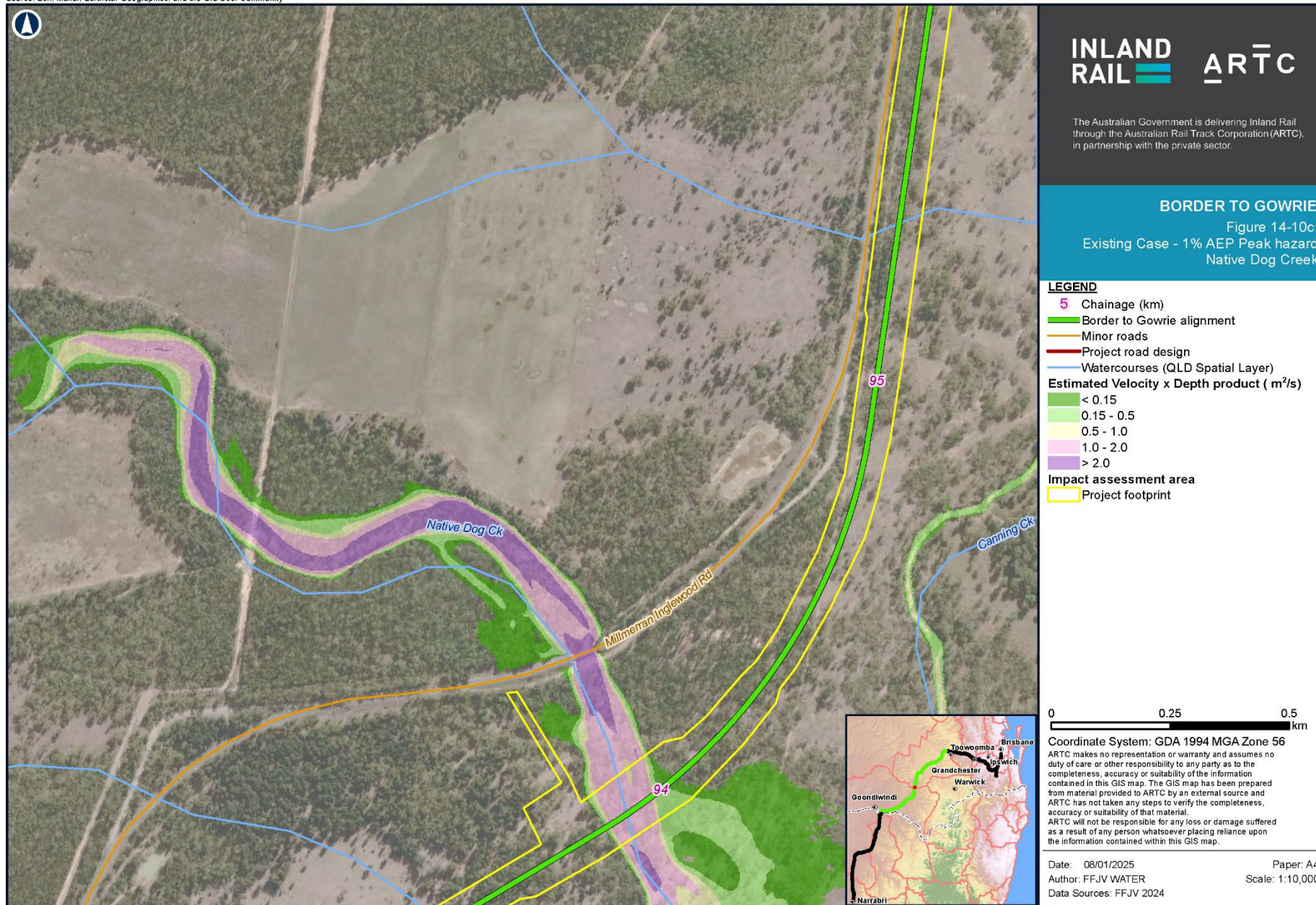
Peak 1% AEP time of inundation within the Native Dog Creek channel are generally in the order of 3 to 4 hours. On the floodplain, time of inundation is generally in the order of 2 to 3 hours as shown in Figure 14-10d.

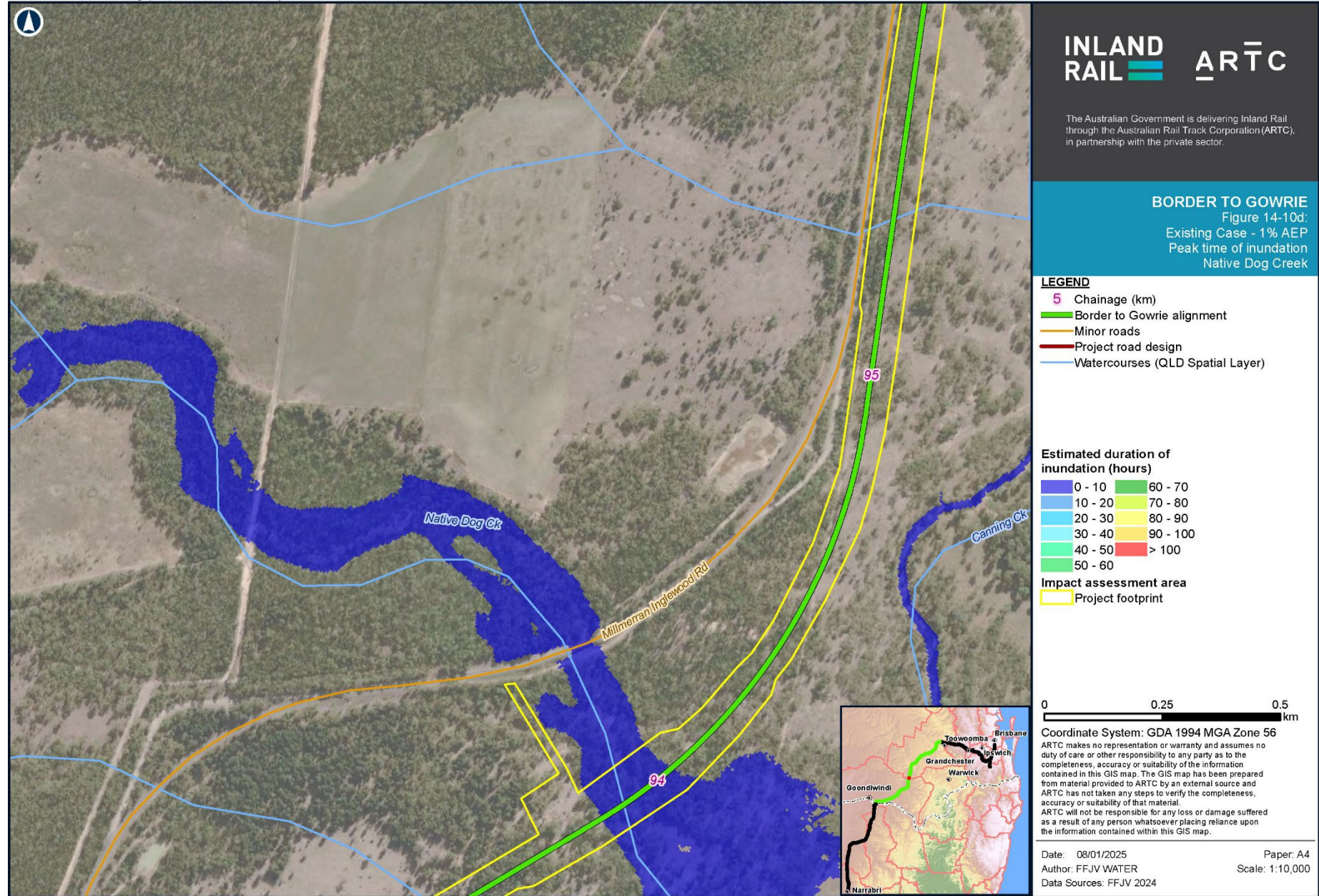
The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.





Map by: JA/DTH Z:\GIS\GIS_310_B2GITasks\310-IHY-202211212154_Chapter_14_EIS_Figures\310-IHY-202211212154_ARTC_F14_Xx_EX_Velocity_v4.mxd Date: 9/01/2025 14:29





Cattle Creek

Cattle Creek is a well-defined watercourse with minor breakout flow paths in the meandering sections of the creek. The creek system has well-vegetated overbank areas, which assists flow to remain within the main channel rather than breaking into overbank areas.

Under the 1% AEP event, the flood depth in Cattle Creek channel is up to 4.5 m and around 1.5 m on the floodplain area. The floodplain inundated extent is approximately 100 m wide.

Table 14-21 presents a summary of overtopping depths for Millmerran–Inglewood Road, near the Project, under a range of design events. The 1% AEP flood levels are shown in Figure 14-11a.

TABLE 14-21 CATTLE CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

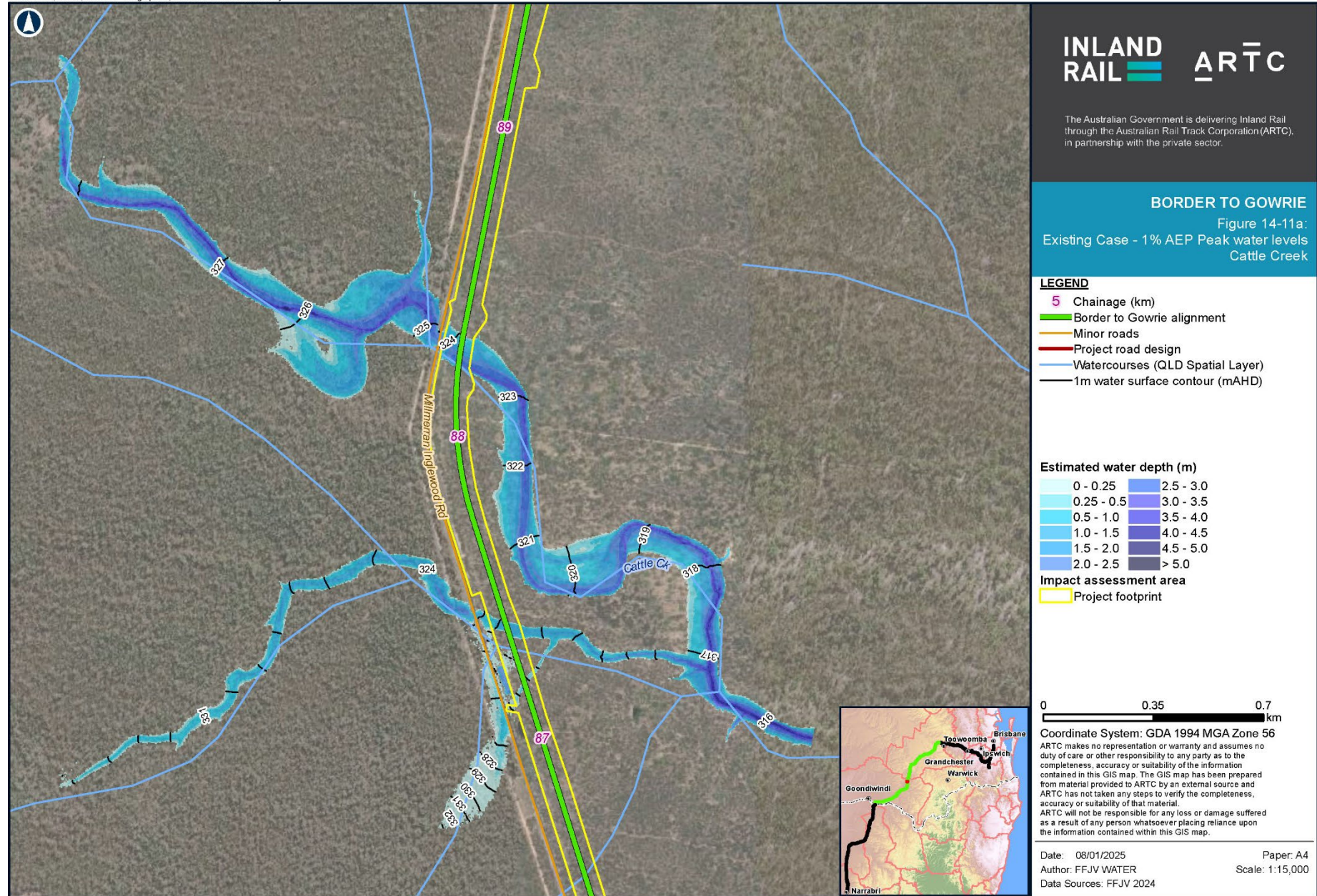
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	3.13	2.51	2.15	1.80	1.57	1.37

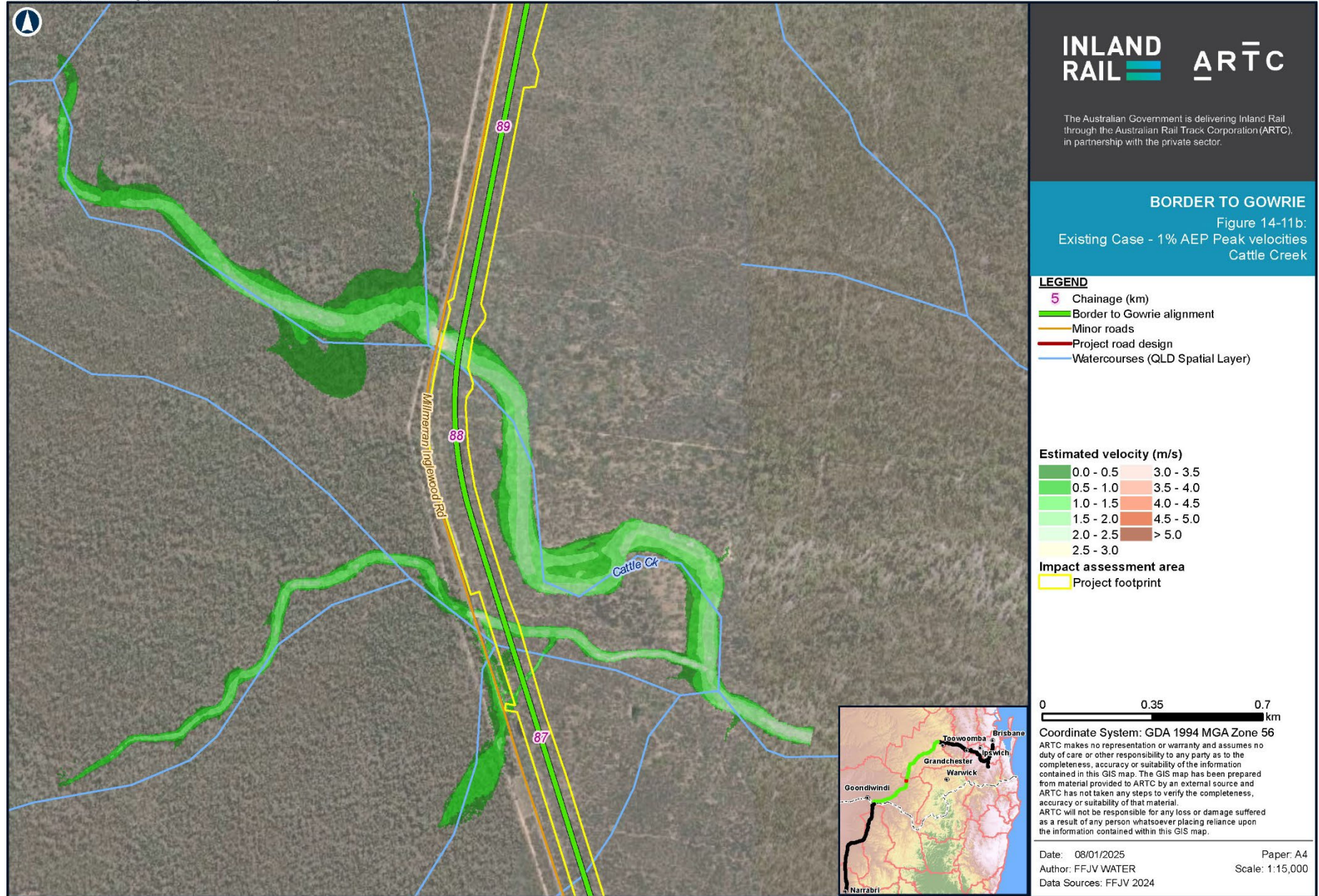
Peak 1% AEP velocities are expected to reach up to 3.5 m/s in localised areas of the main creek channel, while the average velocity across the floodplain is approximately 0.9 m/s as shown in Figure 14-11b.

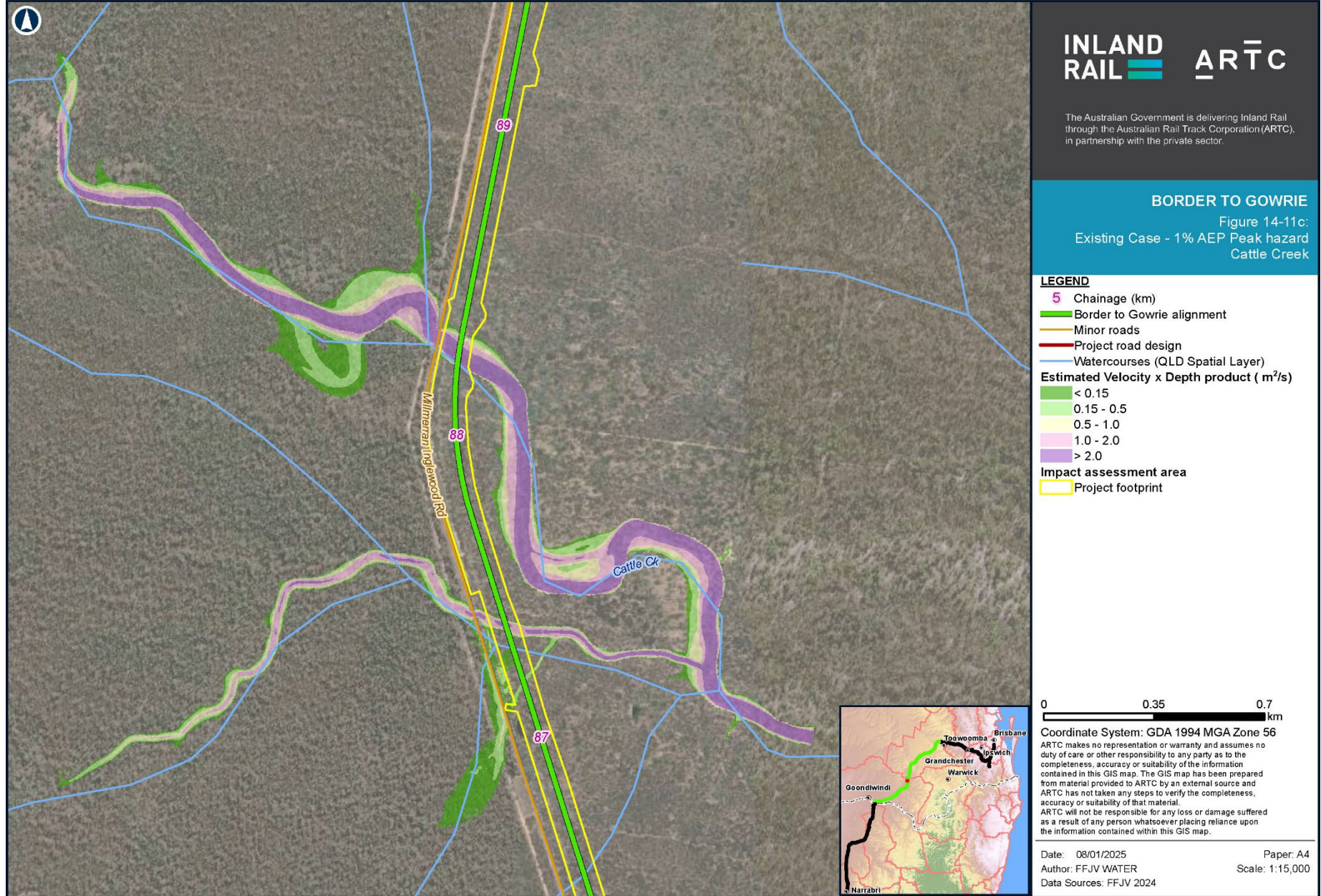
Peak 1% AEP hazard (i.e. velocity-depth product) within the channels of Cattle Creek at the Project alignment are in the order of 4.0 m²/s to 4.5 m²/s, and on the floodplain velocity-depth product are generally in the order of 0.3 m²/s to 0.6 m²/s as shown in Figure 14-11c.

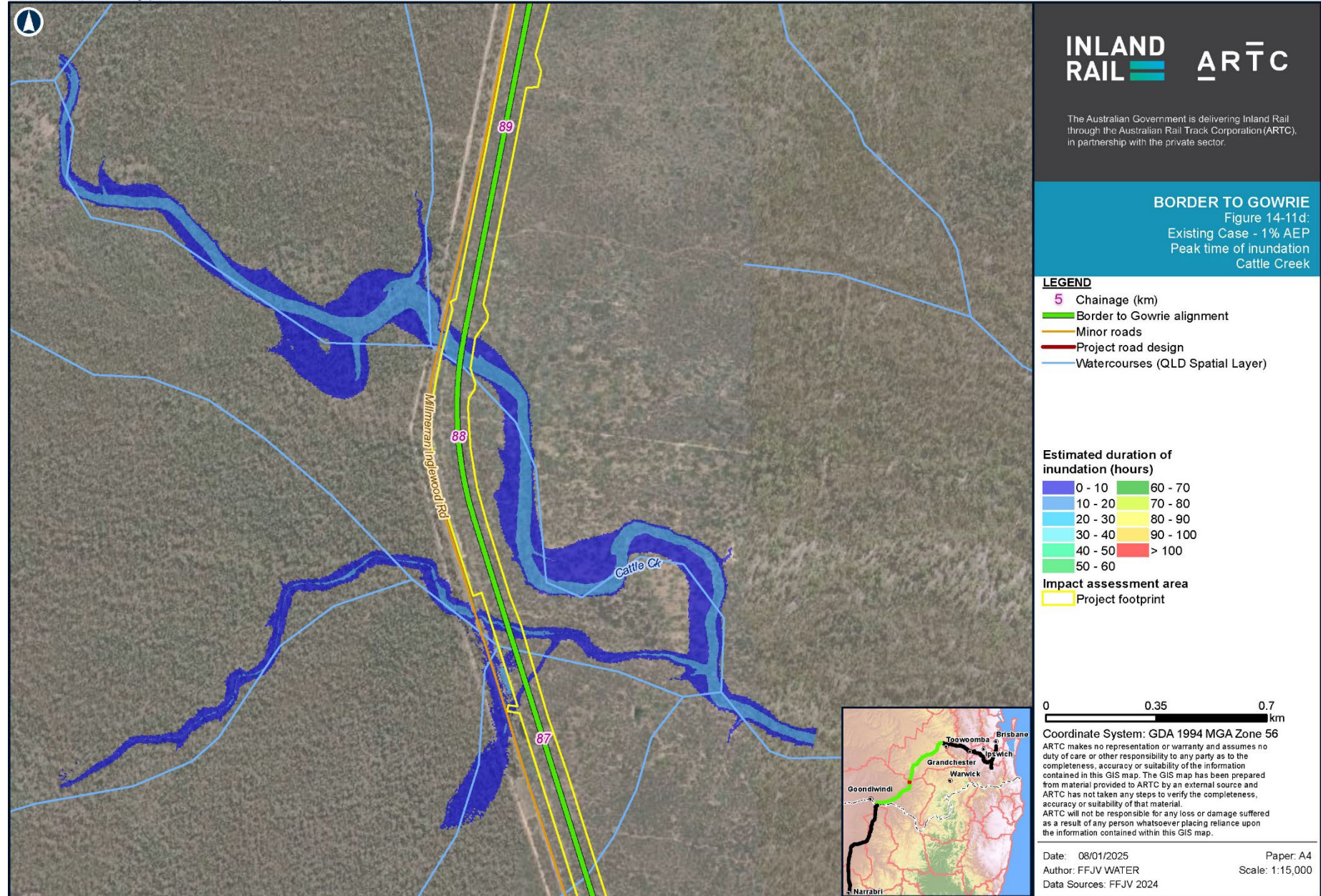
Peak 1% AEP time of inundation within the Cattle Creek channel are generally in the order of 10 to 12 hours. On the floodplain, time of inundation is generally in the order of 5 to 9 hours as shown in Figure 14-11d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.









Pariagara Creek

Portions of Pariagara Creek and smaller tributaries are well-defined channels containing runoff from the adjacent hills; however, closer to the Project, the terrain flattens out and, consequently, more overland flow occurs. This is particularly prevalent between the Project alignment and Millmerran–Inglewood Road, where the topography is relatively flat and less vegetated.

Under the 1% AEP event, the flood depth in the Pariagara Creek channel is up to approximately 6 m and approximately 1.9 m on average on the floodplain area. The floodplain inundated extent is approximately 2.7 km wide where the Project alignment crosses.

Table 14-22 presents a summary of overtopping depths for key roads near the Project under a range of design events. The 1% AEP flood levels are shown in Figure 14-12a.

TABLE 14-22 PARIAGARA CREEK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

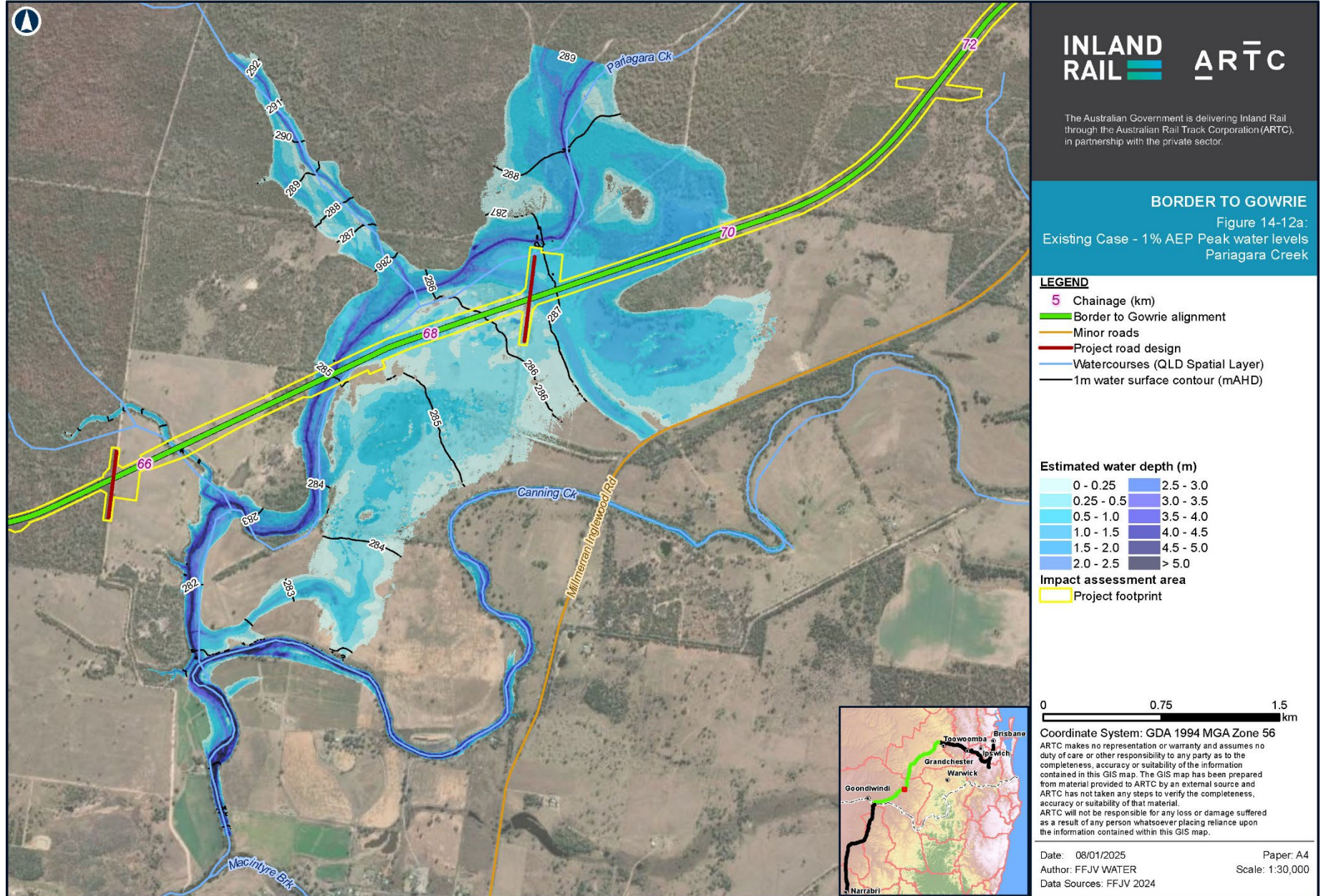
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	0.14	Dry	Dry	Dry	Dry	Dry
Thornton Road	4.35	4.06	3.95	3.76	3.58	3.36

Peak 1% AEP velocities are expected to reach up to 4.9 m/s in localised areas, while the average velocity across the floodplain is approximately 0.5 m/s as shown in Figure 14-12b.

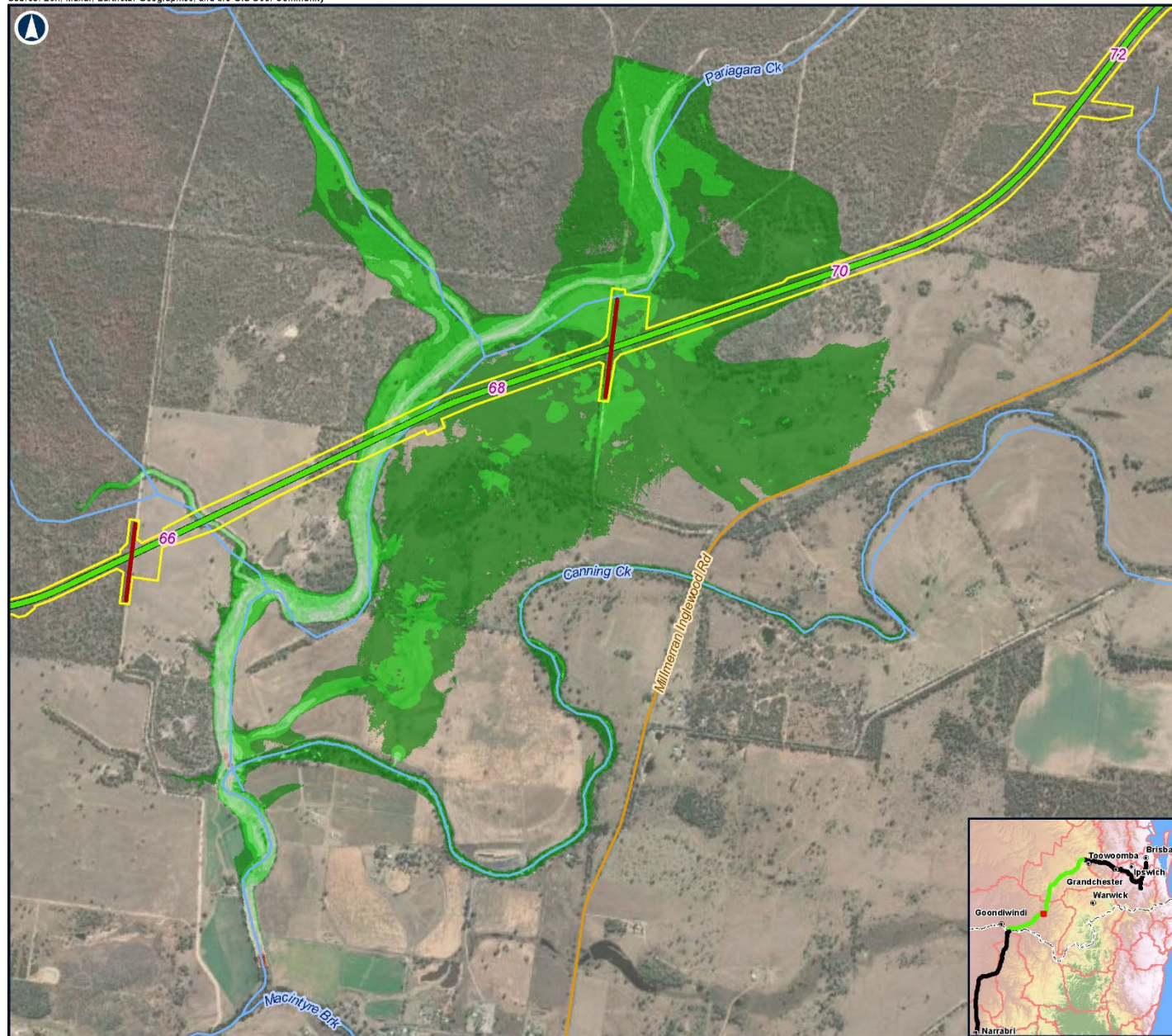
Peak 1% AEP hazard (i.e. velocity-depth product) within the channels of Pariagara Creek at the Project alignment are in the order of 9 m²/s, and on the floodplain velocity-depth product are generally in the order of 0.5 m²/s as shown in Figure 14-12c.

Peak 1% AEP time of inundation upstream of Millmerran–Inglewood Road for a period greater than 10 hours. On the floodplain, time of inundation is generally in the order of 10 to 18 hours as shown in Figure 14-12d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-12b:
Existing Case - 1% AEP Peak velocities
Pariagara Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated velocity (m/s)

- | | | | |
|---|-----------|---|-----------|
|  | 0.0 - 0.5 |  | 3.0 - 3.5 |
|  | 0.5 - 1.0 |  | 3.5 - 4.0 |
|  | 1.0 - 1.5 |  | 4.0 - 4.5 |
|  | 1.5 - 2.0 |  | 4.5 - 5.0 |
|  | 2.0 - 2.5 |  | > 5.0 |
|  | 2.5 - 3.0 | | |

Impact assessment area

-  Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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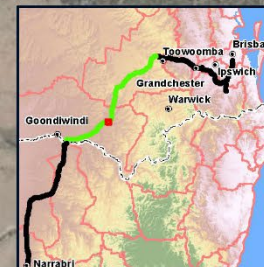
Author: FFJV WATER

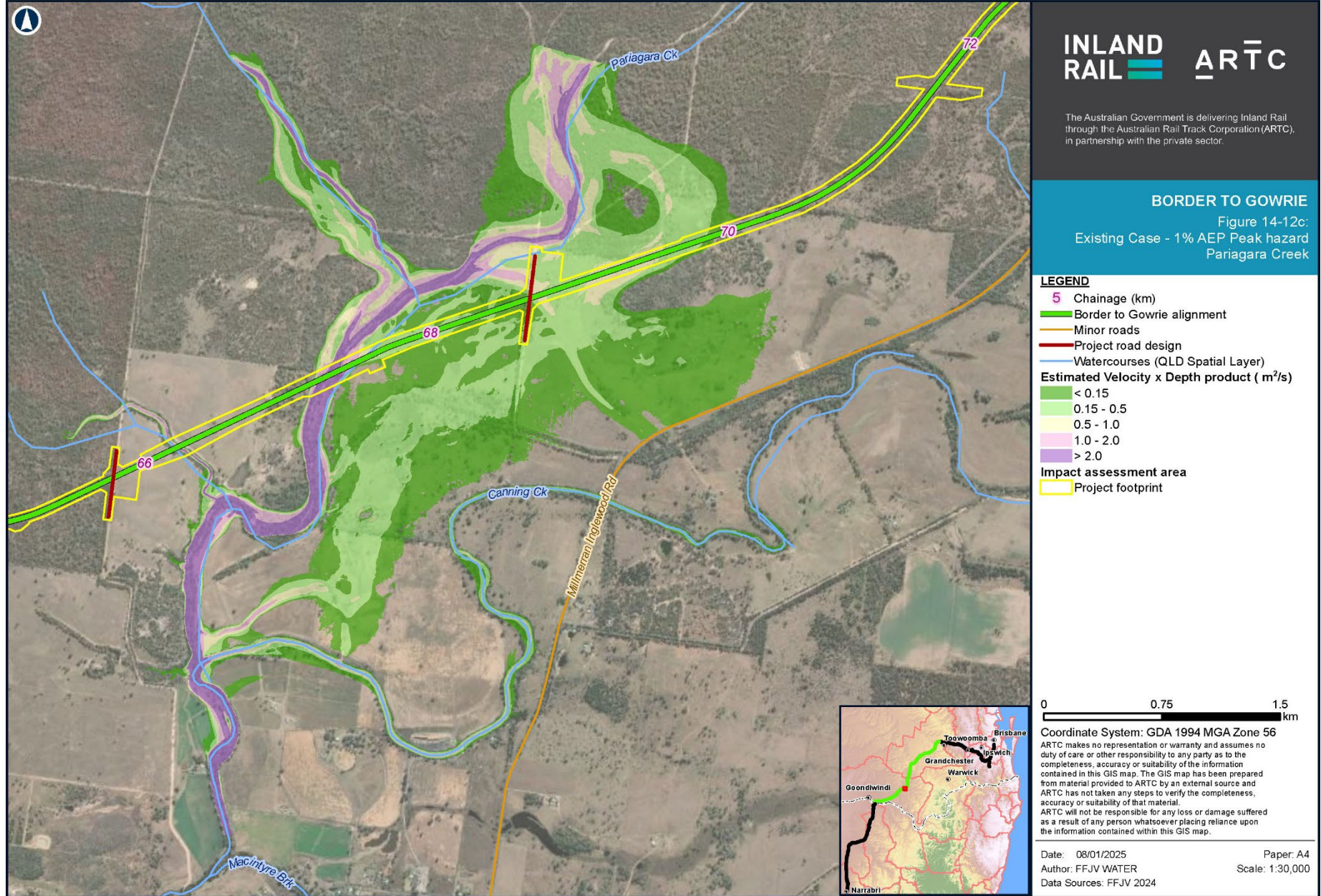
Data Sources: FFJV 2024

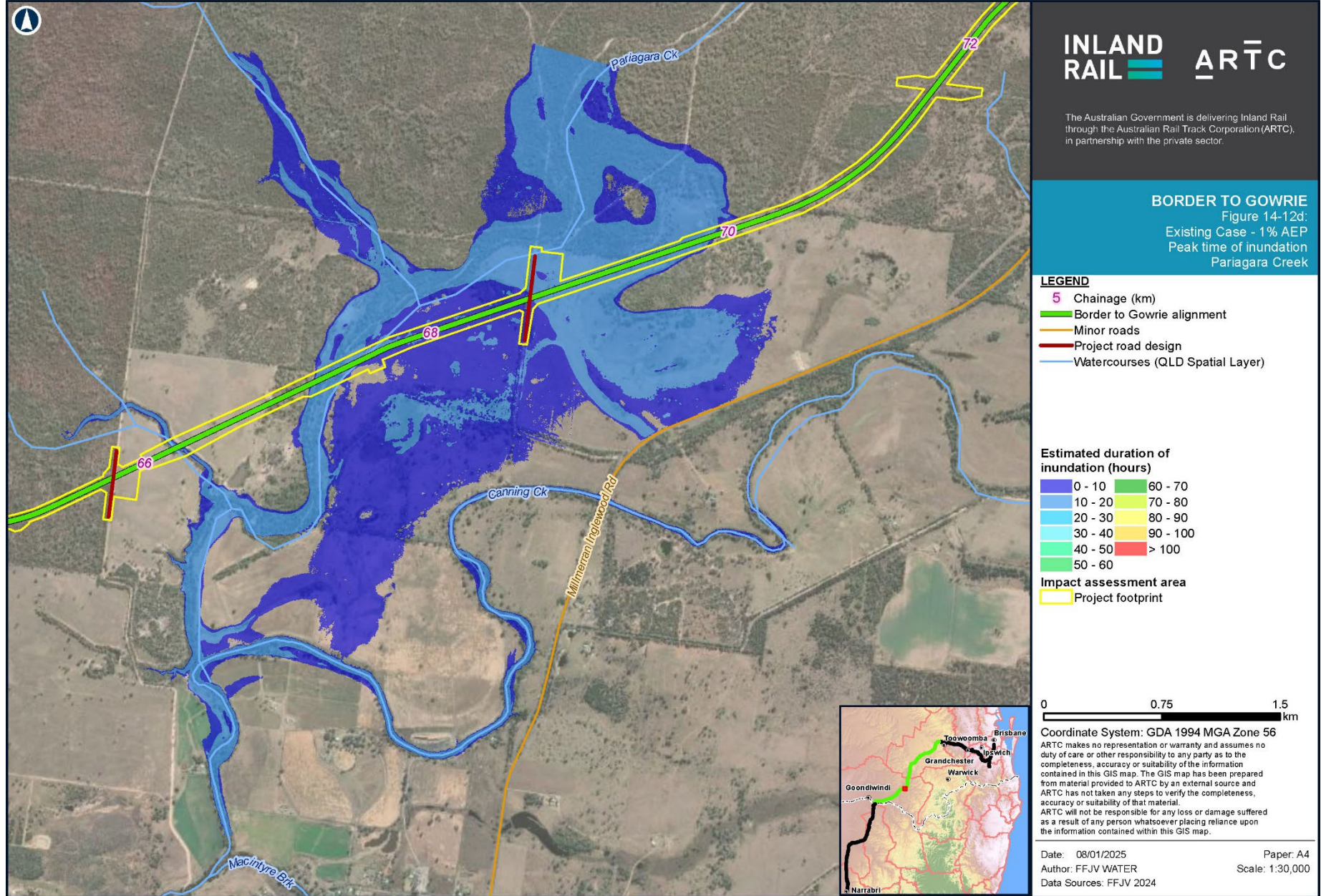
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Macintyre Brook

Macintyre Brook runs in a westerly direction through Inglewood and to the south of Yelarbon. The Macintyre Brook is fed by several creek systems as it flows from the east of Inglewood westwards towards Yelarbon including Mosquito Creek and Canning Creek. Coolmunda Dam is situated on Macintyre Brook upstream of Inglewood. Kippenbung Creek runs from east to west along the southern side of Yelarbon flowing into the Dumaresq River approximately 24 km downstream of the Macintyre Brook confluence with the Dumaresq River. Brigalow Creek, a tributary of the Weir River, runs from east to west to the north of Yelarbon.

The hydraulic model predicts Existing Case 1% AEP event depths of up to 11 m will occur in the Macintyre Brook main channel through Inglewood. On the floodplain, average depths of approximately 1.5 m are predicted across the town of Inglewood. Flow remains mainly in the Macintyre Brook up to the 20% AEP event through Inglewood and breakouts occur between 20% AEP and 10% AEP events.

Table 14-23 presents a summary of overtopping depths for key infrastructure near the Project under a range of design events. The 1% AEP flood levels are shown in Figure 14-13a.1 (Ch 55.0 km to Ch 75.0 km), Figure 14-13a.2 (Ch 35.0 km to Ch 55.0 km) and Figure 14-13a.3 (Ch 15.0 km to Ch 35.0 km).

TABLE 14-23 MACINTYRE BROOK: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

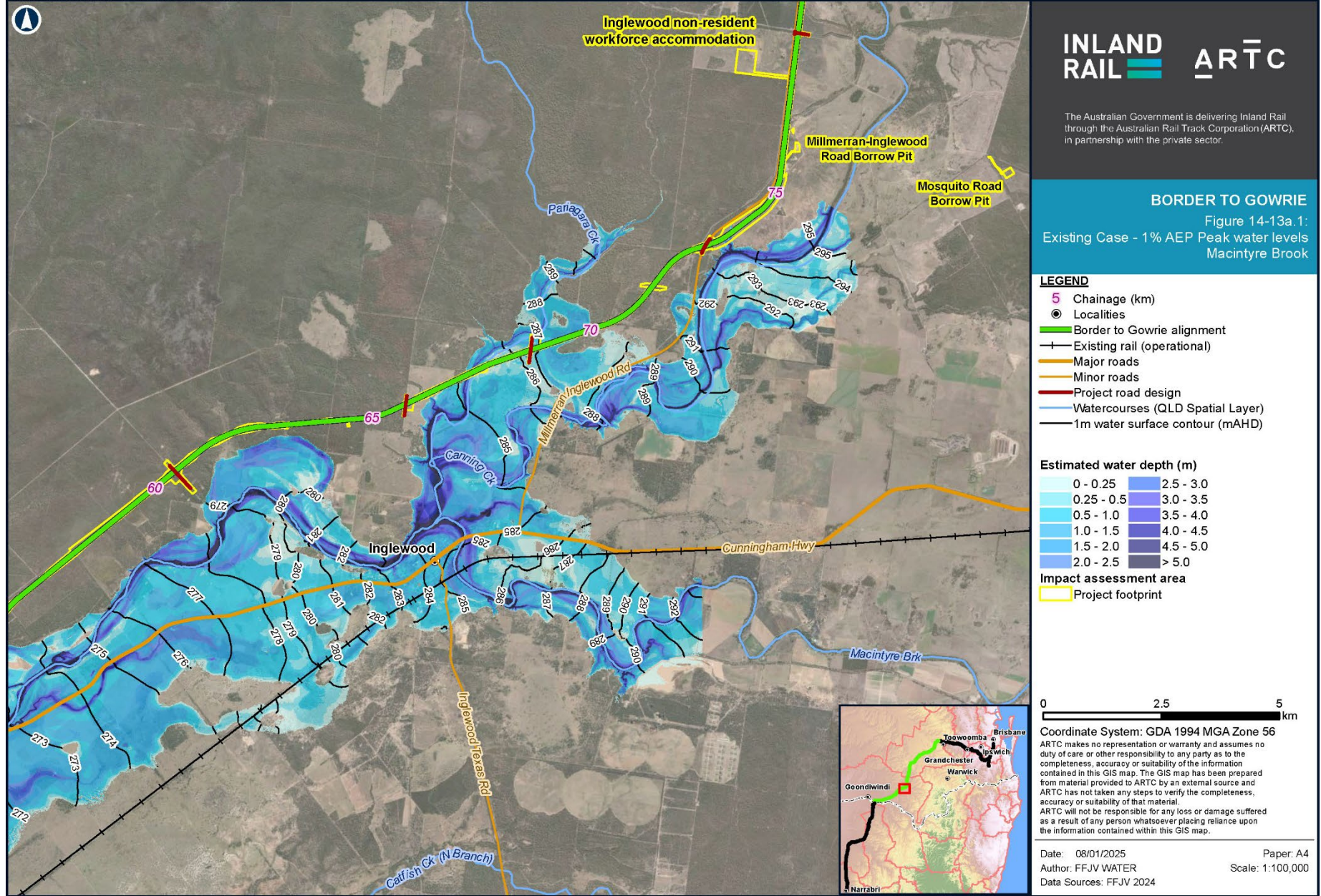
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Cunningham Highway (Yelarbon)	0.97	0.46	0.43	0.35	0.40	0.39
Cunningham Highway—existing levee (Yelarbon)	1.63	1.00	0.82	0.69	0.62	0.08
Adjacent existing road bridge—Cunningham Highway, Inglewood	4.25	2.30	1.79	0.69	0.02	Dry
Existing road bridge—Millmerran—Inglewood Road	2.92	2.05	1.86	1.32	0.77	Dry

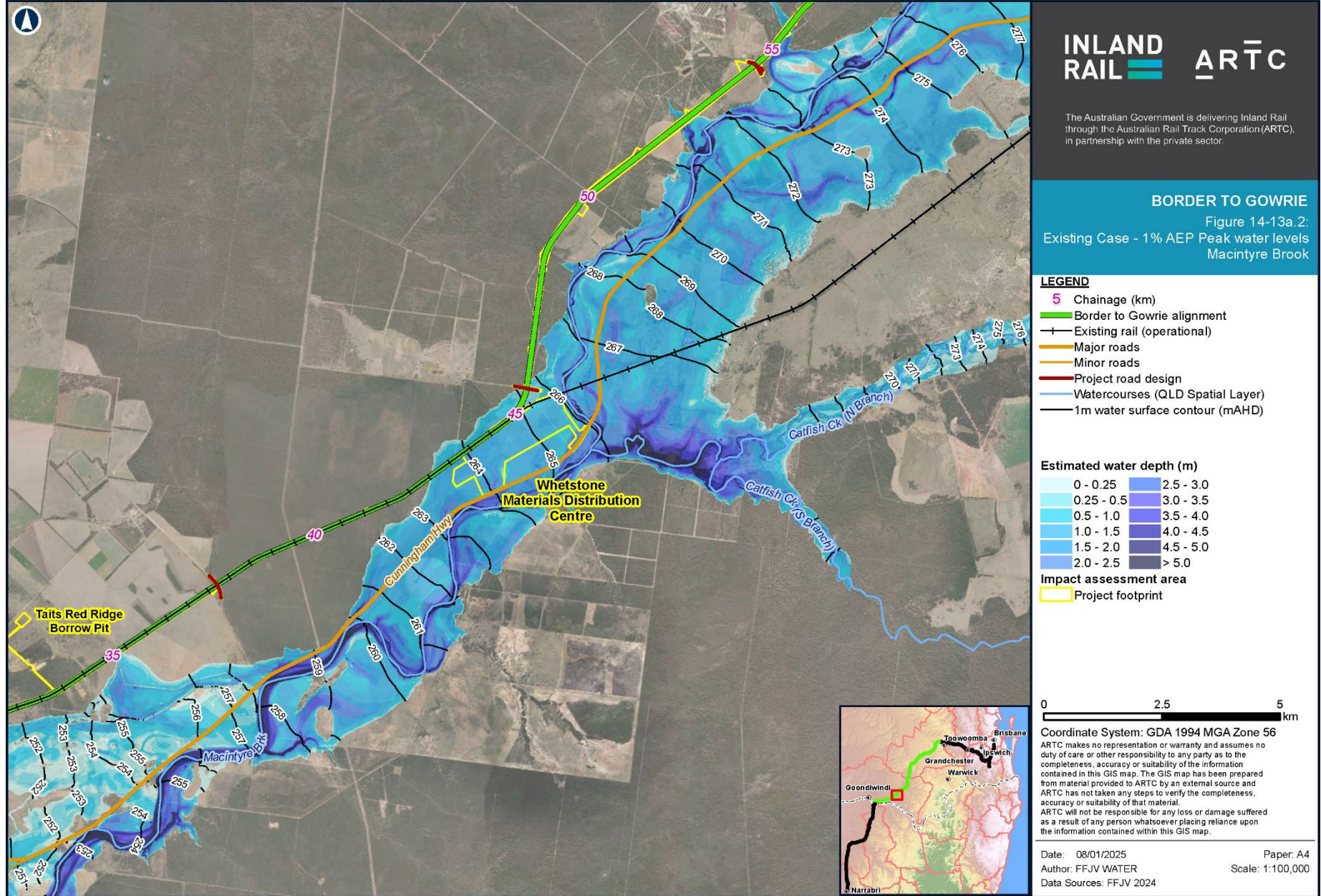
At Inglewood, velocities of approximately 2.0 m/s are predicted across the floodplain area under the 1% AEP event with higher velocities in the Macintyre Brook of up to 2.4 m/s. At Yelarbon velocities are predicted to be up to 2.0 m/s at the peak of the flood during a 1% AEP event. Generally, the average velocity across the floodplain is approximately 0.5 m/s as shown in Figure 14-13b.

At Inglewood, the average hazard (i.e. velocity-depth product) across the floodplain is 1.25 m²/s. At Yelarbon the average velocity-depth product across the floodplain is 0.16 m²/s as shown in Figure 14-13c.

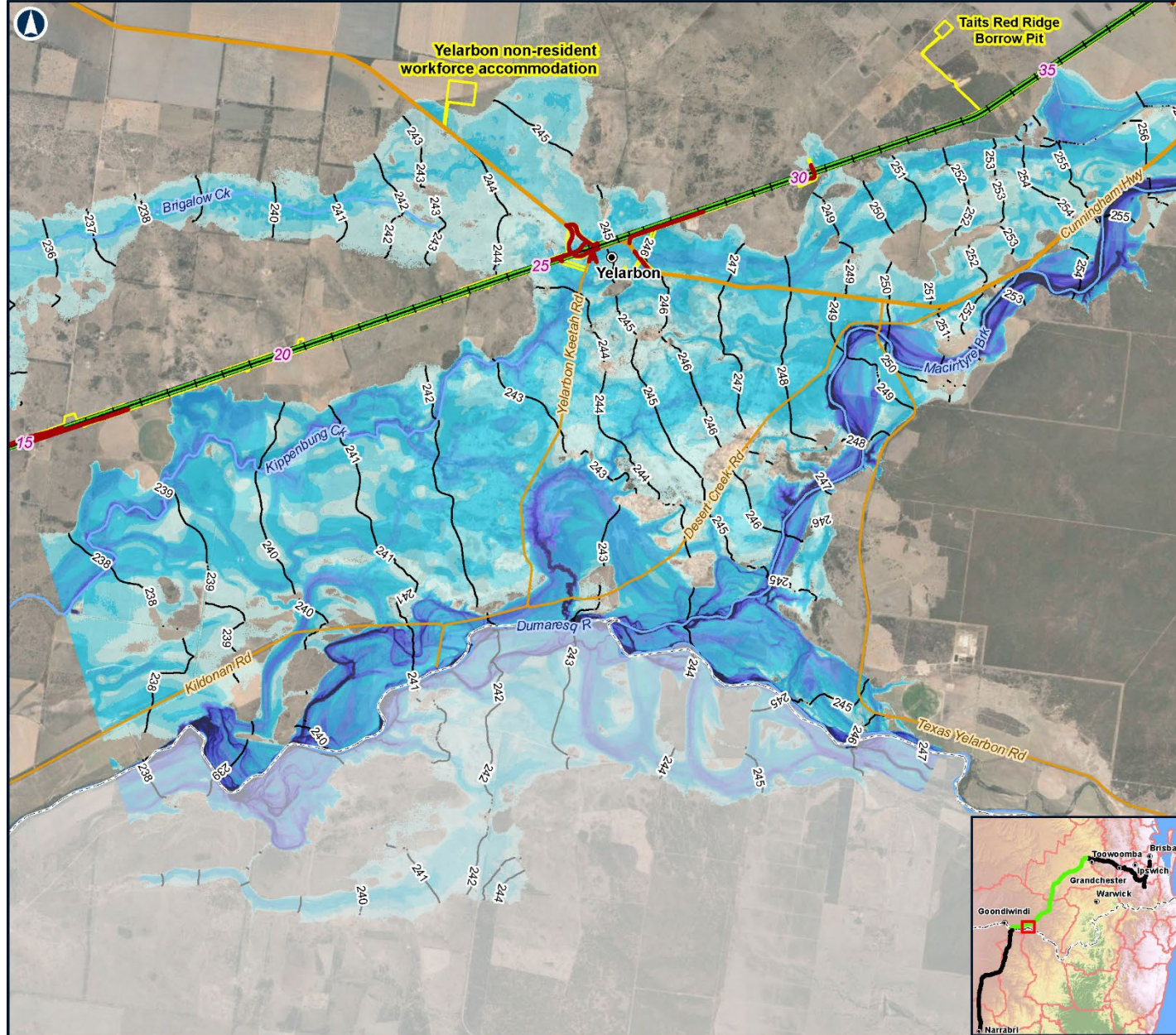
At Inglewood, the average time of inundation across the floodplain is 25 hours, with some areas on and adjacent to the Macintyre Brook experiencing longer inundation times of up to 4 days. At Yelarbon, the average time of inundation across the floodplain is 26 hours. Furthermore, there are some localised low spots around the town where water appears to pond, including behind the levee, which then extends across to Yelarbon-Keetah Road. These localised areas experience a time of inundation of up to 4 days as shown in Figure 14-13d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.





Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-13a.3:
Existing Case - 1% AEP Peak water levels
Macintyre Brook

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- NSW Qld border
- 1m water surface contour (mAHD)

Estimated water depth (m)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Impact assessment area

- Project footprint

0 2.5 5 km

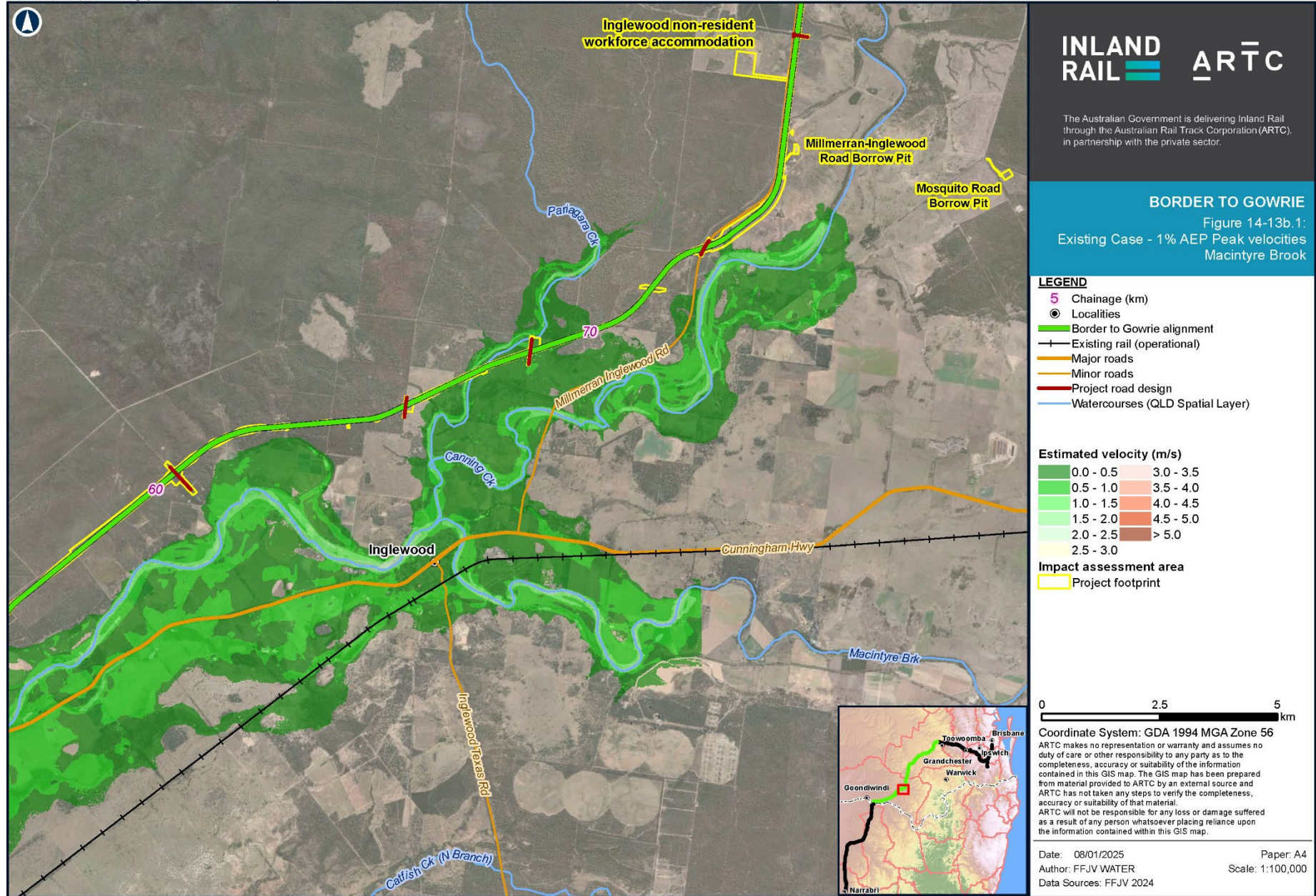
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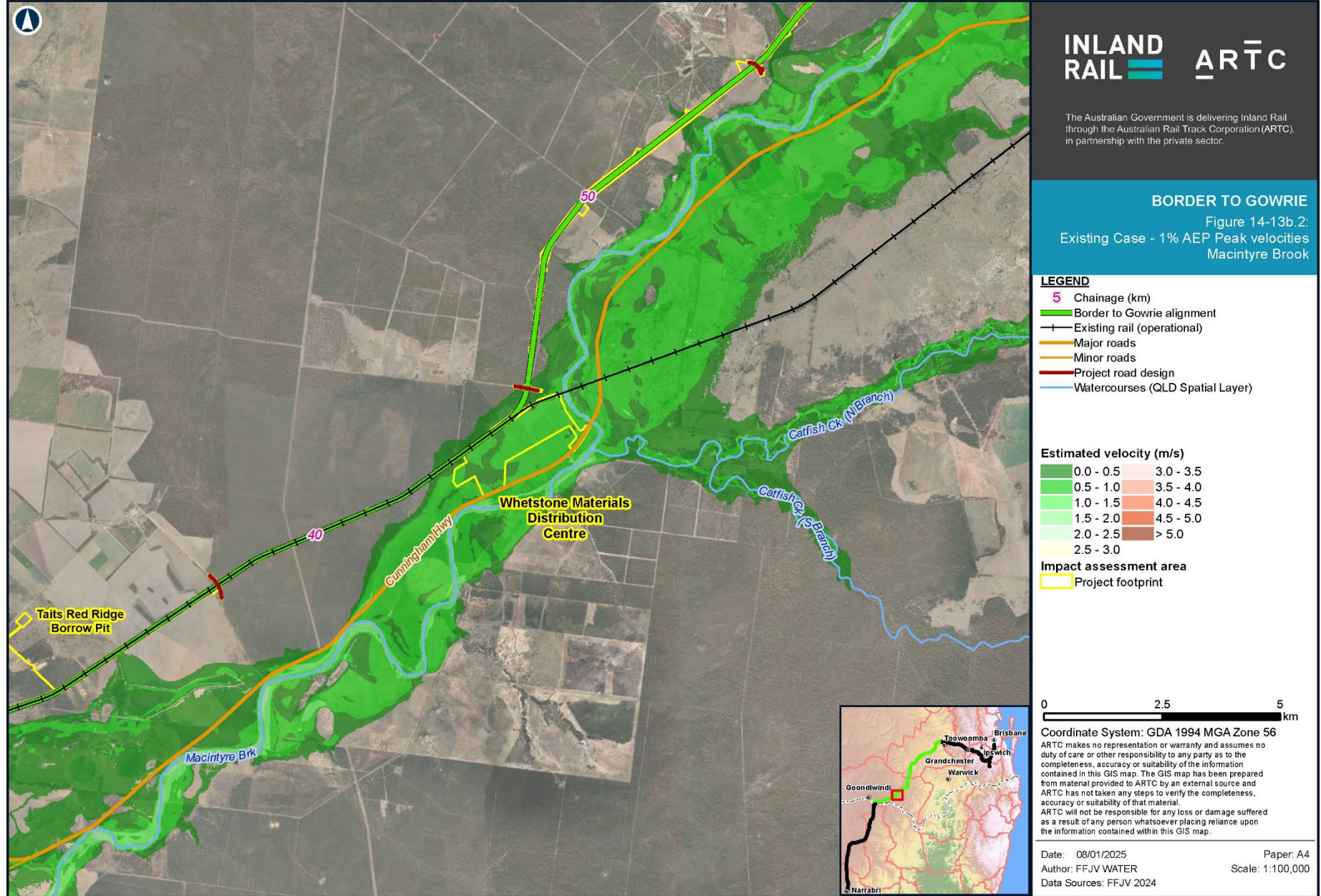
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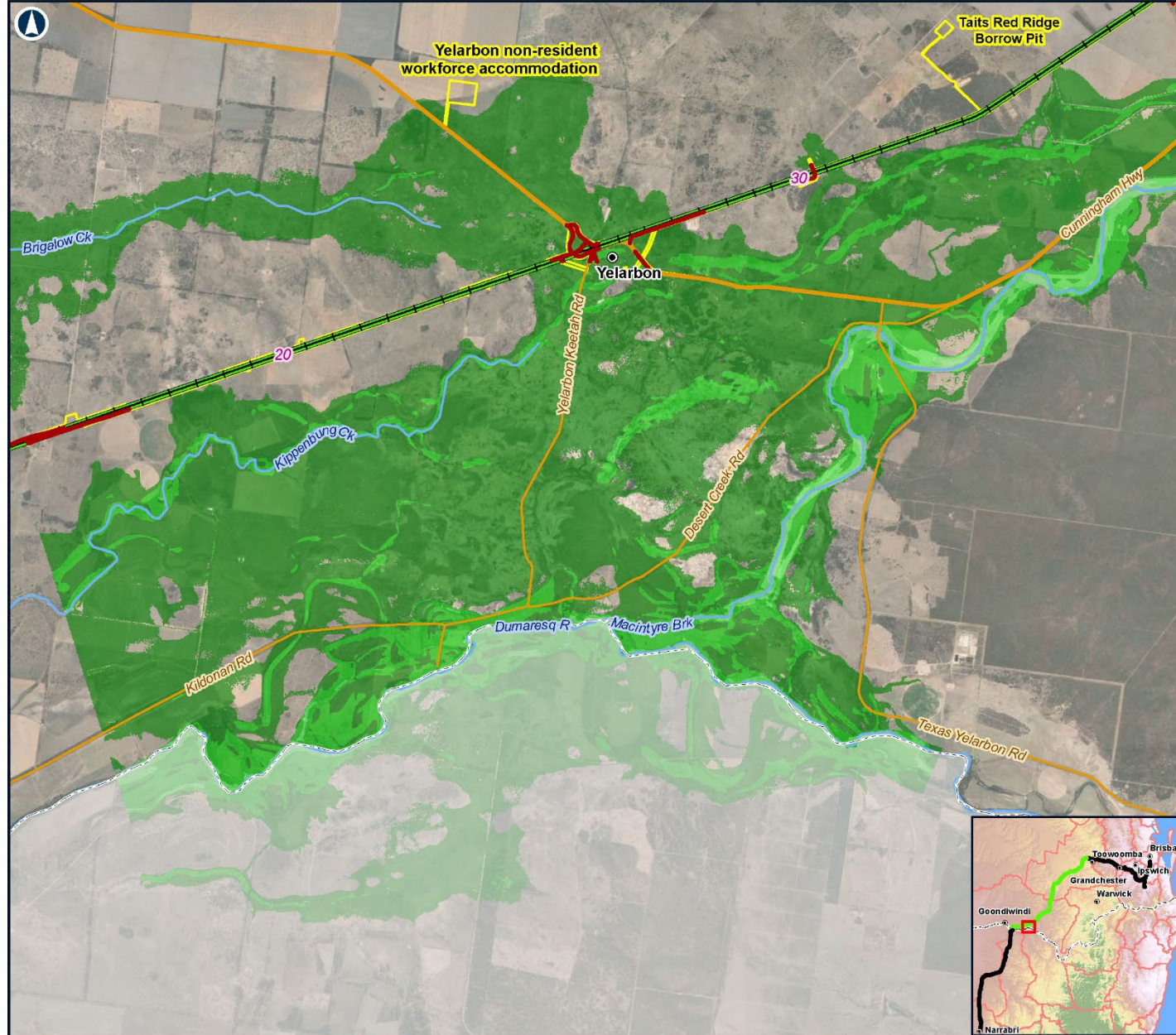
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-13b.3:
Existing Case - 1% AEP Peak velocities
Macintyre Brook

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- NSW Qld border

Estimated velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

Impact assessment area

- Project footprint

0 2.5 5 km

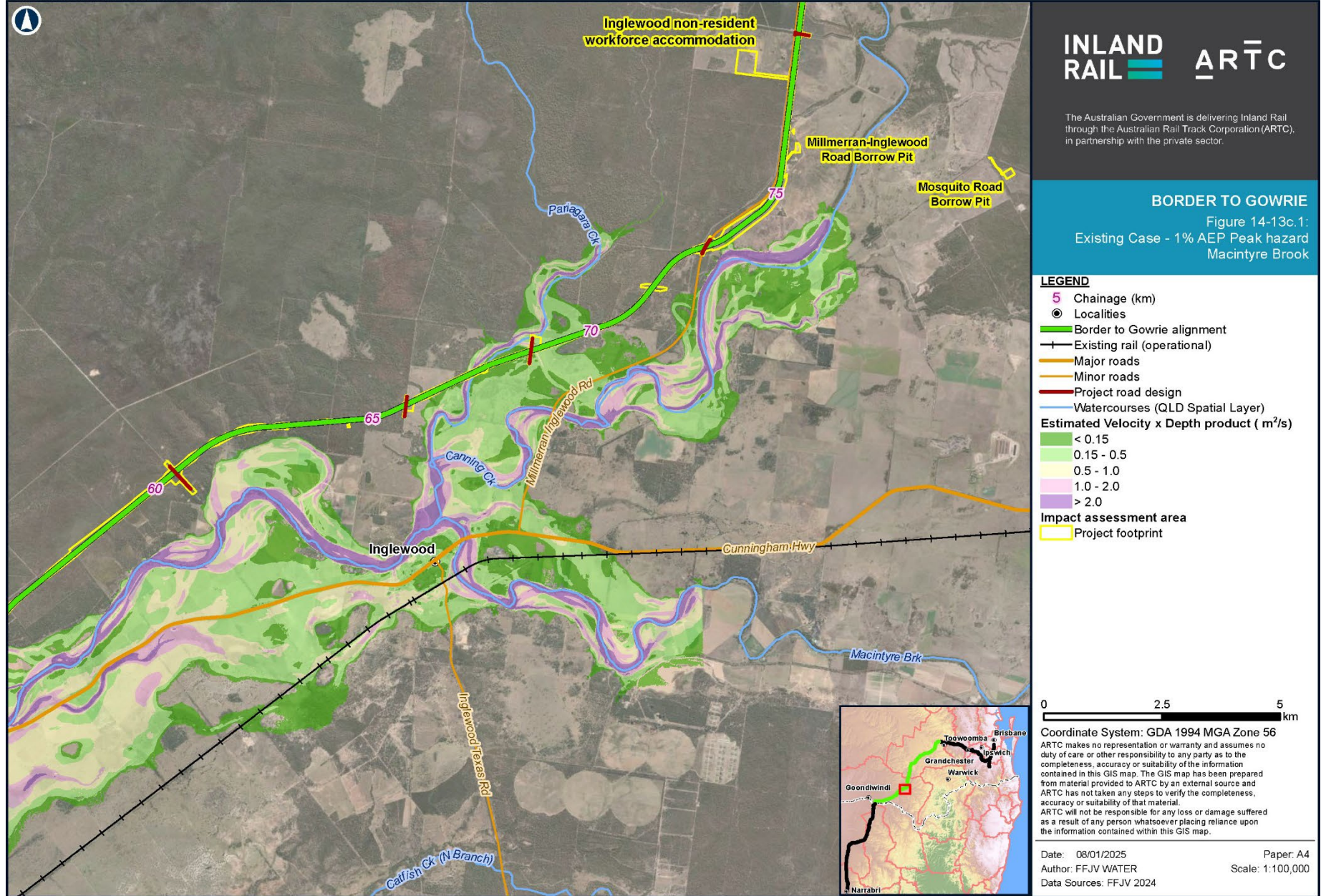
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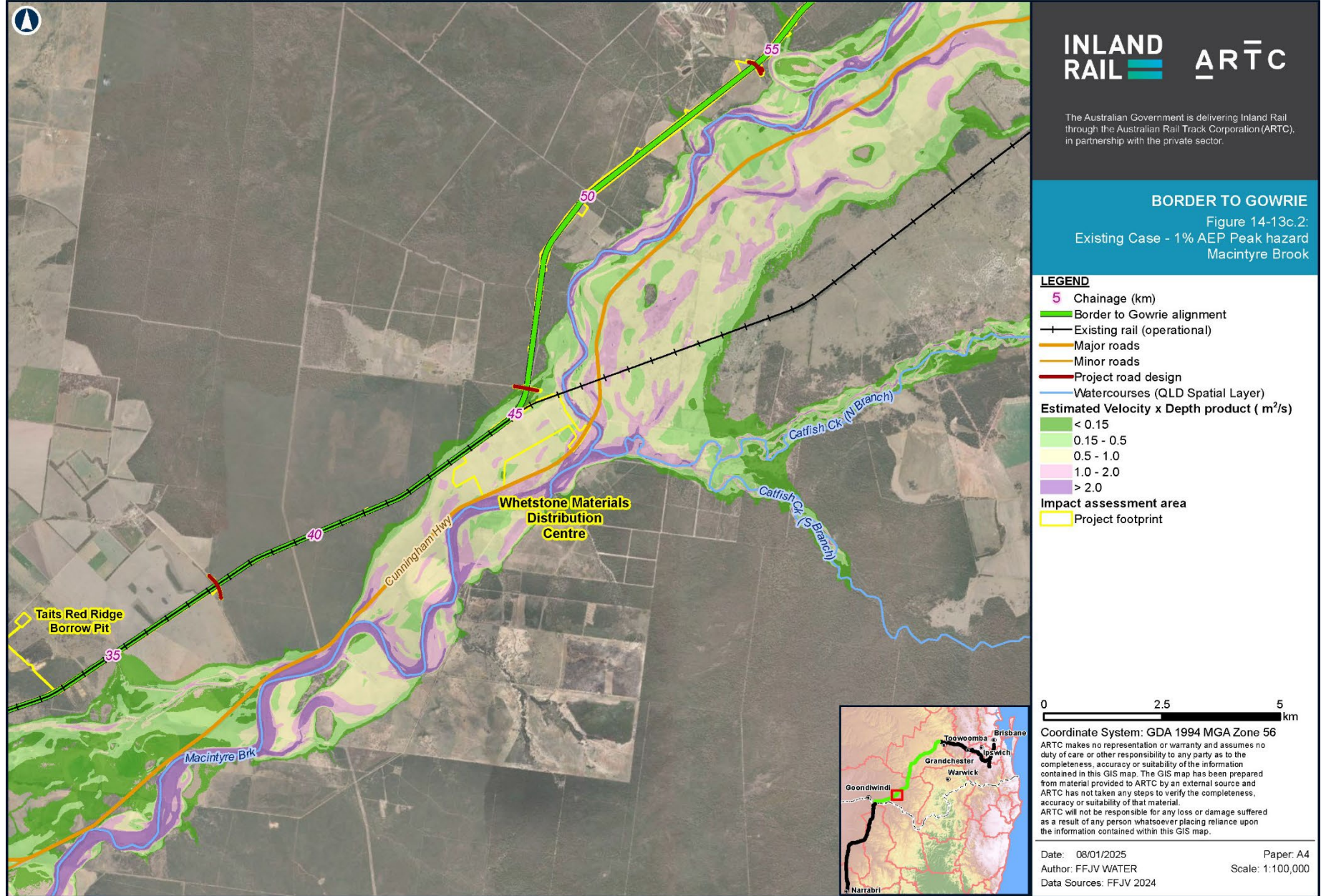
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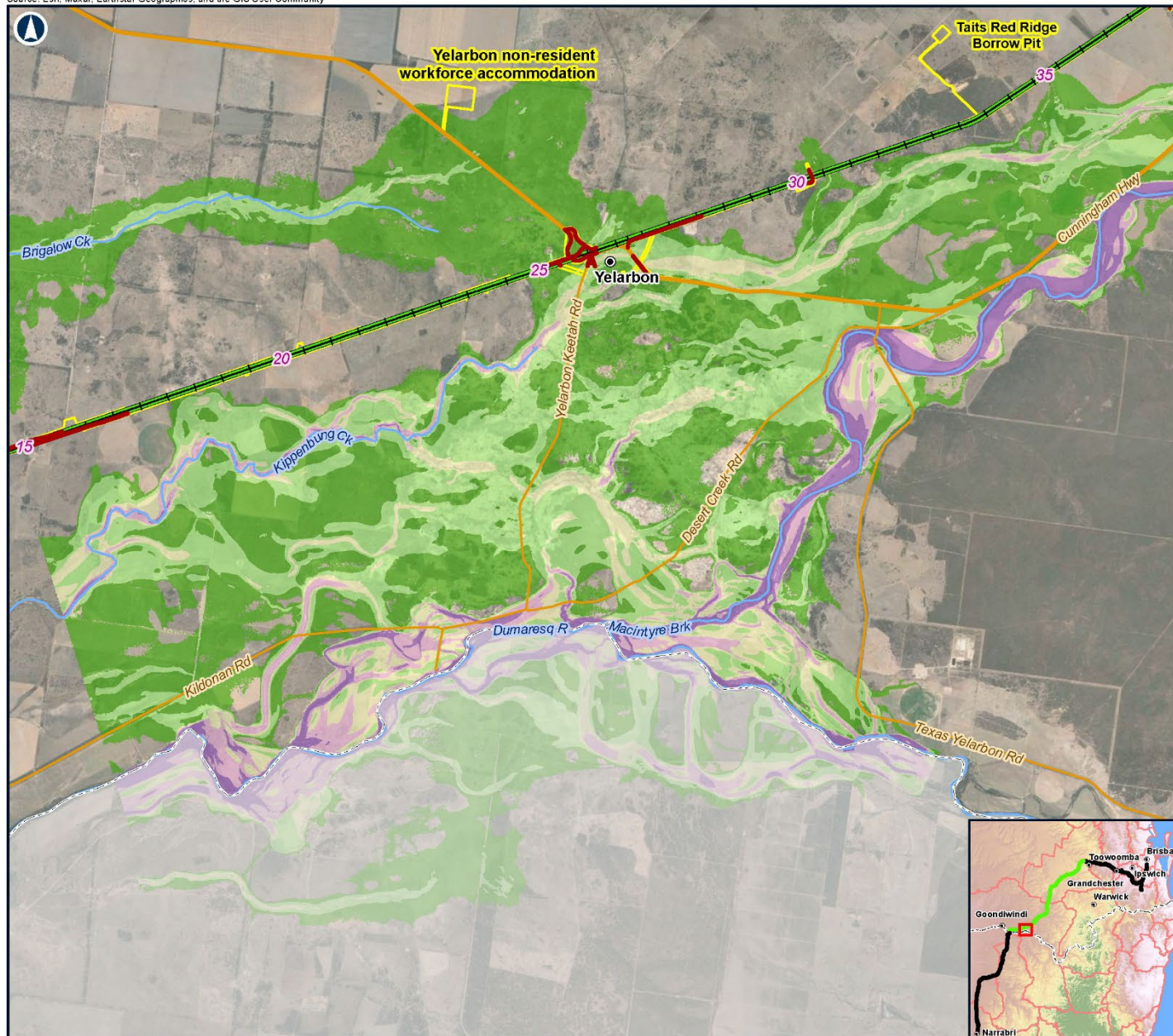
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-13c.3:
Existing Case - 1% AEP Peak hazard
Macintyre Brook

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  NSW Qld border
- Estimated Velocity x Depth product (m^2/s)**
 -  < 0.15
 -  0.15 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  > 2.0
- Impact assessment area**
 -  Project footprint

0 2.5 5 km

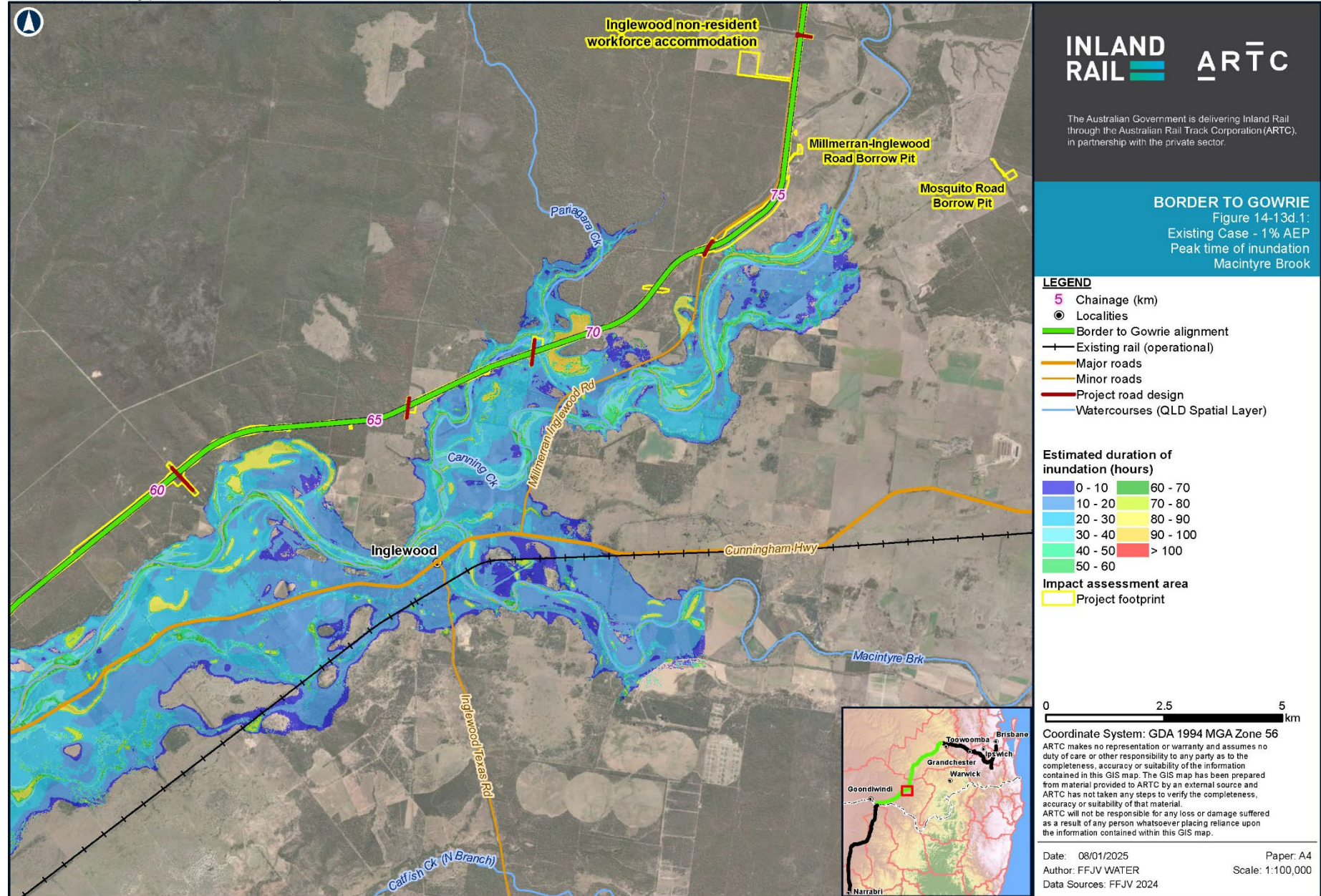
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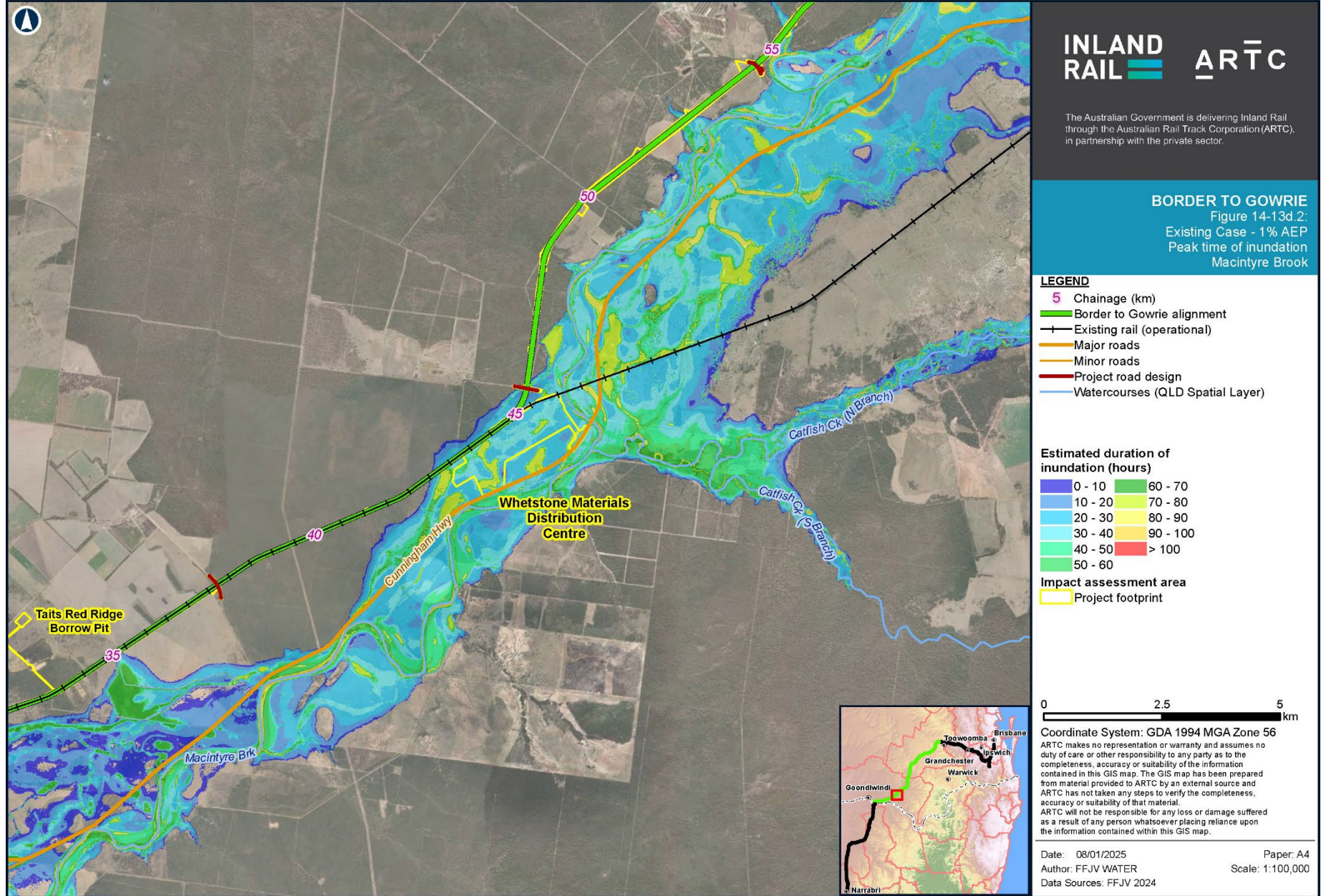
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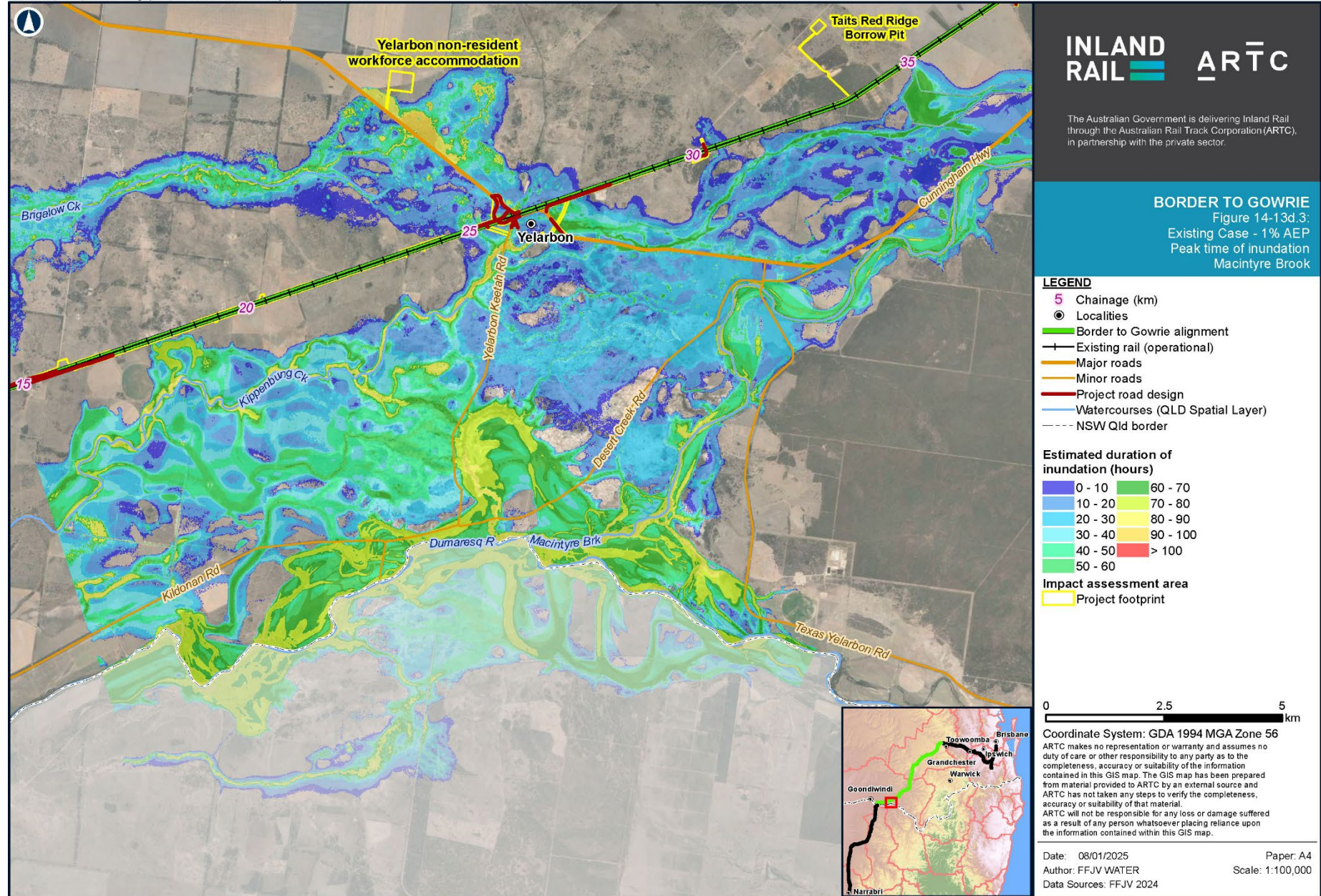
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Macintyre River

Widespread floodplain inundation is predicted under the 1% AEP event on the Macintyre River floodplain, with depths of approximately 10 m to 12 m in the Macintyre River channel, 6 m in the Whalan Creek channel and up to 2 m on the floodplain area. The Macintyre River floodplain spans across the border affecting areas in both NSW and Queensland.

Table 14-24 presents a summary of overtopping depths for key roads and the existing rail in the vicinity of the Project under a range of design events north of the NSW/QLD border. The 1% AEP flood levels are shown in Figure 14-14a.

TABLE 14-24 MACINTYRE RIVER: EXISTING CASE—ESTIMATED OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE NORTH OF NSW/QLD BORDER

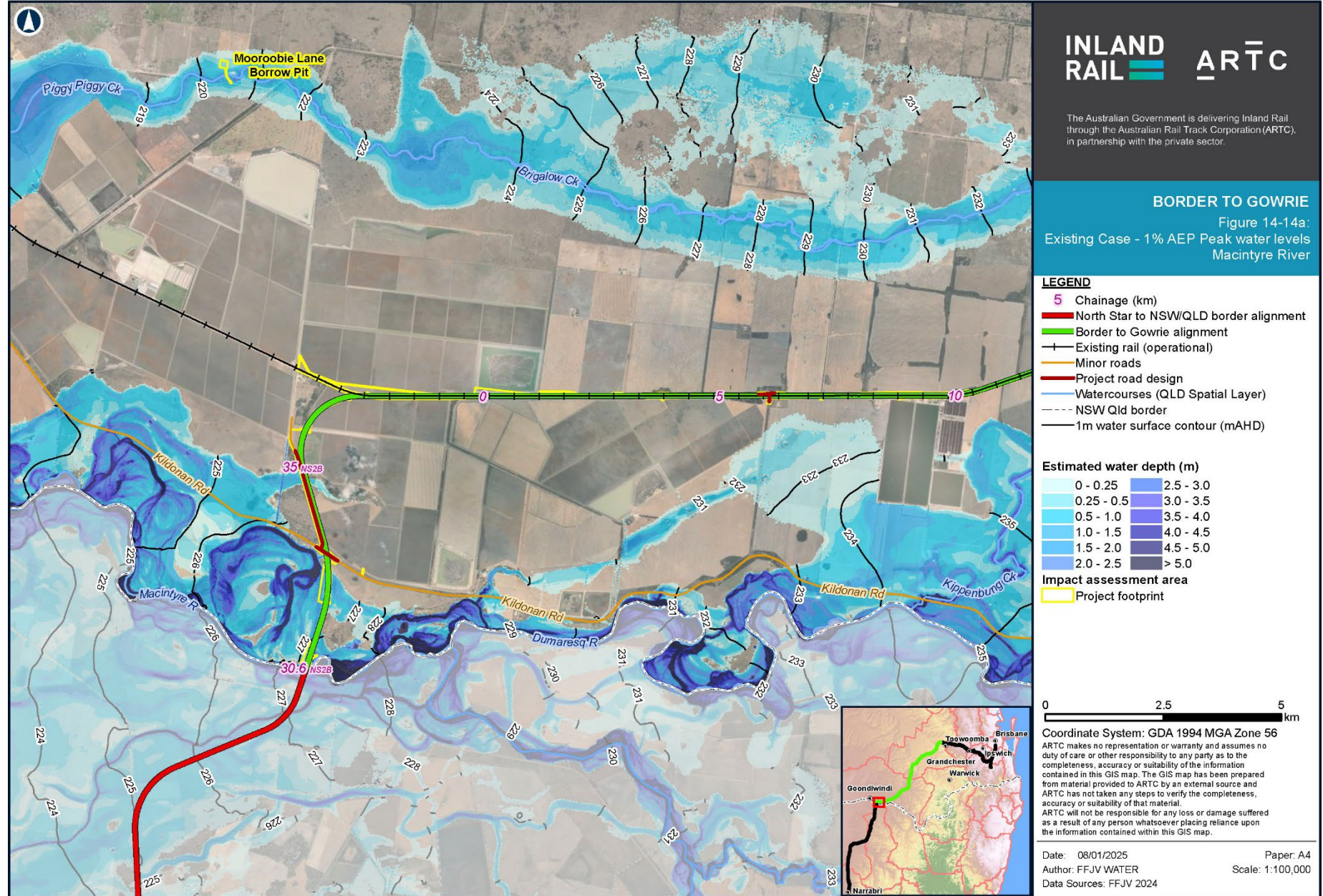
Infrastructure	Approximate overtopping depth (m)					
	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Kildonan Road (1 km downstream of the Project alignment)	0.70	0.28	Dry	Dry	Dry	Dry
Kildonan Road (upstream of the Project alignment)	1.60	Dry	Dry	Dry	Dry	Dry

Velocities of approximately 0.5 m/s are predicted across the floodplain area under the 1% AEP event with higher velocities within the creeks and river channels. Flow remains mainly in the creek and river channels up to the 10% AEP event and breakouts occur downstream of the Toomelah township in NSW between a 10% and 5% AEP event. Velocities on the northern side of the Macintyre River are predicted to be approximately 0.23 m/s in the 1% AEP event. Velocity in the Macintyre River is predicted to be up to 4.5 m/s in the 1% AEP event as shown in Figure 14-14b.

In the 1% AEP event hazard (i.e. velocity-depth product) across the floodplain on average is 0.48 m²/s, to the north of the Macintyre River an average velocity-depth product of 0.68 m²/s is predicted. In the Macintyre River velocity-depth product of up to 26.4 m²/s is predicted in the 1% AEP event as shown in Figure 14-14c.

In the 1% AEP event time of inundation is predicted to be approximately 47 hours across the main floodplain with some locations exceeding 100 hours. To the north of the river the time of inundation is predicted to be approximately 44 hours as shown in Figure 14-14d.

The full range of Existing Case flood maps for all AEP events modelled can be viewed on the **Online Digital Platform**.





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BORDER TO GOWRIE

Figure 14-14b:
Existing Case - 1% AEP Peak velocities
Macintyre River

LEGEND

-  Chainage (km)
-  North Star to NSW/QLD border alignment
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  NSW Qld border

Estimated velocity (m/s)

- | | | | |
|---|-----------|---|-----------|
|  | 0.0 - 0.5 |  | 3.0 - 3.5 |
|  | 0.5 - 1.0 |  | 3.5 - 4.0 |
|  | 1.0 - 1.5 |  | 4.0 - 4.5 |
|  | 1.5 - 2.0 |  | 4.5 - 5.0 |
|  | 2.0 - 2.5 |  | > 5.0 |
|  | 2.5 - 3.0 | | |

Impact assessment area

-  Project footprint

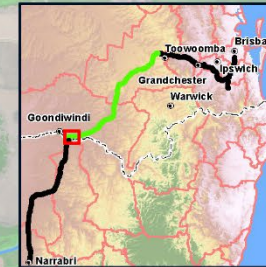
0 2.5 5 km

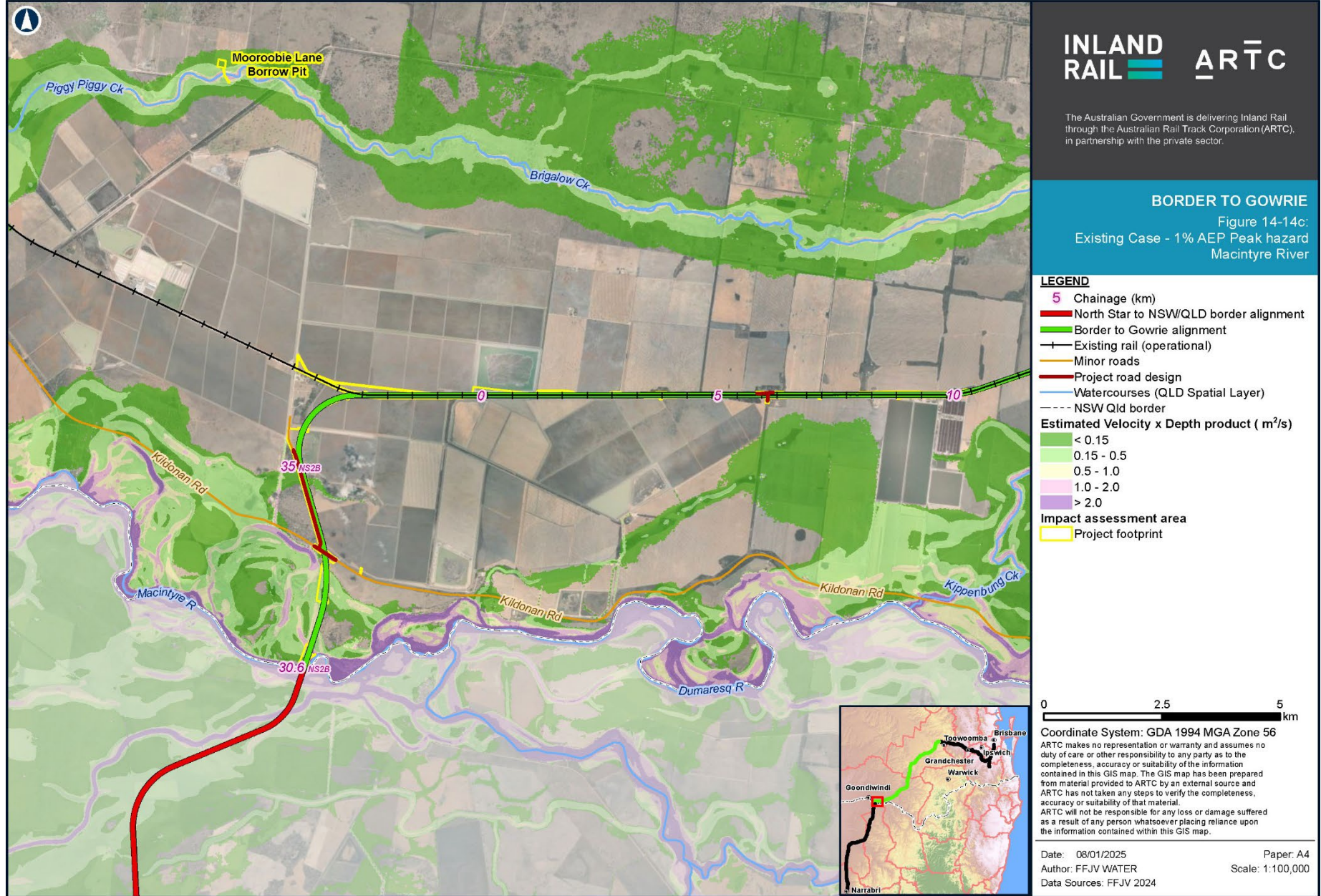
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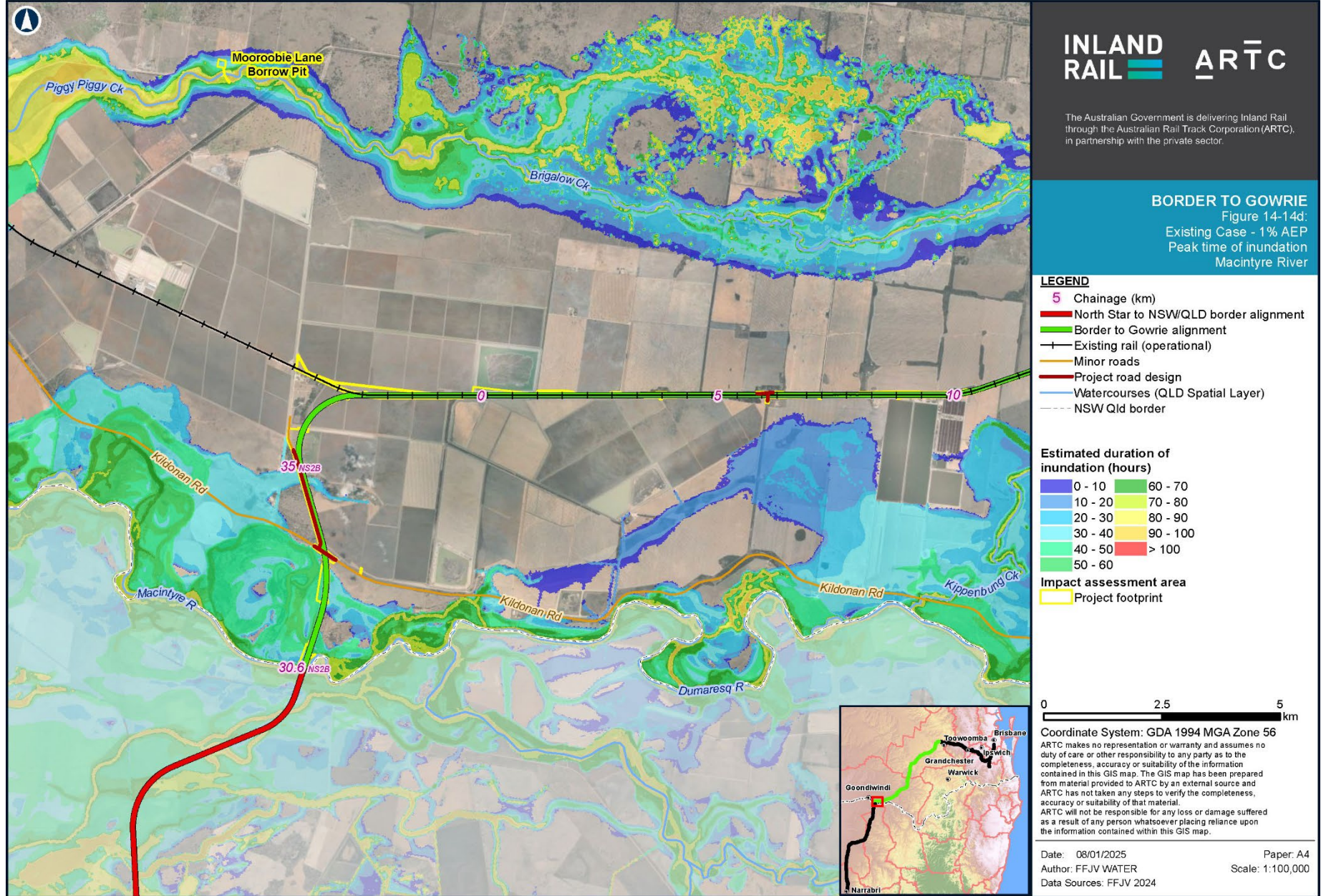
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Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
Scale: 1:100,000







14.7.5 Existing floodplain infrastructure

Key existing infrastructure² on floodplain areas that are located within, or in proximity to the impact assessment area, are as follows:

- ▶ Gowrie Creek floodplain:
 - ▶ QR West Moreton Line
 - ▶ Warrego Highway
 - ▶ Kingsthorpe–Haden, Draper Leasons and Gowrie Junction Roads
- ▶ Westbrook and Dry Creeks floodplain:
 - ▶ Toowoomba Wellcamp Airport
 - ▶ Toowoomba–Cecil Plains and Brimblecombe Roads
- ▶ Condamine River floodplain:
 - ▶ Gore Highway
 - ▶ Town of Pampas
 - ▶ QR Millmerran Branch Line
 - ▶ Pampas–Horrane and Millmerran–Leyburn Roads
 - ▶ Doug Hall Poultry at Yandilla
 - ▶ Several stream gauges including Pampas (Department of Regional Development, Manufacturing and Water), Yarramalong Weir (Sunwater), Centenary Bridge (BoM)
- ▶ Back Creek floodplain:
 - ▶ Commodore Mine
 - ▶ Millmerran Power Station
 - ▶ Millmerran–Inglewood and Kooroongarra Roads
- ▶ Macintyre Brook floodplain:
 - ▶ Cunningham Highway
 - ▶ Town of Inglewood
 - ▶ Town of Yelarbon
 - ▶ Yelarbon flood levee
 - ▶ Inglewood–Texas, Texas–Yelarbon, Desert Creek, Bybera, Cremascos, Yelarbon–Keetah and Kildonan Roads
- ▶ Private levees, dams, ring tanks and pump houses associated with farming practices.

14.7.6 Flood sensitive receptors

A total of 1,329 flood sensitive receptors were identified within the impact assessment area, as shown in Figure 14-15. Labelled flood sensitive receptors in the accompanying figures are those that have been identified as impacted due to the Project. The impacts to these flood sensitive receptors are quantified in Section 14.8. For all flood sensitive receptor IDs, see Appendix T2: Hydrology and Flooding Technical Report–Volume 2 or the **Online Digital Platform**.

² This is not an exhaustive list of local roads. All local roads have been assessed as part of this revised draft EIS, as reported in Section 14.8.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-15a:
Location of flood sensitive receptors

LEGEND

-  Flood sensitive receptor
-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Gowrie to Helidon alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Impact assessment area
-  Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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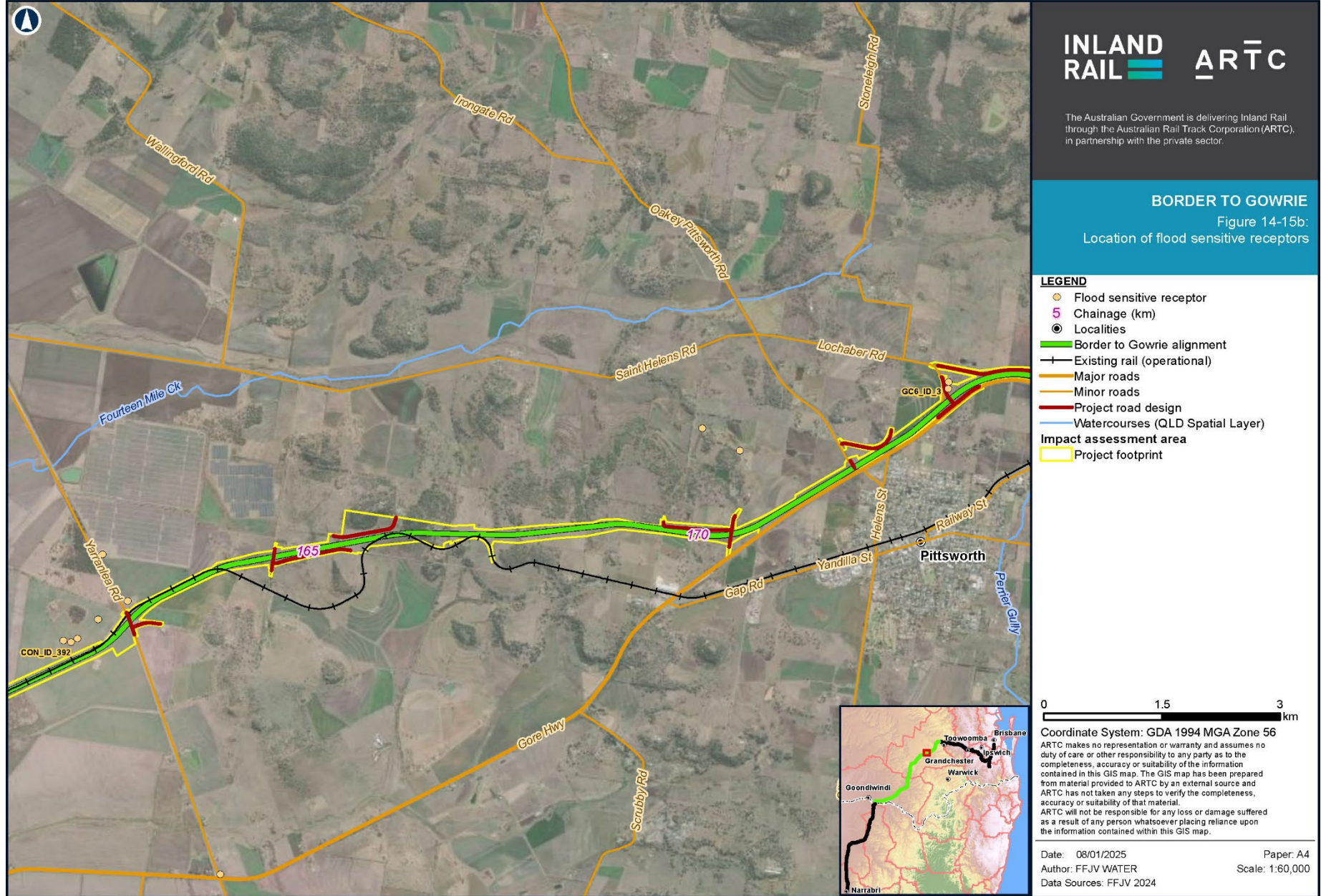
Author: FFJV WATER

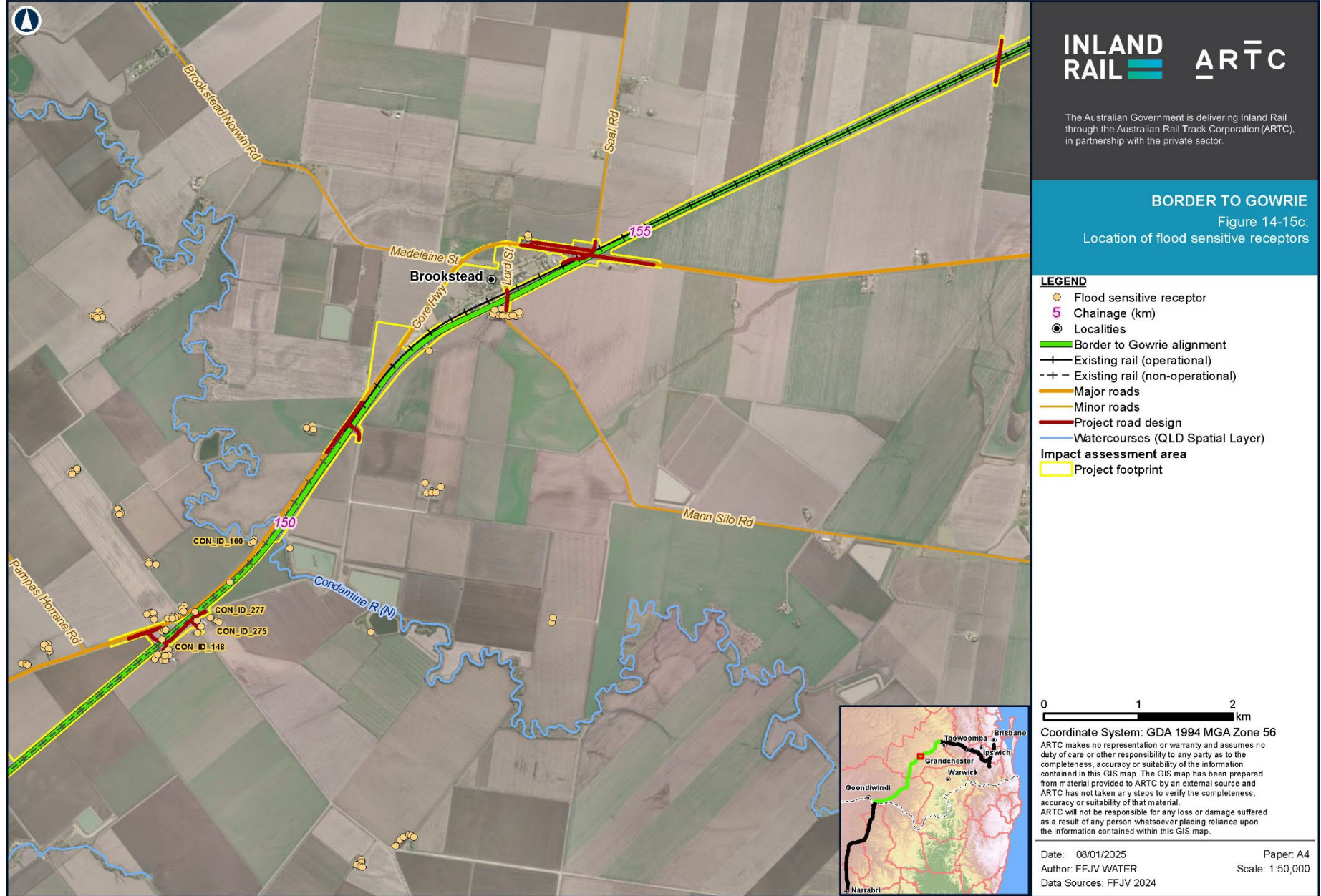
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Paper: A4

Scale: 1:100,000

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BORDER TO GOWRIE

Figure 14-15d:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor
- 5 Chainage (km)
- Border to Gowrie alignment
- - - Existing rail (non-operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- Impact assessment area
- Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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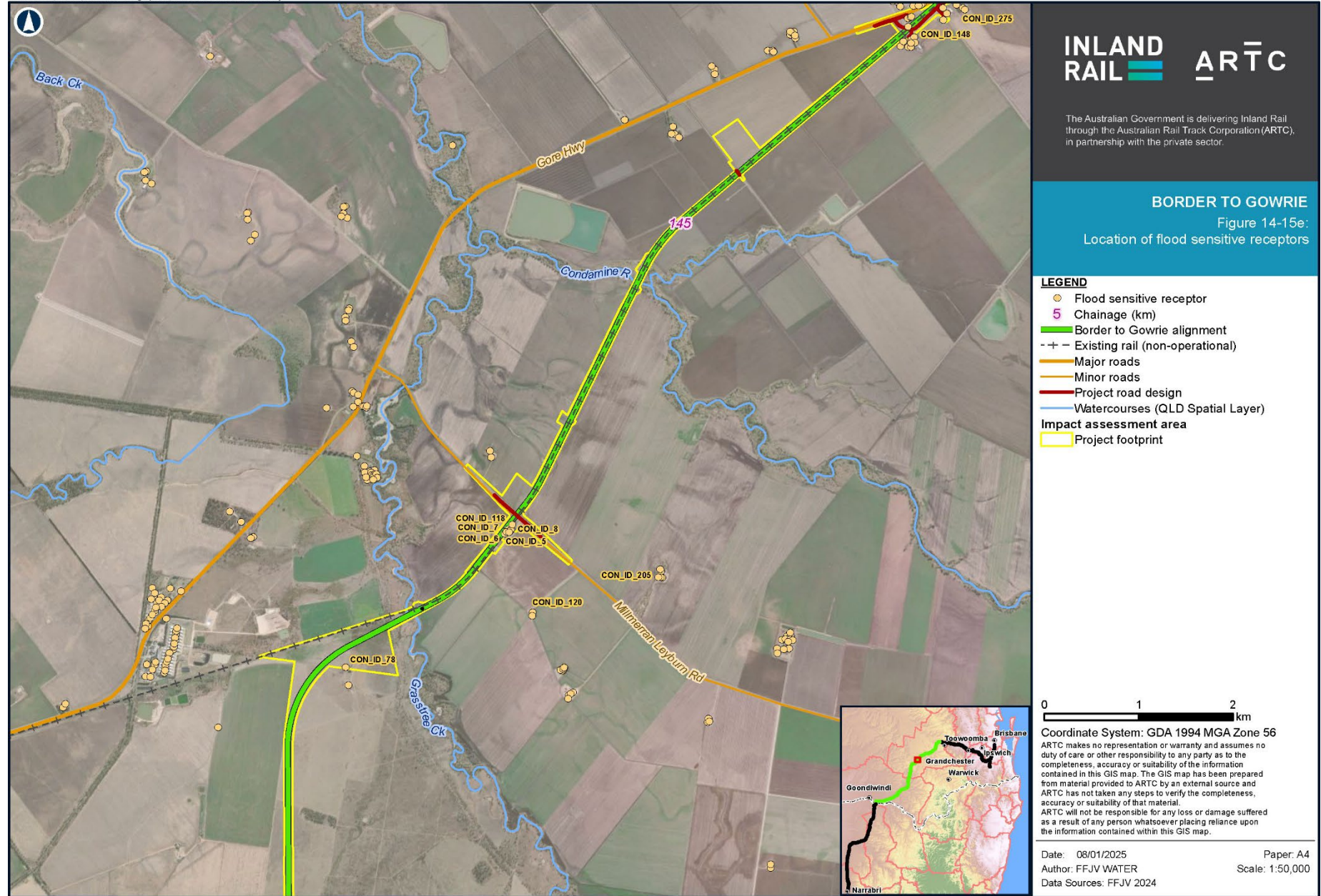
Author: FFJV WATER

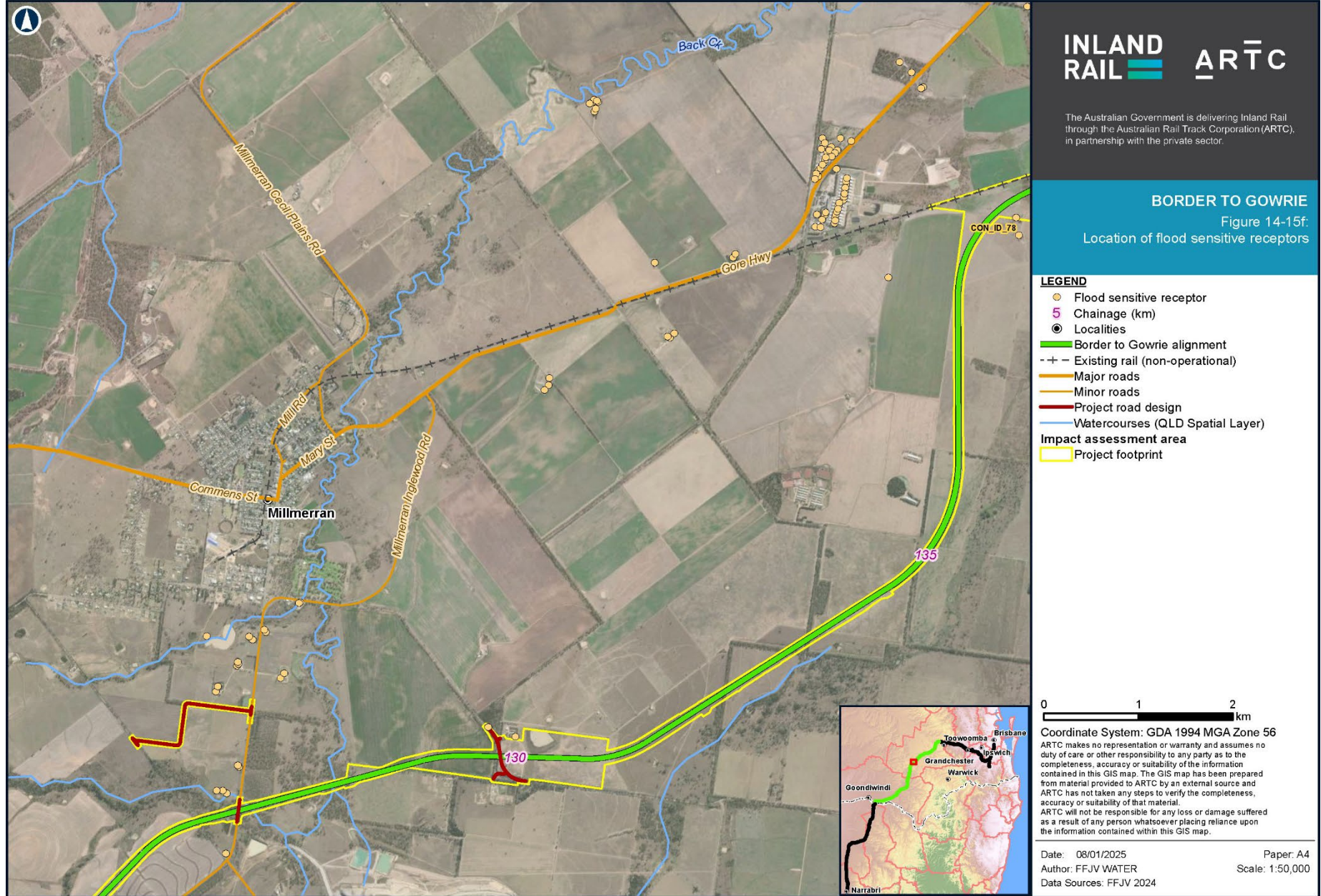
Data Sources: FFJV 2024

Paper: A4

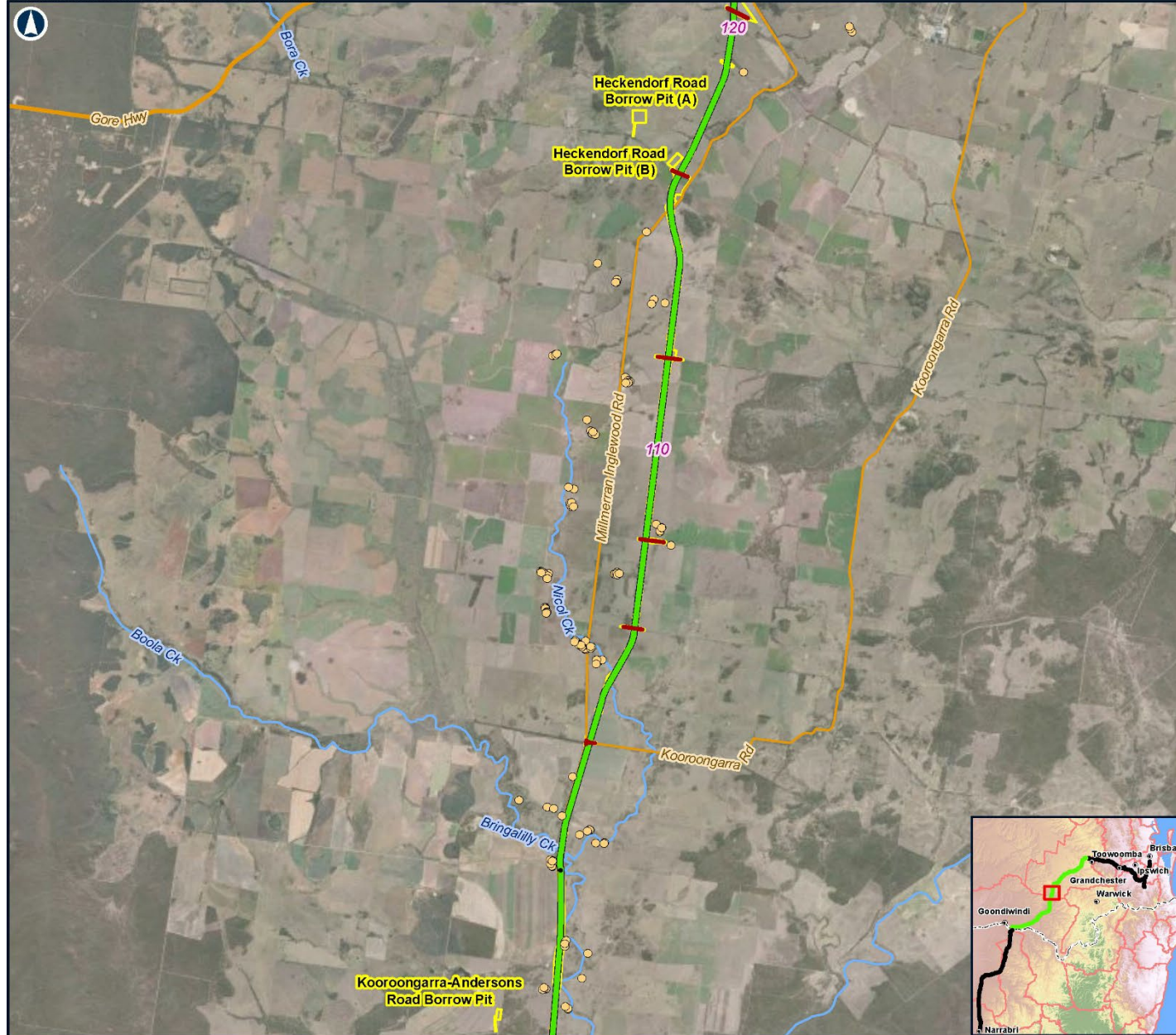
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BORDER TO GOWRIE

Figure 14-15g:
Location of flood sensitive receptors

LEGEND

-  Flood sensitive receptor
-  Chainage (km)
-  Border to Gowrie alignment
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Impact assessment area
-  Project footprint

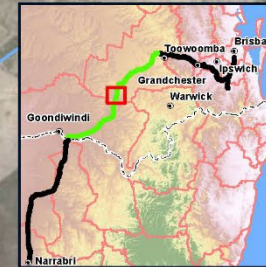
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Coordinate System: GDA 1994 MGA Zone 56

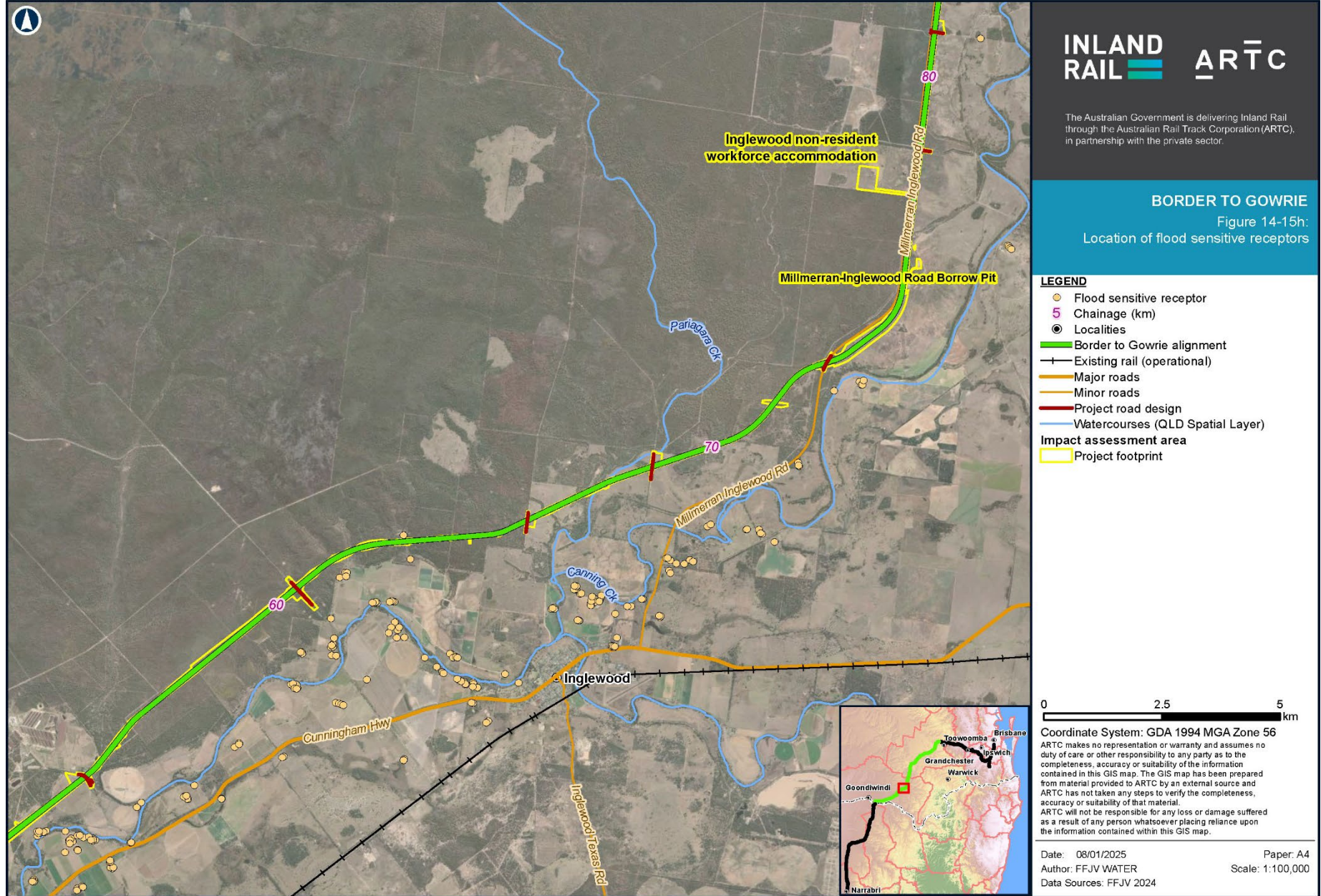
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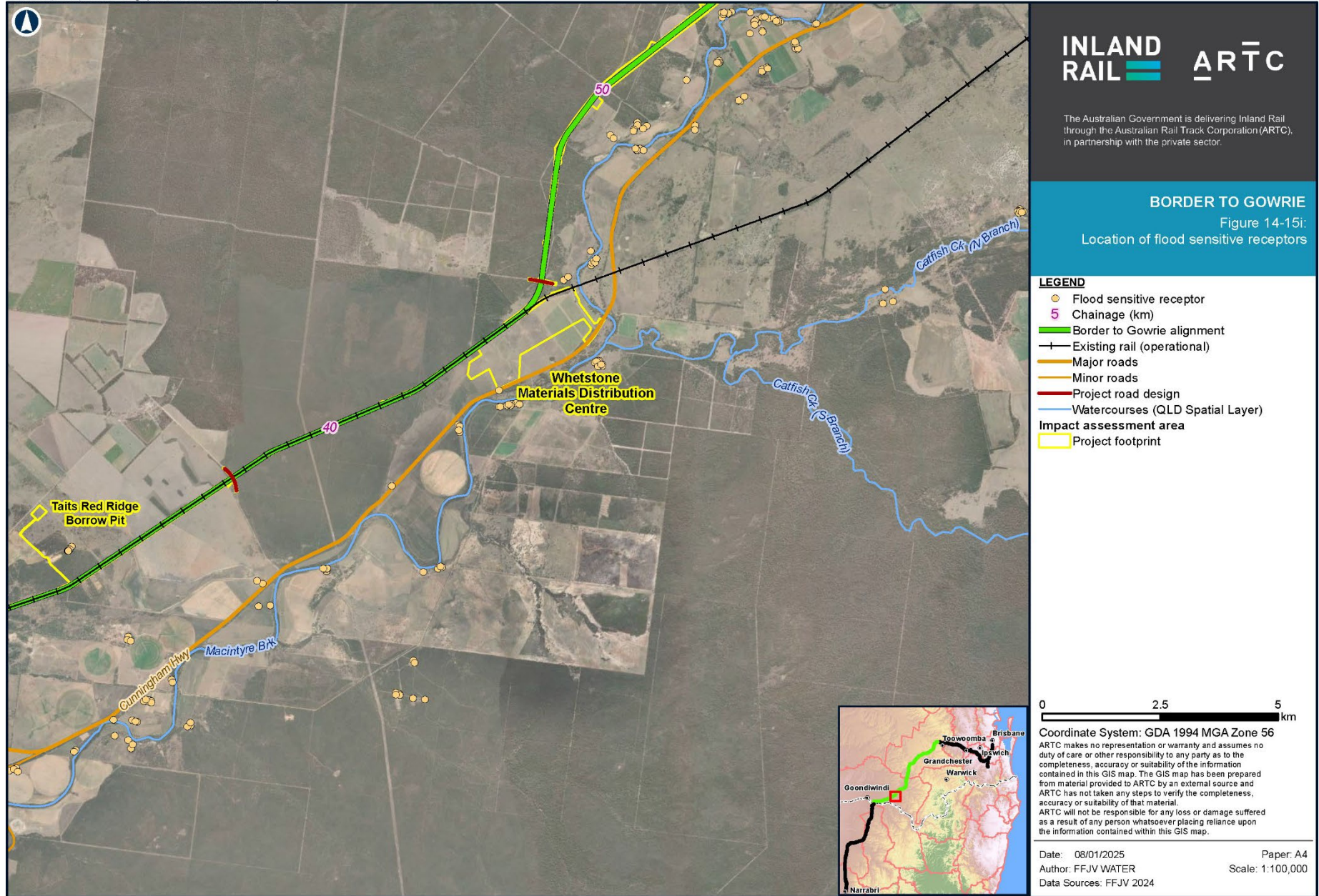
Date: 08/01/2025
Author: FFJV WATER
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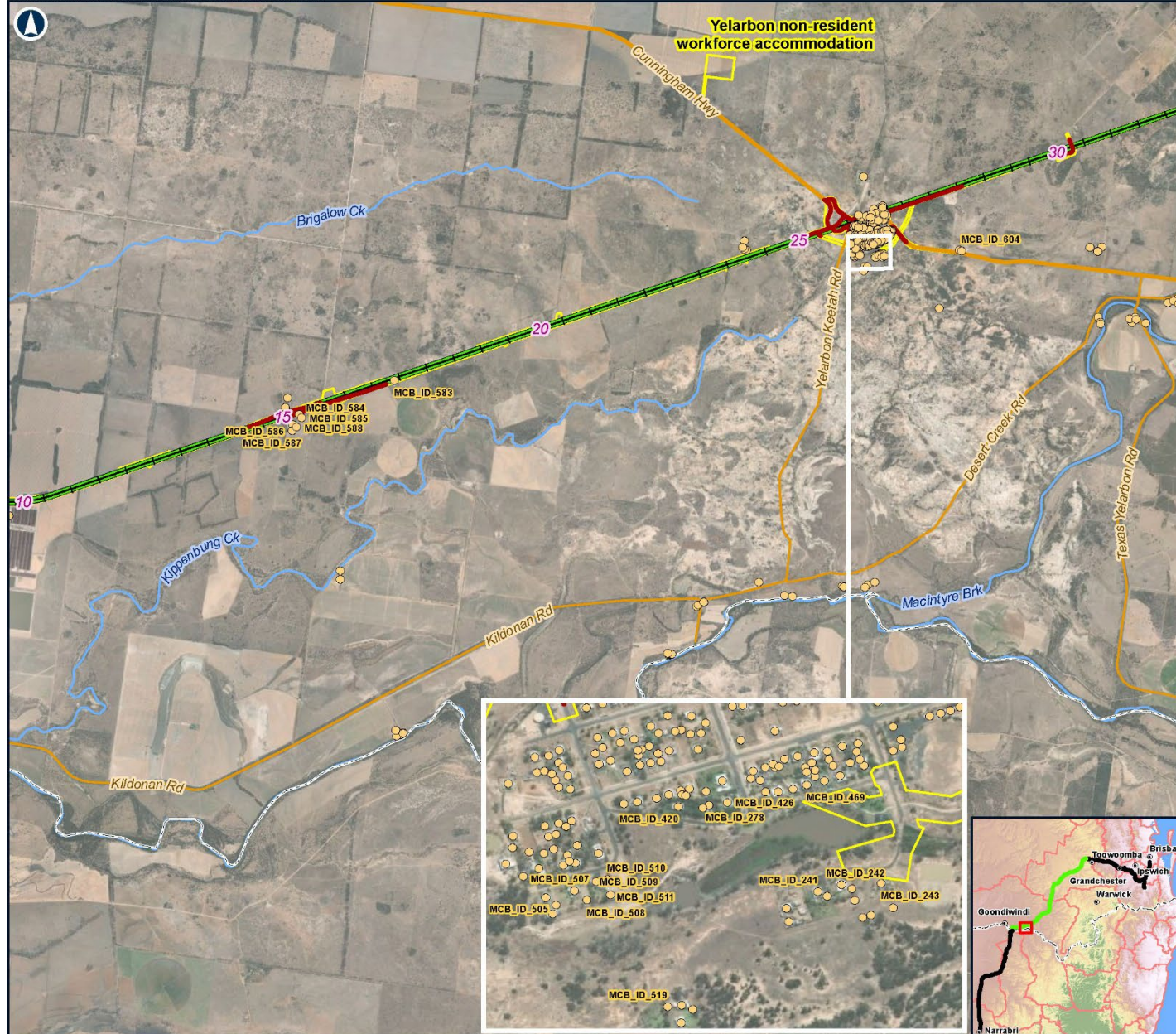
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BORDER TO GOWRIE

Figure 14-15j:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- NSW Qld border
- Impact assessment area
- Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE

Figure 14-15k:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor
- 5 Chainage (km)
- North Star to NSW/QLD border alignment
- Border to Gowrie alignment
- Existing rail (operational)
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- NSW Qld border
- Impact assessment area
- Project footprint

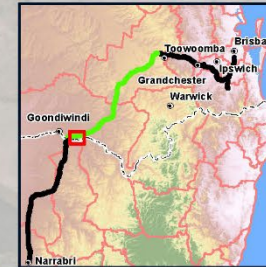
0 2.5 5 km

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BORDER TO GOWRIE

Figure 14-151:
Location of flood sensitive receptors

LEGEND

-  Flood sensitive receptor
-  Chainage (km)
-  North Star to NSW/QLD border alignment
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  NSW/QLD border
- Impact assessment area**
-  Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER
Data Sources: FFJV 2024

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Scale: 1:100,000

14.7.7 Regional geomorphic setting

This section describes the regional geomorphic landscapes within approximately 30 km of the Project alignment and their distribution along the Project alignment.

The Project is located within the eastern uplands and the landscape comprises four regional geomorphic landform types that have distinctive topography and geology.

From youngest to oldest these landscapes are:

- ▶ Valley floor floodplains—these are the presently active valley floors where most of the sites requiring fluvial geomorphic assessment are located. The topography is generally flat with less than 5 m of relief and the primary landforms are active and abandoned channels and adjacent floodplains.
- ▶ Alluvial plains—these occur in two groups:
 - ▶ On lower valley side slopes adjacent to the valley floors, wide flat river plains that formed over millions of years in the later part of the tertiary period (i.e. 25 to 2.5 million years ago). They are no longer actively forming and are mostly high enough to not be affected by floodwaters. They occur up to approximately 400 m above sea level and may vary by approximately 50 m of elevation change, but the surface relief is typically <10 m.
 - ▶ Higher alluvial plains are similar but are more constrained within the low hills landscape. Surface relief can be greater than 10 m possibly indicating they are older. Given the low relief characteristics of these areas there has been limited watercourse development.
- ▶ Moderate relief hills—occupy the highest part of the landscape and are found around Toowoomba. They are formed in the Main Range Volcanics basalt lavas. There the surface relief can be up to approximately 150 m and there are numerous small hills and tablelands that rise greater than 75 m above the surrounding country. The basalt was erupted 20 to 25 million years ago, and the surface has been eroded many tens of metres since then, and some deep weathering and duricrust development has occurred. The higher relief topography has allowed more development of watercourses fed by larger catchment areas.
- ▶ Low relief hills—are the oldest element of the landscape occurring widely in the Macintyre Brook catchments. Underlain by very old sedimentary rocks formed hundreds of millions of years ago, they have been deeply weathered with tablelands and duricrusts occurring widely in the western parts of the Canning Creek sub-catchments. There is generally more than 50 m of relief.

14.7.7.1 Regional geomorphic landscapes of the Border Rivers catchment

The Border Rivers catchment rises within Queensland and flows south into NSW. These catchments occur along the Project alignment, travelling south, from the Macintyre River floodplain to Ch 116.0 km. The watershed divide between the Macintyre River (a Border Rivers catchment) and the Condamine catchment occurs between Canning Creek and Back Creek (a small tributary of the Condamine River). In this section the Project alignment rises from 231 m to 474 m elevation (243 m total), including a combined total elevation gain of 642 m and a combined total elevation fall of -399 m. Over this distance it passes through four different locations along the Project alignment:

- ▶ Ch 30.60 km (NS2B) to Ch 33.00 km—the Project alignment crosses the Macintyre River floodplain.
- ▶ Ch 33.00 km to Ch 40.00 km—this section features gently rising plains along the Weir/Macintyre/Dumaresq drainage divide. The Project alignment crosses and re-crosses the drainage divide so that there are effectively no runoff catchments and thus no organised drainage network. There are few channels requiring fluvial geomorphic assessment.
- ▶ Ch 40.00 km to Ch 65.00 km, near Inglewood—the Project alignment enters the lower Macintyre Brook catchment where low hills on the west come down close to the valley floor. The route skirts along the lower slopes of these hills which support several small catchments with watercourses crossing the Project alignment. These are mostly small 1st and 2nd Strahler order streams with one 3rd order and one 4th order stream.
- ▶ Ch 65.00 km to Ch 116.00 km—the Project alignment enters the Canning Creek catchment and runs near this stream close to the valley floor. It crosses low hills, alluvial plains and floodplains. The sub-catchments are larger and support larger watercourses with distinct channel landforms of 3rd, 4th and 5th Strahler order and these are named including Bringalily Creek, Cattle Creek, Back Creek, Canning Creek, Native Dog Creek, Nicol Creek and Pariagara Creek.

14.7.7.2 Regional geomorphic landscapes of the Condamine River catchment

From Ch 116.00 km to the end of the Project alignment at Ch 208.22 km, the route passes across the Condamine River catchment. There is an overall fall of just 17 m but there is a combined total fall of -596 m and a combined total climb of 579 m; so, it has more local relief change than the Border Rivers section. It passes through four different sections of the Project alignment:

- ▶ Ch 116.00 km to Ch 140.00 km—the route runs down the Back Creek catchment across mostly alluvial plains with some low hills in the upper catchment. This low relief landscape supports a few small sub-catchments and watercourses mostly of 1st and 2nd Strahler order, with a 4th and 5th order stream about halfway down.
- ▶ Ch 140.00 km to Ch 152.00 km—here the route crosses the Condamine River floodplain which is very flat and forms a large flood basin. There are three main anabranches of the river that are fed by a very large 7,017 km² catchment.
- ▶ Ch 152.00 km to Ch 165.00 km—this section features gently rising alluvial plains on the north side of the Condamine River floodplain. The Project alignment runs along this slope, and no mapped watercourses cross the alignment; however, several small catchments can be identified from contour patterns on topographic maps.
- ▶ Ch 165.00 km to Ch 208.20 km—this final section of the route crosses the moderately hilly basalt landscape around Toowoomba. It has many changes in elevation as it passes through the numerous hills in this landscape. Given the greater relief, there are numerous catchments with watercourses crossing the Project alignment. These are mostly 1st and 2nd Strahler order along with one 3rd order and one 4th order stream. Despite the relative low Strahler order, some of the streams are large enough to have been named including Westbrook Creek, Oakey Creek, Gowrie Creek, Dry Creek and One Mile Gully.

14.7.7.3 Land degradation

Land degradation denotes a range of land surface effects resulting in loss of soil and vegetation cover. Processes of specific concern include soil erosion and gullying that result in loss of productive land and delivery of sediment to watercourses. While some level of land degradation is a natural process in the study area environment, accelerated rates often follow in the decades after land is cleared of trees. Accelerated land degradation was observed during the geomorphology assessment. This will have increased the volume of sediment being delivered to the watercourse.

The significance of this land degradation is that it is a response to the previous decades of land use practices that is now becoming evident in the landscape. The sediment that is being delivered to the stream channels has yet to make its way fully down the system, and as it moves down valley, channel aggradation is likely to occur. Future management of watercourses in the Project footprint needs to consider the potential for increased sediment loads that are unrelated to Project activities, but which may result in reduced capacity of the channels to convey flood flows if flow velocities are reduced.

14.7.7.4 Climate change sensitivity

A climate change sensitivity analysis has been undertaken under hydrology and flooding for the 1% AEP event at regional catchments to determine the sensitivity of the Project to the potential long-term changes in climate identified (Appendix T1: Hydrology and Flooding Technical Report—Volume 1). The analysis reports on per cent increase in rainfall for the regional models and change in peak water levels at flood sensitive receptors. The Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario has been adopted for the sensitivity analysis. The assessment was undertaken in accordance with ARR 2019.

An analysis on changes to flow velocity has been undertaken to determine the sensitivity of geomorphic process to potential long-term changes in climate (1% AEP event). To focus the assessment on potential changes in the area of design cross-drainage the assessment considers changes in the regional hydraulic models within the permanent Project footprint. The results of this sensitivity analysis are presented in Appendix H: Geomorphology Report (Section 3.1.8.1), and are summarised below:

- ▶ Potential flow velocity changes are within 0.1 m/s of the Existing Case for 44 to 95 per cent of the regional hydraulic models, little change is expected in these areas.
- ▶ Nine to 49 per cent of the regional hydraulic models have potential flow velocity changes of between 0.1 to 0.5 m/s of the Existing Case; some changes in geomorphic processes including deposition and erosion may occur in these areas where there is no scour protection.
- ▶ Nine of the 12 regional models have potential flow velocity changes of between 0.5 m/s to 1.0 m/s of the Existing Case, this ranges from <0.5 to 6 per cent of the permanent Project footprint within the models. Changes in geomorphic process are likely in these areas.
- ▶ Eight of the 12 regional models have potential flow velocity changes of greater than 1 m/s of the Existing Case, this ranges from <0.5 to 1 per cent of the permanent Project footprint within the models. Major changes to geomorphic process may occur in these areas.

There is a range in sensitivity to flow velocity due to climate change across the 12 regional hydraulic models. Westbrook Creek is the most sensitive and has the largest potential changes in flow velocity due to climate change. More than 50 per cent of the Westbrook Creek regional model within the permanent Project footprint would likely experience changes to geomorphic processes as a result of climate change driven changes in flow velocity. Bringalily Creek, Gowrie Creek, Macintyre Brook, MB 7 and Pariagara Creek may experience geomorphic change of between 44 to 40 per cent of the area within the permanent Project footprint. Back Creek 1, Condamine River and Nicol Creek may experience geomorphic change of between 17 to 33 per cent of the area within the permanent Project footprint. The least changes in flow velocity due to climate change are with the Cattle Creek, MB 6 and Native Dog Creek regional models, where geomorphic change may occur in between 5 to 10 per cent of the area within the permanent Project footprint.

14.7.8 Existing Case geomorphic conditions

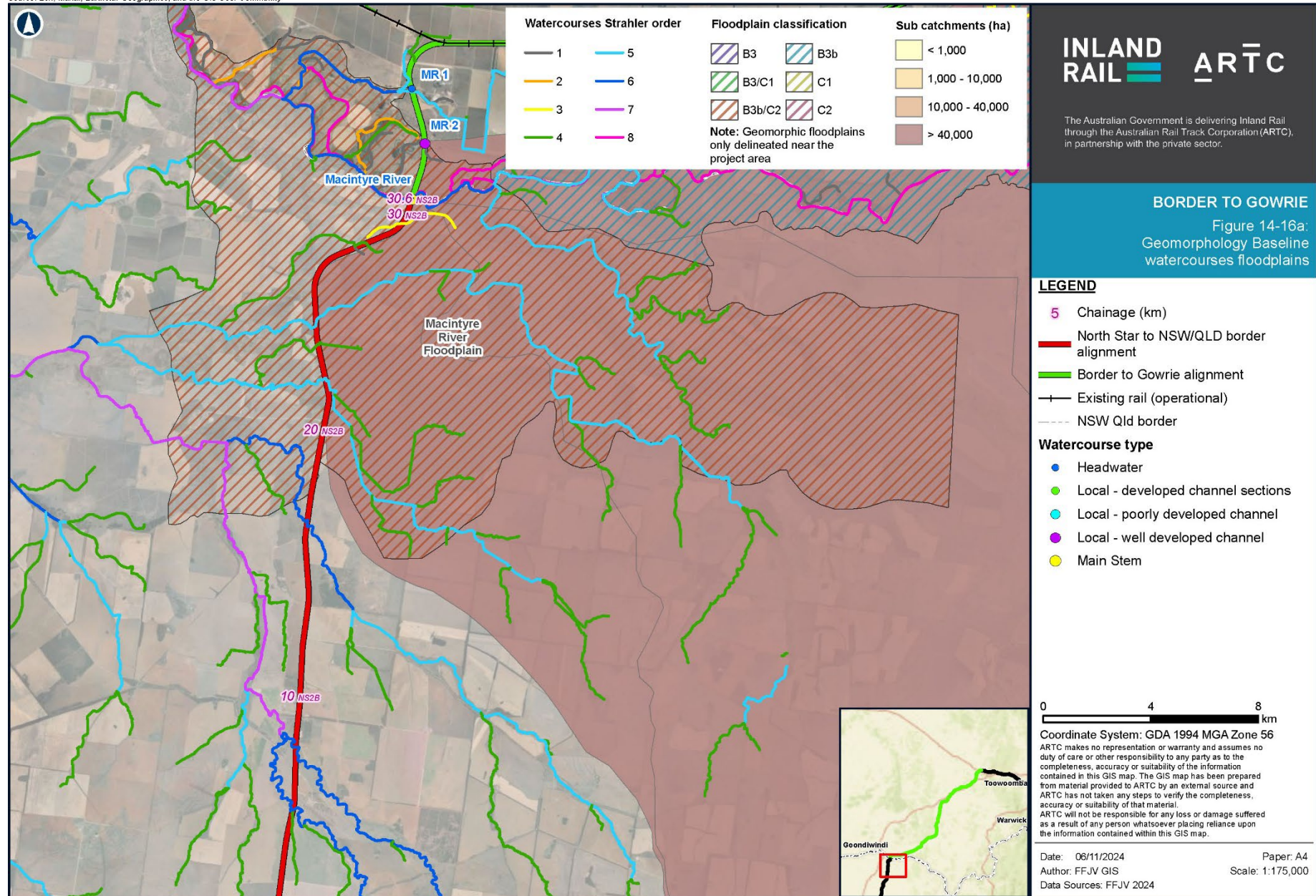
The following sections summarise the existing case conditions including field checking, soils, vegetation cover, watercourse channel and floodplain types, processes and sensitivity to change. The Existing Case watercourse and floodplain types along the alignment are shown in Figure 14-16. Further information including detailed tables of site characteristics and field checking observations and photos are included in Appendix H: Geomorphology Report (Section 3, Appendix C, Appendix D, Appendix F and Appendix G).

14.7.8.1 Field checking

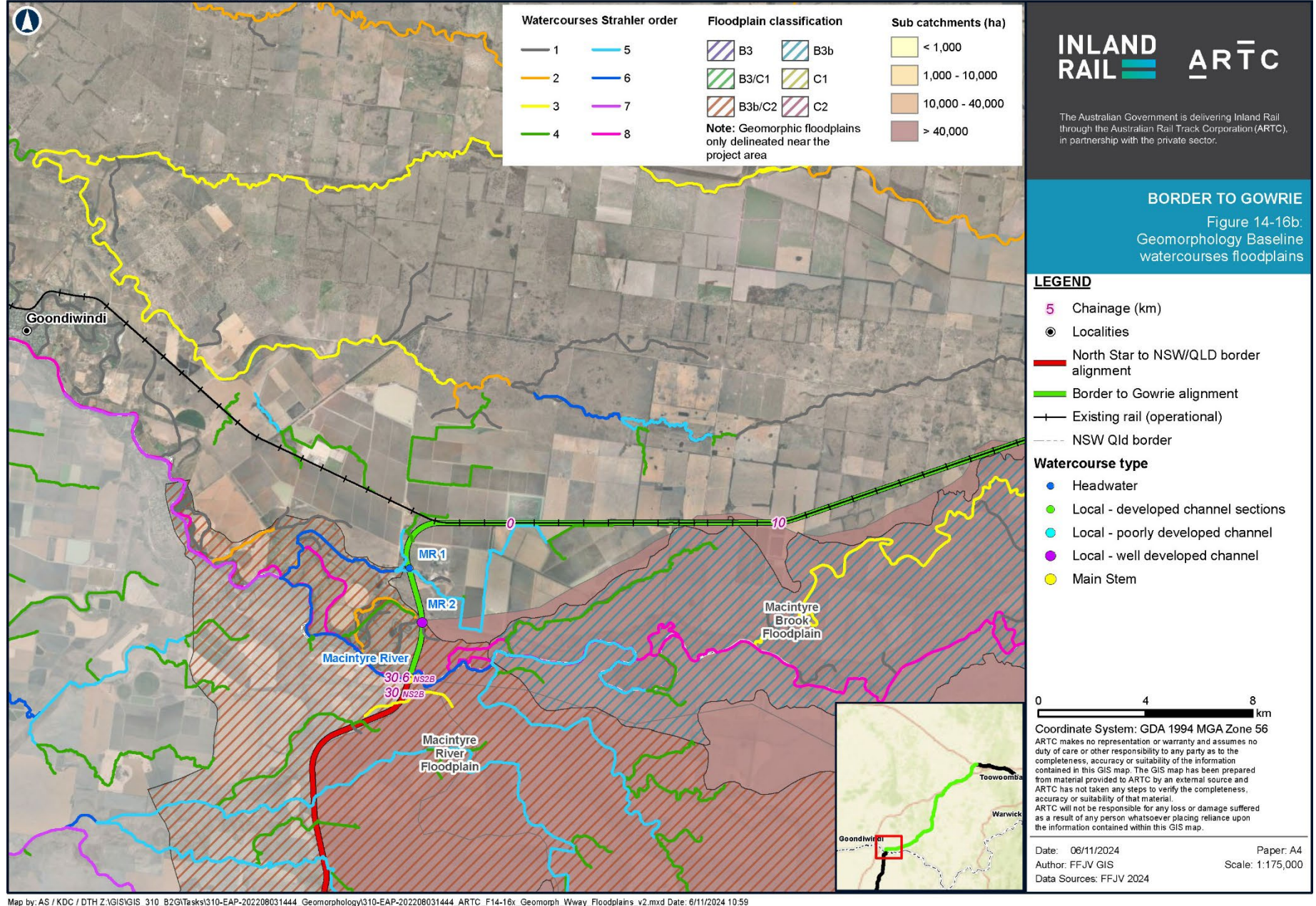
A total of 55 field checking sites were investigated from 7–11 March 2022 to confirm baseline conditions and gather observations on the impacts of existing infrastructure on watercourse and floodplain processes. Field site IDs are either labelled EP, for sites dominantly visited to assess erosion potential, or BL for baseline checking sites; however, fluvial geomorphic observations on the watercourses and floodplains were gathered at all sites (Figure 14-17 for the locations of the field checking sites). As sites visited were accessible from public roads, some of the sites were not on the Project alignment, and due to lack of safe offroad parking, some sites were not able to be assessed.

The site inspections occurred shortly after a significant flood event and river levels were still receding at some sites. It was estimated that the flood events that occurred in the Condamine River in March 2022 were equivalent to a 20% AEP event at Cecil Weir and potentially less than a 20% AEP around Yandilla. This was a flood event close to bankfull conditions for a number of watercourses, where some erosion on the outside of bends and deposition would be expected to occur under natural conditions away from infrastructure. The site inspections occurred approximately a week after this event. See Appendix H: Geomorphology Report (Section 3.6 and Appendix F) for further detail on the baseline field checking.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

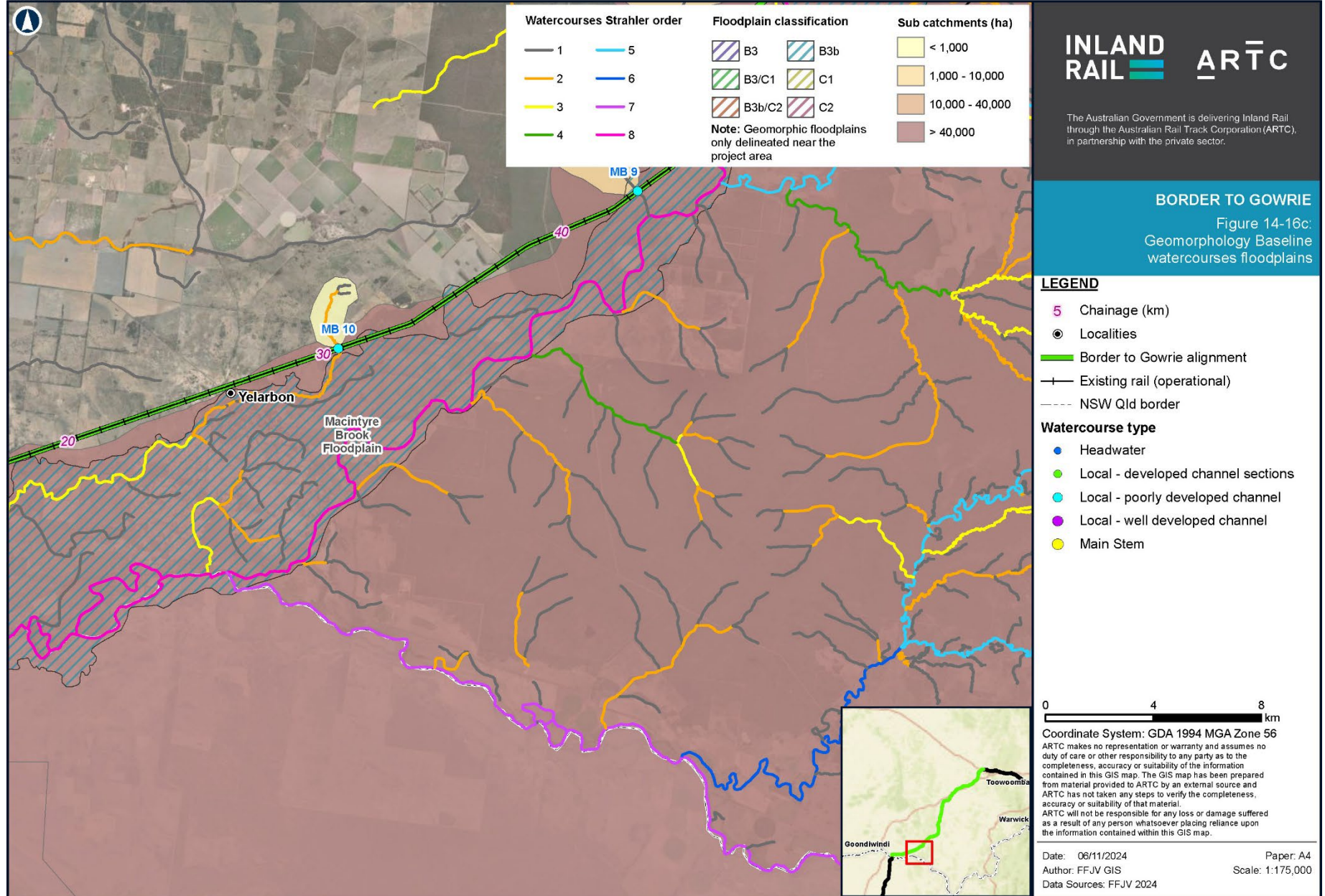


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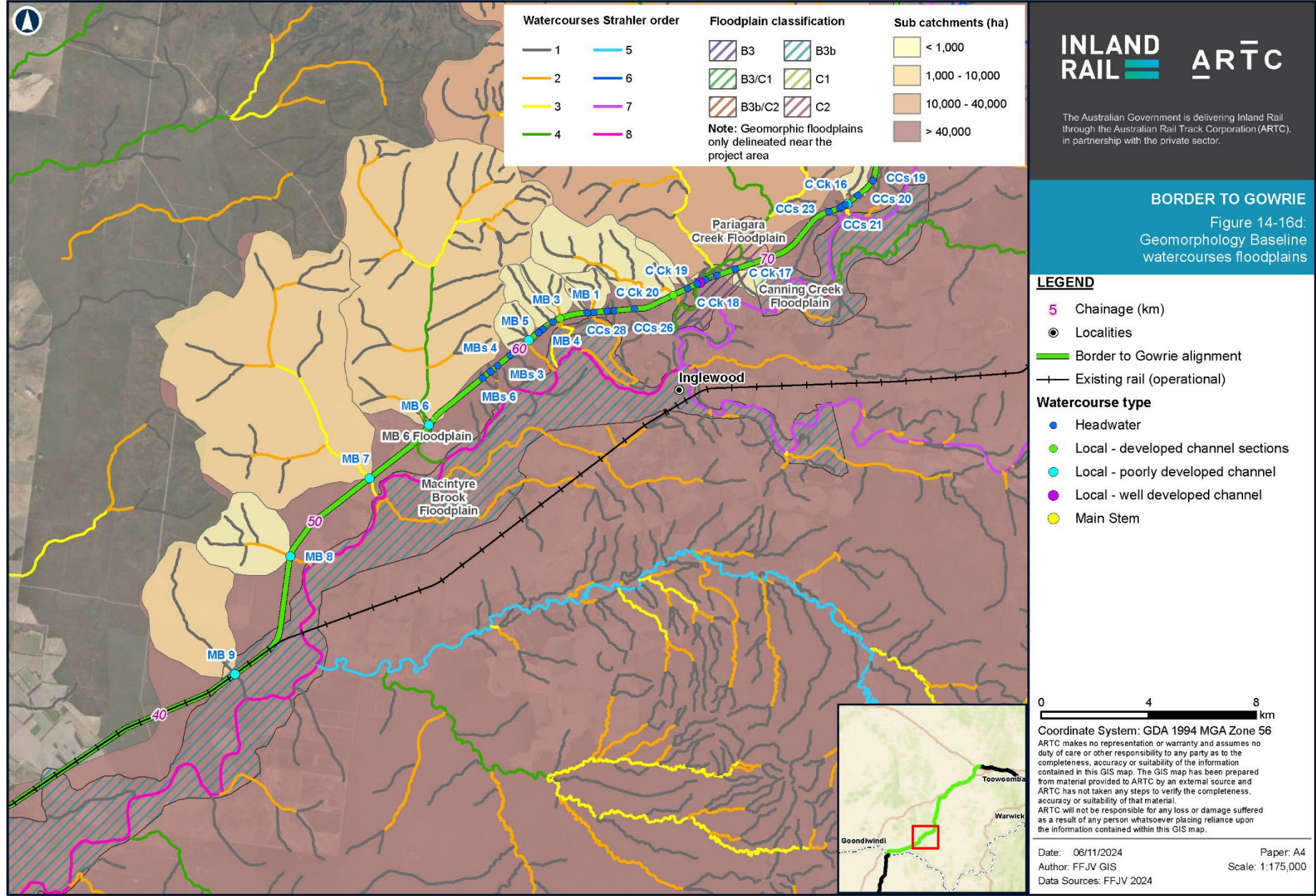


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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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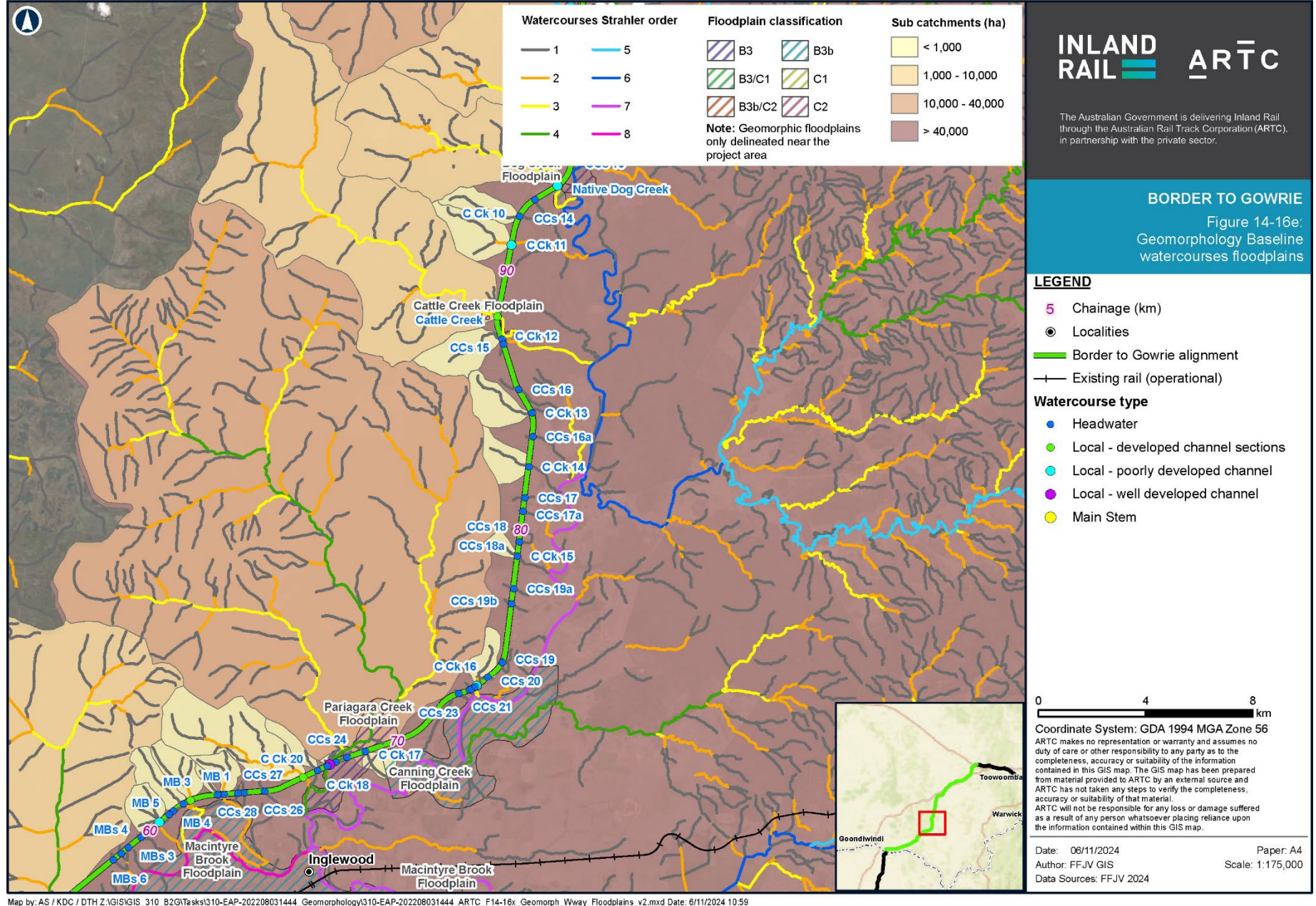


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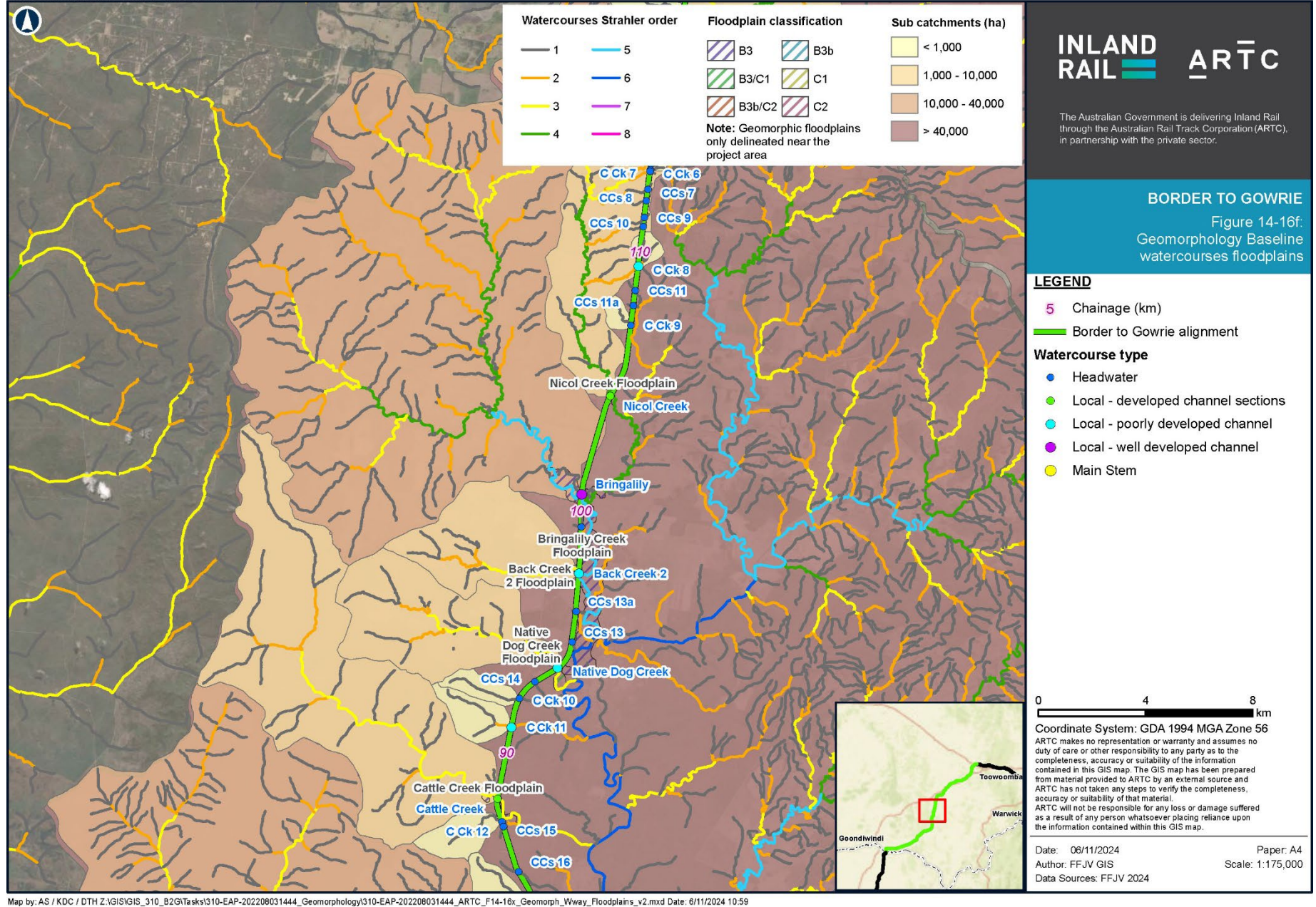
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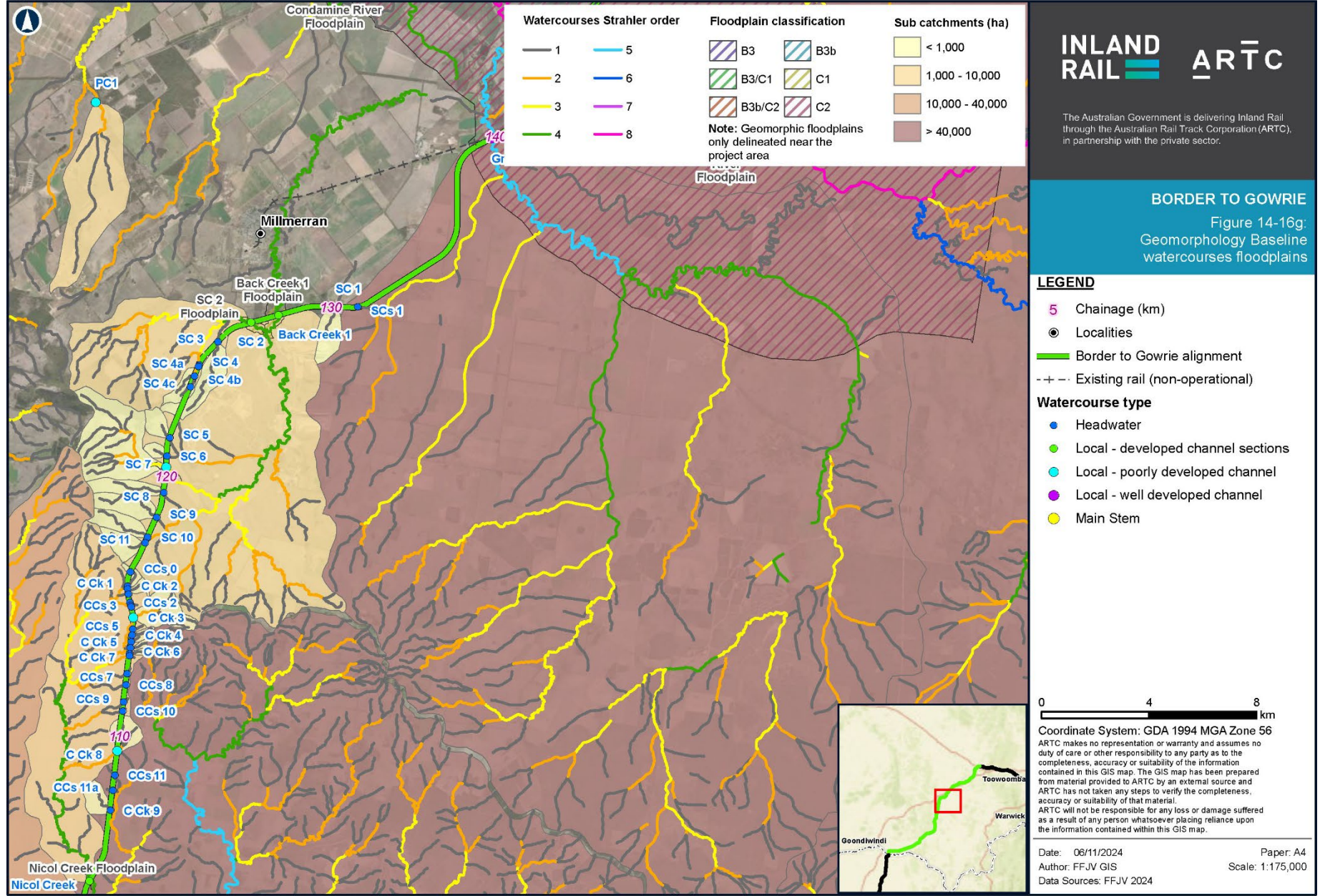


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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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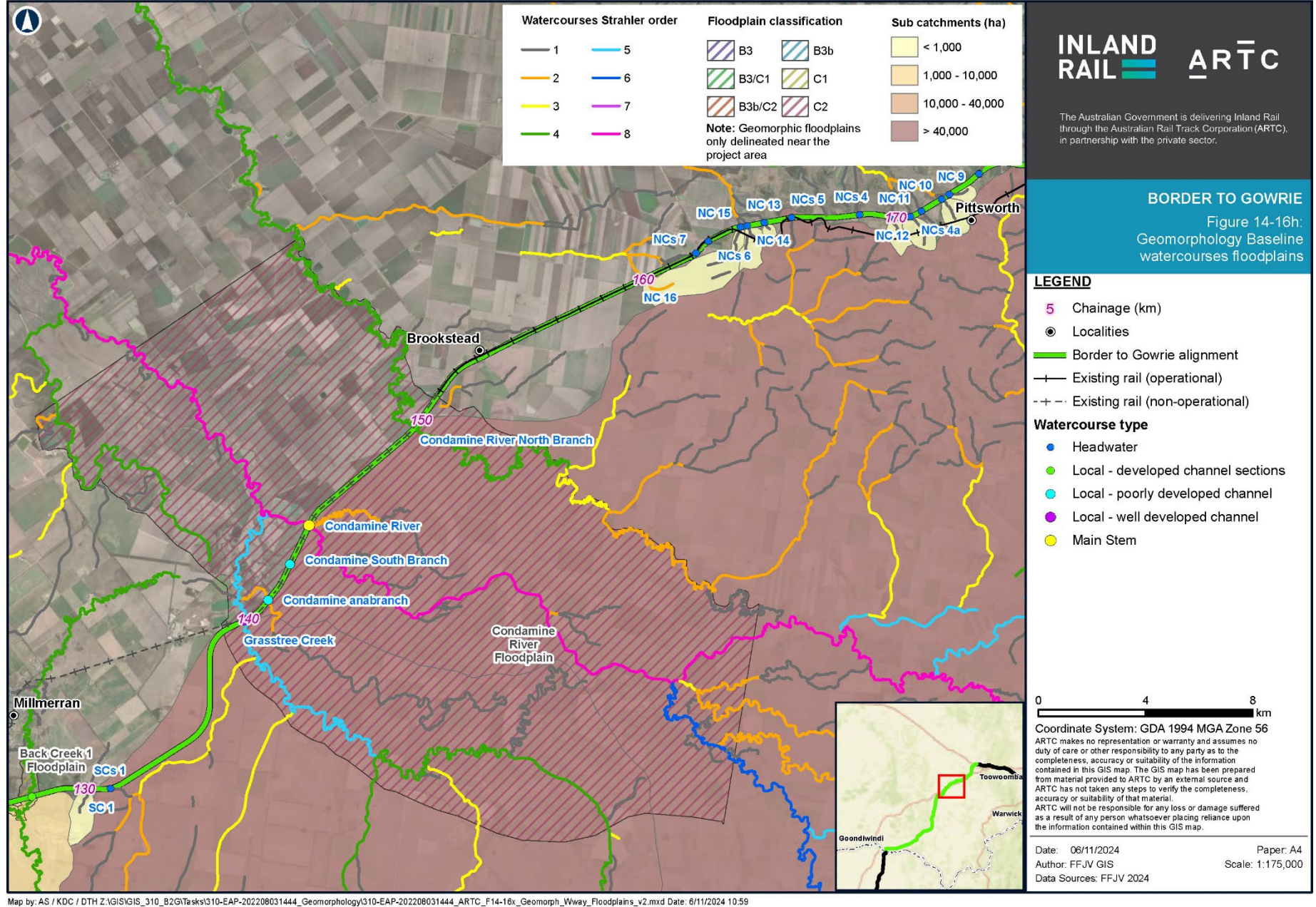


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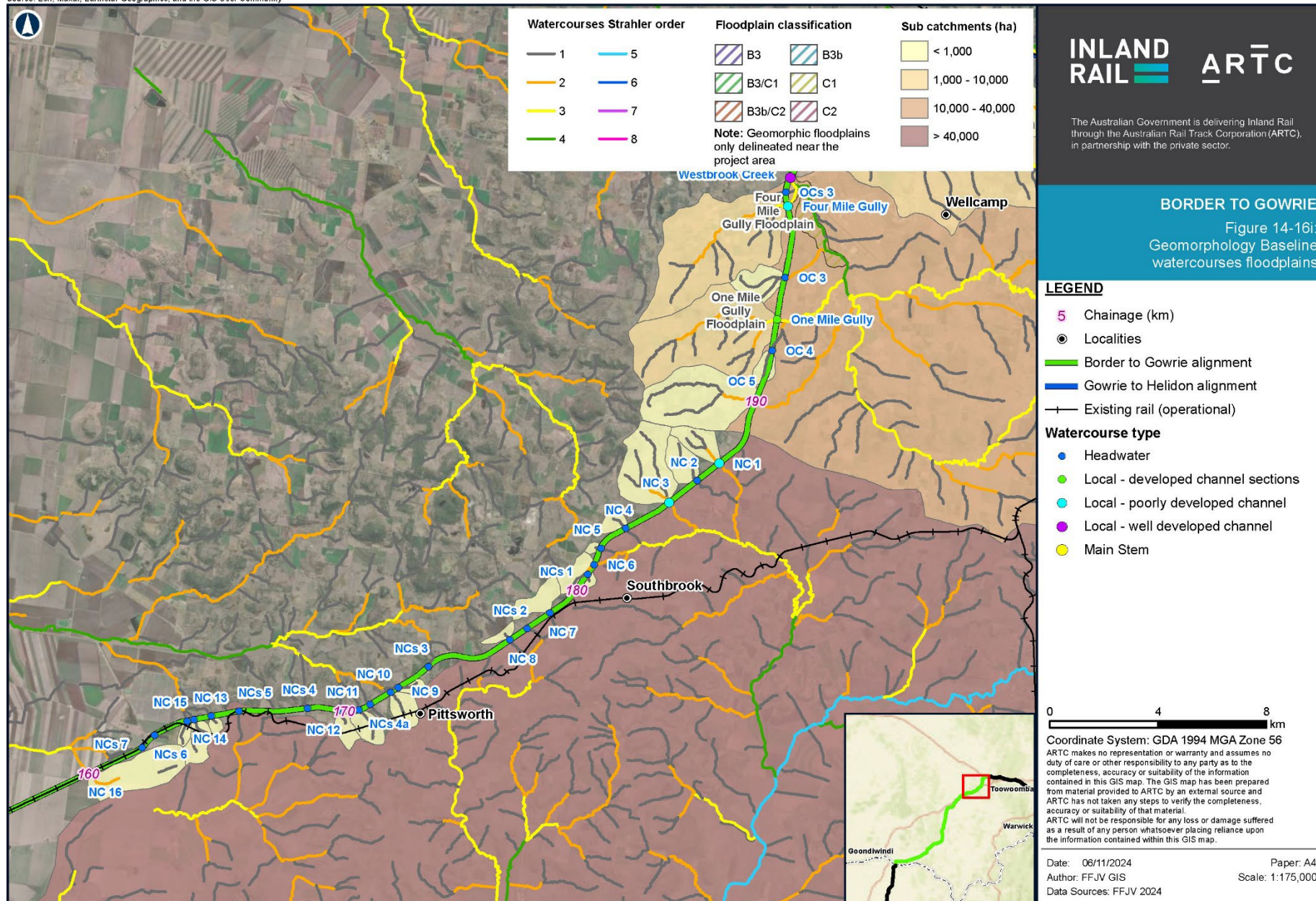


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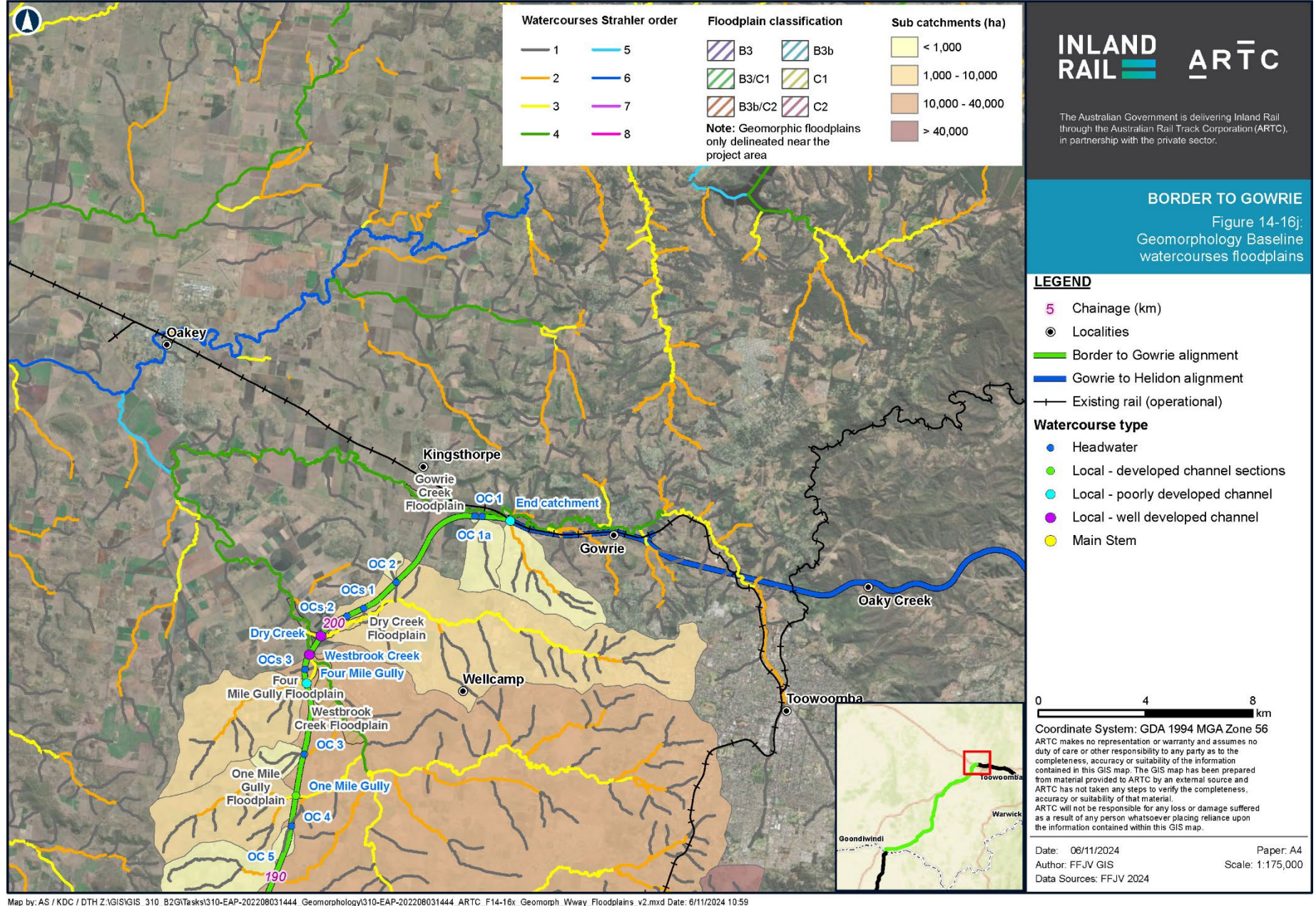


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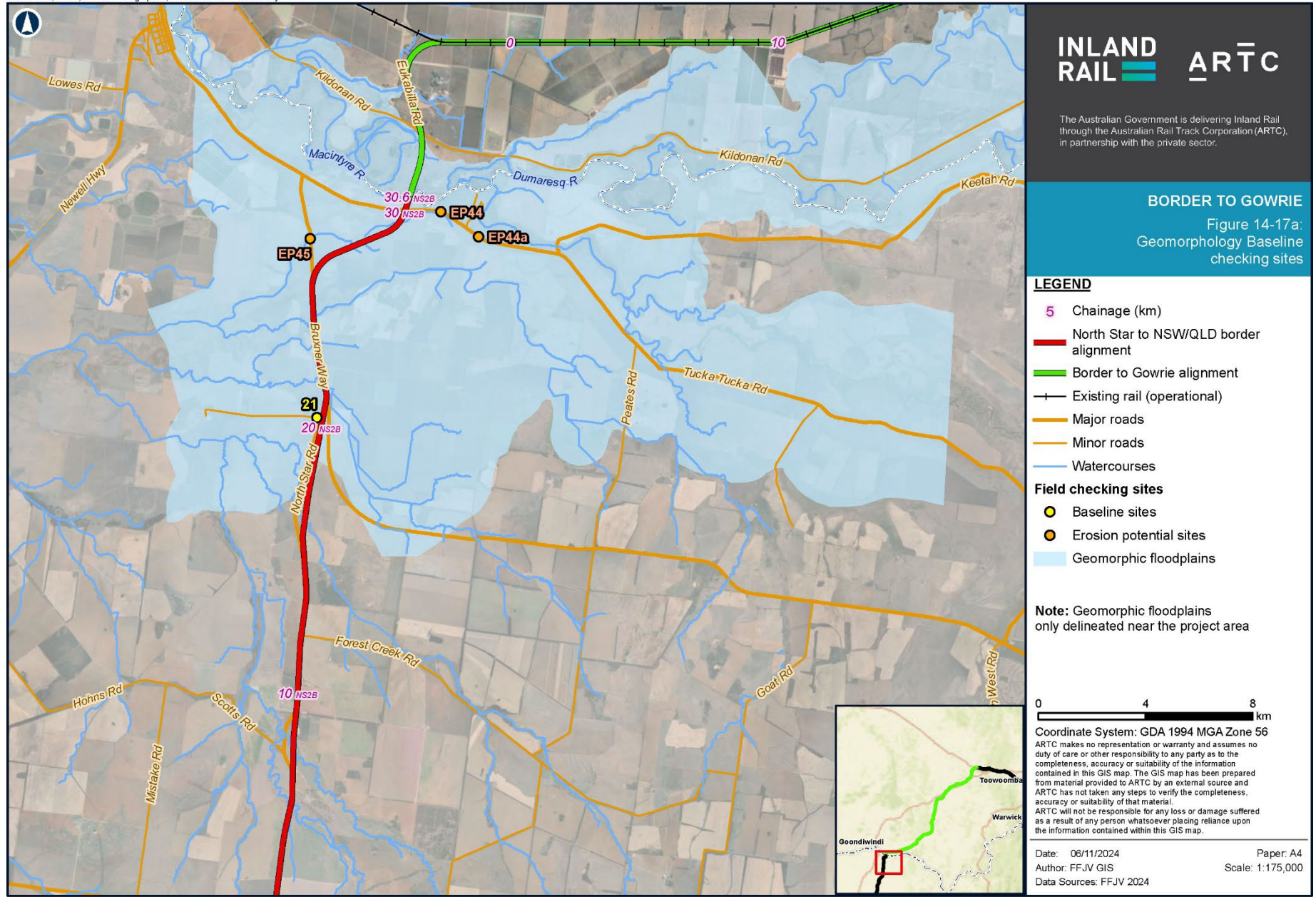


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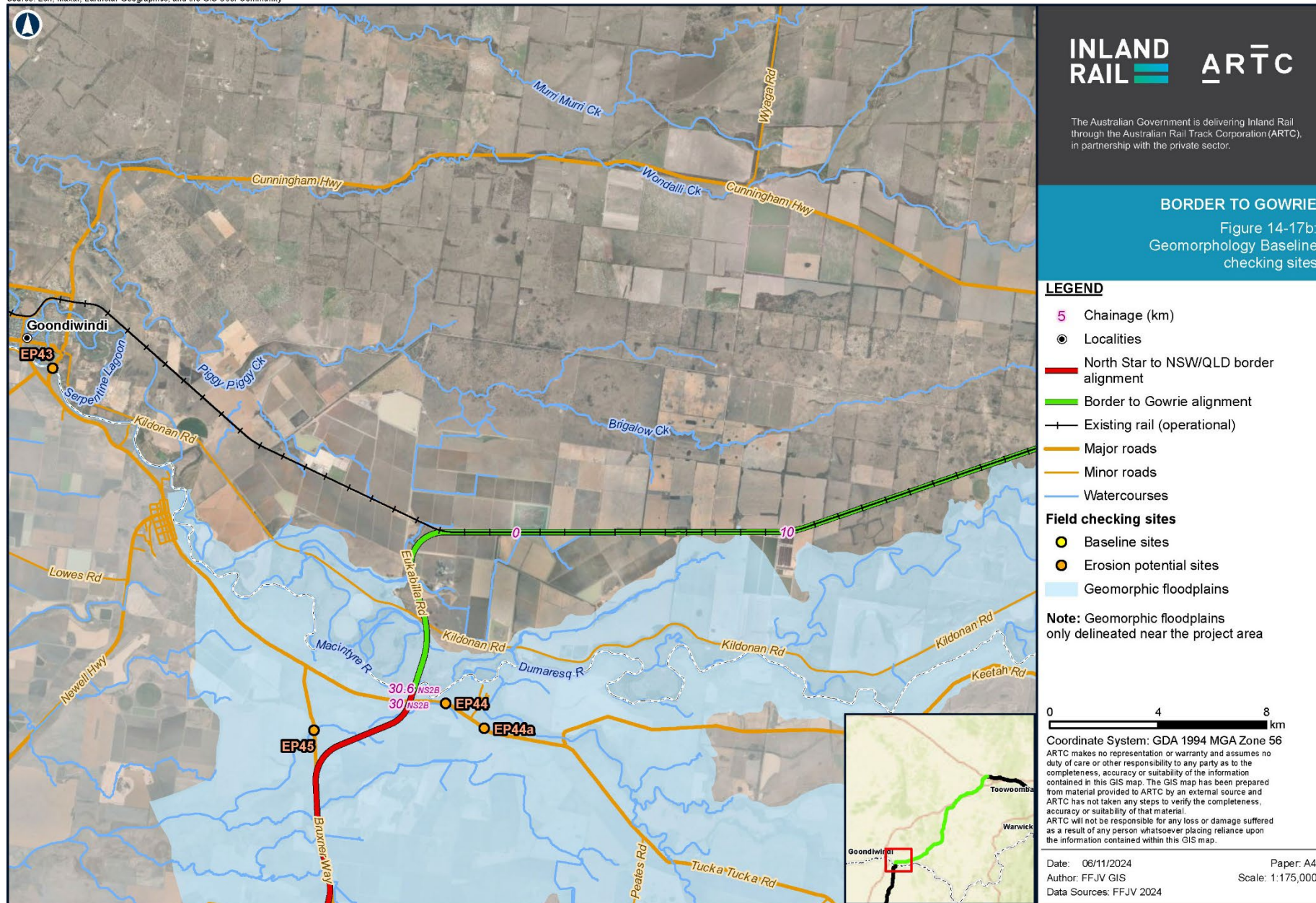


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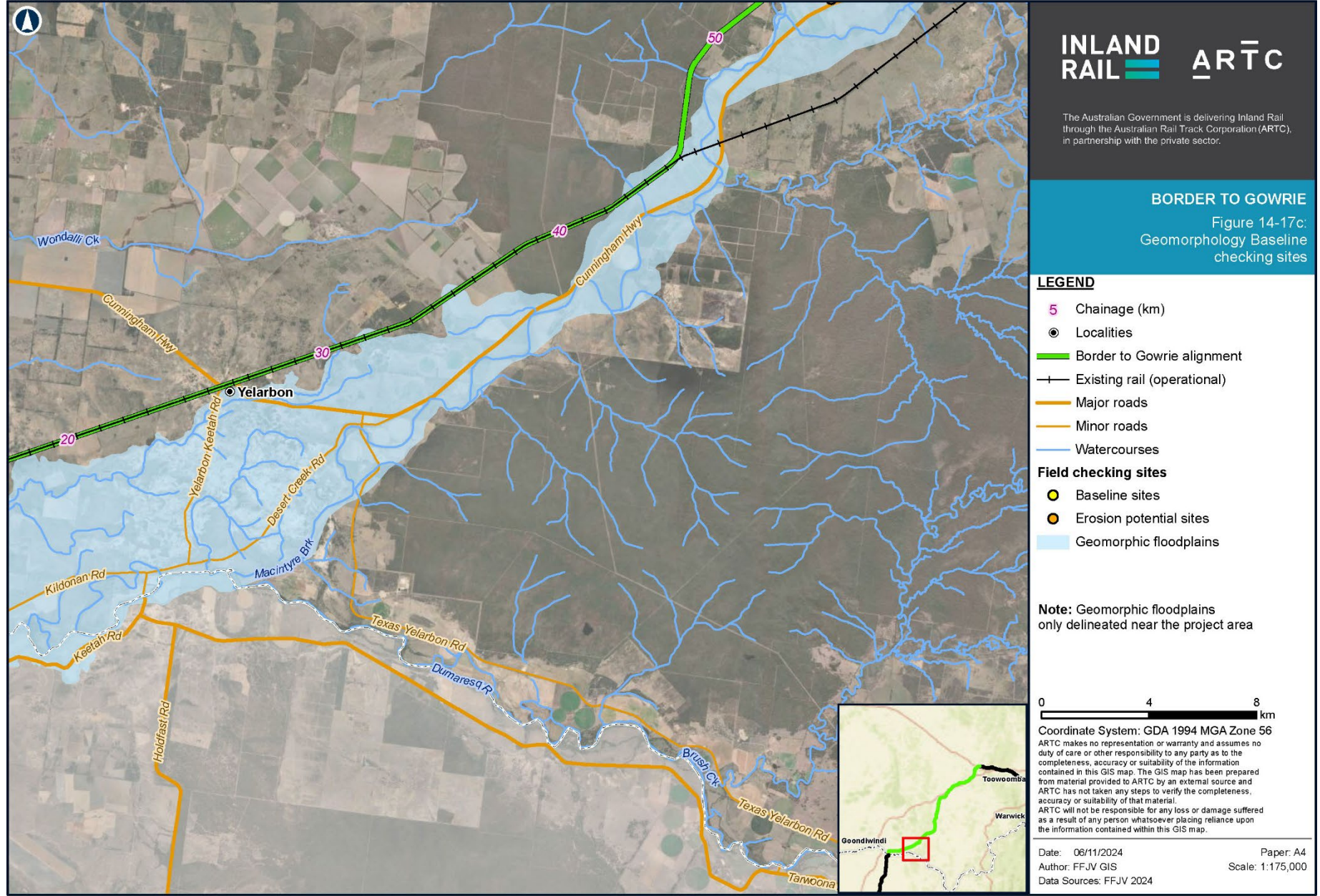
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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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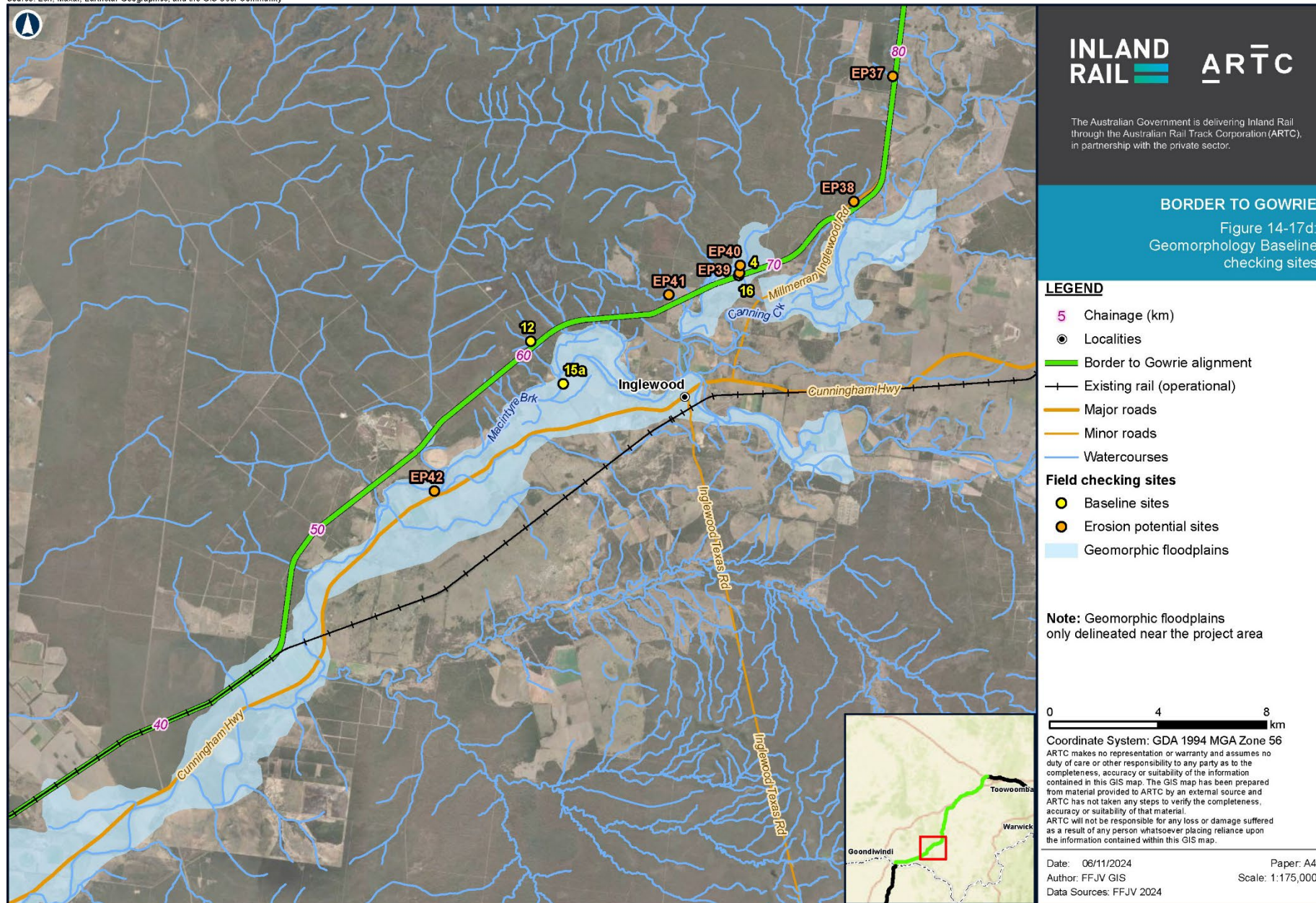


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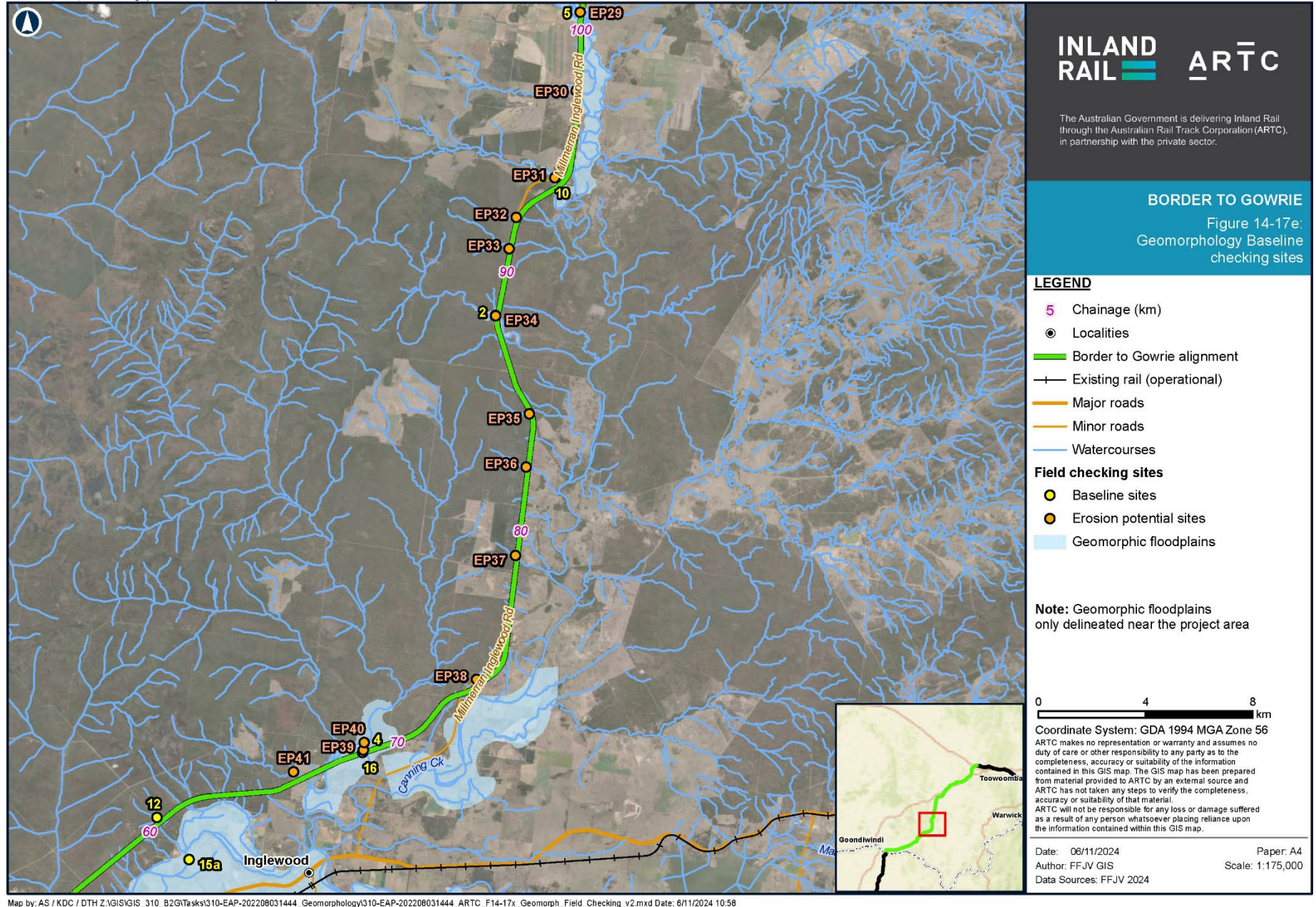
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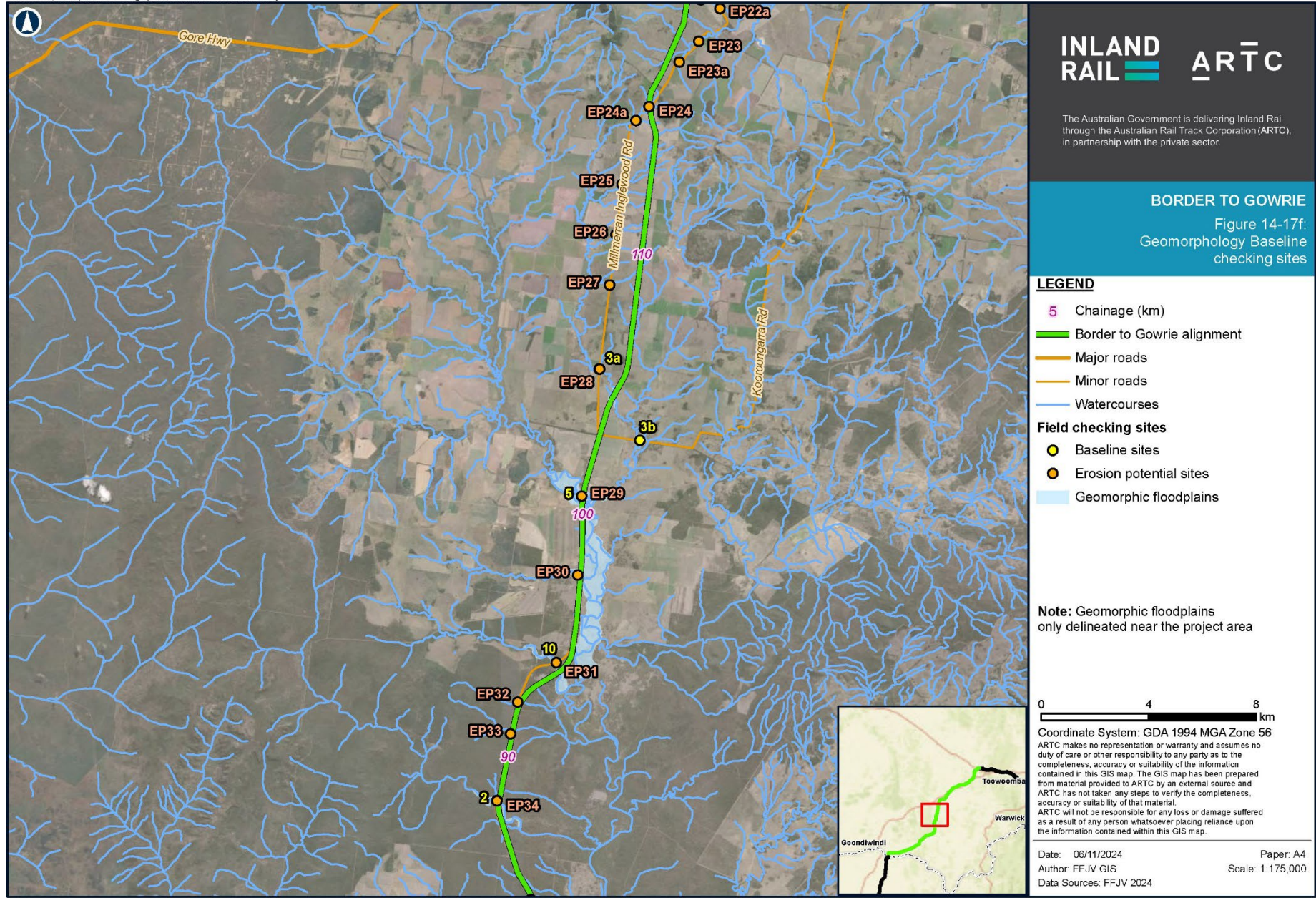
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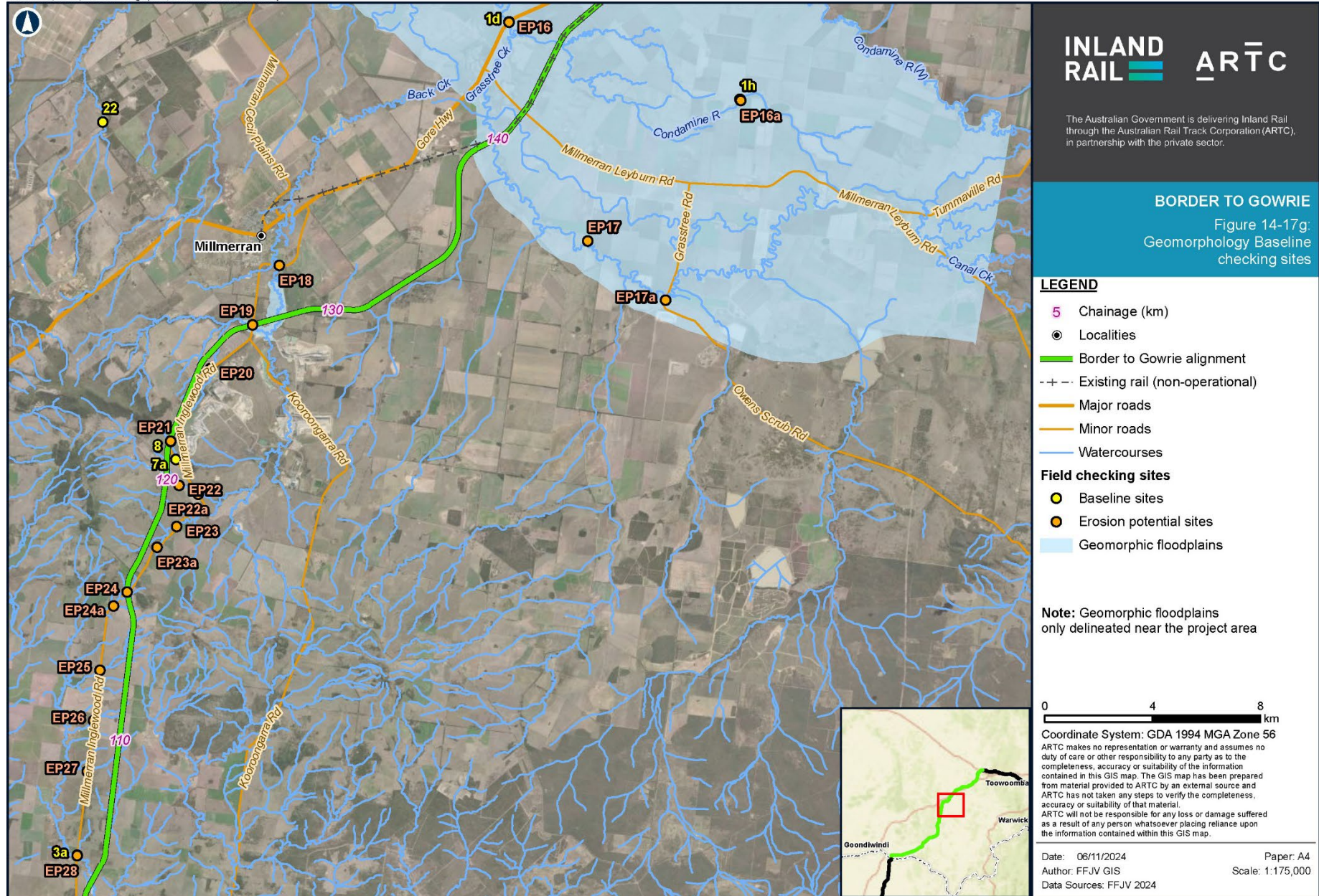


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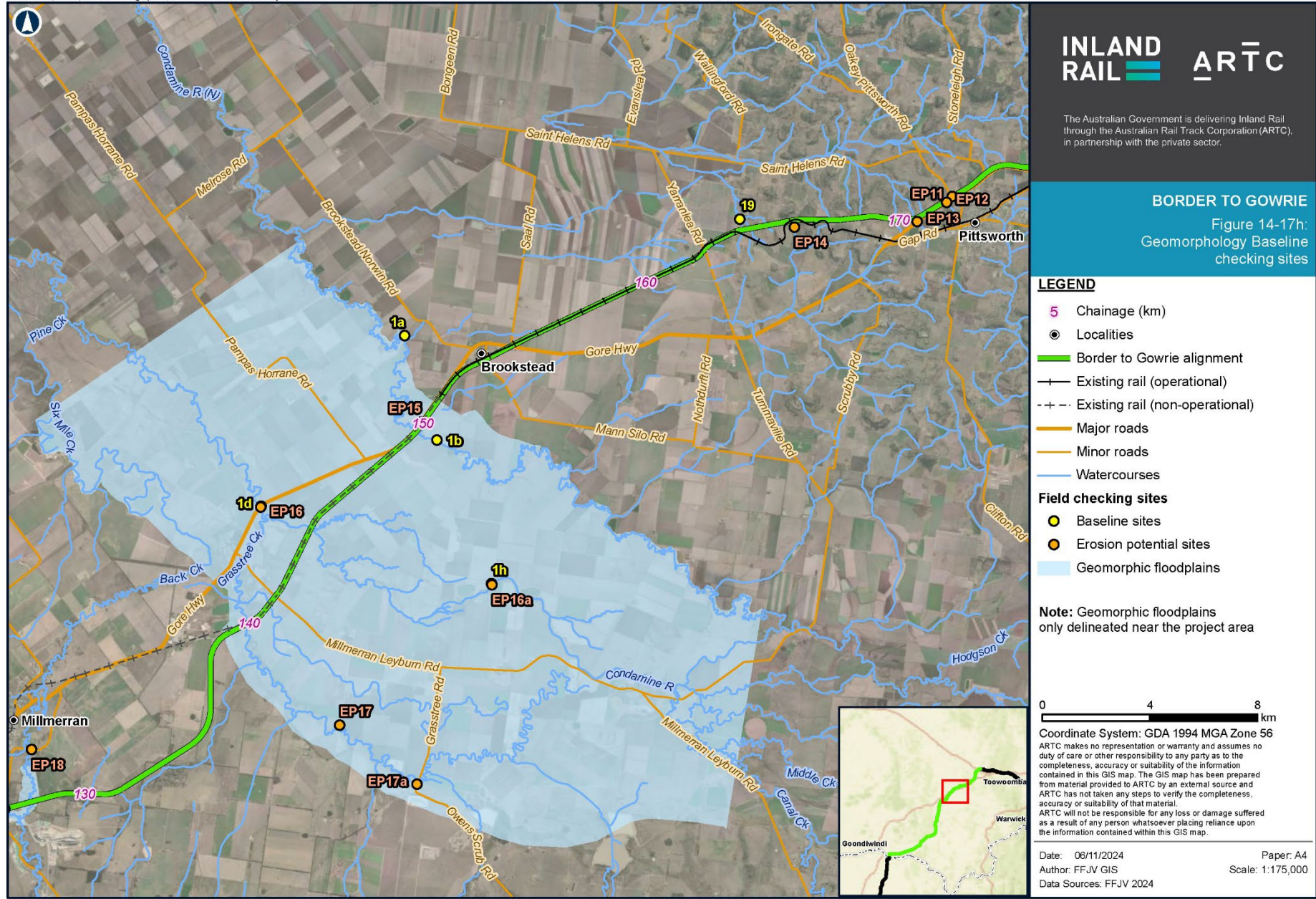


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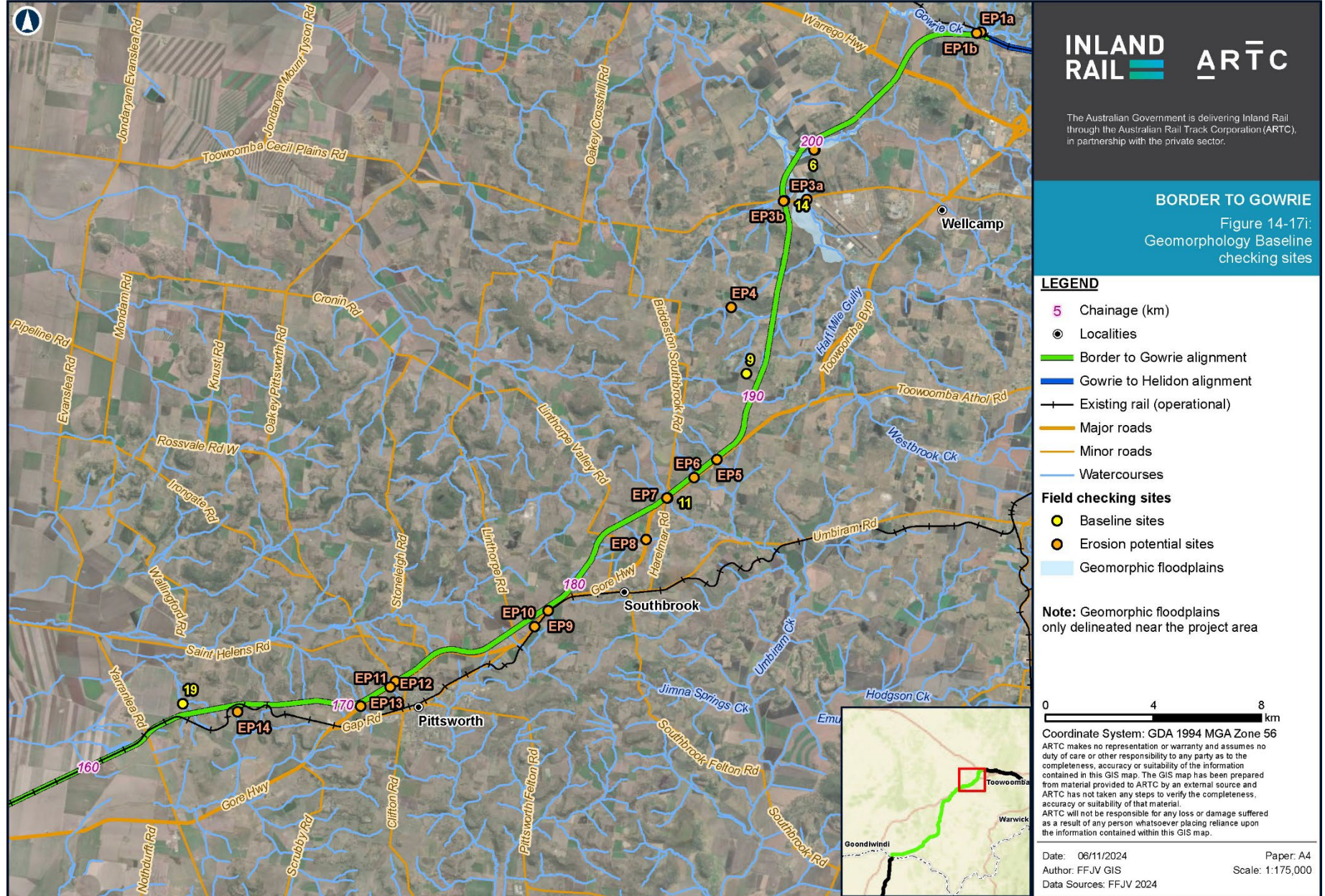
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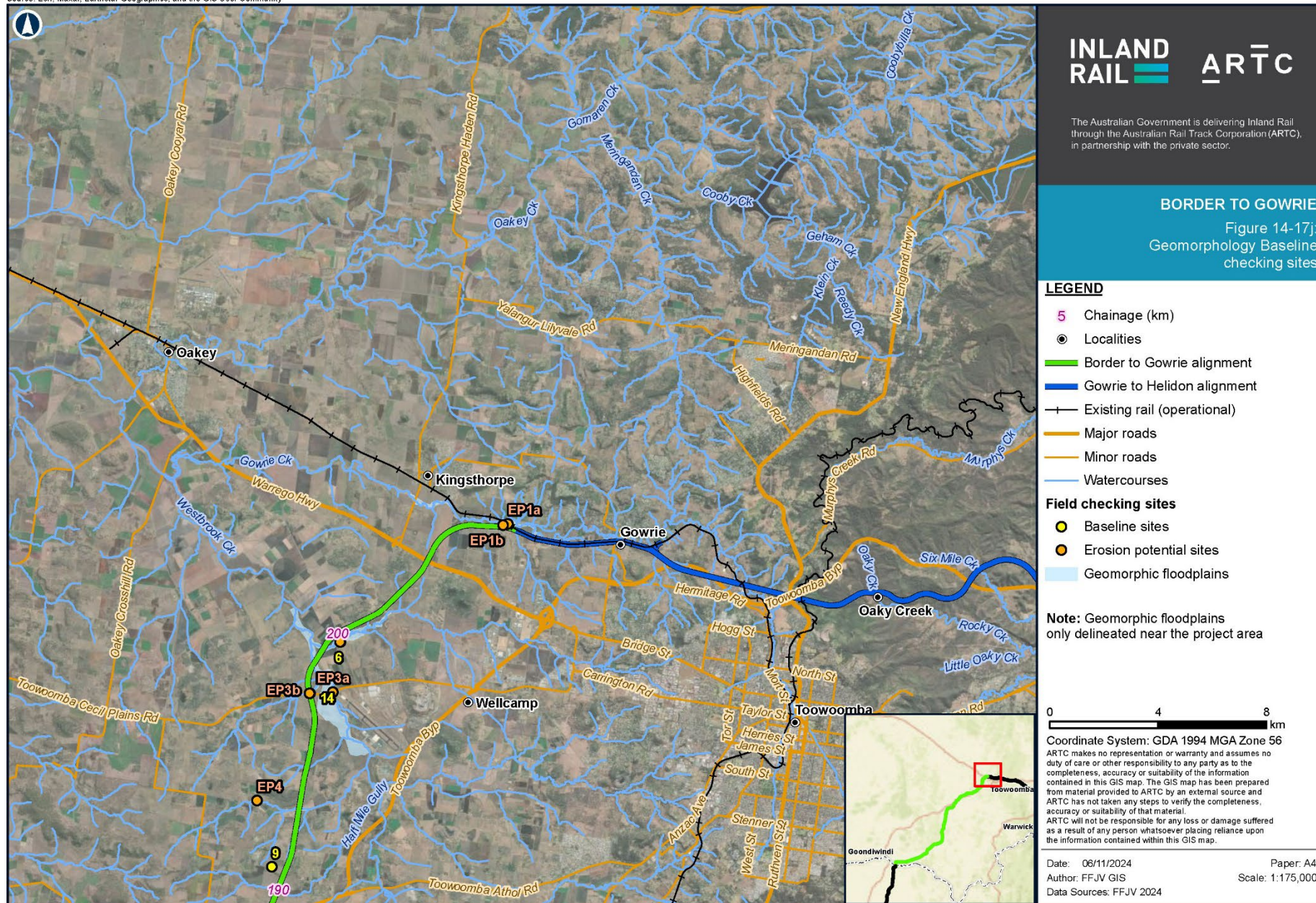


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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



14.7.8.2 Soil types

The main soil types, their general distribution and geomorphic significance are summarised in Table 14-25. In this chapter, soils are defined as any non-consolidated material at the earth's surface, rather than specifically unconsolidated material that supports plant growth.

The soils layer used for the baseline assessment was the Australian Soil Resource Information System Soils: ASC Grid (Commonwealth Scientific and Industrial Research Organisation, 2021). This is referred to as the 'regional ASC' layer. A soil assessment was undertaken within the Project footprint (Appendix J: Soil Assessment Report); however, the regional ASC was used for describing the catchment soil group, as the detailed soils assessment is limited to the Project footprint.

Of particular concern are the sodosols and vertosols as they are susceptible to rapid onset of rilling and gulling erosion if disturbed and can be difficult to revegetate. Vertosols include cracking clays and the shrink/swell characteristics of these soils means that mature woody vegetation does not generally occur, and re-establishing vegetation after disturbance can be problematic.

The performance of existing cross-drainage infrastructure in vertosol and sodosols provides real world examples of the ability to revegetate sites post-construction and erosion performance. In summary, while there is well documented ongoing erosion at some cross-drainage on the existing QR embankment in vertosols between the Condamine River and Grasstree Creek due to inadequate design, review of more recently designed cross-drainage along the Gore Highway shows almost all of the culverts in the Condamine have established grass at culvert inlets and outlets. Refer to Appendix H: Geomorphology Report (Sections 3.3.3 and 3.6.3.4) for further discussion of existing infrastructure performance by ASC soil type.

TABLE 14-25 AUSTRALIAN SOIL CLASSIFICATION REGIONAL SOIL DESCRIPTORS

Soil type and ASC	Soil description ASC	Occurrence in the landscape	Geomorphic significance	Erodibility rating
Vertosol–uniform cracking clays, lack soils	Vertosols are high plasticity clays that shrink and crack open when dry and swell when wet. Gilgai micro relief is common. Parent materials range from intermediate, mafic to ultramafic in composition. High agricultural potential with high chemical fertility and water-holding capacity.	Moderate relief hill country around Toowoomba, old alluvial plains and across the Condamine River floodplain. Also occur in low hill landscapes either side of the Condamine/ Macintyre Brook drainage divide associated with basalt outcrops in that area.	The clay-rich characteristics of Vertosols mean they are cohesive and typically form stable channel banks. These soils are typically on gentle slopes so tend to be geomorphologically stable unless disturbed. Channels formed in Vertosol may be more susceptible to geotechnical failure modes than those formed in non-cracking clays.	Low (2) to moderate (3)
Dermosol–uniform and/or structured loams, clay loams and clays	Dermosols have structured profiles with well-developed horizons and relatively high clay content. They do not display strong texture contrast or cracking clay characteristics. Dermosols generally have high agricultural potential with good structure.	Scattered occurrences in the moderate relief hill landscapes around Toowoomba, and valley floors and low hills in the lower Macintyre Brook catchment.	The clay-rich characteristics of these soils mean they are cohesive and typically form stable channel banks. These soils landscapes are typically on gentle slopes so tend to be geomorphologically stable unless disturbed.	Very low (1) to moderate (3)

Soil type and ASC	Soil description ASC	Occurrence in the landscape	Geomorphic significance	Erodibility rating
Kandosol–uniform and gradational sandy, loam and clay soils	Kandosols are uniform loams and clays with a massive to strong structure. Texture can grade down profile; however, abrupt texture contrasts do not occur. They have low to moderate agricultural potential with moderate chemical fertility and water-holding capacity.	Minor areas mainly in Low relief hills in the Macintyre Brook and Canning Creek catchments.	The clay-rich characteristics of these soils mean they are cohesive and typically form stable channel banks. These soils landscapes are typically on gentle slopes so tend to be geomorphologically stable unless disturbed.	Very low (1) to moderate (3)
Ferrosol	Ferrosols are structured, highly-permeable and, hence, well-drained soils with high iron content. Usually developed on volcanic rocks they have moderate to high fertility and water-holding capacity and are often used for intensive crops production.	Occur scattered among the Vertosols through the moderate relief hills around Toowoomba.	The clay-rich characteristics of these soils mean they are cohesive and typically form stable channel banks. These soils landscapes are typically on gentle slopes so tend to be geomorphologically stable unless disturbed.	Very low (1) to moderate (3)
Texture contrast soils–sodosol and chromosol	Both Sodosols and chromosols exhibit strong texture contrast between sandy or loamy A horizons and a dense clay-rich B horizon. In Sodosols the B horizon is strongly dispersive and disaggregates on contact with water. Chromosols have similar structure but are less dispersive or non-dispersive. They have moderate agricultural potential.	Associated with the low relief hill country and old alluvial plains in the Canning Creek and Macintyre Brook catchments. Chromosols are similarly distributed.	When the vegetation cover is disturbed, these soils are susceptible to rilling, piping and gully erosion, and in extreme cases badlands erosion. High sediment load delivery to channels is likely with aggradation downstream.	High (4) to very high (5) Moderate (3) to high (4)

14.7.8.3 Watercourse identification and classification

A total of 143 watercourses were identified that cross the Project alignment. Ten watercourses were identified in addition to the Murray Darling watercourse dataset based on review of imagery and hydraulic data.

Stream flow regimes can be classified as perennial, intermittent, or ephemeral. Perennial streams flow all year round and are fed by baseflow (e.g. groundwater runoff) and some storm flow (e.g. surface or shallow subsurface runoff after rainfall). Intermittent streams are fed by storm flow, and some baseflow in the weeks or months after a rainfall event. Ephemeral streams are fed entirely by stormflow and only flow for a few hours after a rainfall event.

Only four watercourses in the study area are listed as perennial in the Murray Darling watercourse lines dataset: Macintyre River, Westbrook Creek, Condamine North Branch and the Condamine River. All other watercourses are listed as 'non perennial' and are either intermittent or ephemeral.

Channel types

The following channel types are present in the study area. They are derived from Erskine et al., (2017) and modified for Project-specific conditions. A high-level channel evolution model for each channel type is included and linked to sensitivity to change. See Appendix H: Geomorphology Report (Section 2.2.5) for the methodology for assessment of sensitivity to change, which includes site specific factors such as soils, geomorphic process, historic change and catchment characteristics. The following channel types present in the study area include.

- ▶ **Bedrock confined**—a small number of localised sections of bedrock confined channels were observed. Bedrock confined and constrained rivers are those with channels impinged against and/or flowing over bedrock with less than 90 per cent, but more than 10 per cent, of channel in contact with bedrock. In some cases, other material of limited erodibility can form the confining and constraining media. These channel types typically have limited development of floodplain as pockets in localised expanses, in channel bars and benches often form where it is too narrow for a floodplain. These channels are unlikely to evolve and have a low sensitivity to change.
- ▶ **Anastomosing river**—is a type of anabranching river comprising multiple interconnected channels that enclose flood basins, they generally form at or near low gradient sections of rivers. They can include straight to highly sinuous channel planforms are low gradient and have stable cohesive banks. Stream power is usually low (<10 Watts per square metre (W/m²). Erskine et al., (2017) do not clearly differentiate anastomosing and anabranching rivers, but the Condamine River is an example of an anastomosing river having numerous highly sinuous channels and therefore this terminology has been used for this assessment. Flood basins can develop between channels of an anastomosing river where channels have natural levees.

Anastomosing rivers evolve through avulsion events with relatively stable periods of increased meander sinuosity development between. Anastomosing channels are usually formed by avulsion whereby the river quickly shifts from its existing channel to form a new one. The process is primarily driven by aggradation of the channel and strongly linked to, but not only due to, floodplain gradient. The anastomosing channels transport floodwaters, and typically have a small sediment load, therefore aggradation, if occurring, is a slow process. As a result, anastomosing channels are typically quite stable. Distribution of discharge over various channels reduced stream power in any one channel, resulting in relatively low stream power per channel, explaining why channels in anastomosing systems tend to be quite stable laterally (Makaske, 2001).

Channel sinuosity can indicate how frequently avulsive switching occurs, and how sensitive the channels are to change. If channels are subject to frequent avulsive switching, the meanders may not fully develop because time of channel-belt occupation is too short, indicating a higher sensitivity to change. In contrast highly sinuous channels indicate long term and very slow avulsion rates, with a lower sensitivity to change. Meander bends develop by erosion on the outside of the bend, and deposition on the inside. Over time, as the meander bend loops back on itself more and more, a meander cut-off can occur.

- ▶ **Low sinuosity channel**—is a single channel with a sinuosity <1.35, usually with a defined floodplain. The majority of the low sinuosity channels in the Project area occur as very small discontinuous baseflow channels between ponds in chain of ponds channel types, or in non-channelised valley floor channels. The evolution of these channel types and their sensitivity to change are discussed in the definitions of chain of ponds and non-channelised valley floors below.

There are four watercourses that cross the proposed alignment with larger and more developed low sinuosity channel types: Pariagara Creek, Westbrook Creek, Dry Creek and One Mile Gully. These low sinuosity channels evolve through minor lateral migration and typically have a low sensitivity to change; however, bed lowering leading to channel widening and development of side erosion channels and gullies can occur, typically in reaches adjusting to long term changes within the catchment. Of the channel reaches that cross the proposed alignment, channel widening was observed only on One Mile Gully. Channel widening and side gully development was observed on Dry Creek upstream of the proposed alignment; however, not along the reach that crosses the alignment. Low sinuosity channels that have active channel widening and side gully development have a high sensitivity to change, other reaches have a low to medium sensitivity to change.

- ▶ **Chain of ponds**—refers to a series of natural ponds unconnected by a continuous channel or connected by a small capacity continuous channel, typically low sinuosity. Many small watercourses in the study area have multiple small dams along them so that they now function as chain of ponds streams. Interestingly, a tributary of Macintyre Brook to the east of the study area is named Chain of Ponds Creek. It runs alongside the Cunningham Highway into Lake Coolmunda. These channel types do not have a coherent continuous channel and are typically low energy environments. Several chain of ponds channels in the study area have a meandering planform, and paleo meander cut offs were observed in imagery. Little is known about the long-term evolution of this channel type. Based on observations of historic change and the lack of flow energy by which to drive change, they are considered low sensitivity to change.
- ▶ **Gully**—refers to relatively deep, recently-formed, steep-sided eroded channels that are cut into unconsolidated materials where no well-defined channel previously existed. A gully can be continuous or discontinuous. Gullies evolve through headward erosion and extension of the landform upstream and they have a high sensitivity to change. Most gully channel types along the alignment occur on alluvial plains of Tertiary age in sodosols along Canning Creek.

- ▶ Non-channelised valley floor—is a distributed flow drainage pathway that features swampy, unchanneled valley floors usually well-vegetated and characterised by high water tables, at least during the wet season. Valley floors are either without any channel or are with a very small capacity channel that only contains baseflows. In the study area, these are often identified by the relatively greener colour of the vegetation together with review of elevation data.
- ▶ Non-channelised valley floor channel types are typically relatively stable and they have functioned in the fluvial system without developing a coherent channel for a long period; however, they can develop into gullies which erode headward, in particular where they form in valley fill material and flows become concentrated. Valley fill deposits are likely to occur where tertiary alluvium is mapped (Appendix H: Geomorphology Report, Appendix A). A total of 17 non-channelised valley floor channels occur in Tertiary alluvium (Appendix H: Geomorphology Report, Appendix C), the majority of which occur between Ch 107.212 km to Ch 119.377 km. Along this chainage, the Millmerran–Inglewood Road traverses the same watercourses in the same tertiary alluvium within ~1 km of the alignment. Gully development was not observed at the 17 channel locations, even at sites of cross-drainage under the Millmerran–Inglewood Road. The cross-drainage typically comprises bridges over wider channels, or multi-cell culvert groups with wingwalls and aprons. All but one of the 17 non-channelised valley floor channels that occur in tertiary alluvium are in Vertosol soils, with one in Sodosol. Gully development was observed between Ch 73.363 km and Ch 76.969 km extending up from Canning Creek on alluvial plains of tertiary age, all in Sodosols (Appendix H: Geomorphology Report, Appendix C). This indicates that in the Project area, the presence of valley fill alone may not necessarily mean that gully erosion may develop, but that gully erosion has, and therefore may develop in non-channelised valley floor channel types in intact valley fills in Sodosols.
- ▶ Non-channelised valley floor channel types in intact valley fills in Sodosols and Vertosols have a medium to high sensitivity to change; in other soil types they have a low to medium sensitivity to change. Unchanneled valley floors are usually well vegetated and characterised by high water tables, at least during the wet season. They may have a very small capacity channel that only accommodates low volume flows.
- ▶ Washslopes—these are not channels as such, rather they are slopes that have overland flow across wide areas. Washslopes are not recognised by Erskine et al. (2017) as a channel type but were included as a landform in this assessment as they play a role in the hydrology and geomorphology of the study area and occur in all landscape types. A number of Strahler Stream Order 1 flow paths are washslopes in the Murray Darling Watercourse dataset. The washslopes within the Murray Darling Watercourse dataset flow paths often develop into a recognised channel type downslope. They can occur intermittently along the same flow path as recognised channel types. As washslopes have distributed flow, it is likely that they would follow a similar evolution model as non-channelised valley floor channels. Washslopes on intact valley fills in sodosols have a medium to high sensitivity to change, in other soil types they have a low sensitivity to change.

Watercourse types of the study area

Project watercourse classification was undertaken to systematically document the Existing Case fluvial system variability in the study area. The classification of the watercourse types is based on:

- ▶ Contributing catchment characteristics and associated dominant fluvial processes
- ▶ Channel types
- ▶ Strahler stream order.

Detailed watercourse classification is further outlined in Appendix H: Geomorphology Report (see Appendix C).

Five main watercourse types were identified from the 143 watercourses that intersect the Project alignment as summarised in Table 14-26. They are:

- ▶ Headwaters, 105 watercourses
- ▶ Local stream—poorly developed channel, 22 watercourses
- ▶ Local stream—developed channel sections, seven watercourses
- ▶ Local stream—well developed channel, seven watercourses
- ▶ Main stem stream, two watercourses.

While headwaters are by far the most numerous watercourse type to intersect the Project alignment, their combined catchments are only <1 per cent of the total area of all contributing catchments.

TABLE 14-26 WATERCOURSE TYPES OF THE STUDY AREA

Watercourse type (process zone)	Number	Stream order range (mode)	Typical channel types	Floodplains	Catchment			
					Area (ha) mean (min-max)	Slope (rise/run) mean (min-max)	Vegetation cover %	Soil cover% ¹
Headwater (source)	105	1 to 2 (1)	Washeslopes, non-channelised valley floor. May have short sections of low sinuosity channel.	None.	53 ha (<10 to 355.4)	0.0344 (0.0000 to 0.0915)	Bush 19% Grassland/bush 16% Grassland/crops 63% Grassland 2%	K 10% S 31% V 52% D 3 % D/V 4%
Local–poorly developed channel (transfer)	22	2 to 4 (2)	Non-channelised valley floor with some short sections of low sinuosity channel. Can have small natural pools along flow path.	Four with floodplains, remainder have none to local narrow floodplains.	50,958 ha (94 to 654,611)	0.0194 (0.0047 to 0.0783)	Bush 16% Grassland/bush 28% Grassland/crops 56%	K 4% S 24% V 48% D 16% V/F 4% K/C 4%
Local–developed channel sections (transfer)	7	2 to 4 (3)	Low sinuosity or chain of ponds with non-channelised valley floor or low sinuosity channel between.	Four with floodplains, remainder have local narrow floodplains.	2707 (<10 to 9416)	0.0141 (0.0047 to 0.0271)	Bush 22% Grassland/bush 44% Grassland/crops 33%	K 11% S 44% V 33% V/S 11%
Local–well developed channel (transfer)	7	3 to 5 (4)	Low sinuosity would form closely spaced chain of ponds in low flow.	All have floodplains.	313,332 (4062 to 868,479)	0.0089 (0.0043 to 0.0156)	Grassland/bush 50% Grassland/crops 50%	S 38% V 50% C 13%
Main Stem (transfer/ temporary sink)	2	8	Meandering channel form, main anabranch of multi-channel types.	All have broad floodplains.	761,545 (654,611 to 868,479)	0.0050	Grassland with bush 100%	V 50% S 50%

Table note:

1. K = Kandosols, S = Sodosols, V = Vertosol, D = Dermosol, C = Chromosol, F = Ferrosol

14.7.8.4 Watercourses geomorphic process

All watercourse channels are subject to geomorphic changes arising from water flow. These changes may range from trivially small to catastrophic and can occur imperceptibly slowly to very rapidly. The Project will occur in an environment that has always changed and will continue to change as it is a naturally dynamic fluvial environment. Thus, to assess the potential for fluvial geomorphic change to occur because of the Project it is necessary to attempt to separate the changes that are naturally occurring now from changes to these fluvial systems potentially arising from the Project.

Types of watercourse processes

The main watercourse geomorphic processes include:

- ▶ Erosion
 - ▶ bank retreat—the movement of a channel bank into the adjoining land caused by the action of channel flow
 - ▶ scour holes—localised erosion features generated on a sediment surface by water
 - ▶ bed degradation—lowering of the channel bed elevation over time by removal of bed material
 - ▶ erosion of in-channel features—erosion of features such as in-channel bars, pools or sand sheets.
- ▶ Deposition
 - ▶ bed aggradation—increase in the elevation of the channel bed over time due to the deposition of sediment
 - ▶ bar aggradation—development of a bar, an elevated region of sediment, that has been deposited by water flow
 - ▶ pond or pool infilling—infilling of pools or ponds in a watercourse channel, with sediment, woody debris or a combination or both.
- ▶ Planform change
 - ▶ meander bend migration—movement, typically downstream, of meander bends by on-going erosion on the outside of the bend and deposition on the inside
 - ▶ avulsion—when a watercourse relatively suddenly ‘jumps’ out of its existing channel to form a new one, primarily driven by aggradation/blockage of the channel.
- ▶ Channel type change
 - ▶ change from one channel type to another (e.g. development of a multi-thread channel in a location where the channel was single thread), or development of a non-channelised valley floor into a gully.

Note that ‘sediment transport’ is the erosion and deposition of sediment.

Project watercourse processes and historic changes at Condamine River channels are detailed further in Appendix H: Geomorphology Report.

Project watercourse processes

There is a strong link between channel typology and processes. The channel type is the physical manifestation of the fluvial processes acting on the watercourse, including water flow, sediment transport, deposition and erosion, for example the channel type gully has active gully erosion.

Change observed in historic aerial imagery, which generally covers the period of the last 70 years through to current conditions, captures a visual record of the complex interplay of geomorphic processes as recorded in resulting landforms. It does not consider more rare extreme events which may happen at any site, unless evidence for them can be interpreted from the available aerial imagery.

Refer to Appendix H: Geomorphology Report (Appendix G) for processes and historic change for watercourses with channels. Significant historic change has occurred on the Condamine River channels, refer to Section 14.7.8.10 for a more detailed description.

The following key observations on processes and historic change of Project watercourses were identified:

- ▶ Most sites show evidence of no/very minor fluvial geomorphic processes or change since the 1940/50s showing the fluvial geomorphic system under existing flow regimes in both greenfield and brownfield sites has generally been changing very slowly.
- ▶ Changes that have occurred are usually due to human intervention particularly the construction of ponds and other water collection and storage reservoirs long channels/overland flow paths.
- ▶ Channel straightening has occurred on the north Condamine, and a small number of other watercourses.

- ▶ South Condamine is an active erosion feature downstream of the existing rail, and imagery shows ongoing erosion.
- ▶ Channel straightening, construction of diversions and an avulsion event has occurred on the main Condamine River channel (from historic records predating imagery).
- ▶ Natural channel planform changes have also occurred, such as increased sinuosity at Westbrook Creek and the 20 m to 30 m downstream migration of two meander bends of the Macintyre River.
- ▶ Gully erosion sites (C Ck 16, 16a, CCs 21, CCs 21a, CCs 22, CCs 19) were already present in the 1950s and have continued to develop since then.

14.7.8.5 Watercourse sensitivity to change

As fluvial systems respond to changes in their catchments, the systems will change their processes and sensitivity to change over time from things outside of the Project's control or influence. These include potential future land use changes, such as changes in agricultural practices, construction of dams, vegetation change, or flow regime change. Therefore, the assessed sensitivity to change is a tool to determine relative potential change from current condition and should not be used to indicate levels of existing sensitivity outside of this context or under different future conditions.

A wide range of channels occur in the study area, thus there will be a wide range of sensitivities to changes in the existing environment prior to the Project. More geomorphic change will occur in high energy channel systems with erodible soils, than in low energy systems with vegetated channels. The following categories of sensitivity to change for the Project watercourses were identified:

1. No observed change in channel type or channel planform (including width) observed since earliest aerial imagery.
2. No observed change in channel type or channel planform (including width) since earliest aerial imagery at sites where geomorphic change might otherwise have been expected (e.g. cracking clays or soils with a high erodibility rating such as texture contrast soils), poor catchment vegetation cover (e.g. grassland/crops).
3. Some natural historic channel change observed, such as meander cut-off, or downstream meander migration.
4. Human interventions in watercourses to create potentially unstable channel forms (e.g. straight sub-reaches, ponds/embankments) resulting in or the potential for downstream scour. Channel widening occurring. Distributed flow channels on intact valley fill in Sodosol soils, as there is evidence of gully development in these systems in the project area.
5. Rapid channel or planform change such as avulsion or gully development, human induced or natural.

Category 1 sites have the lowest potential for change, through to Category 5 with the highest potential for change. Of the 86 potentially sensitive watercourses, the following existing condition sensitivity to change was assessed:

- ▶ Category 5—nine sites, including six gully erosion sites: the Condamine River (due to the historic human-induced avulsion event), Condamine South Branch (due to ongoing erosion), SC 7 (which has been dammed, causing a cut-off of the natural channel and development of erosion channels downstream) and MB 5 (which has gully development approximately 200m upstream from alignment)
- ▶ Category 4—18 sites, mainly due to human straightening of the channel The Condamine North Branch has been assessed separately upstream to downstream, and this category includes the North Condamine upstream.
- ▶ Category 3—four sites, including the Macintyre River
- ▶ Category 2—42 sites, including the downstream Condamine North Branch
- ▶ Category 1—14 sites

Summary of the Condamine watercourses sensitivity to change:

- ▶ Grasstree Creek—Category 2—largely unchanged in the Project footprint except for the road bridge
- ▶ Condamine anabranch—Category 4—potentially unstable landforms due to human channel straightening
- ▶ Condamine South Branch—Category 5—due to the erosion resulting from the existing rail
- ▶ Condamine River—Category 5—due to the historic diversion resulting in an avulsion event (noting that the channel has remained stable since the earliest imagery)
- ▶ Condamine North branch:
 - ▶ Upstream—Category 4—potentially unstable landforms due to human channel straightening
 - ▶ Downstream—Category 2—largely unchanged in the Project footprint.

The sensitivity to change of the Condamine watercourses can be seen to be closely linked to human intervention and the modification of the channel shape and planform. Areas which have had little modification from the natural system are generally stable, and their high sinuosity indicates this has been the case for some time. The 'new' Condamine main channel has been largely stable since its formation following an avulsion event. Artificial channel modification and diversions act to significantly increase the watercourses sensitivity to change.

14.7.8.6 Floodplain identification and classification

Many of the watercourses that cross the Project alignment have associated floodplains extending a few metres to hundreds of metres on either side of the channels. For the smaller streams these may be termed 'hydraulic floodplains' where there is no alluvial landform, and the area is merely inundated during floods. 'Geomorphic floodplains' occur where alluvial sediment has been deposited to form a flat area that carries out of bank flow during floods and where fluvial landform development occurs.

Nanson and Croke (1992) have developed a classification for geomorphic floodplain types, based in part on examples of Australian rivers, that provides guidance on the way these landform systems can change as environmental systems change, that is relevant to river management.

The following floodplain types are present in the study area, modified for Project specific conditions after Nanson and Croke (1992):

► Low Energy Cohesive—Class C

These floodplains are formed by regular flow-events along laterally stable single or anastomosing low-gradient channels. Two main subclasses are recognised and both occur in the study area:

- Laterally stable, single-channel floodplains Class C1—are floodplains comprised of abundant silts and clays with organics materials, erosional and depositional processes include overbank vertical accretion. Typical landforms include flat floodplains with low levees and backswamps with a single thread straight to meandering channel. The sediment load comprises abundant fine-grained material.
- Anastomosing river floodplains Class C2—are floodplains typically very low-gradient and wide, comprised of gravel and sand with abundant silts and clays, erosional and depositional processes include overbank vertical accretion. Typical landforms include flat floodplains with extensive levees, island and flood basins, crevasse-channels and splays, with multiple anastomosing channels.

► Medium energy non-cohesive—Class B

These floodplains are formed by regular flow-events in relatively unconfined valleys. Three main subclasses are recognised and one occurs in the study area:

- Meandering river, lateral migration floodplains Class B3—features typical stream power of 10 to 60 W/m². Sediment comprises gravels, sand, silts and organics, although gravels can be absent. Erosional and depositional processes include cut-band erosion, lateral point-bar accretion, overbank vertical and abandoned-channel accretion, counterpoint accretion. Typical landforms include flat to undulating floodplain surface with ox-bows and backswamps.

The presence and location of scroll bars landforms are indicative of floodplain sediments. Class B3 can be further divided based on the presence of scrolls and associated sediment as follows:

- B3a—non-scrolled, gravel sand and silt floodplain
- B3b—distinctly scrolled, sands and minor gravels floodplain
- B3c—centrally scrolled with flanking backswamps, sands, silts and organics floodplain
- B3d—concave benches scrolled floodplains, sands with abundant silts and organics floodplain.

The classification system is more appropriately applied to larger floodplains and 17 floodplains in the Project footprint can be classified this way. The classification was based on aerial imagery, regional digital elevation model data, regional soils data and field checking. The floodplains in the Project footprint are summarised in Table 14-27.

The Project alignment traverses to the west of Canning Creek floodplain, and while it intersects a number of tributaries, the Project alignment does not intersect Canning Creek floodplain. The tributaries have been included in this assessment under watercourses, but not Canning Creek floodplain.

Bringalily Creek is a tributary to Canning Creek, and the Project intersects Bringalily Creek floodplain near its confluence with Canning Creek floodplain and this creek has been assessed as part of Bringalily floodplain.

TABLE 14-27 SUMMARY OF FLOODPLAINS IN THE STUDY AREA

Floodplain	Chainage (km)	Watercourse type ¹	Characterisation	Channel Strahler order
Macintyre River ²	30.6 (NS2B) to 36.00 (NS2B)	Main stem	B3b /C2	8
Macintyre Brook	26.700 to 27.625 35.030 to 35.300 42.800 to 45.682	N/A	B3b	8
MB 6	55.3 to 55.655	Local–poorly developed channel	B3	4
Pariagara Creek	67.170 to 67.4	Local–well developed channels	B3	4
Cattle Creek	88.2 to 88.3	Local–developed channel sections	B3	4
Native Dog Creek	93.86 to 94.02	Local–poorly developed channel	B3 – C1	3
Back Creek 2	97.4 to 98.6	Local–poorly developed channel	B3	2
Bringally Creek	95.030 to 99.635 99.635 to 100.692	Local–well developed channels	B3	5
Nicol Creek	104.34 to 104.425	Local–developed channel sections	B3	3
SC 7	120.31	Local–poorly developed channel	B3	3
SC 2	126.96	Local–developed channel sections	C1	4
Back Creek 1	127.95 to 128.19	Local–developed channel sections	C1	4
Condamine River	139 to 151.4	Main stem	C2	8
One Mile Gully	193.1 to 193.14	Local–developed channel sections	C1	3
Four Mile Gully	196.73 to 197.4	Local–poorly developed channel	C1	3
Westbrook Creek	198.4 to 199.04	Local–well developed channels	C1	4
Dry Creek	199.11 to 199.32	Local–well developed channels	C1	3

Table notes:

1. Watercourses that intersect the Project alignment only

2. Macintyre Floodplain chainage is only for the floodplain in Queensland, not New South Wales

14.7.8.7 Floodplain geomorphic processes

Floodplains result from the deposition and erosion of alluvial sediment by the river. Water out of the channel and flowing across the floodplain will deposit generally fine sand and silt as overbank deposits, or clay in very low energy systems such as the Condamine River. If the channel is migrating, it will erode the adjacent floodplain on the outside of channel bends while depositing material on the inside of bends. Several styles of channel deposition can therefore contribute to floodplain growth including lateral accretion, and oblique accretion.

Floodplain landforms include levees and scrolls, abandoned channels (e.g. paleo-channels), ox-bows and backswamps. Levees are low mounds of sediment built up above floodplain level at the junction of the channel and floodplain and are formed by deposition as floodwaters leave the channel. Scrolls are groups of former levees where the channel has migrated away. Abandoned channels occur where the main channel moves away from part of the floodplain, often due to a single avulsion event where a flood breakout occurs, and a new river course is formed. These may become occupied by backswamps or ox-bow lakes.

Types of floodplain processes

Typical floodplain features and geomorphic processes are included in the descriptions of floodplain type. Floodplain landforms and processes, such as backswamps or ox-bow lakes which form important habitats for flora and fauna, require connectivity to the main channel/s to function. All of the geomorphic processes linked to these floodplain types occur in nature, but can be influenced by land use change. In summary, the main floodplain geomorphic processes include:

- ▶ Erosion
 - ▶ scour holes—localised erosion features generated on a sediment surface by water
 - ▶ erosion of floodplain landforms such as wetlands, pond and flood channels, or the development of new ones
 - ▶ floodplain stripping—removal of floodplain sediment and landforms by flood events over wide areas, usually occurring as part of long-term cycles of sandy floodplain deposition/erosion

- ▶ Deposition
 - ▶ deposition can lead to floodplain accretion and infilling of floodplain landforms, such as flood channels, wetlands, ponds and pools
 - ▶ natural levees can develop over time adjacent to channel edges on the floodplain when coarser sediments are deposited in near channel during overbank flow events.

Project floodplain processes

There is a strong link between floodplain typology and processes. The floodplain type is the physical manifestation of the fluvial processes acting on the landform, including water flow, sediment transport, deposition and erosion.

The following key observations on processes and historic change of Project floodplains are summarised below. Appendix H: Geomorphology Report (Appendix D and Section 3.5.2.2) includes further details.

- ▶ Most sites show evidence of no/very minor fluvial geomorphic processes or change since the 1940/50s showing the fluvial geomorphic system under existing flow regimes in both green and brownfield sites has generally been changing very slowly.
- ▶ Changes that have occurred are usually due to human intervention particularly the construction of ponds and other water collection and storage reservoirs, as well as road embankments, cross-drainage and fords. Significant historic human change has occurred on the Condamine River floodplain and the Macintyre River floodplains.
- ▶ South Condamine is an active erosion feature in a flood basin of the Condamine floodplain downstream of the existing rail, and imagery shows ongoing erosion.

14.7.8.8 Floodplain sensitivity to change

As fluvial systems respond to changes in their catchments, the systems will change their processes and sensitivity to change over time from things outside of the Project's control or influence. These include potential future land use changes, such as changes in agricultural practices, construction of dams, vegetation change, or flow regime change. Therefore, the assessed sensitivity to change is a tool to determine relative potential change from current conditions and should not be used to indicate levels of existing sensitivity outside of this context or under different future conditions.

The following categories of sensitivity to change for Project floodplains were identified:

1. No observed change in floodplain geomorphic landforms since earliest aerial imagery.
2. No observed change in floodplain landforms since earliest aerial imagery at sites where geomorphic change might otherwise have been expected (e.g. soils with a high erodibility rating such as texture contrast soils, poor vegetation cover such as grassland/crops, some human intervention such as forestry or farm tracks or minor ponds).
3. Some mainly natural historic change observed, such as downstream meander migration. Some minor human intervention such as forestry or farm tracks or minor ponds.
4. Human interventions on floodplains with potential to create unstable landforms (e.g. straightening of main channel, ponds/embankments resulting in or the potential for downstream scour or floodplain disconnection).
5. Rapid landform change such as avulsion or erosion channel development, human induced or natural.

Category 1 sites have the lowest potential for change, through to Category 5 with the highest potential for change.

Of the 17 geomorphic floodplains in the Project footprint, the following existing condition sensitivity to change was assessed:

- ▶ Category 5—three floodplains, including the Condamine (due to the historic human induced avulsion event, channel straightening, erosion related to the existing rail and large number of ponds), SC 7 (which has been dammed causing a cut-off of the natural channel and development of erosion channels downstream) and Macintyre Brook (which has straightened floodplain channels)
- ▶ Category 4—eight floodplains including the Macintyre River floodplain, all due to human-made change potentially resulting in unstable landforms, including confining bridges and roads and straightening of main channels
- ▶ Category 3—no floodplains were assessed as this category
- ▶ Category 2—six floodplains
- ▶ Category 1—no floodplains were assessed as this category.

The majority of floodplains have extensive human modifications which have either already resulted in rapid geomorphic change or have the potential to create unstable landforms. This is reflected by the large number of Project floodplains with Category 4 or 5 sensitivity to change.

14.7.8.9 Border Rivers Basin existing geomorphic conditions

The Macintyre River and its floodplain (Ch 30.6 km (NS2B) to Ch 6 km)

The Existing Case conditions are summarised in Table 14-28. The Macintyre River in the Project footprint is an anastomosing river system in an unconfined valley setting with two main channels: the Macintyre River and Whalan Creek, located in New South Wales. The two main anabranches appear largely unchanged in planform and location in the Project footprint since the earliest aerial imagery (1949), except for slight downstream migration of two meander bends on the Macintyre River.

Directly upstream of the Project alignment, there are two meander bends on the Macintyre River which show the typical geomorphic process of point bar accretion on the inside of the bends and erosion on the outside and appear to have migrated approximately 20 m to 30 m downstream since 1949. Downstream of the alignment, the Macintyre River is less sinuous for approximately 4 km, where it has historically cut off a large meander bend (some time prior to the earliest aerial imagery) which is now an ox-bow lake.

Five field checking sites occurred in the Macintyre River area, including one on the Macintyre River (EP43) 17.8 km downstream from the alignment crossing at the Newell Highway bridge near Goondiwindi. No obvious erosion or deposition was observed at the bridge, but water was still high. One site (BL21) was an overview of the floodplain, the other sites were on Whalan Creek in New South Wales.

Approximately 3.5 km downstream along Whalan Creek from the alignment, it is intersected by the Bruxner Highway Road ford crossing (field site EP45). This ford has resulted in ponding and wider channel development upstream. Approximately 1.3 km upstream from the alignment along Whalan Creek, the channel is crossed by two fords (EP44), and a further 500 m upstream by the Tucka Road bridge (EP44a). The Tucka Road bridge has a span of approximately 17 m, with a slight encroachment of its abutments into Whalan Creek channel. Two scour holes on the order of 1 m deep and 3 m to 7 m wide have developed at the bridge.

TABLE 14-28 EXISTING CASE GEOMORPHIC CONDITIONS CH 30.9 KM (NS2B) TO CH 6.0 KM

Feature	Description
Watercourses	1 Main stem–Macintyre River Anastomosing meandering channel type
Floodplains	Macintyre River floodplain Class C2, becoming C1 downstream Approximately 11.2 km wide and comprises multiple back channels and flood channels including Forrest Creek. Lagoons have developed in paleo-channels. Evidence of past avulsion events and cut-off channels are visible on the floodplain surface. Upstream of the confluence of the Macintyre River and Dumaresq River, approximately 4 km along river upstream from the alignment, the floodplain shows some medium energy (Class B3) characteristics.
Catchment area	868,480 ha
Catchment soils	Sodosols, Chromosols and Vertosols
Catchment vegetation	Crops/grassland
Historic change	Largely unchanged except for approximately 20 m to 30 m downstream migration since 1949 of two meander bends on the Macintyre River directly upstream of the alignment. Several large ponds have been constructed on the floodplain, some up to 100 ha, and over 100 km of drains have been constructed within 10 km upstream of the alignment.
Site checking	Five sites (EP43, EP44, EP44a, EP45 and BL21), ponding, erosion and scour holes observed adjacent to fords and bridges across Whalan Creek.

Macintyre Brook floodplain siding (Ch 6.0 km to Ch 63.9 km)

The Existing Case conditions are summarised in Table 14-29. The Project sidles along the north-western edge of the Macintyre Brook floodplain, intersecting the floodplain for between lengths of 0.3 km to 3 km at five locations. A total of 18 tributaries of the Macintyre River cross the Project alignment over this section up until the confluence of the Macintyre Brook and Canning Creek.

Three field sites occurred along this section, two on the Macintyre Brook and its floodplain (BL15a and EP42), and one on a tributary of the Macintyre Brook, MB5 (BL12) 250 m upstream of the alignment. Access to publicly available field checking sites was limited by Bringalily State Forest. Minor bank erosion was observed along the Macintyre Brook near the Inglewood bridge (BL15a).

Minor bank erosion was observed downstream of the Cremascos Road Bridge (EP42) and slight channel widening was observed directly upstream. The site at MB5 had active gully erosion and deposition of sand, a clear channel form only occurred over a short distance before it developed into a washslope. Bed material was typically sand/silt with some gravel and banks are typically vegetated.

TABLE 14-29 EXISTING CASE GEOMORPHIC CONDITIONS CH 6.0 KM TO CH 63.9 KM

Feature	Description
Watercourses	18 tributaries of the Macintyre River, 11 headwaters, six local–poorly developed channel watercourses, and one local–developed channel sections. Non-channelised valley floor and low sinuosity channels in unconfined to semi-confined valley settings.
Floodplains	Macintyre River floodplain Class B3b Single main channel which is sinuous to meandering, paleo channels, backswamps and scroll bars.
Catchment area	From <10 ha to 6,041 ha
Catchment soils	Kandosols
Catchment vegetation	Bush
Historic change	Aerial imagery review indicates no change in channel planform and location since 1949.
Site checking	Three sites (EP42, BL12 and BL15a), minor bank erosion and channel widening, gully erosion and sand deposition, washslopes observed adjacent to bridges.

Pariagara Creek and floodplain (Ch 64.7 km to Ch 68.7 km)

Over this section, the Project alignment crosses eight watercourses including Pariagara Creek. The Existing Case conditions are summarised in Table 14-30.

Pariagara Creek has a 3 m to 4 m deep and 15 m to 25 m wide low sinuosity channel and an unconfined valley setting. The bed material is sand with some silt, and in channel features include bars and benches with ripple formations and sand sheets. Banks are vegetated with grass and trees. Approximately 1.6 km up channel from the alignment, Pariagara Creek is crossed by a ford which has resulted in upstream ponding and narrowing of the channel downstream. Local areas of bank erosion were noted downstream of the ford. Watercourse C Ck 20 has a vegetated channel, the road surface had eroded at this site, resulting in minor deposition near the watercourse.

TABLE 14-30 EXISTING CASE GEOMORPHIC CONDITIONS CH 64.7 KM TO CH 68.7 KM

Feature	Description
Watercourses	Eight watercourses including Pariagara Creek a local–well developed watercourse, one local–developed channel sections watercourse, and six headwaters ¹ .
Floodplains	Pariagara Creek floodplain ² Medium energy floodplain with paleochannels and wetlands
Catchment area	23,320 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland/crops and bush
Historic change	Aerial imagery review indicates channel planforms and locations are largely unchanged since 1949; one tributary appears to have developed a more defined channel, and some increase in riparian vegetation was noted.
Site checking	Two sites (EP40 and EP41), upstream ponding above ford and downstream channel narrowing and bank erosion, road surface eroded at C Ck 20 site.

Table notes:

1. Pariagara Creek–low sinuosity channel and an unconfined valley setting
2. Class B3

Canning Creek Sidling (Ch 72.9 km to Ch 85.4 km)

The Project traverses northward to the west of Canning Creek floodplain, crossing 19 tributaries, but not intersecting the Canning Creek floodplain landform. The Existing Case conditions are summarised in Table 14-31.

This section includes six active gully erosion channels. The gully floors are typically well vegetated with woody debris and ponds, gully sides slopes comprise sand, silt and some gravel. Three field checking site occurred along this section, including one at watercourse C Ck 16, 260 m upstream from the alignment (EP38). At this site the channel is non-channelised valley flow, and minor erosion was observed adjacent to the road culvert outlet.

Two of these sites, CCs 21 and C Ck16, were further assessed with detailed field investigations as part of the assessment of initial high-risk sites (Section 14.8.2.3). The other two field checking sites were on C Ck 14 and C Ck 15 (EP36 and 37). At one of the sites, the channel was vegetated and stable with no erosion or deposition associated with the culvert; at the other site minor erosion downstream of the culvert was observed.

TABLE 14-31 EXISTING CASE GEOMORPHIC CONDITIONS CH 72.9 KM TO CH 85.4 KM

Feature	Description
Watercourses	19 tributaries, all headwaters except for one local–poorly developed channel ¹ .
Floodplains 4	Canning Creek floodplain ² Medium energy floodplain with paleo-channels and scroll bars
Catchment area	Most <10 ha, largest 283 ha
Catchment soils	Sodosols
Catchment vegetation	Mainly grassland/crops with some bush
Historic change	Six active gully erosion channels (watercourses CCs22, CCs21, CCs21a, CCK16a, CCK16 and CCs19) have shown upstream erosion of up to 210 m since 1959. Other than the gully erosion sites, an aerial imagery review did not identify any areas of channel planform or location changes since 1949.
Site checking	Three sites (EP36, EP37, EP38), minor erosion adjacent and downstream to road culvert.

Table notes:

1. Washslopes, non-channelised valley flow and active gully erosion channels

2. Class B3b

Cattle Creek and floodplain (Ch 87.2 km to Ch 88.3 km)

The Existing Case conditions are summarised in Table 14-32. Cattle Creek's channel is generally vegetated, with sand, silt and gravel exposed in the low sinuosity channel sections. Approximately 60 m upstream from the alignment (at site EP34), Cattle Creek is crossed by a 45 m long bridge of the Millmerran–Inglewood Road.

The bridge has restricted non-channelised valley floor flow and resulted in minor erosion/incision of a small channel downstream.

TABLE 14-32 EXISTING CASE GEOMORPHIC CONDITIONS CH 87.2 KM TO CH 88.3 KM

Feature	Description
Watercourses	Cattle Creek, local–developed channel sections ¹ and two headwater tributaries ² .
Floodplains	Cattle Creek floodplain ³ Semi-confined valley setting and medium energy floodplain
Catchment area	6,506 ha
Catchment soils	Sodosols
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since 1959.
Site checking	One site (EP34), 45 m long Millmerran Inglewood Road bridge has restricted non-channelised valley floor flow resulting in minor erosion/incision of a small channel downstream.

Table notes:

1. Cattle Creek–non-channelised valley floor 70 m wide and 4 m deep, short sections of low sinuosity channel

2. Headwaters–washslope and non-channelised valley floor

3. Class B3

Canning Creek Sidling (Ch 91.0 km to Ch 92.9 km)

The Existing Case conditions are summarised in Table 14-33. Over this chainage, the Project traverses to the west of Canning Creek floodplain, crossing three tributaries, but not intersecting the Canning Creek floodplain landform. Two tributaries are headwaters and one is a local–poorly developed channel watercourse type.

Two field sites occurred along this section (EP32 and EP33). Both were within 100 m of the alignment, had non-channelised valley floor channel types, with well vegetated channels and stable channels with no erosion or deposition near culverts.

TABLE 14-33 EXISTING CASE GEOMORPHIC CONDITIONS CH 91.0 KM TO CH 92.9 KM

Feature	Description
Watercourses	Three tributaries, two headwaters and one local–poorly developed channel watercourse ¹ .
Floodplains	n/a
Catchment area	From <10 ha to 352 ha
Catchment soils	Sodosols
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since 1959.
Site checking	Two sites (EP32 and EP33), no erosion or deposition observed, including adjacent to culverts.

Table note:

1. Non-channelised valley floor and washslopes

Native Dog Creek and floodplain (Ch 93.9 km to Ch 94.0 km)

The Existing Case conditions are summarised in Table 14-34. One field site was located on Native Dog Creek, approximately 350 m upstream of the alignment at the Millmerran–Inglewood Road bridge (EP31).

At this site, Native Dog Creek, the channel type comprises an 80 m wide and 3 m to 4 m deep vegetated non-channelised valley floor with minor (<5 m long) sections of low sinuosity channel, which exposes sand, silt and minor gravel bed material.

TABLE 14-34 EXISTING CASE GEOMORPHIC CONDITIONS CH 93.9 KM TO CH 94.0 KM

Feature	Description
Watercourses	One local–poorly developed channel watercourse ¹ .
Floodplains	Native Dog Creek floodplain ² Medium to low energy floodplain with some backswamps
Catchment area	94 ha
Catchment soils	Sodosols
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since 1959.
Site checking	One site (EP31), Millmerran–Inglewood Road bridge has minor ponding beneath it and the channel widens downstream of the bridge.

Table notes:

1. Non-channelised valley floor with some sections of low sinuosity channels and washouts. Unconfined valley setting.

2. Class B3 to Class C!

Canning Creek tributary (Ch 95.1 km)

Over this chainage, the alignment crosses one tributary of Canning Creek, before crossing the confluence of Canning Creek and the Bringalily floodplain. The Existing Case conditions are summarised in Table 14-35.

TABLE 14-35 EXISTING CASE GEOMORPHIC CONDITIONS CH 95.1 KM

Feature	Description
Watercourses	One headwater tributary ¹ of Canning Creek.
Floodplains	Crosses the confluence of the Canning Creek and Bringalily floodplains (described in the section below Ch 96.2 km to Ch 100.6 km),
Catchment area	<10 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since the earliest imagery.
Site checking	None

Table note:

1. Non-channelised valley floor with washslopes

Bringalily Creek and floodplain (Ch 96.2 km to Ch 100.6 km)

The alignment sidles along the western edge of Bringalily floodplain, crossing three of Bringalily Creeks tributaries, including Back Creek 2, before crossing Bringalily Creek itself. The Existing Case conditions are summarised in Table 14-36.

Two field sites occurred along this section, one at Bringalily Creek (EP29) and one at Back Creek 2 (EP30); both are within 100 m of the alignment crossing.

Bringalily Creek has a chain of ponds channel type, with either narrow low-capacity channels or, in rare cases, non-channelised valley floor between. The channel is typically 8 m to 15 m wide. The channel is generally vegetated, with silt, sand, clay and minor gravel observed at the edge of ponds.

The Millmerran–Inglewood Road crosses Back Creek 2 approximately 80 m upstream of the alignment crossing (field site EP 30), with a row of 14 culverts with a total span of approximately 16 m. No obvious erosion or deposition was observed at the site, which was vegetated. Back Creek 2 appears to have had two channels where Millmerran–Inglewood Road crossed it; however, culverts were only constructed at the southern channel.

TABLE 14-36 EXISTING CASE GEOMORPHIC CONDITIONS CH 96.2 KM TO CH 100.6 KM

Feature	Description
Watercourses	Bringalily Creek and three tributaries including Back Creek 2. Bringalily Creek is a local–well developed watercourse. Back Creek is a local–poorly developed watercourse, and the remaining two are headwaters ¹ .
Floodplains	Bringalily Creek floodplain ² Medium energy and some backswamps
Catchment area	From <10 ha to 18,790 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland/crops and some bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since the earliest imagery, although human-made ponds have been constructed upstream.
Site checking	Two sites (EP29 and EP30), approximately 45 m upstream of the alignment; Bringalily Creek is crossed by an approximately 25 m long bridge of the Millmerran—Inglewood Road, (field site EP29). The bridge embankments extend up to the channel edge. Ponding occurs at the bridge with the channel widening from 8 m to 12 m upstream of the bridge and narrowing from 12 m to 1 m wide downstream of the bridge. Bank erosion is occurring downstream of the bridge on the outside of the bend as the channel changes from pond to low-capacity channel. A manmade pond approximately 60 x 60 m has been constructed 250 m upstream of the alignment in the Back Creek 2 flow path.

Table notes:

1. *Bringalily Creek—chain of ponds with either low-capacity channels or in rare cases non-channelised valley floor between*
 - Back Creek 2—non-channelised valley floor channel with sections of low sinuosity and small ponds
 - Headwaters—non-channelised valley floor and washslopes
2. Class B3

Nicol Creek and floodplain (Ch 104.3 km to Ch 104.4 km)

Existing Case conditions are summarised in Table 14-37. Nicol Creek has a chain of ponds channel type and is generally vegetated, with silt and clay observed at the edge of ponds.

The Millmerran—Inglewood Road crosses Nicol Creek approximately 1.7 km upstream of the alignment (field site EP 28), with a row of four culverts.

TABLE 14-37 EXISTING CASE GEOMORPHIC CONDITIONS CH 104.3 KM TO CH 104.4 KM

Feature	Description
Watercourses	Nicol Creek, local–developed channel sections watercourse ¹ .
Floodplains	Nicol Creek floodplain ² Medium energy
Catchment area	3780 ha
Catchment soils	Vertosols and Sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location changes since the earliest imagery.
Site checking	One site (EP28), the Millmerran–Inglewood Highway crosses Nicol Creek approximately 1.7 km upstream of the alignment, with a row of four culverts. Ponding occurs directly upstream of the culverts and the channel width narrows downstream. Downstream of the culverts there is bank erosion on the outside of bends.

Table notes:

1. Chain of ponds channel type with either low-capacity channels or non-channelised valley floor between
2. Class B3

Nicol Creek headwaters (Ch 107.2 km to Ch 116.2 km)

The Existing Case conditions are summarised in Table 14-38. Five field checking sites occurred in this area along the Millmerran-Inglewood Road.

TABLE 14-38 EXISTING CASE GEOMORPHIC CONDITIONS CH 107.2 KM TO CH 116.2 KM

Feature	Description
Watercourses	22 watercourses, 20 headwaters ¹ and two local–poorly developed channel watercourses.
Floodplains	n/a
Catchment area	From <10 ha to 214 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops and some bush
Historic change	One watercourse appears to have been straightened over a short distance and a number of small ponds have been constructed along flow paths of some watercourses, otherwise watercourse planforms appear unchanged since the earliest aerial imagery.
Site checking	Five sites (EP24, EP24a, EP25, EP26, and EP27), all well vegetated and stable with no erosion or deposition evident. Minor ponding occurred at two culvert sites.

Table note:

1. Washslope or non-channelised valley floor channel types

14.7.8.10 Condamine River Basin existing geomorphic conditions

Back Creek 1 headwaters (Ch 117.4 km to Ch 130.2 km)

The Existing Case conditions are summarised in Table 14-39. SC 7 and SC 2 were assessed with detailed field investigations as part of the assessment of initial high-risk sites (Section 14.8.2.3).

Eight field checking sites occurred in this area along Millmerran–Inglewood Highway (EP18, EP19, EP21, EP22, EP22a, EP23, EP23a, BL7a). Three of these sites were along Back Creek 1 (EP18, EP 23 and EP 23a). EP18, the closest site to the alignment, comprised a road crossing with nine box culverts. Highwater was still receding during the site visit and no erosion/deposition was observed.

TABLE 14-39 EXISTING CASE GEOMORPHIC CONDITIONS CH 117.4 KM TO CH 130.2 KM

Feature	Description
Watercourses	Back Creek 1 and 14 tributaries. Of the tributaries, 12 are headwaters ¹ , one is local–poorly developed channel ² , one is a local–developed channel section ³ (as is Back Creek 1).
Floodplains	Back Creek 1 floodplain ⁴ Low energy
Catchment area	Back Creek 1 9,416 ha Other local–developed channel section watercourse (SC2) 2127 ha All other watercourses between <10 ha to 720 ha
Catchment Soils	Vertosols and some Sodosols
Catchment Vegetation	Grassland/crops and some bush
Historic change	For all watercourses except SC7, aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery. At SC 7, scour downstream, of a manmade pond constructed directly upstream of the Project alignment, has occurred.
Site Checking	Eight sites (EP18, EP19, EP21, EP22, EP22a, EP23, EP23a and BL7a). Field checking site BL7a, 370 m downstream of the alignment, occurred along watercourse SC 6 and comprised a culvert infilled with sandy silt. The sediment may have come from the human made pond upstream, which appears to have bare soil exposed, as the channel bed is well vegetated with no obvious scour or bedload. Minor local ponding and erosion was observed adjacent to culverts at other field checking sites, away from the culverts the channels were stable and generally vegetated.

Table notes:

1. Headwaters–washslope or non-channelised valley floor channel types

2. Local–poorly developed channel–non-channelised valley floor channel type with sections of low sinuosity channel

3. Local–developed channel section–chain of ponds channel type

4. Class C1

Grasstree Creek tributary (Ch 131.0 km)

The Existing Case conditions are summarised in Table 14-40. This section includes one headwater tributary to Grasstree Creek. The alignment crosses at the upstream extent of the channel.

A pond has been constructed in the flow path 400 m downstream. The channel is vegetated with sections of bare soil along the low sinuosity channel.

TABLE 14-40 EXISTING CASE GEOMORPHIC CONDITIONS CH 131.0 KM

Feature	Description
Watercourses	One headwater ¹ tributary to Grasstree Creek.
Floodplains	n/a
Catchment area	<10 ha
Catchment Soils	Vertosols
Catchment Vegetation	Grassland/crops
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site Checking	None

Table note:

1. Non-channelised valley floor channel type with a short section of low sinuosity channel

Condamine River and floodplain (Ch 139.9 km to Ch 150.0 km)

The Condamine River is an anastomosing multi-channel river. Five watercourse features are recognised, as presented in Table 14-41. The Existing Case conditions are summarised in Table 14-42.

TABLE 14-41 CONDAMINE RIVER CHANNELS

Channel	Chainage (km)	Description
Grasstree Creek	139.85	Local stream with a well-developed channel. Meandering to chain of ponds channel types.
Unnamed Condamine anabranch	141.03	Ephemeral floodplain channel.
Condamine South Branch	142.75	Erosion feature downstream of the existing rail embankment in a flood basin between Grasstree Creek and the Condamine River main branch. Not a formal channel and has no geomorphic channel expression upstream of the existing rail embankment.
Condamine River	144.20	Main stem stream and channel of the Condamine River. Meandering channel type.
Condamine North Branch	150.00	Local stream with a well-developed channel. Secondary channel of the Condamine River. Meandering channel type.

Anastomosing channels in cohesive material are typically laterally stable; however, the historical changes include significant avulsion events triggered by diversions and accumulation of woody debris. The current main channel that crosses the Project alignment has been initiated by human intervention.

The Condamine River Main Branch has a channel bed width of 10 m to 20 m, and a full channel width of 30 m to 50 m. Sand sheets were observed in the channel in aerial imagery. In low flow conditions, ponds occur with small connecting channels. The main channel upstream of the confluence of Grasstree Creek, in the Project footprint, is moderately meandering, while downstream it is sinuous.

The channel straightening along the Condamine North Branch has reduced the sinuosity of the channel, and the associated volume of water accommodated in the channel over the same down valley distance. The straightened channel section includes a 90-degree bend approximately 430 m upstream of the alignment, adjacent to Pampas Pit Road. This sharp bend is directly downstream of about 1.2 km of straightened channel, along which greater than natural case velocities can occur due to its lowered sinuosity. This bend represents an avulsion risk that could impact both the Gore Highway and the Project.

Aerial imagery review shows the Condamine South Branch displays backward erosion features in a flood basin downstream of the existing embankment from Ch 142.0 km to Ch 143.0 km, which come together to reoccupy a paleo-channel approximately 400 m to 650 m downstream of the rail embankment before flowing into Grasstree Creek. The Condamine River floodplain is a low energy, low relief, cohesive Class C2 type floodplain. It is used for extensive agriculture. The floodplain comprises anabranches separated by flood basins. Type C floodplains are formed by overbank deposition and avulsion. The sinuosity of existing channels and state of preservation of abandoned (paleo) channels provides information on the lateral activity of the channels. The sinuous nature of the Condamine North Branch in particular, indicates long term and very slow avulsion rates.

TABLE 14-42 EXISTING CASE GEOMORPHIC CONDITIONS CH 139.9 KM TO CH 150.0 KM

Feature	Description
Watercourses	Condamine River—anastomosing multi-channel river (Table 14-41).
Floodplains	Condamine River floodplain ¹ Low energy, low relief
Catchment area	654,600 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops and some bush
Historic change	The Condamine River channels have undergone several structural changes in recorded history. The following information comes from Uebergand (1992) and Fysh (1910 to 1945): ▶ 1873: Diversion drain 1 was constructed between what is now the Condamine River Main Branch (then the 'Broadwater', which used to come to a dead-end) and Grasstree Creek. ▶ 1885-87: Diversion drain 2 was constructed between the Condamine North Branch and what is now the Condamine River Main Branch. It 'scoured badly' and became the current main Condamine River Channel. Fysh (1910 to 1945) has the construction timing of the diversion the other way around. ▶ 1886-7: A section of channel on what is now the Condamine River Main Branch formed downstream of diversion 1 after flooding. ▶ 1914: tree fell across the mouth of the Condamine North Branch and resulted in sediment aggradation such that it 'closed the mouth completely'. ▶ 1945: A tree fell across the Condamine River, diverting water from the Condamine down the Black Gully. Upstream from the alignment for ~1.75 km the Condamine North Branch channel has been realigned and straightened between 1985 and 2001 to flow between and around three constructed ponds, which are up to 10 ha each. The natural channel has a chain of ponds channel type, while the upstream realigned channel is effectively a low sinuosity channel type. Just upstream of the Gore Highway bridge near the Project alignment, a 40 m by 60 m pond has developed in the channel. Ongoing erosion downstream of the existing rail embankment has occurred on the Condamine South branch since earliest aerial imagery.
Site checking	Five sites (BL 1a, BL 1b, EP16, EP16a and EP 17), two on the Condamine North Branch, one on the Condamine Main Branch and one on Grasstree Creek. The inspections were undertaken in early to mid-March 2022, during the receding flows of what was estimated by FFJV hydrologists as a 20% AEP flow event at Cecil Weir, located on the Condamine River. Up to 8 m of along bank erosion was observed adjacent to bridges/culverts on the North Condamine River associated with infrastructure impacts. Up to 20 m to 30 m of along bank erosion was observed on the outside of channel bends on the Condamine Main Branch, during an event close to (but slightly above) bankfull conditions, which is what would be expected under natural conditions. Minor deposition with no erosion was observed at the Grasstree Creek field site.

Table note:

1. Class C2

North Condamine headwaters (Ch 160.0 km to Ch 187.2 km)

Along this section the Project alignment crosses 24 watercourses. The Existing Case conditions are summarised in Table 14-43. Channel bed material ranged from vegetated to silt and sand with minor gravels. Watercourse NC 11 was further assessed with detailed field investigations as part of the assessment of initial high-risk sites (Section 14.8.2.3).

TABLE 14-43 EXISTING CASE GEOMORPHIC CONDITIONS CH 160.0 KM TO CH 187.2 KM

Feature	Description
Watercourses	24 watercourses, 22 headwaters ¹ , two local–poorly developed channels ² .
Floodplains	n/a
Catchment area	Eight <10 ha, up to 496 ha
Catchment soils	Vertosols and some Dermosols
Catchment vegetation	Grassland/crops and some bush
Historic change	Except for NC 11, the planforms of the watercourses appear unchanged since the earliest aerial imagery. At watercourse NC 11, a pond constructed to the right of the channel has resulted in local changes to channel planform.
Site checking	Five sites; minor erosion at the transition of natural bed and culverts was observed at two sites; one site had minor erosion on a downstream bank and one had minor silt deposition in the culvert.

Table notes:

1. Headwaters–washslope to non-channelised valley floor channel types

2. Local–poorly developed channels–non-channelised valley floor with some sections of low sinuosity channel with some small natural ponds

Westbrook Creek and floodplain (190.0 to 202.8 km)

The Existing Case conditions are summarised in Table 14-44. The channel bed material is silt/clay or vegetated.

TABLE 14-44 EXISTING CASE GEOMORPHIC CONDITIONS CH 190.0 KM TO CH 202.8 KM

Feature	Description
Watercourses	Eleven watercourses, two local–well developed channel watercourses ¹ (Westbrook Creek and Dry Creek), three local–poorly developed channels ² , one local–developed channel sections ³ and five headwaters ⁴ .
Floodplains	One Mile Gully Floodplain Four Mile Gully Floodplain Westbrook Creek Floodplain Dry Creek Floodplain All Class C1 Low energy
Catchment area	From <10 ha to 20,550 ha (Westbrook Creek)
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops
Historic change	Except for One Mile Creek, Westbrook Creek and Dry Creek, the planforms of the watercourses along this section appear unchanged since earliest aerial imagery. The channel of One Mile Creek has become slightly straighter, while the channel of Westbrook Creek has become slightly more sinuous. Both of these minor planform changes are within normal conditions. The channel of Dry Creek has been artificially straightened downstream of the alignment for approximately 330 m.
Site checking	Five sites (EP2, EP3a, EP3b, EP4 and BL9). Minor erosion was observed at the interface of all bridges/culverts and natural channels and ponding upstream of culverts was observed at two sites. Minor deposition was observed at two sites. The natural channels appeared stable.

Table notes:

1. Local–well developed channels–low sinuosity, would form chain of ponds in low flow

2. Local–poorly developed channels–non-channelised valley floor with some sections of low sinuosity channel with some washouts and small manmade ponds

3. Local–developed channel sections–non-channelised valley floor with sections of low sinuosity channels and washouts and a few natural pools

4. Headwaters–washslope to non-channelised valley floor channel types

Gowrie Creek floodplain sidling (Ch 206.8 km to Ch 208.2 km)

This section the alignment sidles along the edge of Gowrie Creek floodplain and crosses three watercourses, all of which are tributaries to Gowrie Creek. The Existing Case conditions are summarised in Table 14-45.

TABLE 14-45 EXISTING CASE GEOMORPHIC CONDITIONS CH 206.8 KM TO CH 208.2 KM

Feature	Description
Watercourses	Three watercourses all tributaries to Gowrie Creek, two headwaters and one local–poorly developed channel. Headwaters–washslope and non-channelised valley floor channels. Local–poorly developed channel–non-channelised valley floor with some sections of low sinuosity channels and washouts.
Floodplains	Gowrie Creek Floodplain Class C1 Low energy
Catchment area	From <10 ha to 733 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site checking	None

Turallin facility

The Existing Case conditions are summarised in Table 14-46.

TABLE 14-46 EXISTING CASE GEOMORPHIC CONDITIONS: TURALLIN FACILITY

Feature	Description
Watercourses	One watercourse (PC1), local–poorly developed channel. Non-channelised valley floor with some sections of low sinuosity channels and chain of ponds.
Floodplains	n/a
Catchment area	1,081 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site checking	None

14.8 Potential impacts

14.8.1 Potential impacts–flooding

14.8.1.1 Construction, early works and construction works stage

Potential impacts are described in Chapter 5: Project Description, including a discussion with regards to the criteria used to determine suitable sites for these activities. Methodology used to assess pre-construction, early works and construction works impacts as part of this EIS is detailed in Section 14.6.3.4 with further details of how impacts will be assessed and managed within the temporary disturbance footprint detailed in Section 14.9.1.3.

A screening of temporary project facilities, including concrete batching plants, fuel depots, laydown and stockpile areas against the 1% AEP flood risk mapping was carried out to determine the works and activities that are likely to occur within areas at risk of flooding. The at-risk construction works and activities are discussed below.

14.8.1.1.1 Temporary project facilities

One material distribution centre (at Whetstone), three non-resident workforce accommodation facilities (one at each of Yelarbon and Inglewood and one unknown location), and one site facility (at Turallin near Millmerran) are proposed as part of the Project. These facilities, excluding the unknown location for the non-resident workforce accommodation facility, have been assessed for flood risk and the key results are discussed below. Further details regarding the material distribution centre, non-resident workforce accommodation facilities and site facility flood risk assessments are provided in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 20).

Whetstone Material Distribution Centre

ARTC will establish a temporary material distribution Centre in Whetstone, Queensland (the Whetstone site).

A detailed description of the Whetstone site, including proposed staging, is presented in Appendix AE: Whetstone Material Distribution Centre: Supporting Technical Information. A flood risk assessment was undertaken for the Whetstone site using the Macintyre Brook–Yelarbon to Inglewood regional flood model to assess the existing flooding behaviour within and around the site for the 10%, 5% and 1% AEP flood events. The main outcomes of the Whetstone site flood risk assessment are summarised as follows:

- ▶ The Whetstone site is located in a high-risk flood zone on the Macintyre Brook floodplain and the northeastern parts of the site starts to become partially inundated in the 10% AEP event
- ▶ The Whetstone site becomes fully inundated in the 5% AEP event with surrounding access roads also being inundated in this event
- ▶ In a 5% AEP and 1% AEP event the Whetstone site would be subject to flood depths over 1 m in locations and, as per the Australian Institute for Disaster Resilience (2017a) guidelines, would be considered hazardous for vehicles and people, with potential for structural damage and/or failure to less robust building types
- ▶ The Whetstone site's proposed access roads along with the connecting roads, Whetstone Access Road and Cunningham Highway, are predicted to be inundated with over 1 m of depth and a velocity x depth product > 0.6 m²/s. These roads would be considered unsafe for people and vehicles and inaccessible during a 5% AEP and 1% AEP event.

Non-resident workforce accommodation–Cunningham Highway, Yelarbon–Lot 30 MH 721

The proposed Yelarbon non-resident workforce accommodation facility is not affected by a 1% AEP flood risk; however, the proposed access road between the site and the Cunningham Highway is liable to flood by up to 0.6 m deep. Flood risk at this site can be managed appropriately by considering the location and nature of the access road during detailed design to ensure that safe access and egress to and from the site is achievable, and that any road works will not exacerbate flood risk elsewhere.

Non-resident workforce accommodation–Millmerran–Inglewood Road, Inglewood–Lot 5 MH 75

Some parts of the proposed Inglewood non-resident workforce accommodation facility are subject to overland flow in the 1% AEP event. The overland flow conditions within the proposed site area are assessed as generally low-risk, with no obvious vulnerability or constraints identified for future patrons or proposed site use. Flood risk at this site can be managed appropriately during detailed design by maintaining the existing flow regimes within and around the site.

Turallin facility–553 Turallin Road, Turallin–Lot 135 DY 1033

The Turallin facility is subject to Pine Creek flooding in the 1% AEP event. It is not exposed to flooding risk from overland flow or regional flooding sources. The central portion of the site is flood-free in the 1% AEP event and therefore imposes no constraints on future site activities. The eastern site area traversed by the Pine Creek main channel corridor is considered highly hazardous, which should be avoided by all non-essential development activities. The eastern corner of the site is subject to relatively deep inundation and may pose an increased flood risk. Flood risk at this site can be managed appropriately during detailed design by considering alternative access arrangements from Ellerslie Road, and by steering any formal development away from the areas on site at risk of 1% AEP flooding.

14.8.1.1.2 Borrow pits

Earthwork assessments for the revised reference design confirm a material deficit associated with the various components of the Project, necessitating the sourcing of suitable fill from a number of borrow pit sites to support Project construction. Fill will be sourced from seven borrow pits at six locations (one site, with two nominated pits) established for the Project to supply an estimated 298,000 m³ of the Project's fill deficit. Appendix AD: Borrow Pits: Supporting Technical Information provides a summary of supporting technical information associated with the borrow pits. The approach to assessment and mitigation as described in this chapter apply to all components of the Project including the borrow pit sites.

14.8.1.1.3 Laydown, stockpile and storage areas

Seventy-seven laydown areas have been allocated within the temporary footprint along the length of the alignment. A full list of laydown areas and their planned uses is provided in Chapter 5: Project Description with their flood risk identified in Table 14-47.

TABLE 14-47 LAYDOWN AREAS RISK OF FLOODING—UP TO THE 1% AEP EVENT

Laydown ID	Location	Chainage (km)	Laydown uses	Flood risk quantification
NS2B—LDN031.0	Kildonan Road	31.0	General construction laydown	Impacted in the 5% AEP event
NS2B—LDN032.5	Kildonan Road	32.5	Bridge laydown	Impacted in the 5% AEP event
NS2B—LDN033.2	Kildonan Road	33.2	General construction laydown	Not impacted up to and including the 1% AEP event
NS2B—LDN035.6	Eukabilla Road	35.6	Major construction laydown: Site offices Fuel storage (<20,000 litres (L))	Not impacted up to and including the 1% AEP event
B2G—LDN000.9	Georges Lane (extension)	0.4	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN006.3	Yelarbon—Kurumbul Road	6.2	General construction laydown: Fuel (<10,000 L)	Impacted by local drainage Flooding in the 20% AEP event
B2G—LDN016.0	Yelarbon—Kurumbul Road	16.0	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN020.3	Yelarbon—Kurumbul Road	20.4	General construction laydown	Impacted by local drainage Flooding in the 5% AEP event
B2G—LDN025.9	Yelarbon (south)	25.8	General construction laydown: Fuel storage (<10,000 L)	Impacted by the 20% AEP event Regional flooding
B2G—LDN025.9	Yelarbon (north)	25.9	General construction laydown: Site offices Bridge laydown for Cunningham Highway bridge	Impacted by the 20% AEP event Regional flooding
B2G—LDN030.0	Suttons Road	30.0	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN037.6	Springborg Road	37.6	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN049.8	McDougalls Crossing Road	49.70	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN052.8	Cremascos Road	52.8	Bridge construction laydown for UT1 Macintyre Brook rail bridge #1	Minor impact in the 20% AEP event
B2G—LDN054.2	Cremascos Road	54.3	General construction laydown: Site offices Fuel storage (<10,000 L)	Impacted by local drainage Flooding in the 20% AEP event
B2G—LDN055.4	Cremascos Road	55.4	Bridge construction site Laydown for UT2 Macintyre Brook rail bridge	Impacted by the 20% AEP event
B2G—LDN060.4	Bybera Road	60.5	General construction laydown	Impacted by local drainage Flooding in the 20% AEP event
B2G—LDN065.8	Lovells Crossing Road	65.8	General construction laydown	Not impacted up to and including the 1% AEP event
B2G—LDN067.6	Thornton Road	67.6	Bridge construction site Laydown for Pariagara Creek rail bridge	Impacted in the 5% AEP event

Laydown ID	Location	Chainage (km)	Laydown uses	Flood risk quantification
B2G-LDN069.0	Thornton Road	68.8	General construction laydown	Impacted in the 20% AEP event
B2G-LDN073.0	Millmerran–Inglewood Road	72.9	Laydown for Millmerran–Inglewood Road rail bridge #1	Not impacted up to and including the 1% AEP event
B2G-LDN074.0	Millmerran–Inglewood Road	74.2	General construction laydown: Site offices Fuel storage (<10,000 L)	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN081.0	Wongavale–Yugibar Road	81.1	General construction laydown: Fuel storage (<10,000 L)	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN088.0	Millmerran–Inglewood Road	88.1	Bridge construction site Laydown for Cattle Tree Creek rail bridge	Impacted in the 20% AEP event
B2G-LDN091.8	Site track off Millmerran–Inglewood Road	91.9	General construction laydown	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN093.8	Millmerran–Inglewood Road	93.8	Bridge construction site Laydown for Native Dog Creek rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN098.0	Millmerran–Inglewood Road	97.9	Bridge construction site Laydown for Bringalily Creek #1 rail bridge	Impacted in the 20% AEP event
B2G-LDN100.6	Millmerran–Inglewood Road	100.7	Bridge construction site Laydown for Bringalily Creek #3 rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN104.5	Partons Road	104.6	General construction laydown Bridge construction site Laydown for Nicol Creek rail bridge	Impacted in the 10% AEP event
B2G-LDN112.1	Millwood Road	112.2	General construction laydown	Minor impacted by local drainage Flooding in the 20% AEP event
B2G-LDN115.6	Millmerran–Inglewood Road/Heckendorf Road via LDN 116.00	115.7	Bridge construction site Laydown for Millmerran–Inglewood Road rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN116.0	Heckendorf Road	116.2	General construction laydown: Site offices Fuel storage (<20,000 L)	Not impacted up to and including the 1% AEP event
B2G-LDN120.2	Blackwell Road	120.2	General construction laydown	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN123.6	Scragg Road	123.7	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN123.8	Scragg Road	123.8	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN126.9	Schwartens Road	126.9	Bridge construction site Laydown for Millmerran–Inglewood #3 road bridge	Impacted in the 20% AEP event
B2G-LDN128.2	Owens Scrub Road	128.4	Bridge construction site Laydown for Back Creek rail bridge	Impacted in the 20% AEP event
B2G-LDN129.5	Foxwood Road	129.4	General construction laydown	Not impacted up to and including the 1% AEP event

Laydown ID	Location	Chainage (km)	Laydown uses	Flood risk quantification
B2G-LDN130.0	Owens Scrub Road	130.0	Laydown for Owens Scrub road bridge	Not impacted up to and including the 1% AEP event
B2G-LDN130.6	Owens Scrub Road	130.6	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN130.4	Owens Scrub Road	130.7	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN138.5	Hall Road	138.6	General construction laydown: Precast facility Concrete batch plant	Impacted in the 20% AEP event
B2G-LDN139.0	Hall Road	139.2	Bridge construction site Laydown for Grasstree Creek #1 & #2 rail bridge	Impacted in the 20% AEP event
B2G-LDN140.2	Millmerran Leyburn Road	141.6	General construction laydown	Impacted in the 20% AEP event
B2G-LDN141.3	Millmerran Leyburn Road	142.6	Bridge construction site Laydown for Condamine River South Branch rail bridge	Impacted in the 20% AEP event
B2G-LDN143.0	Gilgai Lane	144.4	Bridge construction site Laydown for Condamine River Main rail bridge	Impacted in the 20% AEP event
B2G-LDN144.6	Gilgai Lane	146.0	Laydown for Condamine River Main Branch rail bridge	Impacted in the 20% AEP event
B2G-LDN147.1	Fysh Road	148.4	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN149.0	Gore Highway	150.1	Laydown for Condamine River North Branch rail bridge	Impacted in the 20% AEP event
B2G-LDN150.5	Dieckmann Road	152.1	Potential precast facility and concrete batch plant	Not impacted up to and including the 1% AEP event
B2G-LDN150.9	Ware Street	152.1	General construction laydown	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN152.9	Madelaine Street	153.3	General construction laydown	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN153.1	Gore Highway	154.6	Bridge construction site for Gore Highway bridge	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN161.0	Yarralea Road	162.3	Major construction laydown: Site offices Fuel storage (<20,000 L) Laydown for Yarranlea Road rail bridge	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN163.3	Roche Road	164.7	General construction Laydown for Roche Road rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN164.3	Murlaggan Road	165.6	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN165.6	Kahler Road	166.9	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN169.6	Gore Highway	171.0	General construction laydown	Impacted by local drainage Flooding in the 20% AEP event

Laydown ID	Location	Chainage (km)	Laydown uses	Flood risk quantification
B2G-LDN171.0	Oakey Pittsworth Road	172.3	Bridge construction site Laydown for Oakey–Pittsworth Road rail bridge	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN172.0	Lochaber Road	173.3	General construction laydown	Minor impact by local drainage Flooding in the 20% AEP event
B2G-LDN172.6	Lochaber Road	173.8	Laydown for Lochaber Road rail bridge	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN173.5	Paint Mine Road	174.8	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN175.5	Linthorpe Road	176.9	Multi-use construction laydown including satellite offices Fuel storage (<10,000 L) Road upgrade laydown	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN179.0	Geitz Road via Linthorpe Valley Road	180.2	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN183.0	Bushy Lane	184.3	General construction laydown	Not impacted up to and including the 1% AEP event
B2G-LDN183.8	Biddeston Southbrook Road	185.1	Laydown for Biddeston–Southbrook Road rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN185.0	Gore Highway	186.5	General construction laydown	Impacted by local drainage Flooding in the 20% AEP event
B2G-LDN188.2	Athol School Road	189.5	Major construction laydown: Site offices Fuel storage (<10,000 L)	Not impacted up to and including the 1% AEP event
B2G-LDN192.3	via Athol Road	193.6	General construction laydown: Fuel storage (<10,000 L)	Not impacted up to and including the 1% AEP event
B2G-LDN196.2	Toowoomba–Cecil Plains Road via existing side road	197.4	Bridge construction site for Toowoomba–Cecil Plains Road rail bridge	Impacted in the 20% AEP event
B2G-LDN197.0	Toowoomba–Cecil Plains Road	198.3	Bridge construction site for Westbrook Creek rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN198.1	Brimblecombe Road	199.4	Bridge construction site for Dry Creek rail bridge	Impacted in the 1% AEP event
B2G-LDN198.7	Brimblecombe Road	200.0	Bridge construction site for Brimblecombe Road rail bridge	Impacted in the 20% AEP event
B2G-LDN203.0	Warrego Highway	204.3	Bridge construction site for Warrego Highway rail bridge	Impacted in the 20% AEP event
B2G-LDN204.2	Chamberlain Road	205.5	Laydown for Chamberlain Road rail bridge	Not impacted up to and including the 1% AEP event
B2G-LDN206.3	Leesons Road	207.6	General construction laydown: Site offices Fuel storage (<10,000 L)	Not impacted up to and including the 1% AEP event
B2G-LDN206.9	Draper Road	208.2	General construction laydown	Impacted in the 20% AEP event

The assessment completed above identifies that 44 of the 77 laydown areas are potentially impacted by flooding up to the 1% AEP event. During the detailed design stage, a high-level flood risk assessment will be completed on the laydown areas that are impacted utilising existing case modelling results or freely available information from government sources.

14.8.1.2 Potential impacts during commissioning and operations stage

The following guidance should be used when interpreting the quantitative flood impact assessment results which relate to the operations stage of the Project and are presented in the following sections:

- ▶ In some instances, significant percentage changes are identified within the flood impact objective exceedance tables. Percentage increases should be read in conjunction with Existing Case and Developed Case results. The FIOs require that change be presented in percentage change for time of inundation, velocity and hazard and can sometimes produce large increases when Existing Case results are significantly small. Some locations were identified to experience significant percentage increases; however, the 'absolute' difference between Existing Case and Developed Case results is relatively small.
- ▶ Exceedances such as these have been identified in the following sections below with an asterisk (*).
- ▶ The flood impact objective analysis has determined large magnitude exceedances in cases where the flood extent has locally increased as a result of the Project. These exceedances can be attributed to locations where modelling has shown an area that is dry in the Existing Case scenario becoming wet in the Developed Case scenario, at times within a single modelling cell, typically 10 x 10 m /20 x 20 m.
- ▶ This increase in flood extent may result in large increases in depth, velocity, hazard and time of inundation and can be attributed to an artefact of the modelling. Large increases in water level, velocities, hazard and time of inundation due to the change in flood extent are extremely unlikely to occur in reality during a flood event and can be considered an anomaly of the modelling. This phenomenon is recognised in the industry and by the Expert Flood Panel. Further investigation into this anomaly will be undertaken in detailed design.

14.8.1.2.1 Summary of potential flooding impacts during commissioning and operations stage of the Project

The existing flood regime without the Project, or Existing Case, was modelled for the floodplain through which the Project is aligned, with results presented in Section 14.7.4.2. For comparison, the Project rail embankment, drainage structures and associated works were included in each of the hydraulic models to form the Developed Case. A range of events, including extreme events, were modelled and the resulting impacts identified along the extent of the Project alignment and at the identified flood sensitive receptors (Figure 14-15).

The hydrological models have been developed to be consistent with the basis of design for the Project, which establishes an avoidance over mitigation hierarchy for impacts from the Project. The impact of the Project on the existing flood regime has been quantified and compared against the FIOs listed in Table 14-4. The impacts at a local and regional scale, principally around water velocity variation caused by the Project, were considered to not significantly alter flow regimes.

The sections below present the outcomes of the flood impact assessment for each of the floodplains crossed by the Project alignment. Detailed results are provided in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (see sections 5.5.3, 6.5.3, 7.5.3, 8.5.3, 9.5.3, 10.5.3, 11.5.3, 12.5.3, 13.5.3, 14.5.4, 15.5.3, 16.5.3, 17.5.3, 18.6.3, 19, 20 and 21), with maps presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for the 20% and 1% AEP events) and the **Online Digital Platform** (for all AEP events).

Where an impact to private land outside the Project permanent footprint has been identified, it should be noted that impact specifically relates to the lot and its associated land use, and not necessarily a lot's dwelling/building. Impact to dwelling/buildings have been identified through the flood sensitive receptor assessment where a building or dwelling has been identified on a lot.

Table 14-48, Table 14-49 and Table 14-50 provide a summary of potential impacts to sensitive receptors, other infrastructure (e.g. State-controlled/local roads and existing rail infrastructure) and private land outside the permanent footprint that have been identified to exceed the flood impact objective targets specified in Table 14-4. Impacted flood sensitive receptors can be seen in Figure 14-15.

It is important to note that a flood impact objective exceedance would not necessarily cause an impact. As discussed in Section 14.6.3.3, the FIOs define the threshold as to the point at which a more detailed consideration of impacts is required when they are exceeded. Depending on land use, the underlying ground conditions and gradient, a site-specific assessment in consultation with the landowner will determine if the flood impact objective exceedance is likely to lead to an impact.

TABLE 14-48 SUMMARY OF POTENTIAL FLOODING IMPACTS ON FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor type	Number of receptors impacted by an increase in peak water levels	Number of receptors impacted by an increase in peak hazard
House	21	-
Shed	11	2
Silos	4	-
Stockyards	1	-

Table 14-49 provides a summary of potential impacts associated with State-controlled roads, local roads and existing rail.

TABLE 14-49 SUMMARY OF POTENTIAL FLOODING IMPACTS ON OTHER INFRASTRUCTURE

	Length of afflux impact (m)	Length of time of inundation impact (m)	Length of velocity impact (m)	Length of hazard impact (m)	Total length of impact (m)
State-controlled roads	7,456	2,501	122	1,114	8,295 ¹
Local roads	23,780	8,978	2,454	4,858	27,858 ¹
Existing rail	5,580	2,470	588	2,291	6,388 ¹

Table notes:

1. It should be noted that in some instances multiple types of exceedances (e.g. afflux, time of inundation, velocity and hazard) can occur in the same location and overlap. The calculation of the total length of impact is based on a combined exceedance footprint and does not sum the length of these locations separately.

Table 14-50 provides a summary of potential impacts on private land outside the permanent footprint.

TABLE 14-50 SUMMARY OF POTENTIAL FLOODING IMPACTS ON PRIVATE LAND OUTSIDE THE PERMANENT FOOTPRINT

Land use	Area of afflux impact (ha)	Area of time of inundation impact (ha)	Area of velocity impact (ha)	Area of hazard impact (ha)	Total area of impact (ha) ¹
Agriculture/animals	39.0	1,367.4	136.3	106.8	1,516.0
Commercial	20.7	11.4	0.3	0.1	25.9
Infrastructure	1.2	0.2	-	-	1.4
Residential	9.3	3.6	1.1	1.9	10.4
Sports clubs, facilities, showgrounds	20.4	17.7	0.3	0.3	24.6
Vacant land	51.8	50.8	9.5	12.4	94.1
Cemetries	0.8	0.8	-	-	0.8
Other land use	134.3	73.8	20.4	20.9	160.7
Total	277.5	1,525.7	167.9	142.4	1,833.9

Table notes:

1. It should be noted that in some instances multiple types of exceedances (e.g. afflux, time of inundation, velocity and hazard) can occur in the same location and overlap. The calculation of the total area of impact is based on a combined exceedance footprint and does not sum the area of these locations separately.

The following sections present individual floodplain impact assessment results.

14.8.1.2.2 Gowrie Creek

On the Gowrie Creek floodplain, the revised reference design includes:

- ▶ Nine reinforced concrete pipe (RCP) locations (a total of 51 culvert cells)
- ▶ One reinforced concrete box culvert (RCBC) location (a total of 16 culvert cells)
- ▶ Two rail-over-road bridges that also convey flows within minor drainage lines.

Details of the proposed floodplain structures required to convey Gowrie Creek flood flows are presented in Table 14-51 and Table 14-52 with structure locations presented in Figure 14-18a. Figure 14-18a also presents the location of proposed local catchment drainage structures. Two new rail bridges are proposed over the Warrego Highway and Chamberlain Road, which also convey flows within minor drainage lines.

TABLE 14-51 GOWRIE CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Structure name	Soffit level (m AHD)	Bridge length (m)
204.34	310-BR34	Bridge	Warrego Highway rail bridge	481.45	132
205.83	310-BR35	Bridge	Chamberlain Road rail bridge	463.43	299

Table notes:

m AHD = metres above Australian Height Datum

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-52 GOWRIE CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
204.45	C204.45	RCP	2	1.05
206.17	C206.17	RCP	2	1.05
206.36	C206.36	RCP	12	1.05
206.42	C206.42	RCP	2	1.05
206.57	C206.57	RCP	4	1.05
206.65	C206.65	RCP	15	1.05
206.75	C206.75	RCP	5	1.05
206.88	C206.88	RCP	2	1.05
207.15	C207.15	RCP	7	1.35
208.21	C208.21	RCBC	16	2.40 x 1.50

Table notes:

1. For RCP height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-18b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 5.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Gowrie Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for three lots within the Gowrie Creek floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 28 mm on Lot Plan 11SP285307, 479 mm on Lot Plan 43AG109 to 645 mm on Lot Plan 33SP294200.

Of the three lots identified, two are impacted due to the change in flood extent and identified due to a newly flood-affected area. A summary of impacted lots is provided below:

- ▶ One lot experiences a change in peak water level of between 500 mm and 1 m
- ▶ One lot experiences a change in peak water level of between 100 mm and 500 mm
- ▶ One lot experiences a change in peak water level of less than 50 mm.

Other infrastructure

A total of six roads (State-controlled roads and local roads) are impacted by a change in peak water level as detailed in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Table 5.23 and Table 5.24). Of these only one State-controlled road, the Warrego Highway, is identified as being impacted with a change in peak water level. Potential exceedances were identified along the eastbound and westbound carriageway of the Warrego Highway heading to and from Toowoomba. Existing flood conditions demonstrate the eastbound lane has less than a 20% AEP flood immunity, while the westbound lane does not show overtopping until the 1% AEP event. The maximum change in water level occurs during the 1% AEP event, and is approximately 80 mm.

These exceedances will be reviewed in the detailed design stage, as a review of the modelling files and aerial imagery indicates that the eastbound lane was constructed in 2017, with light detection and ranging (LiDAR) utilised in the hydraulic modelling dated 2015. The discrepancy in data timelines has led to the eastbound lane not being captured within the current flood modelling, and hence demonstrating a lower immunity and greater impacts. It is likely the immunity of the eastbound lane is higher than that modelled and potentially has similar immunity to that of the westbound lane.

Five local public roads have been identified as impacted by a change in peak water levels with Draper Road (directly adjacent the Project alignment) experiencing the greatest increase in peak water level of 784 mm in the 10% AEP event. This change can be attributed to an increase in flood extent and a newly flood-affected area within the hydraulic model. A summary of impacted local roads is provided below:

- ▶ One local road experiences a change in peak water level of between 500 mm and 1 m
- ▶ One local road experiences a change in peak water level of between 100 mm and 200 mm
- ▶ One local road experiences a change in peak water level of between 50 mm and 100 mm
- ▶ Two local roads experience a change in peak water level of between 10 mm and 50 mm.

One segment of existing rail infrastructure, Rosewood to Miles, has been identified as impacted by an increase in peak water level. A maximum increase of 181 mm is identified across a length of 4 m. This change in water level can be attributed to a change in flood extent and a newly flood-affected area within the hydraulic model and will be explored further in detailed design.

Change in velocity

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-18c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of six lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Impacted lots are located at the outlets of cross-drainage structures, and along banks of Gowrie Creek. Of these, Lot 29 SP294200 experiences the largest increase in velocity of 1.78 m/s. Some order of change in velocity is expected to be experienced across 0.034 ha (less than 1 per cent of the total lot area) and can be attributed to a change in flood inundation extent and a newly flood-affected area. A summary of peak velocity increases is provided below:

- ▶ Three lots experience an increase in peak velocity greater than 1.0 m/s
- ▶ One lot experiences an increase in peak velocity of 0.5 m/s to 1.0 m/s
- ▶ Two lots experience an increase in peak velocity of less than 0.1 m/s.

Other infrastructure

One State-controlled road has been identified to experience a change in velocity due the presence of the Project alignment: the Warrego Highway. Large increases in velocity are expected to occur on the eastbound lane of the Warrego Highway (where the Project alignment crosses the road) with a maximum change of 2.3 m/s. This significant change can be attributed to a newly flood-affected area and change in inundation extent. As mentioned above, this segment of road has not been captured within the current flood modelling due to construction occurring after the date of the utilised data for hydraulic modelling, and hence a review of these exceedances will be completed as part of detailed design to mitigate and better represent the current road surface.

Four local roads have been identified to experience a change in velocity due to the Project alignment. Kingsthorpe Haden Road experiences the largest increase in velocity due to the Project alignment with a maximum increase of 4.26 m/s across 4 m. This significant change can be attributed to a newly flood-affected area and an increase in inundation extent. A review of Existing Case results demonstrates that similar velocities are experienced directly adjacent this exceedance and therefore the exceedance can be attributed to the flood extent increase. A summary of peak velocity changes on the four local public roads is provided below:

- ▶ Two local road experiences an increase in peak velocity greater than 1 m/s
- ▶ One local road experiences an increase in peak velocity of less than 0.1 m/s
- ▶ One local road experiences an increase in peak velocity of 20 per cent (0.27 m/s).

No existing rail infrastructure is expected to experience a change in peak velocity within the Gowrie Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 5.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project footprint boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the velocity-depth product for the Existing Case and Developed Case with results presented in Figure 14-18d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Gowrie Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of six lots were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Exceedances can be attributed to increased flow velocities and flood depths the inlets and outlets of bridges and culverts. The maximum increase for flood hazard is approximately 0.16 m²/s on Lot Plan 44AG109, with changes in hazard predicted across a total area of 0.07 ha (less than 1 per cent of the total lot area).

The peak hazard changes on the six impacted lots are:

- ▶ Three lots experience a change in hazard of greater than 500 per cent
- ▶ One lot experiences a change in hazard of between 100 per cent and 500 per cent
- ▶ Two lots experience a change in hazard of less than 25 per cent.

Other infrastructure

Similar to velocity, the eastbound lane of the Warrego Highway experiences an increase in hazard (i.e. velocity-depth product) of 24 per cent (from 0.45 m²/s to 0.55 m²/s) in the 1% AEP event. This can be attributed to the misrepresentation of the eastbound lane in the utilised LiDAR and will be reviewed in detailed design.

Three local roads experience increase in hazard (i.e. velocity-depth product) with Draper Road recording the largest increase of 0.46 m²/s (or 1,368 per cent), from 0.03 m²/s to 0.49 m²/s. Both Leeson's Road and Kingsthorpe Haden Road experience maximum increase in hazard of 59 per cent and 28 per cent, respectively.

No existing rail infrastructure is expected to experience a change in peak hazard within the Gowrie Creek floodplain.

Figures showing the change in hazard presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 5.5.3).

Potential changes in time of inundation

The change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-18e for the 1% AEP event.

Private land outside the Project permanent footprint

A total of six lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 43 AG109 has been identified as experiencing the largest percentage increase in time of inundation of 961 per cent (increasing from 1.04 hours in the Existing Case to 11.05 hours in the Developed Case). Lot Plan 33 SP294200 experiences the largest 'absolute' change of 10.53 hours, with the identified area being impacted not wet in the Existing Case scenario and newly flood-affected area in the Developed Case scenario. The lots impacted by a change in time of inundation are:

- ▶ Four lots experience a change in time of inundation of between 500 per cent and 1,000 per cent
- ▶ Two lots experience a change in time of inundation of between 10 per cent and 65 per cent.

Other infrastructure

A total of five roads (State-controlled roads and local roads), Warrego Highway, Draper Road, Leeson's Road, Kingsthorpe Haden Road and Kingsthorpe Tilgonda Roads, respectively, are impacted by a change in time of inundation. One State-controlled road, the Warrego Highway, experiences a change of 11 per cent in the 1% AEP event (increasing from 0.006 hours to 0.007 hours). Although some change occurs on this road due to the Project alignment, the Existing Case time of inundation results indicate this segment is submerged for up to 1.54 hours and therefore the 11 per cent increase recorded in the Developed Case is considered negligible.

Of the four local public roads impacted, Draper Road experiences the largest percentage increase in time of inundation of 5,071 per cent (from 0.19 hours to 9.67 hours), although it is noted that the Existing Case time of inundation along this segment is 10.29 hours. This large increase can be attributed to the Project constraints altering existing flow paths. The three other local public roads impacted, Leeson's Road, Kingsthorpe Haden Road and Kingsthorpe Tilgonda Road, experience a maximum percentage increase in time of inundation of 62 per cent, 57 per cent and 13 per cent, respectively.

One segment of existing rail infrastructure, Rosewood to Miles, has been identified as impacted by an increase in time of inundation. A maximum increase of 30 per cent (from 3.54 hours to 4.62 hours) in the 1% AEP event has been identified. It should be noted that the time of inundation in the Existing Case for this segment of rail is 13.02 hours and therefore this exceedance of the flood impact objective is not expected to impact on the operational capacity of the rail.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 5.5.3).

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage, with significant floodplain structures included to maintain or improve the existing flood regime.

The following observations are made regarding change in flow distribution in the Gowrie Creek floodplain:

- ▶ Regionally, the proposed Project produces small to moderate changes (+/-10 per cent) within the main channel of Gowrie Creek for all events assessed up to the PMF. Larger changes (positive and negative) are noted along the floodplain edges. The changes are mostly likely due to small increases and decreases in the flood extent.
- ▶ Locally, the flow distribution is governed by the relative flood interactions with various hydraulic controls, including the rail embankment, cross-drainage, road levels, and floodplain storage. Local flow redistributions primarily occur along the alignment, with a list of key sensitivities summarised below:
 - ▶ Flow increases occur upstream and downstream of culverts between Chamberlain Road and Leeson's Road for all events. This behaviour is expected due to the constriction and channelisation of flow through the culverts along this reach. This is particularly evident for all minor to moderate events up to the 1% AEP event, where the Project alignment does not overtop.
 - ▶ Due to the high immunity of the Chamberlain Road Bridge and approach (>PMF), large changes in flow distribution are noted as the floodplain is restricted to culvert and bridge openings.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary. Change in flow distribution for the Gowrie Creek floodplain can be seen in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping of the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events has been provided in an **Online Digital Platform**. In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-53 outlines the changes in peak water levels of more than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event. It is not anticipated that flood sensitive receptors will be impacted by flood waters above the flood impact objective target in the 1 in 2,000 AEP event.

TABLE 14-53 GOWRIE CREEK: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
GOW_ID_2	Pump Station	-	-	+39	0.14	+77	0.75
GOW_ID_4	Shed	-	-	-	-	+264	0.74
GOW_ID_5	Shed	-	-	-	-	+240	0.15
GOW_ID_6	House	-	-	-	-	+96	0.21
GOW_ID_7	Shed	-	-	-	-	+51	0.07

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. During these extreme events, the Project alignment is inundated at a few locations. Table 14-54 outlines the overtopping locations and depths.

TABLE 14-54 GOWRIE CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
207.15	C207.15	-	0.01	2.28
208.21	C208.21	-	-	0.83

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the culverts allow adequate passage of flow during the flood events and ‘damming’ effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events. Further details of embankment overtopping failure risk can be found at the end of Section 14.8.1.2.

Climate change

The climate change guidelines set out in ARR 2019 have been followed and used to assess the potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment.

The Representative Concentration Pathways 8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 21 per cent across the Gowrie Creek catchment area.

Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change. The inclusion of climate change slightly increases the change in peak water levels around the Project alignment. Climate change results in increased peak water levels of up to 0.1 m in the vicinity of the Project under the 1% AEP event. The Project rail formation level is higher than the 1% AEP climate change water level.

The climate change sensitivity result indicated there are no predicted changes in peak water levels at flood sensitive receptors in the Gowrie Creek modelled floodplain for the 1% AEP climate change event.

Blockage

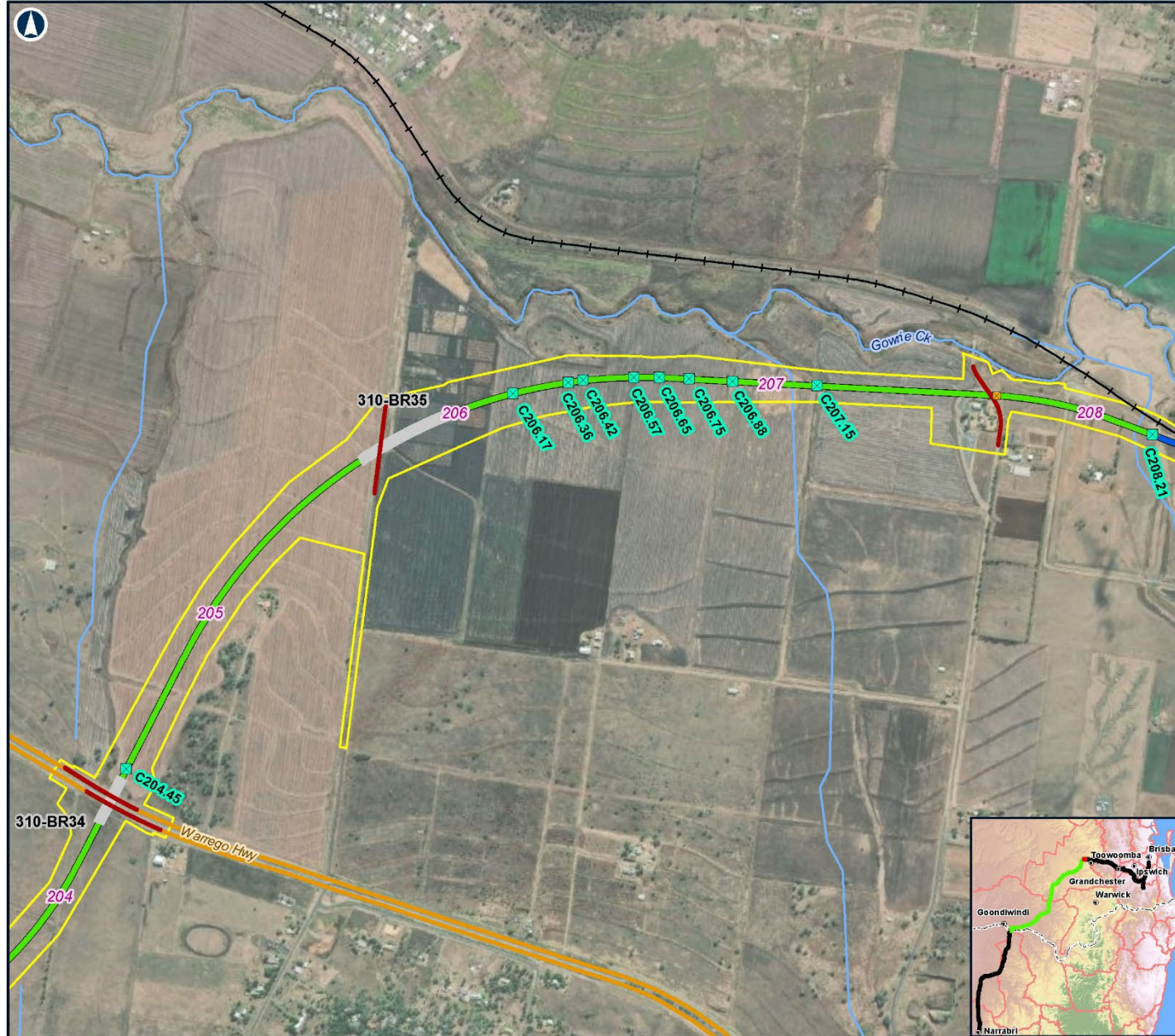
Blockage of drainage structures has been assessed in accordance with ARR 2019 requirements. ARR 2019 guidelines are focused on the potential blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are multi-span large bridges and ARR 2019 notes that there are limited instances of multi-span bridges being observed with blockages similar to those seen at single-span bridges or culverts.

The blockage assessment, therefore, resulted in a blockage factor of 5 per cent to 10 per cent being applied to bridges and a blockage factor of 25 per cent being applied to culverts. A minimum culvert size of 900 mm diameter was also adopted, to reduce potential for blockage and for ease of maintenance.

Two blockage sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

During detailed design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in varied and/or lower blockage factors being applied along the Project alignment.

The blockage sensitivity result indicates that there are no predicted changes in peak water levels at flood sensitive receptors for the 1% AEP 0 per cent and 50 per cent blockage scenarios in the Gowrie Creek modelled floodplain.



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BORDER TO GOWRIE Figure 14-18a: Floodplain and drainage structures Gowrie Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Project road design
- Watercourses (QLD Spatial Layer)
- Bridges
- Floodplain culvert
- Local drainage culvert
- Impact assessment area
- Project footprint

0 0.4 0.8 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 08/01/2025

Author: FFJV WATER

Data Sources: FFJV 2024

Paper: A4

Scale: 1:17,000

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-18b:
1 % AEP Change in peak water levels
Gowrie Creek

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

Estimated change in peak water levels (m)

- | | |
|----------------|--------------|
| < -0.5 | 0.02 to 0.05 |
| -0.50 to -0.20 | 0.05 to 0.10 |
| -0.20 to -0.10 | 0.10 to 0.20 |
| -0.10 to -0.05 | 0.20 to 0.30 |
| -0.05 to -0.01 | 0.30 to 0.40 |
| -0.01 to 0.01 | 0.40 to 0.50 |
| 0.01 to 0.02 | > 0.5 |

- Decrease in inundation area
- Increase in inundation area

Impact assessment area

- Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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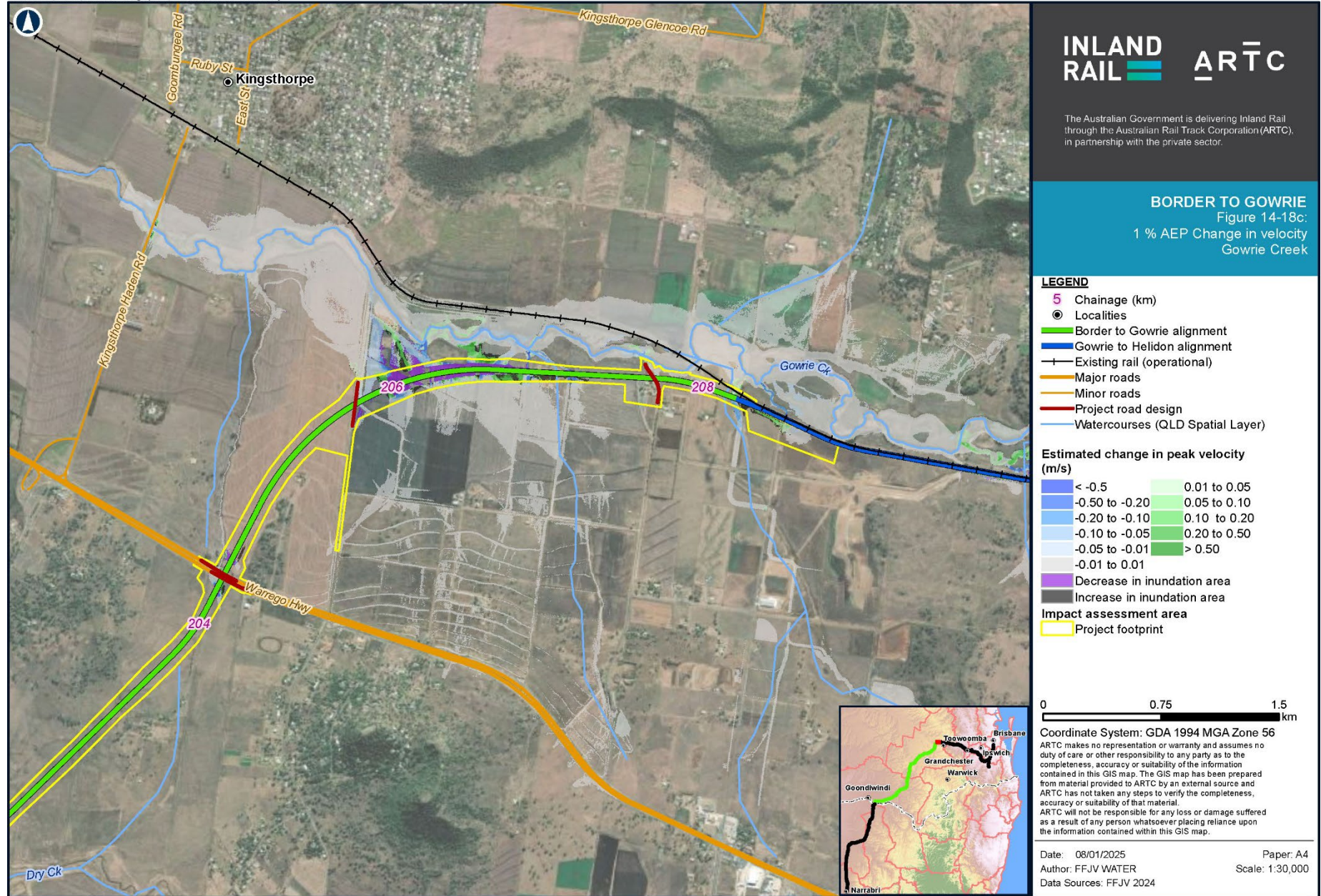
Author: FFJV WATER

Data Sources: FFJV 2024

Paper: A4

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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE Figure 14-18d: 1 % AEP Change in hazard Gowrie Creek

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

Estimated change in velocity x
depth product (m^2/s)

- < -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- > 0.10

■ Decrease in inundation area
■ Increase in inundation area

Impact assessment area
■ Project footprint

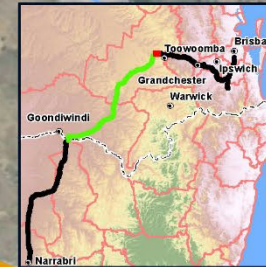
0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

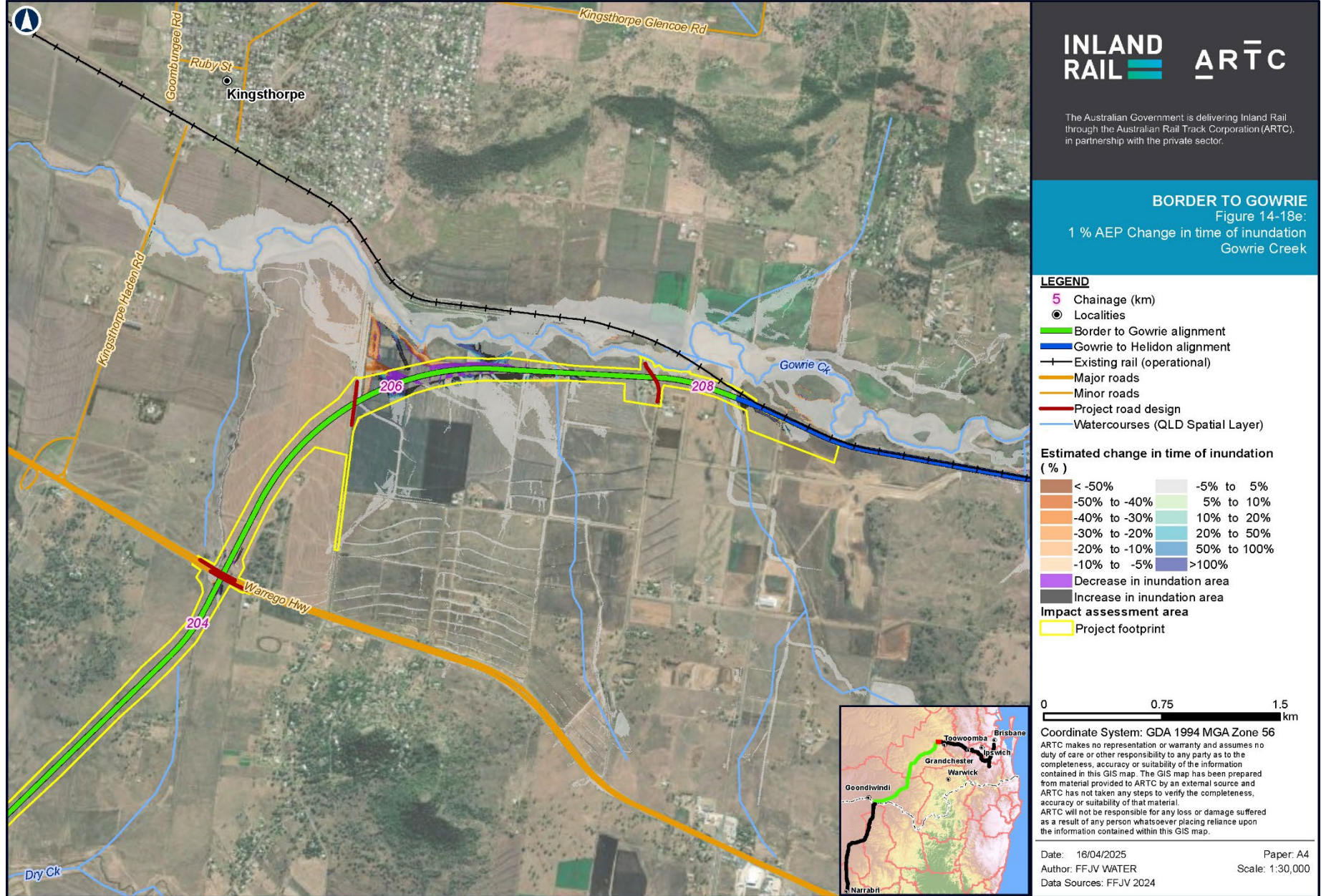
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Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
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14.8.1.2.3 Westbrook Creek and Dry Creek

On the Westbrook/Dry Creek floodplain, the Project's revised reference design includes:

- ▶ Four bridges
- ▶ Ten RCP locations (a total of 94 culvert cells)
- ▶ Two RCBC location (a total of 13 culvert cells).

Details of the floodplain structures required to convey Westbrook Creek and Dry Creek flood flows are presented in Table 14-55 and Table 14-56, with structure locations presented in Figure 14-19a. Figure 14-19a also presents the location of local catchment drainage structures.

TABLE 14-55 WESTBROOK CREEK AND DRY CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Structure name	Soffit level (m AHD ²)	Bridge length (m)
197.40	310-BR20	Bridge	Toowoomba–Cecil Plains Road rail bridge	439.40	92
198.52	310-BR31	Bridge	Westbrook Creek bridge	427.70 ²	230
199.23	310-BR32	Bridge	Dry Creek bridge	430.10	184
200.00	310-BR33	Bridge	Brimblecombe Road rail bridge	437.95 ²	75

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)
2. Average bridge soffit level reported due to changing soffit level of bridges due to rail grade. The reported values may differ from that specified within the hydraulic model.

TABLE 14-56 WESTBROOK CREEK AND DRY CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No of culvert cells	Diameter/width x height (m) ¹
188.99	C189.99	RCBC	11	1.80 x 1.50
193.10	C193.10	RCP	5	3.00
194.66	C194.66	RCBC	2	1.50 x 1.20
194.69	C194.69	RCP	3	1.05
196.92	C196.92	RCP	14	1.35
197.18	C197.18	RCP	2	1.05
197.31	C197.31	RCP	2	1.05
198.68	C198.68	RCP	15	2.40
198.77	C198.77	RCP	11	1.50
198.80	C198.80	RCP	10	1.20
198.98	C198.98	RCP	17	1.05
199.53	C199.53	RCP	15	1.05

Table notes:

1. For RCP height equals diameter
2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-19b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 6.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Westbrook and Dry Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for seven lots within the Westbrook and Dry Creek floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 16 mm on Lot Plan 101SP279839 to 723 mm on Lot Plan 2RP149961. The large increase identified on Lot Plan 2RP149961 can be attributed to newly flood-affected area within the hydraulic model and impact an area generally less than 0.71 ha (or approximately 1 per cent of the total lot area).

Of the seven lots identified, two are impacted due to the change in flood extent and identified due to newly flood-affected hydraulic model cells. The impacted properties are:

- ▶ Two lots experience a change in peak water level of between 500 mm and 1 m
- ▶ Two lots experience a change in peak water level of between 100 mm and 500 mm
- ▶ One lot experiences a change in peak water level of between 50 mm and 100 mm
- ▶ Two lots experience a change in peak water level of less than 50 mm.

Other infrastructure

A total of three roads (State-controlled roads and local roads), are impacted by a change in peak water level. Of these only one State-controlled road, the Toowoomba-Cecil Plains Road, is identified as being impacted with a change in peak water level. Existing flood conditions demonstrate the Toowoomba—Cecil Plain Road has less than a 20% AEP flood immunity. The maximum change in water level occurs during the 2% AEP event, and is approximately 102 mm.

Two local public roads, Anderson Road and Brimblecombe Road, have been identified as impacted by a change in peak water levels with Brimblecombe Road experiencing the greatest increase in peak water level of 38 mm in the 1% AEP event. A summary of impacted local roads is provided below:

- ▶ Two local roads experience a change in peak water level of between 10 mm and 40 mm

No existing rail infrastructure has been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1% AEP event in the Westbrook and Dry Creek floodplain.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-19c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 21 lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Impacted lots are located at the outlets of cross-drainage structures, and within Westbrook Creek. Of these, Lot Plan 1RP155674 experiences the largest increase in velocity of 2.6 m/s. Some order of change in velocity is expected to be experienced across 1.13 ha (approximately 7 per cent of the total lot area) and can be attributed to a change in flood inundation extent and a newly flood-affected hydraulic model cell.

The following provides a summary of changes in peak velocity across the 21 Lots:

- ▶ Three lots experience a change of greater than 1.5 m/s
- ▶ Two lots experience a change of between 1.0 m/s and 1.5 m/s
- ▶ Four lots experience a change between 0.5 m/s and 1.0 m/s
- ▶ 10 lots experience a change of less than 0.5 m/s
- ▶ Two lots experience a percentage change only, of less than 40 per cent.

Other infrastructure

One State-controlled road has been identified to experience a change in velocity due the presence of the Project alignment: Toowoomba-Cecil Plains Road. The change in velocity occurs in the 20%, 10%, 5%, 2% and 1% AEP events with a maximum increase of 45 per cent (from 1.04 m/s to 1.51 m/s) across a length of 15 m.

No local public roads or existing rail infrastructure are predicted to be impacted by a change in peak velocity due to the Project within the Westbrook and Dry Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 6.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-19d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Westbrook Creek and Dry Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of nine lots were identified as being impacted to some degree of change resulting in flood hazard above the flood impact objective targets. Exceedances can be attributed to increased flow velocities and flood depths the inlets and outlets of bridges and culverts. The maximum increase for flood hazard is approximately 0.34 m²/s on Lot Plan 10 RP47857 (from 0.03 m²/s to 0.37 m²/s). Some degree of change as hazard is expected occur across a total area of 0.20 ha (less than 1 per cent of the lot area).

It is noted that large percentage exceedances are recorded on Lot Plan 2AG3200, 2RP149961, 1RP155674 and 2RP48191 which can be attributed to the Existing Case result being extremely small with an increase to a small hazard result in the Developed Case. The 'absolute' change associated with these percentage increases is considered small but when converted to percentages results in a large change. The below provides a summary of results:

- ▶ Five lots experience a change in hazard greater than 1,000 per cent
- ▶ Two lots experience a change in hazard of between 100 per cent and 1,000 per cent
- ▶ Two lots experience a change in hazard of less than 100 per cent.

Other infrastructure

One State-controlled road is impacted, with Toowoomba–Cecil Plains Road experiencing a change in hazard of 14 per cent in the 10% AEP event and 13 per cent in the 20% AEP event. This change in hazard can be attributed to the maturity of the current road design and cross-drainage for the Project.

One local public road, Brimblecombe Road, has been identified as being impacted by a change in hazard in the 5%, 2% and 1% AEP events. The maximum change in hazard occurs in the 5% AEP event with an increase of 364 per cent being recorded (increasing from 0.05 m²/s to 0.22 m²/s).

No existing rail infrastructure are predicted to be impacted by a change in peak hazard due to the Project within the Westbrook Creek and Dry Creek floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 6.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-19e for the 1% AEP event.

Private land outside the Project permanent footprint

Change in time of inundation is the primary exceedance category on lots for the Westbrook Creek and Dry Creek floodplain. A total of 33 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Review of the exceedances show increases are mostly isolated to regions directly upstream and downstream of the Project alignment. Exceedances can be attributed to ponding that is created by the Project alignment crossing a natural waterway, and the localised redirection of flow through culvert structures creating a concentrated flow path downstream.

The maximum increase in time of inundation is approximately 13.38 hours on Lot Plan 2AG3200, with the total impacted area being 0.17 ha (less than 1 per cent of total lot area). It should be noted that the above change is the peak only and does not necessarily occur across the whole impacted area. A maximum percentage change occurs on Lot Plan 2RP149961 with an increase of 989 per cent (increasing from 1.10 hours in the Existing Case to 12.05 hours in the Developed Case).

A summary of results is shown below:

- ▶ Three lots experience a percentage change increase in time of inundation of between 500 per cent to 1,000 per cent (Section 14.8.1.2)
- ▶ Seven lots experience a percentage change increase in time of inundation of between 100 per cent to 500 per cent
- ▶ Two lots experience a percentage change increase in time of inundation of between 50 per cent to 100 per cent
- ▶ Eighteen lots experience a percentage change increase in time of inundation of less than 50 per cent
- ▶ Three lots experience an 'absolute' change in time of inundation only.

Other infrastructure

A total of two roads (one State-controlled and one local), Toowoomba-Cecil Plains Road and Anderson Road, respectively, are impacted by a change in time of inundation. Toowoomba-Cecil Plains Road experiences a maximum change of time of inundation of 373 per cent in the 1% AEP event (increasing from 0.21 hours to 1.01 hours). Although some change occurs on this road due to the Project alignment, Existing Case time of inundation results indicate this segment is submerged for up to 11.65 hours and therefore the 373 per cent increase recorded in the Developed Case is considered negligible as the road is already submerged.

The only local public road impacted by an increase in time of inundation is Anderson Road, which experiences a maximum change of 45 per cent (increasing from 0.74 hours to 1.07 hours) in the 20% AEP event. Although some change occurs on this road due to the Project alignment, Existing Case time of inundation results indicate this segment is submerged for up to 16.72 hours and therefore the 45 per cent increase recorded in the Developed Case is considered minor as the road is already submerged.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events.) Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 6.5.3).

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage, with significant floodplain structures included to maintain or improve the existing flood regime. The following observations are made regarding change in flow distribution in the Westbrook and Dry Creek floodplain:

- ▶ Minor flow decreases (upstream) and increases (downstream) are localised to cross-drainage infrastructure. This behaviour is expected due to the constriction of the flood way through the culvert and bridge openings. This is particularly evident for all flood events up to the 1% AEP event, where the Project alignment is not overtopped.
- ▶ While the Project alignment does impact flow conditions immediately upstream and downstream of the alignment, regional conditions remain relatively unchanged up to the 1% AEP event.
- ▶ During the rarer events (1 in 2,000 AEP, 1 in 10,000 AEP and PMF events), there is generally a positive increase in flow distribution immediately adjacent the Project alignment, with a negative change throughout the majority of the remainder of the floodplain due to the presence of the Project alignment.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Change in flow distribution for the Westbrook Creek and Dry Creek floodplain can be seen in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping of the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-57 outlines the changes in peak water levels of more than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event. It is not anticipated that flood sensitive receptors will be impacted by flood waters above the flood impact objective target in the 1 in 2,000 AEP event.

TABLE 14-57 WESTBROOK CREEK AND DRY CREEK: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
WES_ID_1	Shed	-	0.50	+98	1.16	+373	3.00
WES_ID_2	House	-	0.26	+184	0.95	+445	2.87
WES_ID_3	Shed	-	0.30	+166	0.97	+431	2.88
WES_ID_1	Shed	-	0.50	+98	1.16	+373	3.00

The risk of overtopping along the Project alignment has been assessed at drainage structures for the modelled extreme events. During these extreme events the Project alignment is inundated at several locations. Table 14-58 outlines the overtopping locations and depths.

TABLE 14-58 WESTBROOK CREEK AND DRY CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
194.66	C194.66	0.27	0.60	1.04
194.69	C194.69	0.46	0.86	1.30
198.5	310-BR31	0.77	1.80	4.01
198.68	C198.68	-	0.47	2.21
198.77	C198.77	-	0.74	2.40
198.80	C198.80	-	0.35	1.76
198.98	C198.98	-	-	0.76
199.20	310-BR32	-	-	0.42

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, some overtopping of the formation occurs at culvert and bridge structures. Generally, the bridge structures and culverts allow adequate passage of flow during the flood events and ‘damming’ effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2.

The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Westbrook Creek and Dry Creek catchment area is 21 per cent.

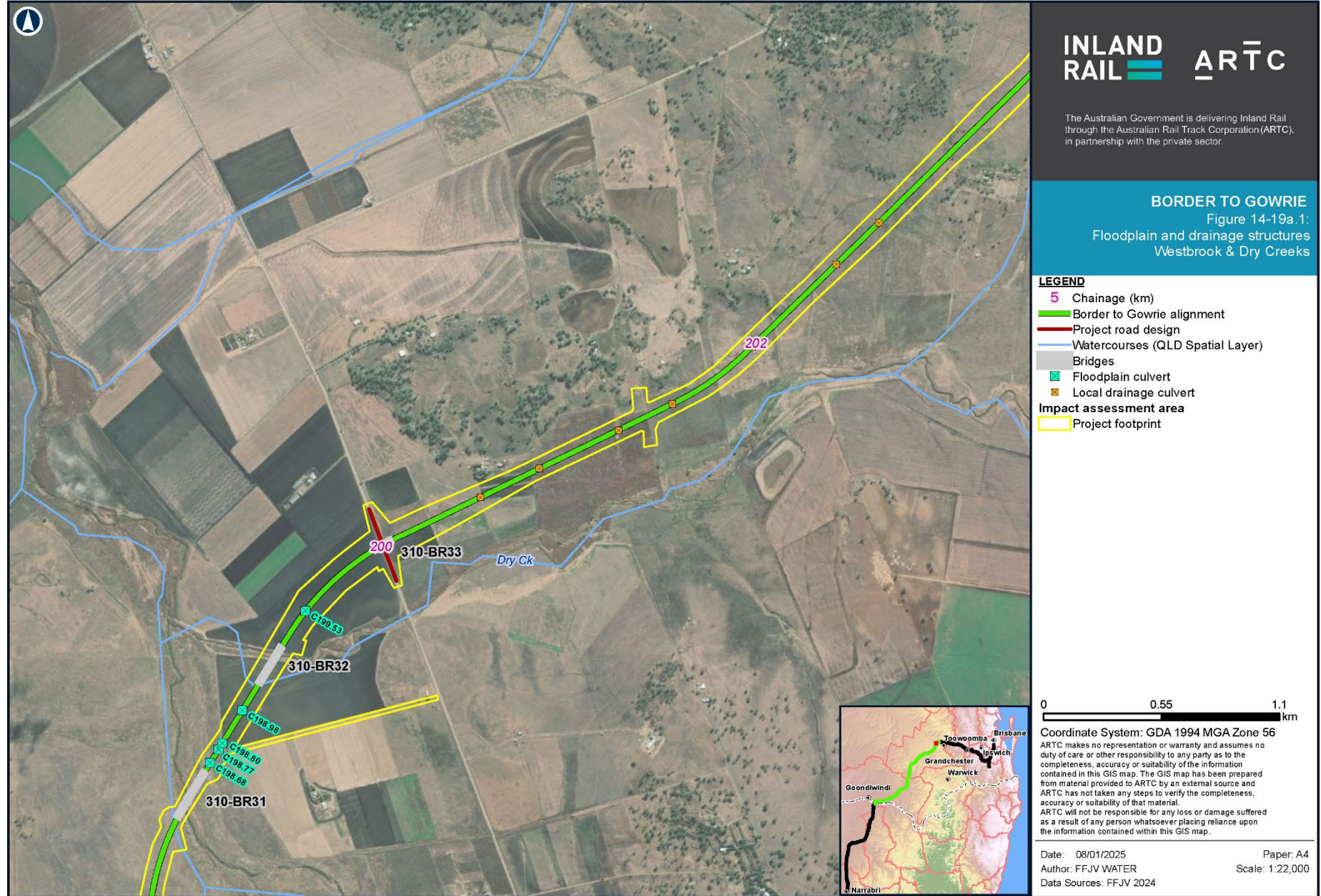
Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

The climate change sensitivity results indicate there are no predicted changes in peak water levels at flood sensitive receptors in the Westbrook and Dry Creeks modelled floodplain for the 1% AEP climate change event.

Blockage

Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

The blockage sensitivity result indicates that there are no predicted changes greater than 10 mm in peak water levels at flood sensitive receptors for the 1% AEP 0 per cent and 50 per cent blockage scenarios in the Westbrook and Dry Creeks modelled floodplain.





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BORDER TO GOWRIE

Figure 14-19a.2:
Floodplain and drainage structures
Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- Bridges
- Floodplain culvert
- Local drainage culvert
- Impact assessment area
- Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE

Figure 14-19a.3:
Floodplain and drainage structures
Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)
- Bridges
- Floodplain culvert
- Local drainage culvert
- Impact assessment area
- Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE

Figure 14-19b:
1 % AEP Change in peak water levels
Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

Estimated change in peak water levels (m)

< -0.5	0.02 to 0.05
-0.50 to -0.20	0.05 to 0.10
-0.20 to -0.10	0.10 to 0.20
-0.10 to -0.05	0.20 to 0.30
-0.05 to -0.01	0.30 to 0.40
-0.01 to 0.01	0.40 to 0.50
0.01 to 0.02	> 0.5

Decrease in inundation area

Increase in inundation area

Impact assessment area

Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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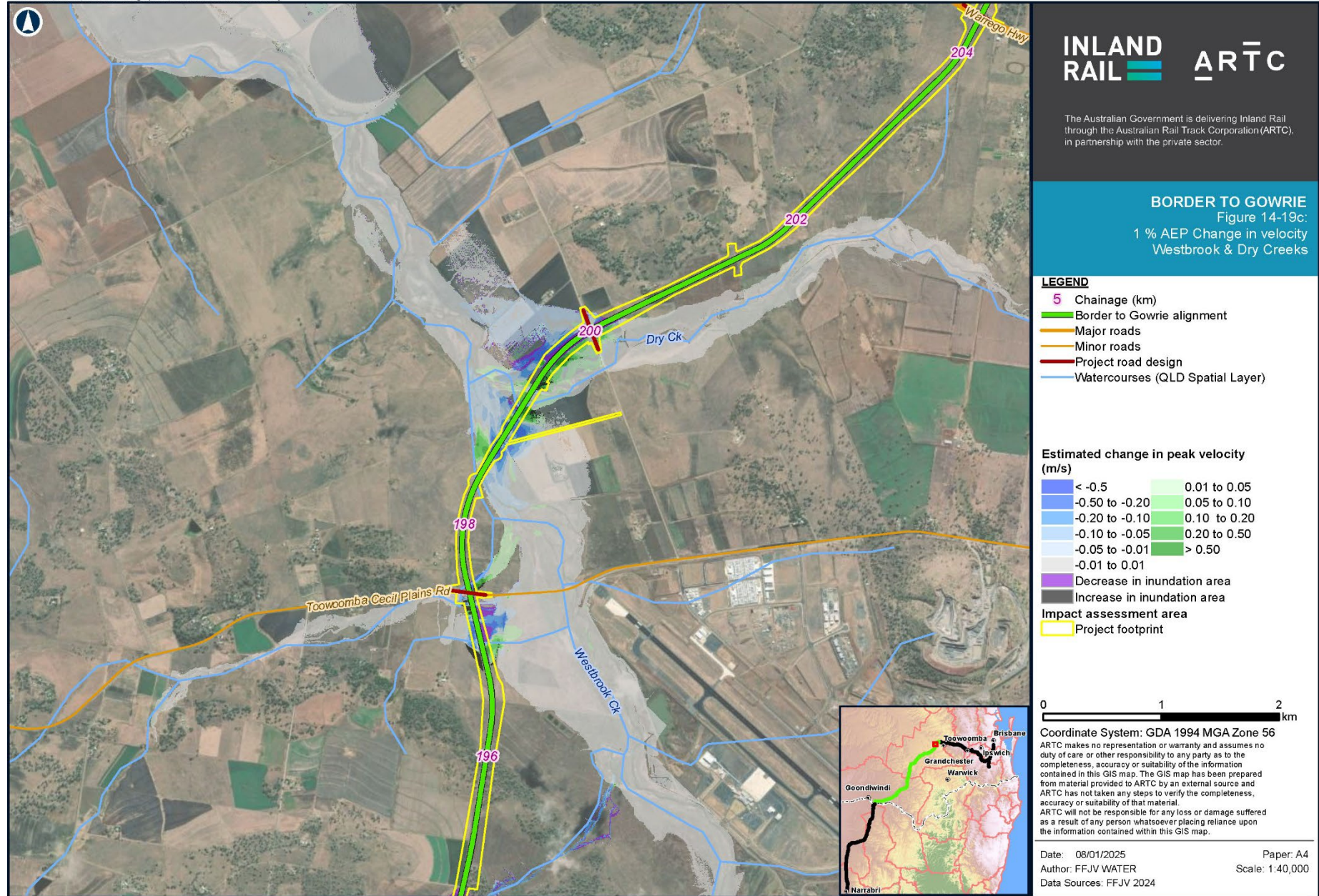
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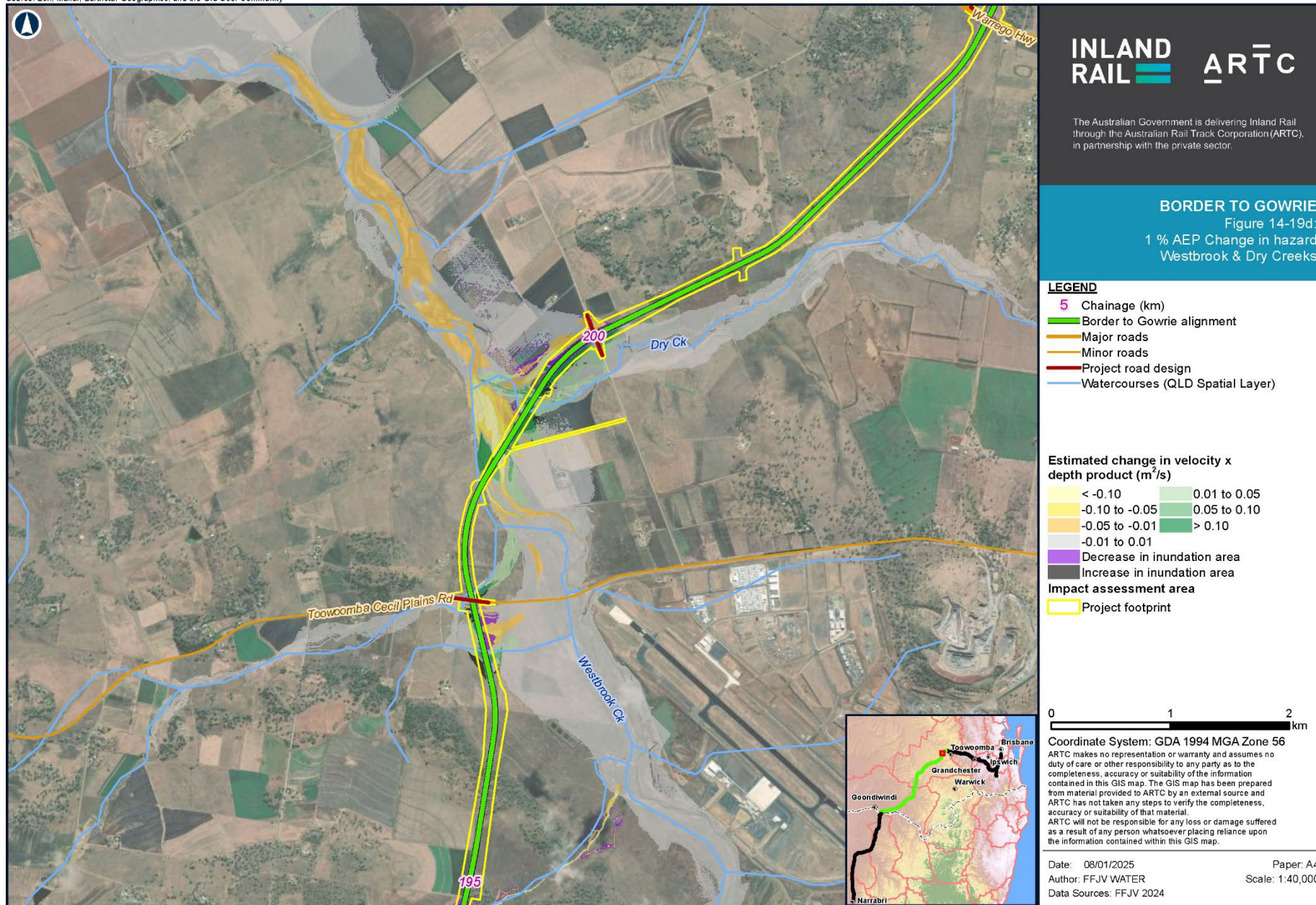
Author: FFJV WATER

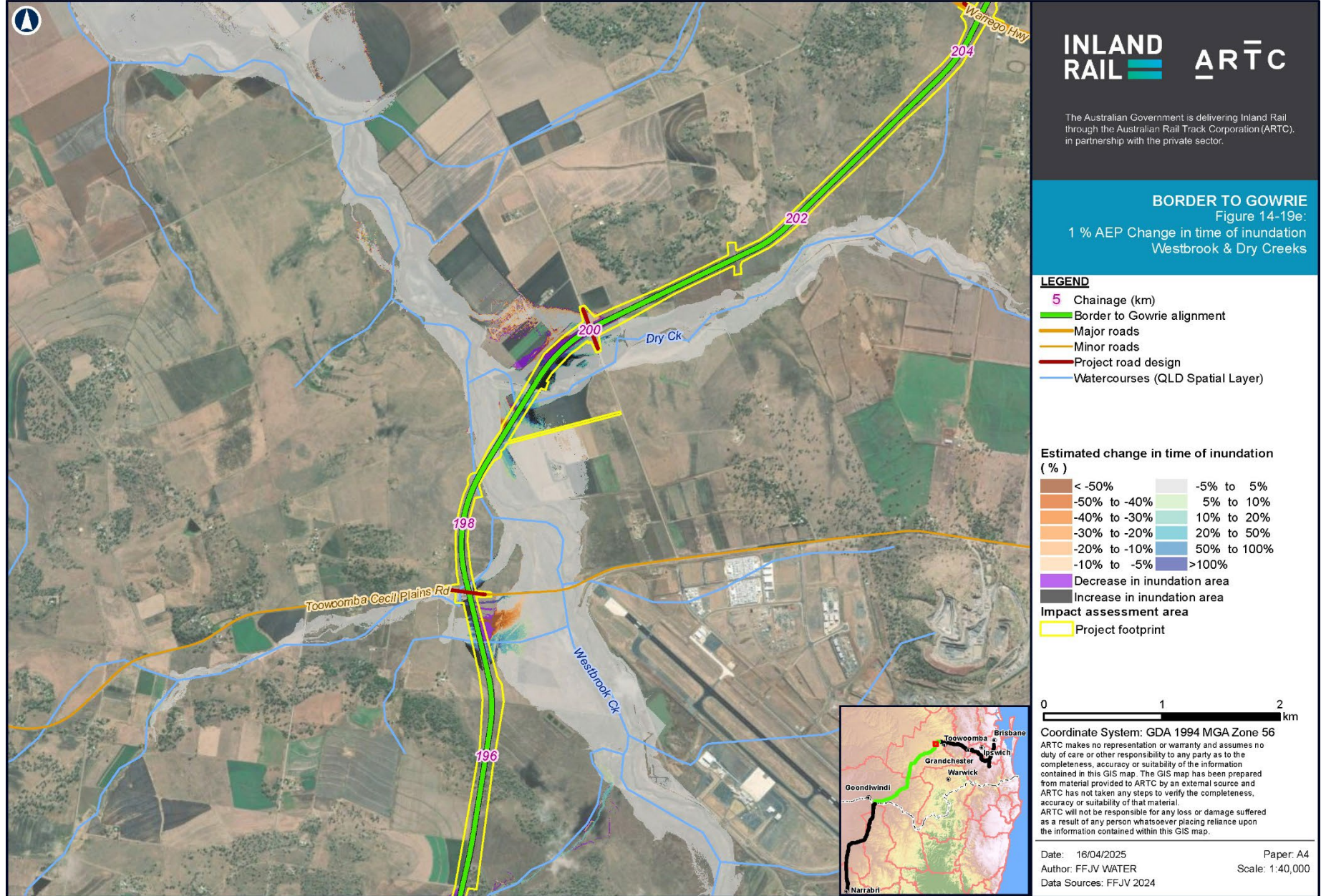
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14.8.1.2.4 Condamine River

On the Condamine River floodplain, the Project's revised reference design includes:

- ▶ Four bridges (at four main locations)
- ▶ 69 RCP locations (a total of 525 culvert cells)
- ▶ 14 RCBC locations (a total of 76 culvert cells).

Noise barriers were incorporated into the hydraulic model through Brookstead and are represented within the TUFLOW model by raising the existing ground levels by 4 m along the length of the barrier, running parallel to the Project alignment and crossing Brookstead Scrubby Road. All barrier is located outside the PMF regional flood extent and does not contribute to an increase in impacts.

Details of the floodplain structures required to convey Condamine River flood flows are presented in Table 14-59 and Table 14-60, with structure locations presented in Figure 14-20a. Figure 14-20a also presents the location of local catchment drainage structures.

TABLE 14-59 CONDAMINE RIVER: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Structure name	Soffit level (m AHD)	Bridge length (m)
139.96	310-BR21/22	Bridge	Grasstree Creek rail bridge	382.05	1,330
142.96	310-BR24	Bridge	Condamine River South Branch rail bridge	382.05	658
145.17	310-BR25/26	Bridge	Condamine River Main Branch combined rail bridge	380.60	2,577
149.83	310-BR27	Bridge	Condamine River North Branch rail bridge	383.79	1,568

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-60 CONDAMINE RIVER: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
139.13	C139.13	RCP	8	1.35
139.17	C139.17	RCP	11	1.65
139.21	C139.21	RCP	8	1.80
140.66	C140.66	RCP	11	1.80
140.73	C140.73	RCP	8	2.10
140.79	C140.79	RCP	8	2.10
140.85	C140.85	RCP	11	1.80
141.00	C141.00	RCP	9	1.65
141.02	C141.02	RCBC	4	2.40 x 2.10
141.07	C141.07	RCP	10	2.10
141.38	C141.38	RCP	7	1.80
141.40	C141.40	RCP	7	1.80
141.46	C141.46	RCP	6	2.10
141.49	C141.49	RCP	6	2.10
141.52	C141.52	RCP	6	2.10
141.54	C141.54	RCP	6	2.10
141.56	C141.56	RCP	6	2.10
141.61	C141.61	RCP	6	2.10
141.67	C141.67	RCP	6	2.10

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
141.69	C141.69	RCP	6	2.10
141.72	C141.72	RCP	7	1.80
141.75	C141.75	RCP	5	2.10
141.78	C141.78	RCP	6	2.10
141.80	C141.80	RCP	6	2.10
141.84	C141.84	RCP	5	2.10
141.88	C141.88	RCP	5	2.10
141.93	C141.93	RCP	6	2.10
141.96	C141.96	RCP	5	2.10
142.07	C142.07	RCP	6	2.10
142.12	C142.12	RCP	6	2.10
142.16	C142.16	RCP	4	2.10
142.20	C142.20	RCP	6	2.10
142.27	C142.27	RCP	6	2.10
142.32	C142.32	RCP	4	2.10
142.36	C142.36	RCP	6	2.10
142.40	C142.40	RCP	6	2.10
142.49	C142.49	RCP	6	2.10
142.53	C142.53	RCP	6	2.10
142.58	C142.58	RCP	6	2.10
142.61	C142.61	RCP	4	2.10
143.29	C143.29	RCP	6	2.10
143.33	C143.33	RCP	6	2.10
143.37	C143.37	RCP	6	2.10
143.42	C143.42	RCP	6	2.10
143.44	C143.44	RCP	6	2.10
143.48	C143.48	RCP	6	2.10
143.51	C143.51	RCP	6	2.10
143.54	C143.54	RCP	6	2.10
143.57	C143.57	RCP	5	2.10
143.65	C143.65	RCP	6	2.10
143.70	C143.70	RCP	6	2.10
143.73	C143.73	RCP	6	2.10
143.77	C143.77	RCP	6	2.10
143.79	C143.79	RCP	5	2.10
143.83	C143.83	RCP	4	2.10
143.87	C143.87	RCP	5	2.10
146.45	C146.45	RCBC	4	1.20 x 0.9
146.50	C146.50	RCBC	4	1.20 x 0.9
146.54	C146.54	RCBC	4	1.20 x 0.9
146.61	C146.61	RCBC	2	1.20 x 0.9
146.69	C146.69	RCBC	6	1.20 x 0.9

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
147.01	C147.01	RCBC	10	1.50 x 0.9
147.12	C147.12	RCBC	4	1.20 x 0.9
147.18	C147.18	RCBC	10	1.50 x 0.9
147.21	C147.21	RCBC	4	1.20 x 0.9
147.27	C147.27	RCBC	4	1.20 x 0.9
147.31	C147.31	RCBC	10	1.50 x 0.9
147.85	C147.85	RCBC	6	1.20 x 0.9
147.91	C147.91	RCBC	4	1.20 x 0.9
148.87	C148.87	RCP	25	1.05
148.92	C148.92	RCP	25	1.05
148.96	C148.96	RCP	25	1.05
149.02	C149.02	RCP	25	1.05
150.68	C150.68	RCP	10	1.35
150.71	C150.71	RCP	12	1.20
150.74	C150.74	RCP	3	1.35
151.08	C151.08	RCP	8	1.20
151.12	C151.12	RCP	8	1.20
151.14	C151.14	RCP	8	1.20
151.17	C151.17	RCP	6	1.35
151.20	C151.20	RCP	6	1.35
151.27	C151.27	RCP	8	1.20
151.30	C151.30	RCP	8	1.05

Table notes:

1. For RCP, height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-20b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 7.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Flood sensitive receptors were identified from aerial imagery and include buildings and assets such as dwellings, sheds, pump stations and silos.

A tabulation of flood sensitive receptors which are likely to experience afflux flood impact objective exceedances in events up to and including the 1% AEP event are presented in Table 14-61. The flood impact objective afflux target is not exceeded during extreme events (i.e. 1 in 2000 AEP event) on the Condamine River floodplain.

Of a total of 384 flood sensitive receptors assessed on the Condamine River regional floodplain, potential afflux flood impact objective exceedances are predicted at 12 flood sensitive receptors including six houses and six non-habitable structures. These exceedances occur due to flow retardation upstream of Project rail embankment in infrequent to rare flood events (i.e. 2% and 1% AEP events).

TABLE 14-61 CONDAMINE RIVER: 1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE THE FLOOD IMPACT OBJECTIVES

Flood sensitive receptor ID	Flood sensitive receptor type	Approximate chainage (km)	FIOs for 1% AEP event	Maximum increase in peak water level for the 1% AEP event (mm)	Comment
CON_ID_78	House	137.70	≤ 10 mm	+25	Existing 1% AEP flood depth: 370 mm
CON_ID_120	House	139.30	≤ 10 mm	+29	Existing 1% AEP flood depth: 300 mm
CON_ID_205	House	140.30	≤ 10 mm	+12	Existing 1% AEP flood depth: 740 mm
CON_ID_275	House	146.90	≤ 10 mm	+34	Existing 1% AEP flood depth: 20 mm
CON_ID_277	House	147.45	≤ 10 mm	+37	Existing 1% AEP flood depth: 100 mm
CON_ID_148	House	140.00	≤ 10 mm	+21	Existing 1% AEP flood depth: 130 mm
CON_ID_118	Shed	139.90	≤ 100 mm	+126	Existing 1% AEP flood depth: 20 mm
CON_ID_160	Shed	139.90	≤ 100 mm	+188 ¹	Existing 1% AEP flood depth: Dry
CON_ID_5	Silos	139.90	≤ 100 mm	+146	Existing 1% AEP flood depth: 30 mm
CON_ID_6	Silos	131.10 to 133.40	≤ 100 mm	+35 ¹	Existing 1% AEP flood depth: Dry
CON_ID_7	Silos	138.55 to 140.10	≤ 100 mm	+144	Existing 1% AEP flood depth: 80 mm
CON_ID_8	Silos	140.10 to 141.30	≤ 100 mm	0 ²	Existing 1% AEP flood depth: Dry

Table notes:

1. Newly flood-affected flood sensitive receptor in the Developed Case, 1% AEP event

2. Newly flood-affected flood sensitive receptor in the Developed Case, 5% AEP event (water level increase of 1 mm)

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for 25 lots within the Condamine River floodplain for all modelled events up to the 1 in 2,000 AEP event. These are concentrated within a narrow corridor upstream of the Project footprint due to topographic changes associated with the Project alignment which have relatively more impact in rarer events. The afflux impacts are associated with general flood level improvements (i.e. reductions) downstream of the alignment, sometimes resulting from balancing the upstream and downstream impacts between frequent and rare events (e.g. oversizing an opening for a rare event may lead to increased impact in another frequent event). Peak changes in water level ranged from 11 mm on Lot Plan 74RP37111 to 157 mm on Lot Plan 202SP124721. A summary of peak water level changes on the 25 impacted lots is provided below:

- ▶ One lot recorded an increase in peak water level greater than 100 mm
- ▶ One lot recorded an increase in peak water level of between 50 mm and 100 mm
- ▶ 21 lots recorded an increase in peak water level of between 20 mm and 50 mm
- ▶ Two lots recorded an increase in peak water level of between 10 mm and 20 mm.

Other infrastructure

Nine roads (two State-controlled and seven local public roads) have been identified to experience an increase in peak water levels due to the presence of the Project alignment. The impacted State-controlled roads include Millmerran-Leyburn Road and the Gore Highway, with the Gore Highway experiencing the largest increase in peak water level of 177 mm in the 10% AEP event. Millmerran-Leyburn Road experiences a maximum increase in peak water levels of 151 mm in the 20% AEP event. Both the Gore Highway and Millmerran-Leyburn Road have been identified to have an existing low immunity with both inundated in the Existing Case 20% AEP event.

Of the seven local public roads impacted, Fysh Road experiences the maximum increase in peak water levels of 150 mm in the 1% AEP event. A summary of the remaining six impacted roads is provided below:

- ▶ Elsdon Road experiences a peak change in water level of 138 mm in the 20% AEP event
- ▶ Hanlon Road experiences a peak change in water level of 125 mm in the 10% AEP event
- ▶ Gibbs Road experiences a peak change in water level of 13 mm in the 20% AEP event
- ▶ Bostock Road experiences a peak change in water level of 28 mm in the 10% AEP event
- ▶ Hall Road experiences a peak change in water level of 15 mm in the 1% AEP event
- ▶ Brose Lane experiences a peak change in water level of 50 mm in the 10% AEP event.

Four segments of existing rail infrastructure are impacted by a change in peak water level due to the presence of the Project alignment including the Millmerran Branch Line and Yandilla Siding (three segments). Of these, the Yandilla Siding experiences the largest increase in peak water level of 663 mm in the 5% AEP event. This siding has been identified as currently abandoned. The Millmerran Branch Line experiences a maximum change in peak water level of 82 mm in the 1% AEP event. This line is also currently identified as abandoned.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-20c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of four lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 4RP55115 experiences the largest increase in velocity of 59 per cent (0.3 m/s) in the 1% AEP event. Some order of change in velocity is expected to be experienced across 0.21 ha (less than 0.5 per cent of the total lot area). The following provides a summary of changes in peak velocity across the four lots:

- ▶ Lot Plan 3RP803554 experiences a maximum change in peak velocity of 16 per cent (increasing from 0.52 m/s to 0.61 m/s)
- ▶ Lot Plan 4RP55115 experiences a maximum change in peak velocity of 59 per cent (increasing from 0.51 m/s to 0.81 m/s)
- ▶ Lot Plan 2RP99467 experiences a maximum change in peak velocity of 0.013 m/s (increasing from 0.49 m/s to 0.50 m/s)
- ▶ Lot Plan 2RP99465 experiences a maximum change in peak velocity of 0.008 m/s (increasing from 0.49 m/s to 0.51 m/s).

Other infrastructure

No State-controlled roads have been identified to be impacted by a change in velocity due to the Project for all modelled events up to the 1% AEP event.

Two local public roads, Hall Road and Bostock Road, are predicted to be impacted by an increase in velocity due to the Project. Hall Road is identified as having the largest impact with a change of 0.004 m/s (increasing from 0.498 m/s to 0.502 m/s) in the 5% AEP event. The other impacted local public road is Bostock Road with an increase of 0.002 m/s in the 1% AEP event (increasing from 0.500 m/s to 0.502 m/s). Both these exceedances are deemed negligible due to the minor nature of the increases above the flood impact objective target.

Three existing rail segments are expected to experience an increase in peak velocity due to the Project. Millmerran Branch Line has a maximum change in velocity of 27 per cent and 0.28 m/s increase. Two segments of the Yandilla Sidings are expected to experience an increase in peak velocity with a maximum change of 0.38 m/s (increasing from 0.27 m/s to 0.65 m/s) in the 2% AEP event.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 7.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the velocity-depth product for the Existing Case and Developed Case with results presented in Figure 14-20d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Condamine River floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of 13 lots were identified as being impacted to some degree of change in hazard above the flood impact objective targets. The maximum increase for flood hazard is approximately 68 per cent (0.07 m²/s) on Lot Plan 2RP61876 (from 0.09 m²/s to 0.16 m²/s) in the 2% AEP event. Some degree of change in hazard is expected to occur across a total area of 0.21 ha (less than 1 per cent of the total lot area). The below provides a summary of results across all lots:

- ▶ Six lots experience an increase in hazard of between 50 to 70 per cent
- ▶ Seven lots experience an increase in hazard of between 20 to 50 per cent.

Other infrastructure

One State-controlled road, the Gore Highway, is impacted by a maximum change in hazard of 39 per cent in the 1% AEP event (increasing from 0.13 m²/s to 0.19 m²/s). This change in hazard can be attributed to the maturity of the current bridge design for the Project.

One local public road, Elsdon Road, has been identified as being impacted by a change in hazard in the 1% AEP event. The maximum change in hazard is an increase of 230 per cent (increasing from 0.05 m²/s to 0.16 m²/s).

Two segments of existing rail infrastructure, Millmerran Branch Line and Yandilla Siding, are identified to be impacted by a change in hazard beyond the flood impact objective targets. The Yandilla Siding experiences the maximum change in hazard of 384 per cent (increasing from 0.09 m²/s to 0.45 m²/s). The Millmerran Branch Line experiences a maximum change in hazard of 218 per cent (increasing from 0.20 m²/s to 0.64 m²/s).

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 7.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-20e for the 1% AEP event.

Private land outside the Project permanent footprint

Change in time of inundation is the primary exceedance category on lots for the Condamine River floodplain. A total of 88 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. These are spread along floodplain fringes and in areas with slow moving floodwater which are generally sensitive to minor disturbances to flood timing or storage modification.

Flood duration exceedances may coincide with improvements in flood levels (i.e. reduced afflux) as a result of improved upstream floodwater retention. The maximum increase in time of flood inundation is approximately 2,101 per cent (increasing from 1.79 hours to 39.37 hours) on Lot Plan 17RP37110, with the total impacted area being 1.61 ha (approximately 6.5 per cent of the total lot area). It should be noted that the above change is the peak only and does not necessarily occur across the whole impacted area. A summary of results is shown below:

- ▶ Four lots experience a percentage change increase in time of inundation of greater than 1,000 per cent
- ▶ Five lots experience a percentage change increase in time of inundation of between 500 per cent and 1,000 per cent
- ▶ 26 lots experience a percentage change increase in time of inundation of between 100 per cent and 500 per cent
- ▶ 24 lots experience a percentage change increase in time of inundation of between 50 per cent and 100 per cent
- ▶ 29 lots experience a percentage change increase in time of inundation of less than 50 per cent.

Other infrastructure

A total of eight roads (three State-controlled and five local public roads) are impacted by a change in time of inundation.

The State-controlled roads impacted include Millmerran—Leyburn Road, the Gore Highway and Pampas—Horrane Road. Of these, the Gore Highway experiences the largest change in time of inundation with a maximum change of 216 per cent (increasing from 2.53 hours to 7.99 hours) in the 10% AEP event. It should be noted that the Existing time of inundation is 144.03 hours for this segment of road and therefore the above change is considered minor. Millmerran-Leyburn Road and Pampas-Horrane Road experience a maximum change in time of inundation of 135 per cent and 38 per cent, respectively.

Five local public roads: Elsdon Road, Hanlon Road, Gilgai Lane, Gibbs Road and Pampas Road experience an increase in time of inundation. Of these, Elsdon Road experiences the largest increase of 444 per cent (increasing from 13.77 hours to 74.92 hours) in the 10% AEP event. The current time of inundation of Elsdon Road in the Existing Case is 122 hours. A summary of maximum change in time of inundation on the remaining impacted local public roads is below:

- ▶ Hanlon Road experiences a maximum change of time of inundation of 74 per cent in the 5% AEP event
- ▶ Gilgai Lane experiences a maximum change of time of inundation of 15 per cent in the 20% AEP event
- ▶ Gibbs Road experiences a maximum change of time of inundation of 45 per cent in the 10% AEP event
- ▶ Pampas Road experiences a maximum change of time of inundation of 13 per cent in the 10% AEP event.

Four segments of existing rail infrastructure experience an increase in time of inundation with these being Millmerran Branch Line and Yandilla Siding (three segments). Of these the Yandilla Siding experiences the largest increase in time of inundation of 363 per cent (increasing from 18.57 hours to 86.01 hours) in the 2% AEP event. The Millmerran Branch Line experiences a maximum percentage change of 265 per cent (increasing from 32.35 hours to 118.10 hours).

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) or the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 7.5.3).

Flood flow distribution

To determine the change in flow distribution maximum velocity-depth modelling results were used to produce change in unit flow maps between Existing Case and Developed Case conditions. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section, or to determine the effective flow corridors within a floodplain.

The presented flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to assist in identifying main channels (i.e. high flow zones) from shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the potential change in flow distribution for the Condamine River floodplain and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

Regionally, the Project alignment produces generally small to negligible flow changes (i.e. within ± 5 per cent) along all key flow paths, including Condamine River, Grasstree Creek, and North Branch, across the Condamine River regional floodplain under all events assessed (20%, 10%, 5%, 2%, 1% AEP events and 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events).

Locally, the flow distribution is governed by the relative flood interactions with various hydraulic controls, including the rail embankment, cross-drainage, road levels, and floodplain storage. Local flow redistributions primarily occur along the Project rail corridor, with a list of key sensitivities summarised below:

- ▶ Local flow redistributions were identified around all design bridge abutments under all modelled events. The bridge abutment induces a local flow concentration along the bridge opening edge, which corresponds to a flow reduction along the approach on the same side. Flow redistributions of this type are typically localised around the abutments and have small to negligible impact on the overall channel conveyance.
- ▶ Areas surrounding the Gore Highway–Millmerran–Leyburn Road intersection would experience flow redistribution exceeding 50 per cent in some localised locations. These impacts are related to modifications of floodplain storage by the raised Millmerran–Leyburn Road intersection. It is expected that further improvement in cross-drainage design maturity during detailed design will mitigate the current impact at this location in frequent and infrequent events (i.e. below 1% AEP event). The flow redistribution at this location is only marginally influenced by storage modification in very rare and extreme events (i.e. above 1 in 2,000 AEP event), where the overtopping depth along the raised Millmerran–Leyburn Road would significantly exceed the raise above the existing road. The flow redistribution is then governed by the flow concentration around the Grasstree Creek bridge and Condamine River South Branch bridge abutments, essentially becoming independent of the road drainage provision.
- ▶ Flow reductions were identified along the left floodplain of North Branch downstream of Pampas, which are in part related to small flow increases under the North Branch bridge. Further model strengthening, including refining the model representation of local roads in this area based on detailed survey, and improvement to drainage maturity, including increasing the opening length between Pampas and North Branch, are expected to mitigate the impact.

In frequent events (e.g. 10% AEP event), moderate flow redistributions (i.e. within $\pm 20\%$) were notable on fringes along the North Branch downstream of the Project alignment. These areas are characterised by slow-moving inundation which are sensitive to small changes in hydrograph timing, despite the overall conveyance (i.e. peak flow) being preserved. It is expected that further improvement to the cross-drainage design maturity during detailed design around Pampas will improve the current flow distribution sensitivities along North Branch fringe downstream of the Project alignment.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping of the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-62 outlines the changes in peak water levels of more than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event. Review of the modelled results and FIOs show there are no impacts above the flood impact objective target from extreme event flooding on flood sensitive receptors within the modelled Condamine River floodplain.

TABLE 14-62 CONDOMINE RIVER: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_4	Silos	+205	0.97	+301	1.92	+66	3.31
CON_ID_5	Silos	+213	0.90	+304	1.85	+65	3.24
CON_ID_6	Silos	+210	0.79	+302	1.75	+65	3.14
CON_ID_7	Silos	+217	0.93	+307	1.89	+65	3.28
CON_ID_8	Silos	+205	1.20	+302	2.15	+66	3.53
CON_ID_9	Silos	+206	1.06	+302	2.01	+66	3.40
CON_ID_10	Silos	+203	1.04	+300	1.99	+66	3.38
CON_ID_68	Shed	+81	1.35	+163	2.31	+89	3.71
CON_ID_78	House	+98	1.25	+188	2.21	+94	3.61
CON_ID_79	House	+19	1.20	+33	2.04	+17	3.34
CON_ID_80	Shed	+21	1.05	+37	1.89	+18	3.19
CON_ID_81	Shed	+22	0.84	+39	1.66	+18	2.96
CON_ID_82	Shed	+21	1.30	+37	2.13	+18	3.44
CON_ID_96	Shed	+49	0.41	+115	1.37	+52	2.80
CON_ID_97	Shed	+48	0.71	+114	1.66	+53	3.10
CON_ID_98	Shed	+48	0.50	+114	1.46	+53	2.89
CON_ID_99	House	+65	0.77	+127	1.76	+55	3.20
CON_ID_100	House	+64	0.61	+126	1.60	+55	3.04
CON_ID_101	Shed	+64	1.10	+126	2.09	+55	3.53
CON_ID_102	Shed	+65	1.19	+127	2.18	+56	3.62
CON_ID_103	Shed	+65	0.88	+127	1.88	+55	3.32
CON_ID_104	Shed	+64	0.81	+127	1.80	+55	3.24
CON_ID_118	Shed	+218	0.87	+309	1.83	+66	3.22
CON_ID_119	Shed	+88	1.26	+159	2.24	+61	3.66
CON_ID_120	House	+91	1.15	+162	2.13	+61	3.55
CON_ID_146	Shed	+103	0.47	+200	1.00	+90	1.83
CON_ID_147	Shed	+103	0.47	+201	0.99	+88	1.80
CON_ID_148	House	+105	0.52	+202	1.04	+91	1.86
CON_ID_149	House	+88	0.26	+193	0.80	+134	1.61
CON_ID_150	House	-15	0.98	-12	1.81	+16	3.11
CON_ID_151	Shed	-17	0.89	-14	1.72	+16	3.02
CON_ID_152	Shed	-17	0.92	-13	1.76	+15	3.06
CON_ID_153	House	+15	1.09	+26	1.97	+13	3.32
CON_ID_154	Shed	-79	0.82	-69	1.66	+14	2.95
CON_ID_155	House	-88	0.72	-74	1.57	+14	2.86
CON_ID_156	Shed	-91	0.54	-77	1.39	+14	2.68
CON_ID_157	Shed	+62	0.05	+202	0.41	+156	1.21
CON_ID_158	Shed	+61	0.05	+194	0.40	+148	1.22
CON_ID_159	Shed	+3	0.51	+25	0.86	+50	1.61
CON_ID_160	Shed	+23	0.45	+70	0.87	+46	1.70
CON_ID_161	House	+25	0.63	+72	1.06	+49	1.88
CON_ID_162	Shed	+24	0.63	+72	1.06	+48	1.88
CON_ID_184	Shed	-	0.00	+168	0.23	+52	1.03

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_185	Shed	-	0.11	-73	0.66	+43	1.43
CON_ID_186	Shed	-121	0.66	-93	1.53	+13	2.81
CON_ID_187	House	-132	0.61	-100	1.49	+13	2.78
CON_ID_188	Shed	-130	0.62	-98	1.50	+13	2.78
CON_ID_189	Shed	-129	0.65	-97	1.52	+13	2.81
CON_ID_190	Shed	-129	0.59	-96	1.46	+13	2.74
CON_ID_191	Shed	-125	0.55	-95	1.42	+13	2.71
CON_ID_192	Shed	-120	0.51	-92	1.37	+13	2.66
CON_ID_193	Shed	+1	1.11	+10	1.73	+14	2.75
CON_ID_194	Shed	+1	1.21	+10	1.82	+13	2.83
CON_ID_195	Shed	+1	1.14	+9	1.75	+13	2.76
CON_ID_196	House	+1	1.19	+10	1.79	+14	2.80
CON_ID_197	Shed	+1	1.15	+9	1.75	+13	2.76
CON_ID_203	Shed	+57	1.18	+124	2.15	+48	3.56
CON_ID_204	Shed	+57	1.30	+124	2.26	+48	3.67
CON_ID_205	House	+58	1.52	+125	2.48	+48	3.89
CON_ID_206	Shed	+58	1.26	+126	2.22	+48	3.63
CON_ID_207	Shed	+58	1.59	+126	2.55	+48	3.96
CON_ID_208	Shed	+16	0.43	+66	1.37	+34	2.81
CON_ID_209	Shed	+20	0.44	+68	1.41	+35	2.85
CON_ID_210	Shed	+17	0.39	+66	1.33	+34	2.77
CON_ID_211	Shed	+17	0.21	+79	0.71	+111	1.61
CON_ID_212	House	+14	0.13	+72	0.36	+104	0.94
CON_ID_213	Shed	+15	0.11	+75	0.62	+107	1.51
CON_ID_214	Shed	+15	0.47	+74	0.98	+107	1.88
CON_ID_215	Shed	+16	0.76	+58	1.73	+30	3.14
CON_ID_216	Shed	+16	1.43	+59	2.39	+30	3.80
CON_ID_217	Shed	+16	1.21	+59	2.16	+30	3.57
CON_ID_218	Shed	+15	1.07	+58	2.02	+30	3.43
CON_ID_219	Shed	+15	0.99	+58	1.94	+30	3.34
CON_ID_220	Shed	+14	0.85	+57	1.80	+29	3.20
CON_ID_221	Shed	+15	0.94	+57	1.89	+29	3.29
CON_ID_222	Shed	+14	0.91	+55	1.86	+29	3.26
CON_ID_223	Shed	+15	0.96	+57	1.91	+30	3.32
CON_ID_224	House	+14	0.85	+56	1.81	+29	3.22
CON_ID_225	House	+15	1.02	+57	1.98	+30	3.39
CON_ID_231	Shed	-4	0.01	-11	0.15	+12	1.09
CON_ID_234	House	-	-	-11	0.25	+18	1.24
CON_ID_236	Shed	-3	-	-9	0.21	+14	1.10
CON_ID_244	Shed	+140	0.34	+235	0.86	+83	1.71
CON_ID_245	House	+122	0.24	+220	0.75	+84	1.58
CON_ID_246	Shed	+113	0.35	+208	0.88	+86	1.72
CON_ID_247	Shed	+107	0.43	+203	0.96	+87	1.80
CON_ID_248	Shed	+106	0.38	+203	0.90	+87	1.73

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_275	House	+68	0.04	+183	0.38	+145	1.22
CON_ID_276	Shed	+64	0.01	+175	0.23	+138	1.07
CON_ID_277	House	+74	0.22	+202	0.54	+165	1.37
CON_ID_278	Shed	+13	0.76	+68	1.07	+69	1.85
CON_ID_279	Shed	+14	0.65	+69	0.95	+78	1.74
CON_ID_285	Shed	-	0.05	-90	0.58	+45	1.33
CON_ID_286	Shed	-	0.13	-99	0.67	+42	1.41
CON_ID_300	House	-	-	-	-	+20	0.59
CON_ID_302	Silos	+1	0.08	+14	0.75	+16	1.99
CON_ID_303	Shed	+1	0.37	+14	1.05	+17	2.30
CON_ID_368	Railway	+3	0.88	+65	1.22	+33	2.05
CON_ID_372	Electricity pole	+7	2.97	+11	3.84	+5	5.15
CON_ID_375	Weighbridge	+218	0.70	+311	1.66	+68	3.04
CON_ID_376	Shed	+46	0.49	+113	1.43	+52	2.87
CON_ID_409	Shed	+15	0.62	+72	1.13	+105	2.03
CON_ID_410	Silos	+28	0.41	+91	0.95	+119	1.86
CON_ID_412	Silos	+14	0.90	+58	1.84	+30	3.24

The risk of overtopping along the Project alignment has been assessed for the modelled extreme events. During these extreme events the Project alignment is inundated at several locations. Table 14-63 outlines the overtopping locations and depths.

TABLE 14-63 CONDAMINE RIVER: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
139.13	C139.13	-	0.28	1.46
139.17	C139.17	-	0.24	1.33
139.21	C139.21	-	0.20	1.29
139.5	310-BR21/22	-	0.20	1.56
140.66	C140.66	-	0.13	1.34
140.73	C140.73	-	0.14	1.30
140.79	C140.79	-	0.16	1.31
140.85	C140.85	-	0.15	1.30
141.00	C141.00	-	0.14	1.24
141.02	C141.02	-	-	1.23
141.07	C141.07	-	0.17	1.26
141.38	C141.38	-	0.15	1.23
141.40	C141.40	-	0.10	1.19
141.46	C141.46	-	0.08	1.14
141.49	C141.49	-	0.10	1.18
141.52	C141.52	-	-	1.16
141.54	C141.54	-	0.10	1.20
141.56	C141.56	-	-	1.16
141.61	C141.61	-	-	1.17

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
141.67	C141.67	-	0.12	1.20
141.69	C141.69	-	0.11	1.19
141.72	C141.72	-	0.06	1.14
141.75	C141.75	-	-	1.13
141.78	C141.78	-	0.11	1.24
141.80	C141.80	-	0.08	1.15
141.84	C141.84	-	0.10	1.17
141.88	C141.88	-	0.11	1.22
141.93	C141.93	-	0.10	1.19
141.96	C141.96	-	0.10	1.16
142.07	C142.07	-	-	1.07
142.12	C142.12	-	0.04	1.05
142.16	C142.16	-	0.02	1.03
142.20	C142.20	-	0.03	1.02
142.27	C142.27	-	0.05	1.11
142.32	C142.32	-	-	0.96
142.36	C142.36	-	-	0.98
142.40	C142.40	-	0.01	1.12
142.49	C142.49	-	-	1.09
142.53	C142.53	-	-	1.09
142.58	C142.58	-	-	1.09
142.61	C142.61	-	-	0.99
142.65	310-BR24	-	-	1.14
143.29	C143.29	-	-	0.86
143.33	C143.33	-	-	0.95
143.37	C143.37	-	-	0.87
143.42	C143.42	-	-	0.79
143.44	C143.44	-	-	0.90
143.48	C143.48	-	-	0.91
143.51	C143.51	-	-	0.89
143.54	C143.54	-	-	0.92
143.57	C143.57	-	-	0.78
143.65	C143.65	-	-	0.77
143.70	C143.70	-	-	0.87
143.73	C143.73	-	-	0.76
143.77	C143.77	-	-	0.87
143.79	C143.79	-	-	0.88
143.83	C143.83	-	-	0.79
143.87	C143.87	-	-	0.77
146.45	C146.45	-	-	0.83
146.50	C146.50	-	-	0.65
146.54	C146.54	-	-	0.87
146.61	C146.61	-	0.05	0.80
146.69	C146.69	-	-	0.65
147.01	C147.01	-	0.19	0.76

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
147.12	C147.12	-	0.25	0.84
147.18	C147.18	-	0.26	0.87
147.21	C147.21	-	0.28	0.89
147.27	C147.27	-	0.23	0.78
147.31	C147.31	-	0.26	0.82
147.85	C147.85	-	0.44	1.10
147.91	C147.91	-	0.52	1.18
148.87	C148.87	-	-	0.44
148.92	C148.92	-	-	0.29
148.96	C148.96	-	-	0.15
149.02	C149.02	-	-	0.12
150.68	C150.68	-	-	1.89
150.71	C150.71	-	-	1.95
150.74	C150.74	-	-	1.98
151.08	C151.08	-	-	2.06
151.12	C151.12	-	-	2.09
151.14	C151.14	-	-	2.08
151.17	C151.17	0.67	1.25	2.10
151.20	C151.20	-	-	2.02
151.27	C151.27	-	-	2.04

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and ‘damming’ effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Condamine River catchment area is 22.8 per cent.

Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

Table 14-64 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the climate change scenario. The flood impacts under the climate change scenario are expected to increase in magnitude but exhibit a consistent pattern to the present day 1% AEP event scenario.

TABLE 14-64 CONDAMINE RIVER: SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1% AEP climate change event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
CON_ID_4	Silos	+141	0.62
CON_ID_5	Silos	+157	0.53
CON_ID_6	Silos	+152	0.39
CON_ID_7	Silos	+162	0.57
CON_ID_8	Silos	+142	0.82
CON_ID_9	Silos	+142	0.69
CON_ID_10	Silos	+139	0.68

Flood sensitive receptor
1% AEP climate change event

ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
CON_ID_68	Shed	+32	0.99
CON_ID_78	House	+43	0.89
CON_ID_96	Shed	+13	0.10
CON_ID_97	Shed	+12	0.41
CON_ID_98	Shed	+12	0.20
CON_ID_99	House	+30	0.39
CON_ID_100	House	+29	0.23
CON_ID_101	Shed	+29	0.72
CON_ID_102	Shed	+29	0.81
CON_ID_103	Shed	+30	0.50
CON_ID_104	Shed	+30	0.43
CON_ID_118	Shed	+162	0.50
CON_ID_119	Shed	+45	0.89
CON_ID_120	House	+47	0.78
CON_ID_146	Shed	+30	0.29
CON_ID_147	Shed	+29	0.26
CON_ID_148	House	+34	0.34
CON_ID_149	House	+29	0.07
CON_ID_157	Shed	+44	0.01
CON_ID_158	Shed	+54	0.02
CON_ID_160	Shed	+13	0.33
CON_ID_161	House	+13	0.51
CON_ID_162	Shed	+12	0.51
CON_ID_203	Shed	+27	0.82
CON_ID_204	Shed	+27	0.93
CON_ID_205	House	+28	1.15
CON_ID_206	Shed	+28	0.90
CON_ID_207	Shed	+28	1.23
CON_ID_244	Shed	+20	0.18
CON_ID_245	House	+11	0.06
CON_ID_246	Shed	+22	0.17
CON_ID_247	Shed	+25	0.14
CON_ID_248	Shed	+24	0.16
CON_ID_275	House	+51	0.02
CON_ID_276	Shed	+31	-
CON_ID_277	House	+55	0.16
CON_ID_375	Weighbridge	+155	0.35
CON_ID_376	Shed	+13	0.18
CON_ID_410	Silos	+15	0.24

Table note:

1. Existing Case flood depth including climate change

The downstream extents of these impacts are slightly more pronounced than those under the 1% AEP event; however, the area affected by decreases in peak water levels downstream under the climate change scenario is also larger than under the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

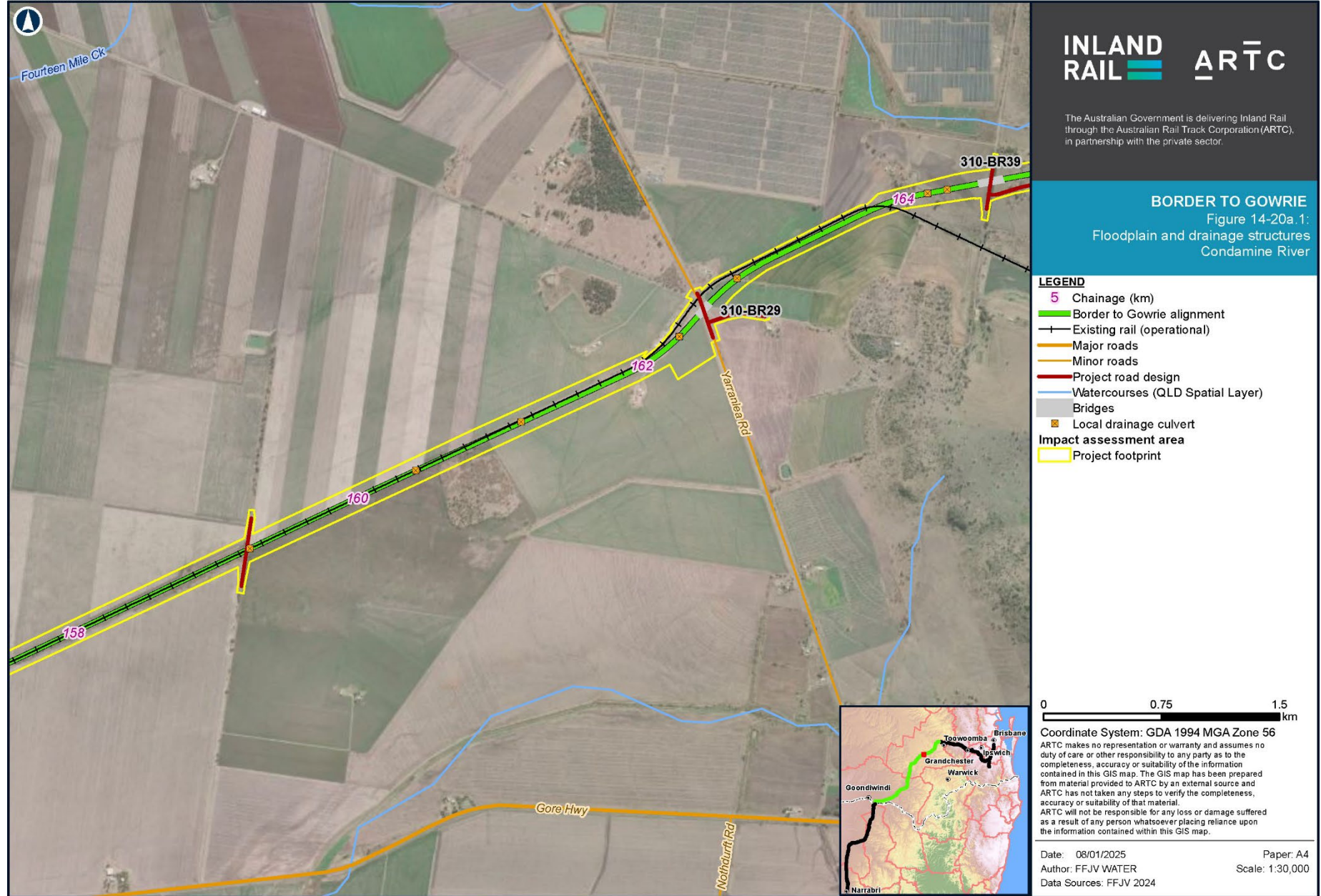
Table 14-65 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the 50 per cent blockage scenario (for a 1% AEP event).

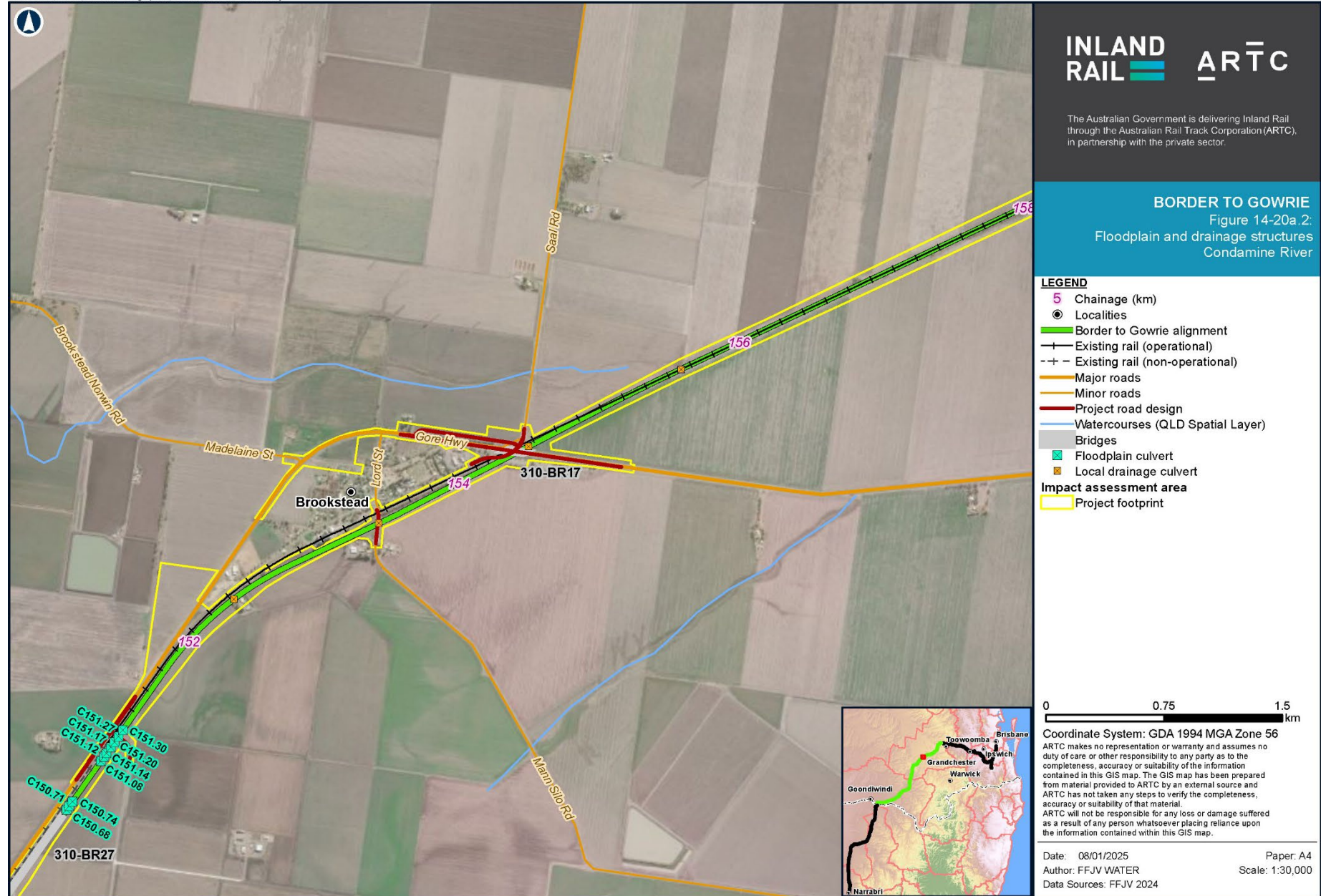
TABLE 14-65 CONDRAMINE RIVER: SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD SENSITIVE RECEPTORS (1% AEP)

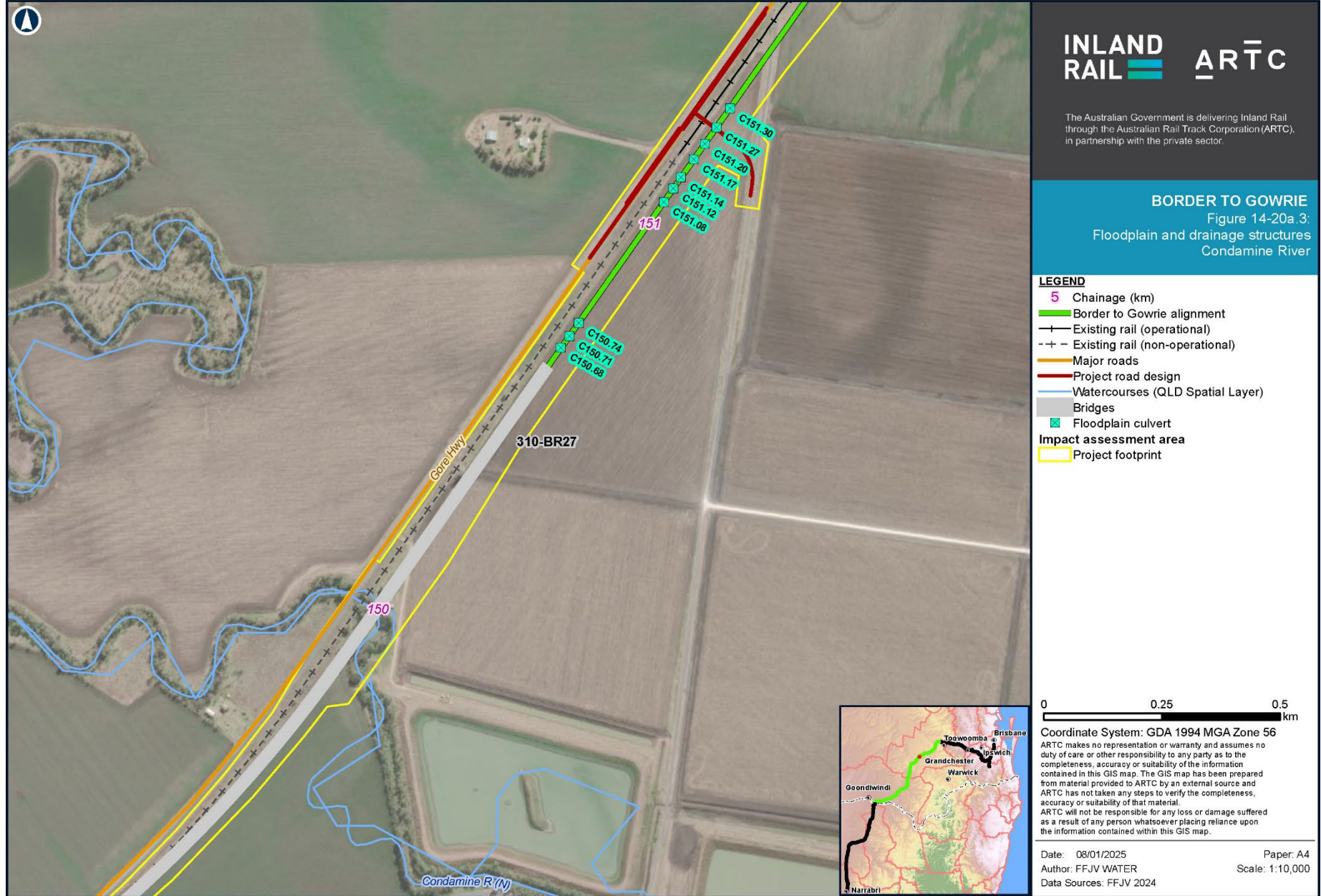
Flood sensitive receptor ID	Flood sensitive receptor type	Existing Case flood depth (m)	Change in peak water level (mm)
CON_ID_4 ¹	Silos	0.17	+102
CON_ID_5 ¹	Silos	0.03	+168
CON_ID_6	Silos	-	+57 ¹
CON_ID_7 ¹	Silos	0.08	+166
CON_ID_8 ¹	Silos	0.37	+107
CON_ID_9 ¹	Silos	0.24	+106
CON_ID_10 ¹	Silos	0.24	+101
CON_ID_68	Shed	0.46	+21
CON_ID_78 ¹	House	0.37	+28
CON_ID_101	Shed	0.21	+21
CON_ID_102	Shed	0.30	+21
CON_ID_103	Shed	0.06	+20
CON_ID_118 ¹	Shed	0.02	+150
CON_ID_119	Shed	0.42	+34
CON_ID_120 ¹	House	0.30	+37
CON_ID_146	Shed	0.09	+19
CON_ID_147	Shed	0.06	+21
CON_ID_148 ¹	House	0.13	+22
CON_ID_160 ¹	Shed	-	+189 ¹
CON_ID_203	Shed	0.41	+15
CON_ID_204	Shed	0.52	+16
CON_ID_205 ¹	House	0.74	+16
CON_ID_206	Shed	0.50	+16
CON_ID_207	Shed	0.83	+16
CON_ID_247	Shed	0.03	+14
CON_ID_248	Shed	0.02	+16
CON_ID_275 ¹	House	0.02	+34
CON_ID_277 ¹	House	0.10	+37

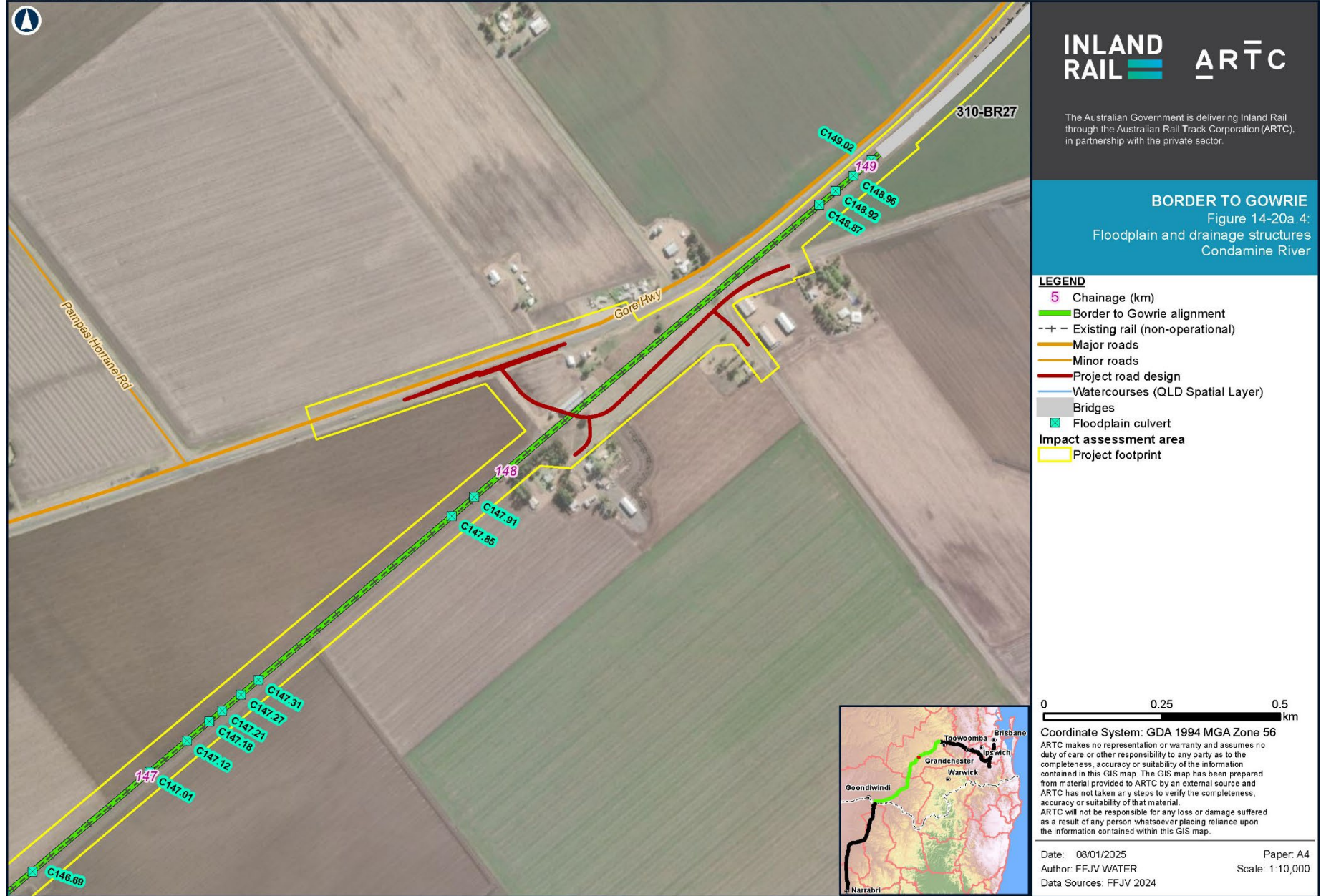
Table note:

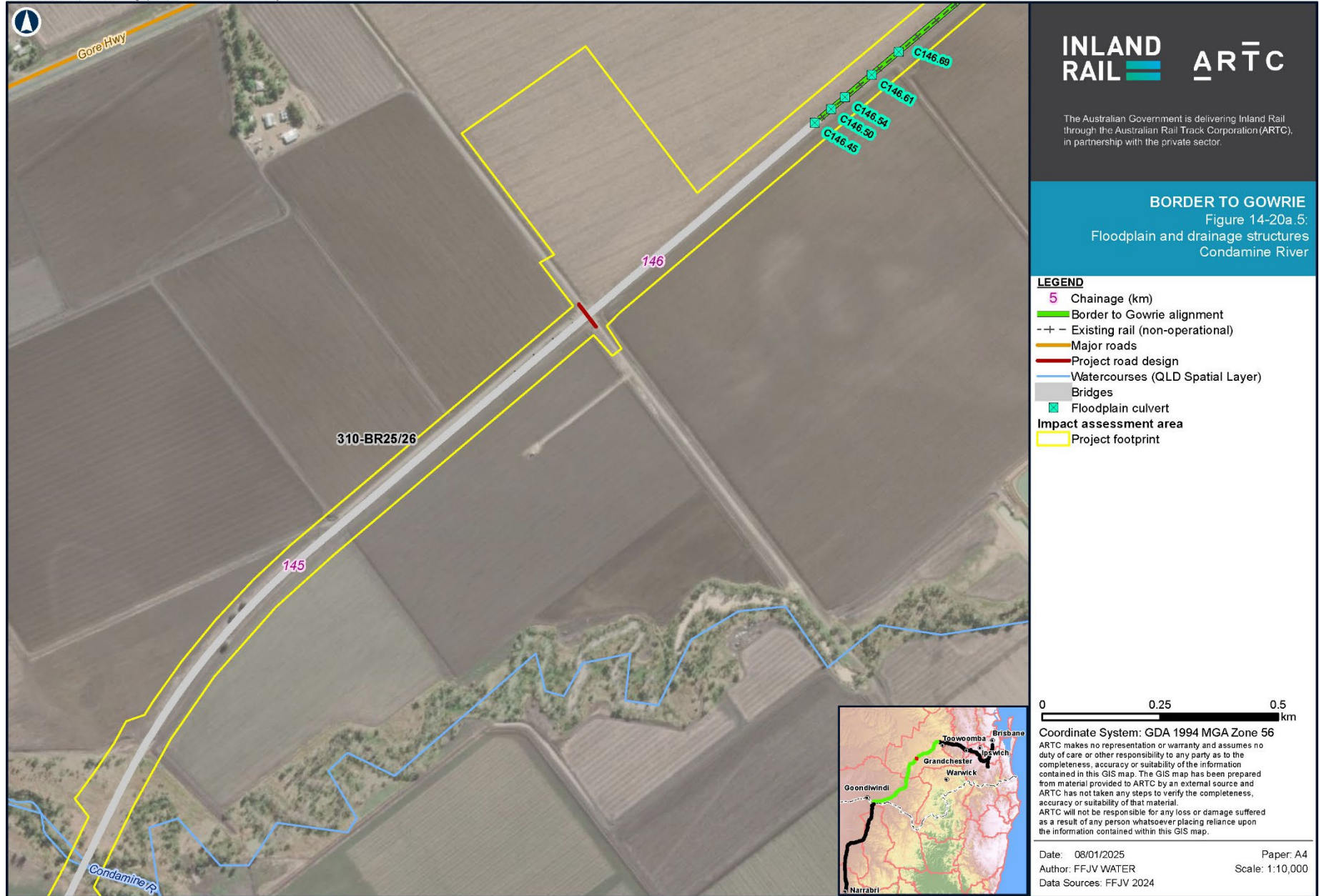
1. Newly flood-affected flood sensitive receptor in the Developed Case, 1% AEP climate change event

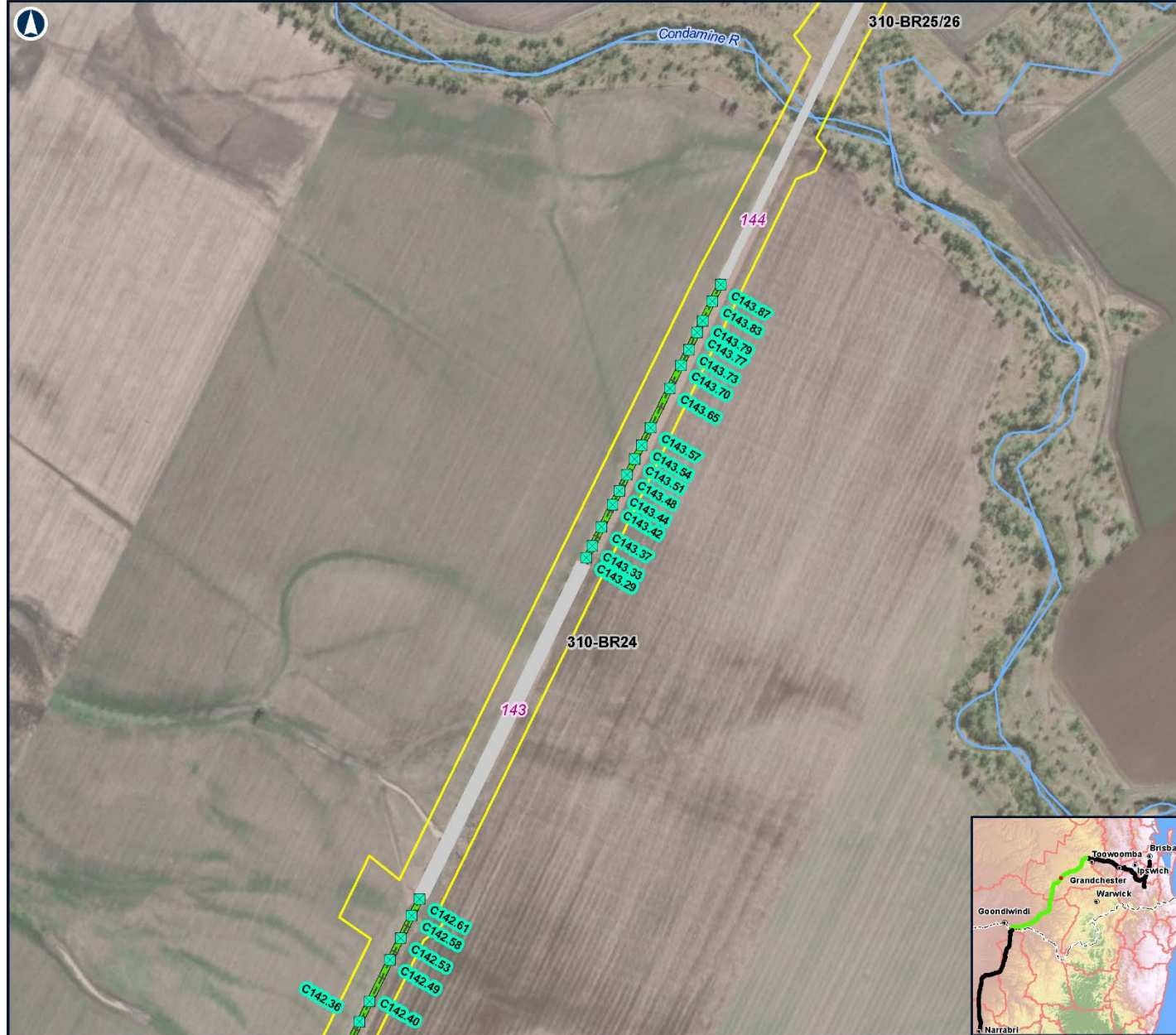












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BORDER TO GOWRIE Figure 14-20a 6: Floodplain and drainage structures Condamine River

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- - - Existing rail (non-operational)
- Project road design
- Watercourses (QLD Spatial Layer)
- Bridges
- Floodplain culvert
- Impact assessment area
- Project footprint

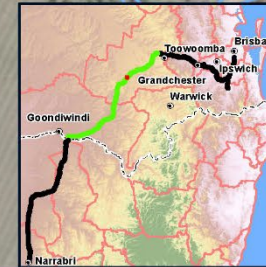
0 0.25 0.5 km

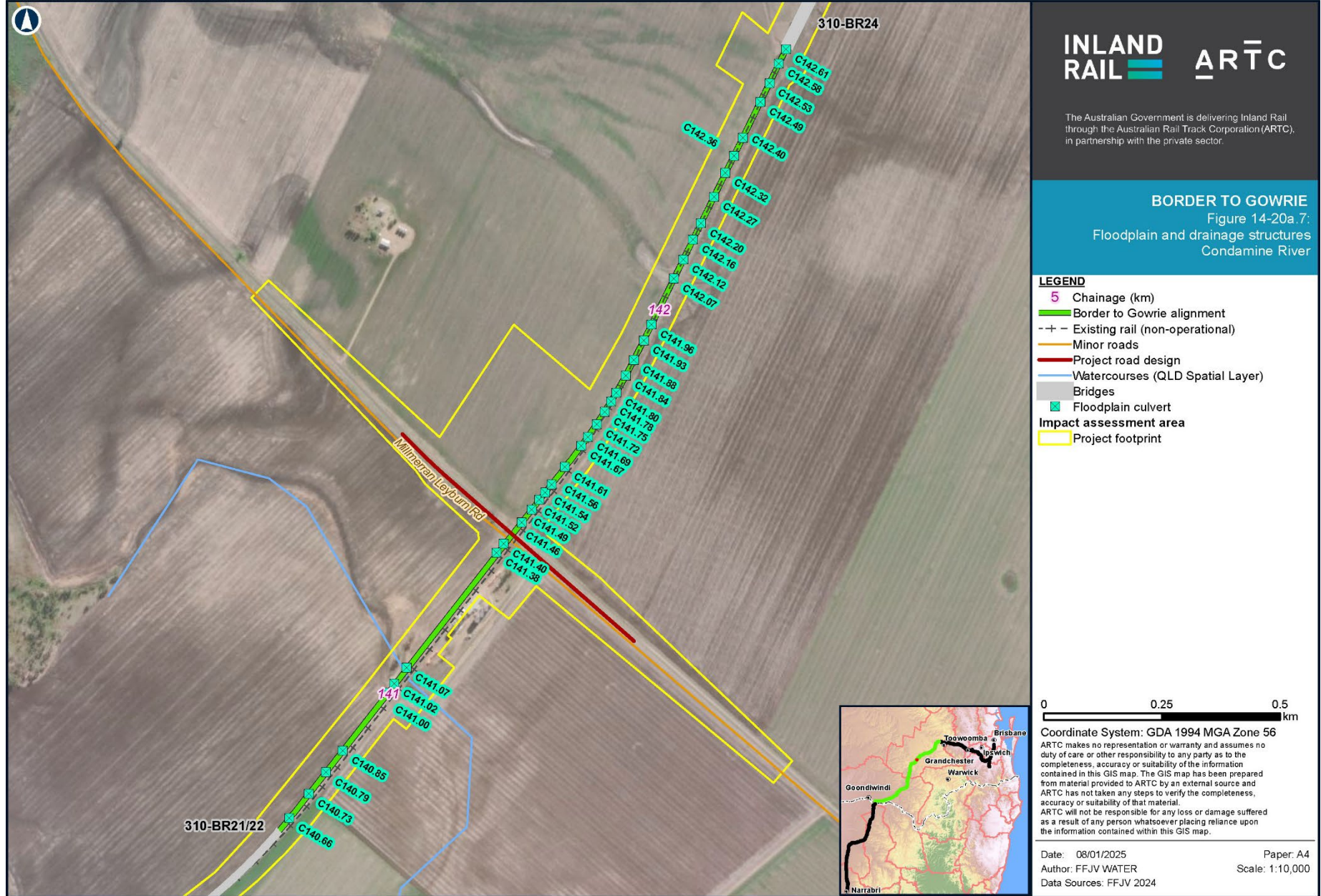
Coordinate System: GDA 1994 MGA Zone 56

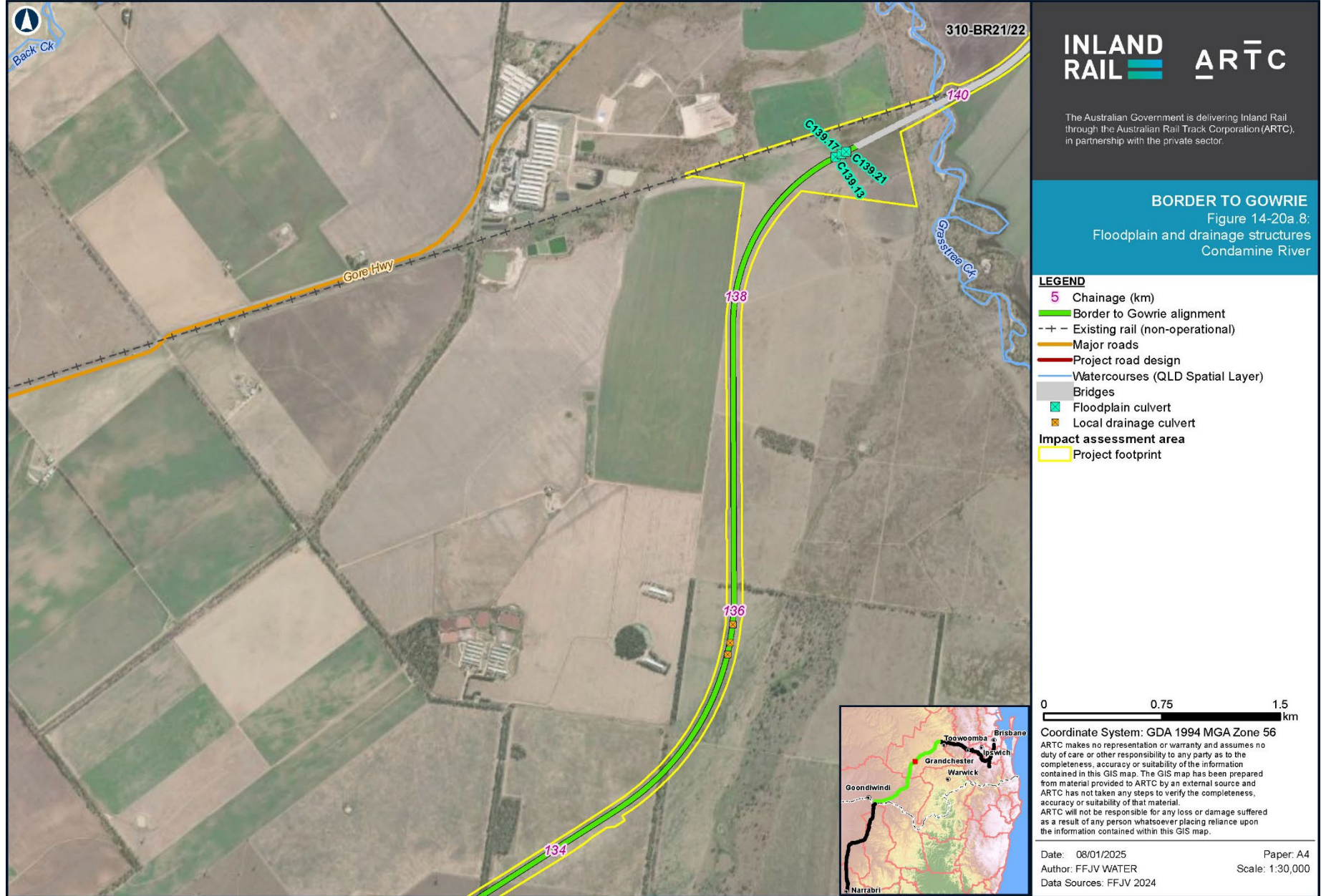
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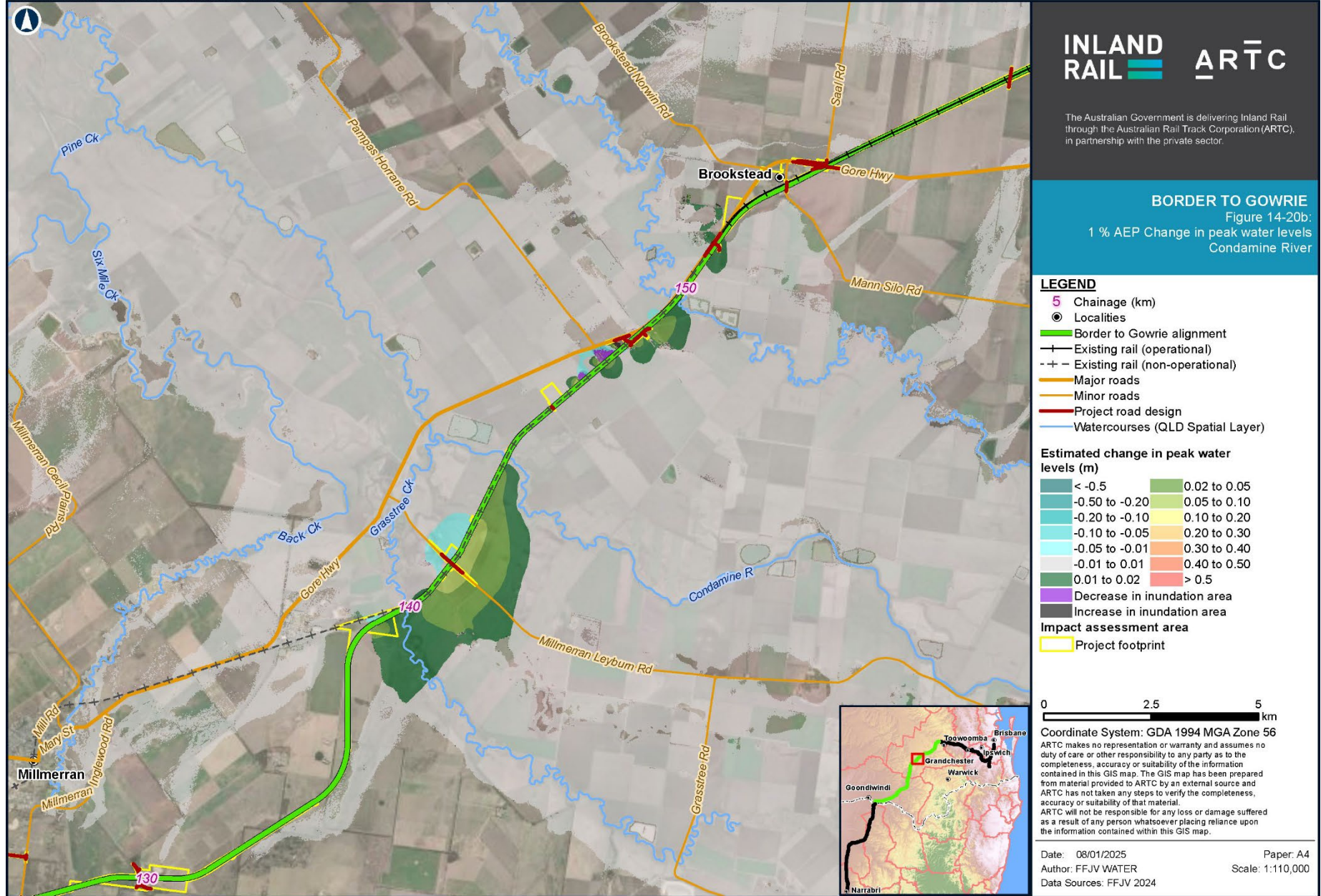
Date: 08/01/2025
 Author: FFJV WATER
 Data Sources: FFJV 2024

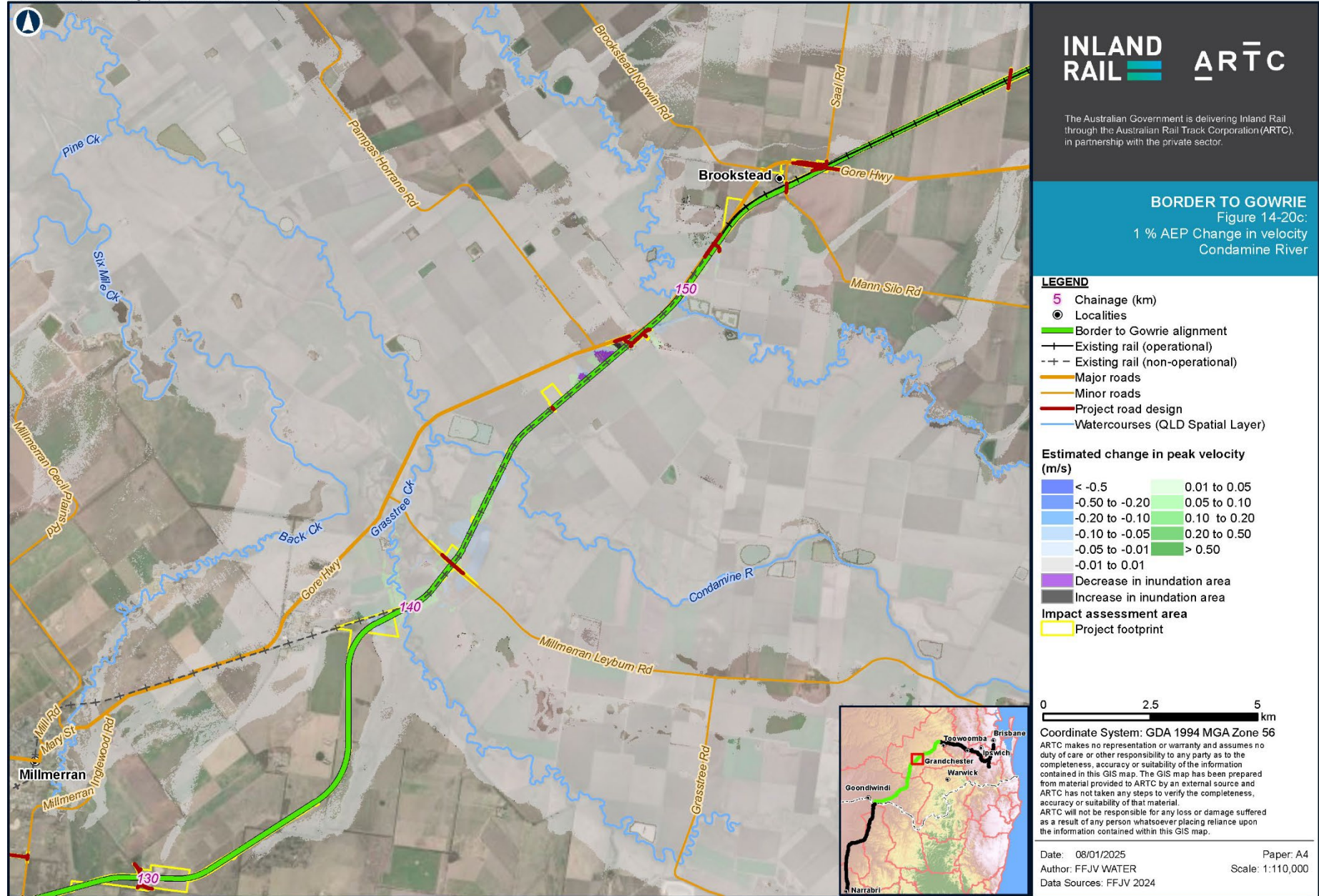
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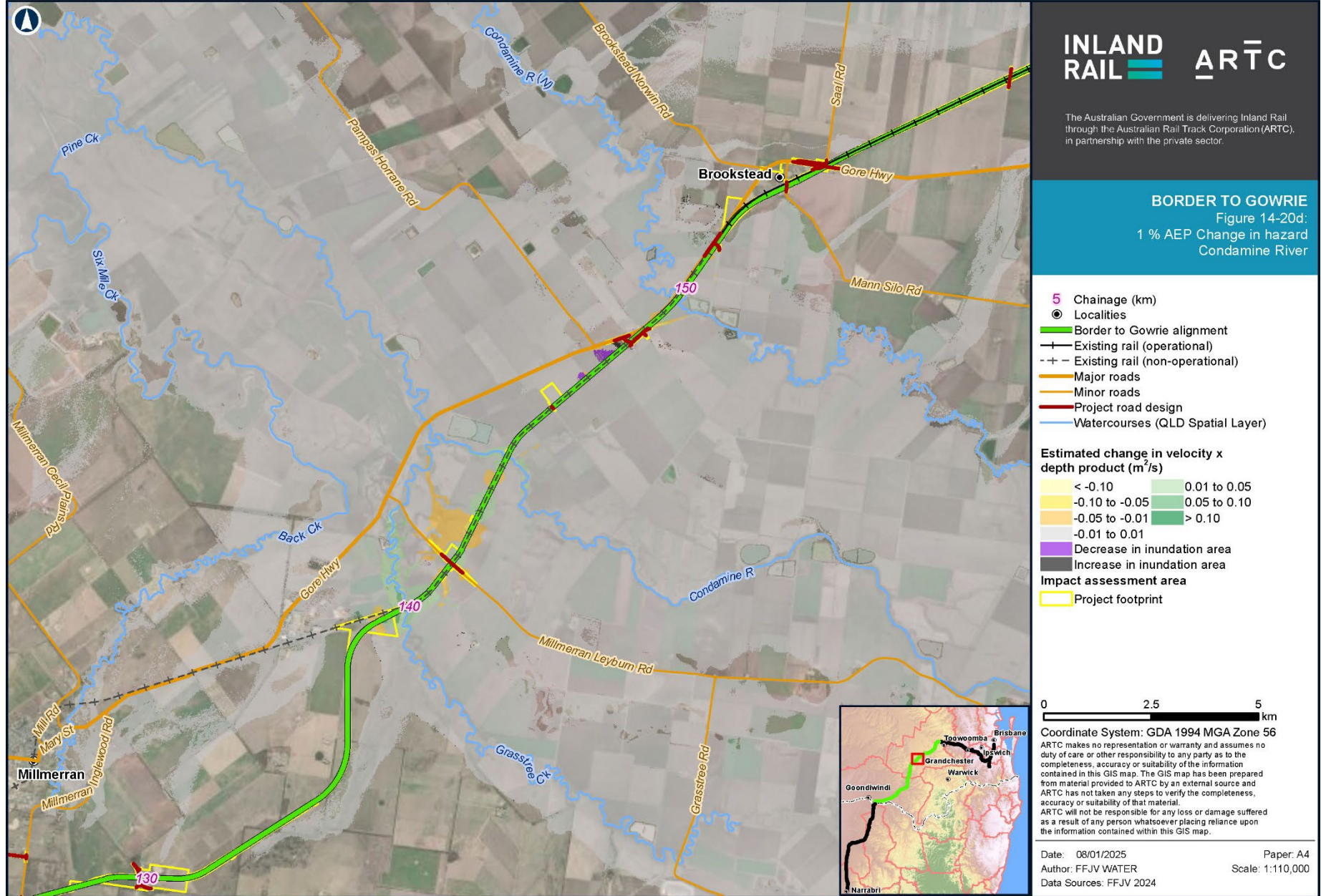




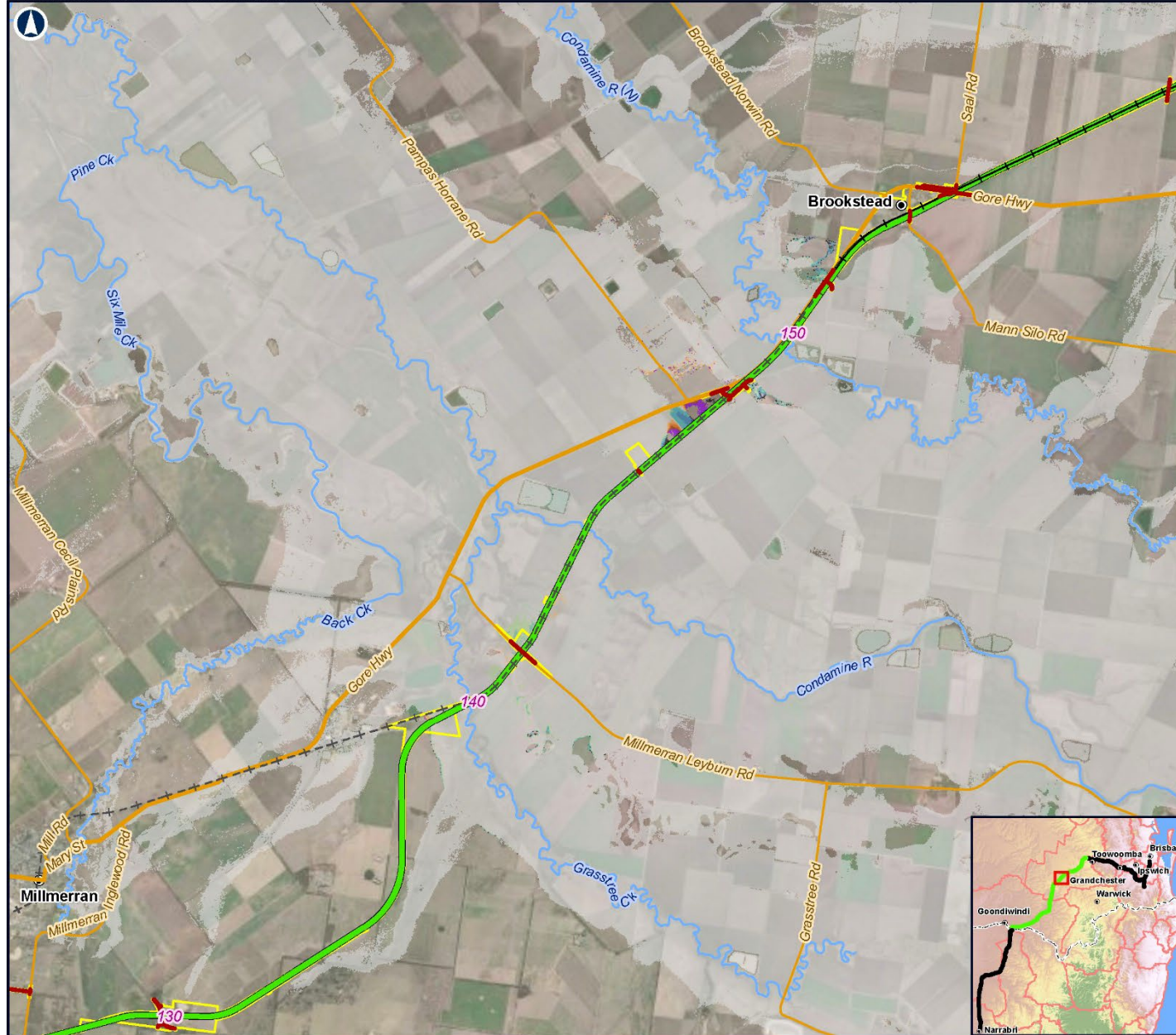








Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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BORDER TO GOWRIE

Figure 14-20e:
1 % AEP Change in time of inundation
Condamine River

LEGEND

- 5 Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Existing rail (non-operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)

Estimated change in time of inundation (%)

- | | |
|--|---|
|  < -50% |  -5% to 5% |
|  -50% to -40% |  5% to 10% |
|  -40% to -30% |  10% to 20% |
|  -30% to -20% |  20% to 50% |
|  -20% to -10% |  50% to 100% |
|  -10% to -5% |  >100% |
|  Decrease in inundation area | |
|  Increase in inundation area | |
|  Impact assessment area | |
|  Project footprint | |

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
Scale: 1:110,000

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14.8.1.2.5 Back Creek

On the Back Creek floodplain, the Project's revised reference design includes:

- ▶ Two bridges
- ▶ Two RCP locations (a total of 24 culvert cells).

Details of the floodplain structures required to convey Back Creek flood flows are presented in Table 14-66 and Table 14-67, with structure locations presented in Figure 14-21a. Figure 14-21a also presents the location of local catchment drainage structures.

TABLE 14-66 BACK CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
126.97	310-BR37 ²	Bridge	417.36	167.0
128.06	310-BR38	Bridge	407.41	230.0

Table notes:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)
2. 310-BR37 is also a rail bridge, and spans across Millmerran–Inglewood Road

TABLE 14-67 BACK CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ¹	Structure type	No. of culvert cells	Diameter (m)
126.77	C126.77	RCP	12	0.90
126.81	C126.81	RCP	12	0.90

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1

Change in peak water levels

Figure 14-21b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 8.5.3). Except for the identified locations. The change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Back Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for three lots within the Back Creek floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 92 mm on Lot Plan 2RP233820 to 320 mm on Lot Plan 2SP260880. Lot Plan 2SP260880 experiences the largest change with peak water levels increasing from 333 mm to 653 mm with some change in peak water levels above the flood impact objective targets across an area of 1.2 ha (less than 1 per cent of the total lot area). A summary of lots impacted by a change in peak water level is provided below:

- ▶ Lot Plan 2SP260880 is impacted by a maximum peak change in water level of 320 mm in the 1% AEP event
- ▶ Lot Plan 140DER34129 is impacted by a maximum peak change in water level of 242 mm in the 1% AEP event
- ▶ Lot Plan 2RP233820 is impacted by a maximum peak change in water level of 165 mm in the 5% AEP event.

Other infrastructure

A total of seven roads (two State-controlled and five local public roads) are impacted by a change in peak water level. The two State-controlled roads impacted include Millmerran–Inglewood Road and the Gore Highway, with Millmerran–Inglewood Road experiencing the greatest change in peak water level of 191 mm in the 2% AEP event. The Gore Highway experiences a maximum change in peak water level of 26 mm in the 2% AEP event.

Five local public roads experience an increase in peak water level: Schwarten Road, Hall Road, Pfeffer Road and two unnamed roads. Of these, one of the unnamed roads experiences the largest increase in peak water levels of 184 mm in the 5% AEP event. This road is proposed to be upgraded as part of the Project's revised reference design and therefore will be revised in detailed design. A summary of maximum changes in peak water level on impacted local public roads is provided below:

- ▶ An unnamed road is impacted by a maximum peak change in water level of 184 mm in the 5% AEP event
- ▶ Schwarten Road is impacted by a maximum peak change in water level of 74 mm in the 10% AEP event
- ▶ An unnamed road is impacted by a maximum peak change in water level of 42 mm in the 1% AEP event
- ▶ Hall Road is impacted by a maximum peak change in water level of 35 mm in the 1% AEP event
- ▶ Pfeffer Road is impacted by a maximum peak change in water level of 22 mm in the 5% AEP event.

One existing rail infrastructure is anticipated to be impacted by a change in peak water levels with a maximum change of 773 mm in the 1% AEP events. The change in peak water level in this area can be attributed to an increase in flood extent and a newly flood-affected hydraulic model cell (Section 14.8.1.2).

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-21c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 15 lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Impacted lots experience percentage change or 'absolute' increases depending on the flood impact objective target. Of the impacted lots, Lot Plan 2DY1006 experiences the largest increase in velocity of 1.39 m/s. This increase can be attributed an increase in flood extent and a newly flood-affected hydraulic model cell. The following provides a summary of changes in peak velocity across the 15 lots:

- ▶ Three lots experience a change in velocity of greater than 1.0 m/s
- ▶ Two lots experience a change in velocity of between 0.1 and 0.5 m/s
- ▶ Ten lots experience a change of less than 0.1 m/s.

Other infrastructure

One State-controlled road has been identified to experience a change in velocity due the presence of the Project alignment, Millmerran-Inglewood Road. The change in velocity occurs in the 20%, 10%, 5%, 2% and 1% AEP events with a maximum increase of 45 per cent (from 1.26 m/s to 1.83 m/s) and an absolute increase of 0.67 m/s (increasing from 0.824 m/s to 1.491 m/s) in the 20% AEP event.

Four local public roads are identified to experience an increase in velocity due to the Project including one unnamed road, Schwarten Road, Hall Road and Pfeffer Road. Schwarten Road experiences the greatest change in velocity with a maximum change of 0.62 m/s in the 10% AEP event. Hall Road and Pfeffer Road experience very minor increases in velocity of 0.004 m/s and 0.002 m/s, respectively.

One existing rail segment, Millmerran Branch Line, experiences a maximum change in peak velocity of 0.689 m/s and can be attributed to an increase in flood extent and newly flood-affected hydraulic model cell.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 8.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-21d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Back Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of seven lots were identified as being impacted by some degree of change in hazard above the flood impact objective targets. Exceedances can be attributed to increased flow velocities and flood depths the inlets and outlets of bridges. The maximum increase for flood hazard is approximately 1,326 per cent (0.14 m²/s) on Lot Plan 2SP260880 in the 5% AEP event. This large percentage increase can be attributed to the Existing Case result being extremely small (0.01 m²/s) with an increase to a small hazard result (0.15 m²/s) in the Developed Case. The 'absolute' change associated with these percentage increases is considered small but when converted to percentages results in a large change. The following provides a summary of changes in peak hazard across the seven lots:

- ▶ One lot experiences a change in peak hazard greater than 1,000 per cent
- ▶ Three lots experience a change in peak hazard of between 100 per cent and 300 per cent
- ▶ Three lots experience a change in peak hazard of less than 50 per cent.

Other infrastructure

Millmerran-Inglewood Road is the only State-controlled road impacted by a change in hazard, with an increase of 152 per cent in the 5% AEP event (increasing from 0.07 m²/s to 0.16 m²/s). This change in hazard can be attributed to the maturity of the cross-drainage design for the Project.

One local public road, Schwarten Road, has been identified as being impacted by a change in hazard in the 5%, 2% and 1% AEP events. The maximum change in hazard occurs in the 1% AEP with an increase of 22 per cent being recorded (increasing from 0.13 m²/s to 0.16 m²/s).

No existing rail infrastructure is identified as being impacted by a change in hazard above the flood impact objective targets within the Back Creek floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 8.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-21e for the 1% AEP event.

Private land outside the Project permanent footprint

Change in time of inundation is the primary exceedance category on lots for the Back Creek floodplain. A total of 28 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events.

The maximum change in time of inundation has been identified to impact Lot Plan 2SP26088 with an increase of 1,159 per cent (from 1.05 hours to 13.19 hours) with associated area of impact of 3.5 ha (or less than 1 per cent of the total lot area). It should be noted that most large increases are localised and don't translate to uniform time of inundation increases across the lot. The following provides a summary of changes in peak velocity across the 28 lots:

- ▶ Two lots experience a percentage change increase in time of inundation of greater than 1,000 per cent
- ▶ Ten lots experience a percentage change increase in time of inundation of between 100 per cent to 500 per cent
- ▶ Six lots experience a percentage change increase in time of inundation of between 50 per cent to 100 per cent
- ▶ Ten lots experience a percentage change increase in time of inundation of less than 50 per cent.

Other infrastructure

A total of 13 roads (three State-controlled and 10 local public roads) are impacted by a change in time of inundation. Of the three State-controlled roads, Millmerran-Inglewood Road, Gore Highway and Charles Street, a maximum change of time of inundation of 490 per cent in the 2% AEP event (increasing from 0.26 hours to 1.531 hours) was recorded on Millmerran-Inglewood Road. The Gore Highway and Charles Street experience a maximum increase in time of inundation of 167 per cent and 19 per cent, respectively.

Ten local public roads are impacted by a change in time of inundation with the maximum change of 390 per cent occurring on Schwarten Road. A summary of impacted on local public roads is provided below:

- ▶ Four local public roads experience a change in time of inundation of between 100 per cent and 400 per cent
- ▶ One local public road experiences a change in time of inundation of between 50 per cent and 100 per cent
- ▶ Five local public roads experience a change in time of inundation of between 10 per cent and 50 per cent.

Two existing rail infrastructure segments (both identified as Millmerran Branch Line) are impacted by a change in time of inundation with a maximum increase of 21 per cent in the 5% AEP event.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 8.5.3).

Flood flow distribution

Maximum velocity-depth modelling results were used to create change in unit flow maps between Existing Case and Developed Case conditions to determine the change in flow distribution. Unit flow is a measure of discharge that is commonly used for assessing peak flow along cross-sections, or to identify the efficient flow corridors within a floodplain.

The presented flow distribution maps were filtered with a depth-velocity product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to identify main channels (i.e. high flow zones), and shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the change in flow distribution for Back Creek and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

- ▶ Minor flow decreases (upstream) and increases (downstream) are localised to cross-drainage infrastructure. This behaviour is expected due to the constriction of the flood way through the culvert and bridge openings. This is particularly evident for all flood events up to the 1% AEP event, where the Project alignment is not overtopped.
- ▶ While the Project alignment does impact flow conditions immediately upstream and downstream of the alignment, regional conditions remain relatively unchanged.
- ▶ In the rarer events (1 in 2,000, 1 in 10,000 AEP and PMF events) some reduction in flow is experienced downstream extending towards the Condamine River in the 1 in 10,000 AEP and PMF events. This can be attributed to the alignment restricting flow at both bridge crossings in these larger events. Some positive change (>20 per cent) occurs upstream of the alignment in all three of these rare events.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime.

Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-68 outlines the changes in peak water levels of more than 10 mm at flood sensitive receptors for these extreme events where the increase exceeds 10 mm under one of the events. The existing depth of flooding is also detailed and, as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event. Review of the modelled results and FIOs show there are no impacts above the flood impact objective target from extreme event flooding on flood sensitive receptors within the modelled Back Creek River floodplain.

TABLE 14-68 BACK CREEK: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor ID	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_85	-	-	-	-	-10	0.51
CON_ID_86	-	-	-	0.05	-10	0.65
CON_ID_83	-	0.11	-	0.25	-10	0.84
CON_ID_84	-	0.08	-	0.22	-10	0.80
CON_ID_70	-	-	-	-	-11	0.32
CON_ID_71	-	-	-	-	-11	0.38
CON_ID_69	-	-	-	-	-11	0.45
CON_ID_73	-	-	-	-	-11	0.43

Flood sensitive receptor ID	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_72	-	-	-	-	-12	0.61
CON_ID_27	-	0.15	-	0.30	-19	0.99
CON_ID_28	-	-	-	0.01	-20	0.69
CON_ID_107	-	0.01	-9	0.06	-21	1.06
CON_ID_108	-	-	-9	0.03	-21	1.03
CON_ID_54	-10	0.06	-24	0.31	-15	0.99
CON_ID_55	-	-	-21	0.24	-16	0.93
CON_ID_56	-	0.02	-17	0.19	-16	0.87
CON_ID_57	-	0.02	-18	0.16	-16	0.88
CON_ID_53	-9	0.08	-26	0.35	-15	1.05
CON_ID_58	-	0.09	-20	0.28	-15	1.01
CON_ID_59	-	0.07	-21	0.29	-15	1.01
CON_ID_29	-	0.31	-8	0.46	-22	1.43
CON_ID_30	-	0.08	-6	0.16	-18	0.88
CON_ID_31	-	0.24	-8	0.38	-19	1.28
CON_ID_40	-	0.08	-8	0.19	-21	1.12
CON_ID_44	-	-	-7	0.09	-21	0.99
CON_ID_45	-	0.21	-9	0.37	-22	1.34
CON_ID_38	-	0.07	-6	0.15	-20	0.93
CON_ID_39	-	0.12	-6	0.21	-20	1.03
CON_ID_41	-	0.06	-2	0.09	-19	0.83
CON_ID_42	-	-	-	-	-18	0.45
CON_ID_43	-	0.05	-7	0.15	-20	0.96
CON_ID_46	-	0.19	-5	0.26	-18	0.93
CON_ID_35	-	0.08	-5	0.14	-19	0.84
CON_ID_36	-	0.04	-6	0.10	-19	0.84
CON_ID_37	-	0.05	-6	0.13	-19	0.89
CON_ID_32	-	-	-	-	-12	0.26
CON_ID_33	-	0.01	-3	0.06	-19	0.66
CON_ID_34	-	0.17	-5	0.24	-19	0.92
CON_ID_109	-	-	-	-	-16	0.53
CON_ID_47	-	0.26	-6	0.35	-14	0.86
CON_ID_49	-	-	-	-	-15	0.51
CON_ID_48	-	0.10	-6	0.18	-14	0.67
CON_ID_115	-	-	-	-	-11	0.36
CON_ID_116	-	-	-	-	-10	0.36
CON_ID_113	-	-	-	-	-10	0.21
CON_ID_114	-	-	-	-	-12	0.17
CON_ID_112	-	-	-	-	-11	0.25
CON_ID_78	-	-	-	-	-10	0.04
CON_ID_131	-	-	-5	0.01	-12	0.52
CON_ID_132	-	0.02	-7	0.12	-12	0.74
CON_ID_136	-	-	-6	0.12	-12	0.68
CON_ID_139	-	-	-	-	-12	0.29
CON_ID_140	-	0.07	-6	0.15	-12	0.70
CON_ID_141	-	-	-5	0.02	-11	0.52

Flood sensitive receptor ID	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
CON_ID_142	-	-	-	-	-10	0.41
CON_ID_135	-	0.06	-6	0.15	-13	0.77
CON_ID_137	-	-	-	-	-12	0.66
CON_ID_138	-	-	-	-	-12	0.36
CON_ID_134	-	-	-	-	-14	0.27
CON_ID_68	-	-	-	-	-12	0.04
CON_ID_50	-	0.23	-6	0.33	-17	1.16
CON_ID_51	-	0.19	-7	0.28	-17	1.07
CON_ID_52	-	0.42	-8	0.54	-20	1.39
CON_ID_60	-	-	-	-	-13	0.67
CON_ID_61	-	-	-9	0.06	-13	0.88
CON_ID_62	-	0.02	-8	0.07	-13	0.87
CON_ID_2	-	0.49	-11	0.60	-6	1.02
BAC_ID_1	-	-	-	-	+33	0.34
BAC_ID_2	-	-	+2	0.07	+32	0.48
BAC_ID_3	-	0.09	+20	0.18	+170	0.63
BAC_ID_4	-	0.18	+19	0.29	+128	0.75
BAC_ID_5	+6	0.23	+20	0.36	+124	0.85
BAC_ID_18	-	-	-	-	-41	0.74
BAC_ID_19	-	-	-	-	-42	0.65
CON_ID_379	-6	0.55	-20	0.83	-14	1.76

The risk of overtopping along the Project alignment has been assessed at structure for the modelled extreme events. As can be seen below, the Project alignment is not expected to overtop at each of the listed structures in extreme events. Some overtopping may occur further along the alignment in lower sections. Table 14-69 outlines the overtopping locations and depths.

TABLE 14-69 BACK CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
126.77	C126.77	-	-	-
126.81	C126.81	-	-	-
127.00	310-BR37	-	-	-
128.00	310-BR38	-	-	-

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure-type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Back Creek catchment area is 23.9 per cent.

Appendix T2: Hydrology and Flooding Technical Report—Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

Table 14-70 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the climate change scenario.

TABLE 14-70 BACK CREEK: SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1% AEP climate change event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
CON_ID_83	Shed	-	0.07
CON_ID_84	Shed	-	0.04
CON_ID_145	Shed	-	0.23
CON_ID_87	House	-	0.11
CON_ID_27	Shed	-	0.11
CON_ID_107	House	-	0.01
CON_ID_58	House	-	0.04
CON_ID_59	Shed	-	0.01
CON_ID_29	Silos	-	0.24
CON_ID_30	House	-	0.05
CON_ID_31	Shed	-	0.19
CON_ID_40	Commercial	-	0.05
CON_ID_45	Commercial	-	0.14
CON_ID_38	Commercial	-	0.04
CON_ID_39	Commercial	-	0.08
CON_ID_41	Commercial	-	0.05
CON_ID_43	Commercial	-	0.01
CON_ID_46	Commercial	-	0.16
CON_ID_35	Commercial	-	0.05
CON_ID_36	Commercial	-	0.02
CON_ID_37	Commercial	-	0.03
CON_ID_34	Commercial	-	0.14
CON_ID_47	House	-	0.22
CON_ID_48	House	-	0.07
CON_ID_140	Commercial	-	0.03
CON_ID_135	House	-	0.02
CON_ID_50	House	-	0.16
CON_ID_51	Shed	-	0.14
CON_ID_52	House	-	0.34
CON_ID_1	House	-	0.18
CON_ID_3	Shed	-	0.20
CON_ID_2	Shed	-	0.42
BAC_ID_5	Shed	-	0.02

Table note:

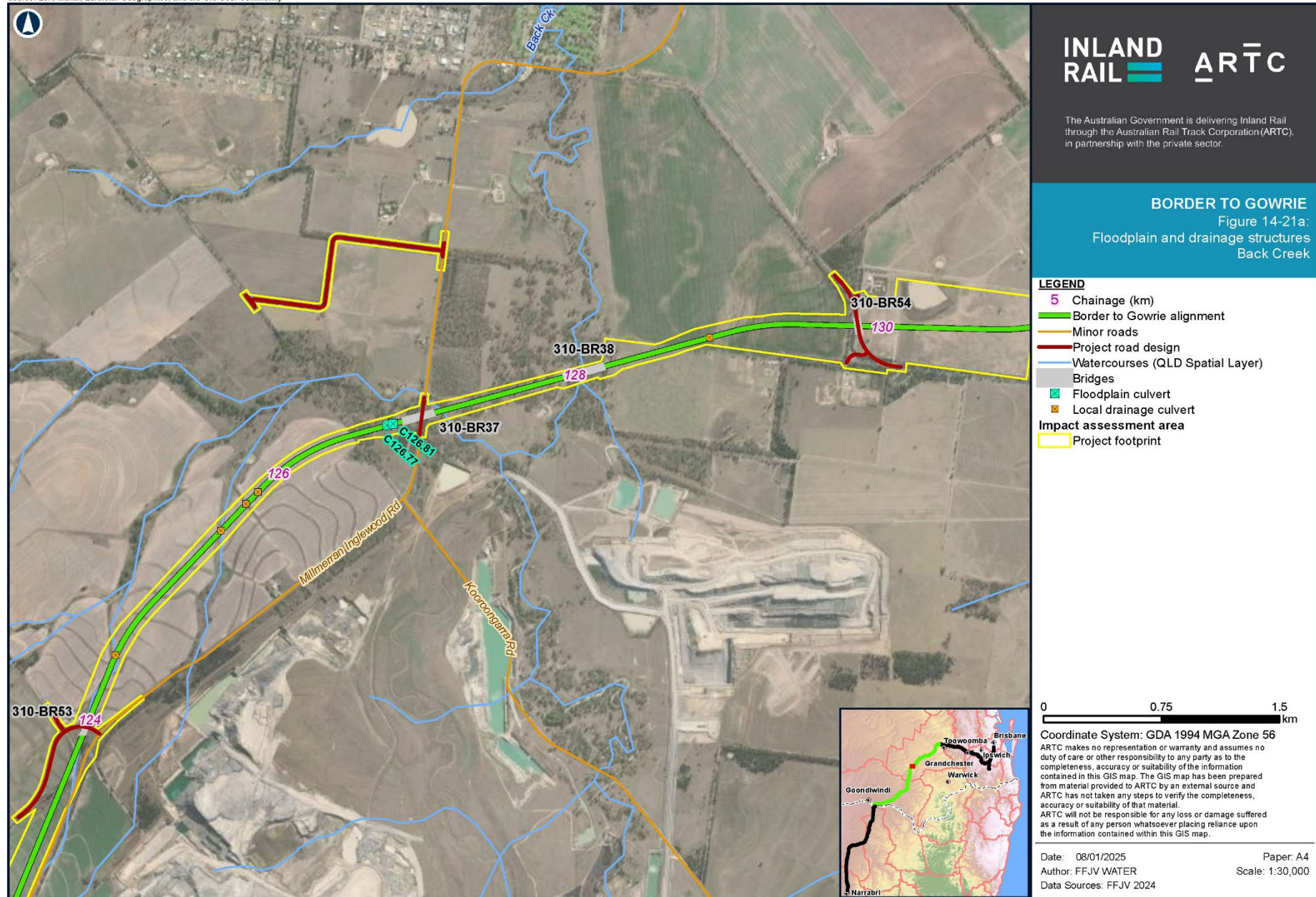
1. Existing Case flood depth including climate change

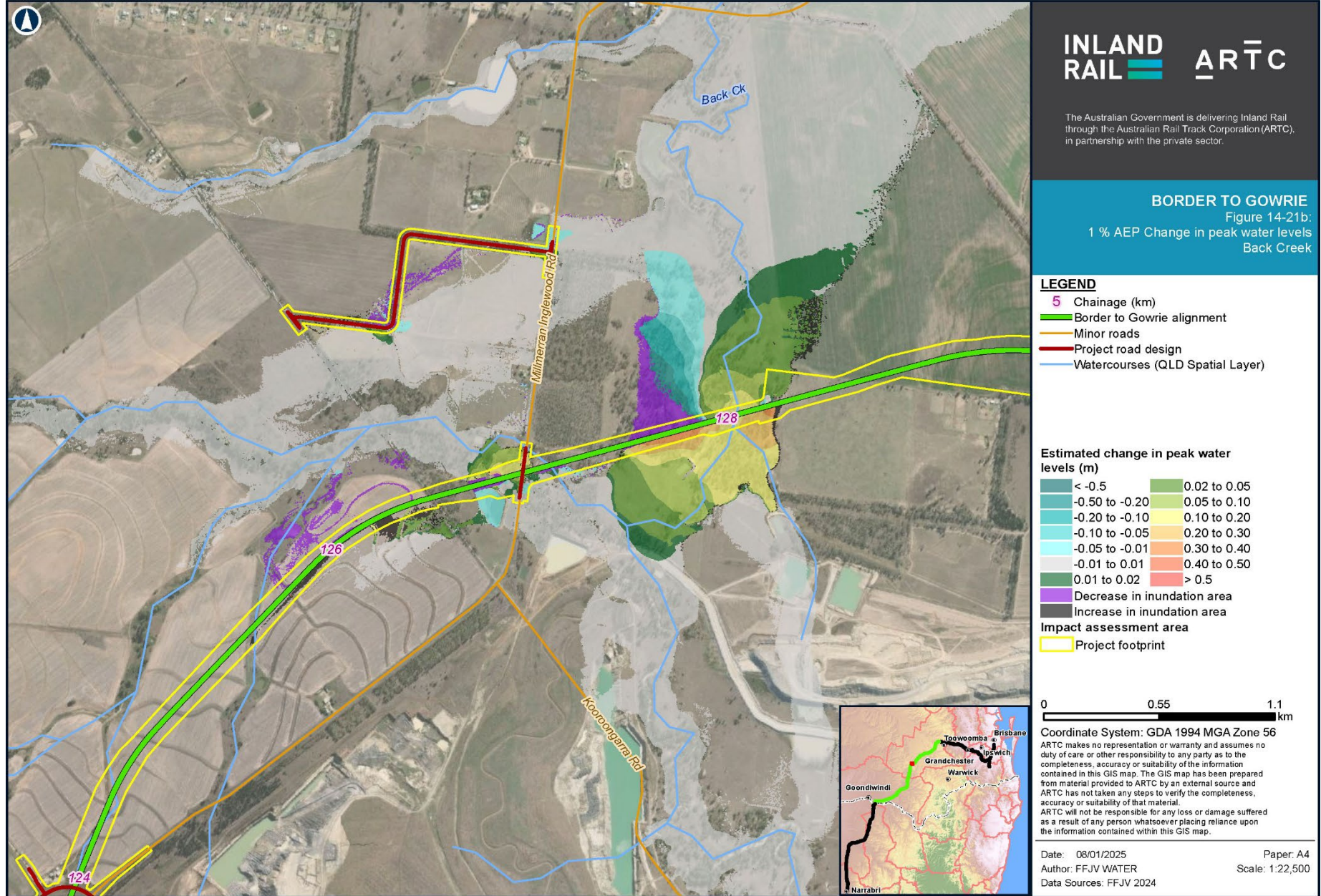
The downstream extents of these impacts are similar to those under the 1% AEP event.

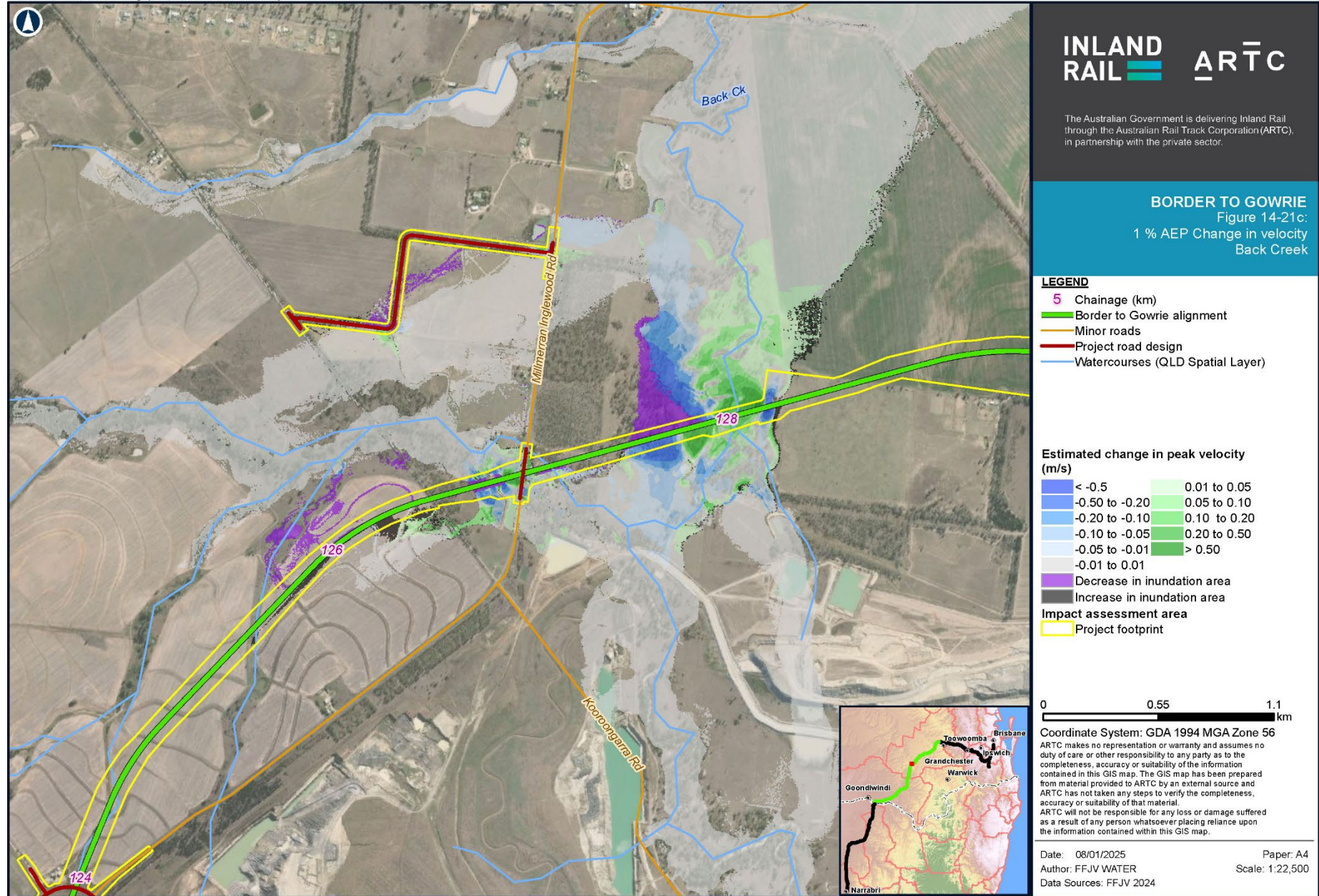
Blockage

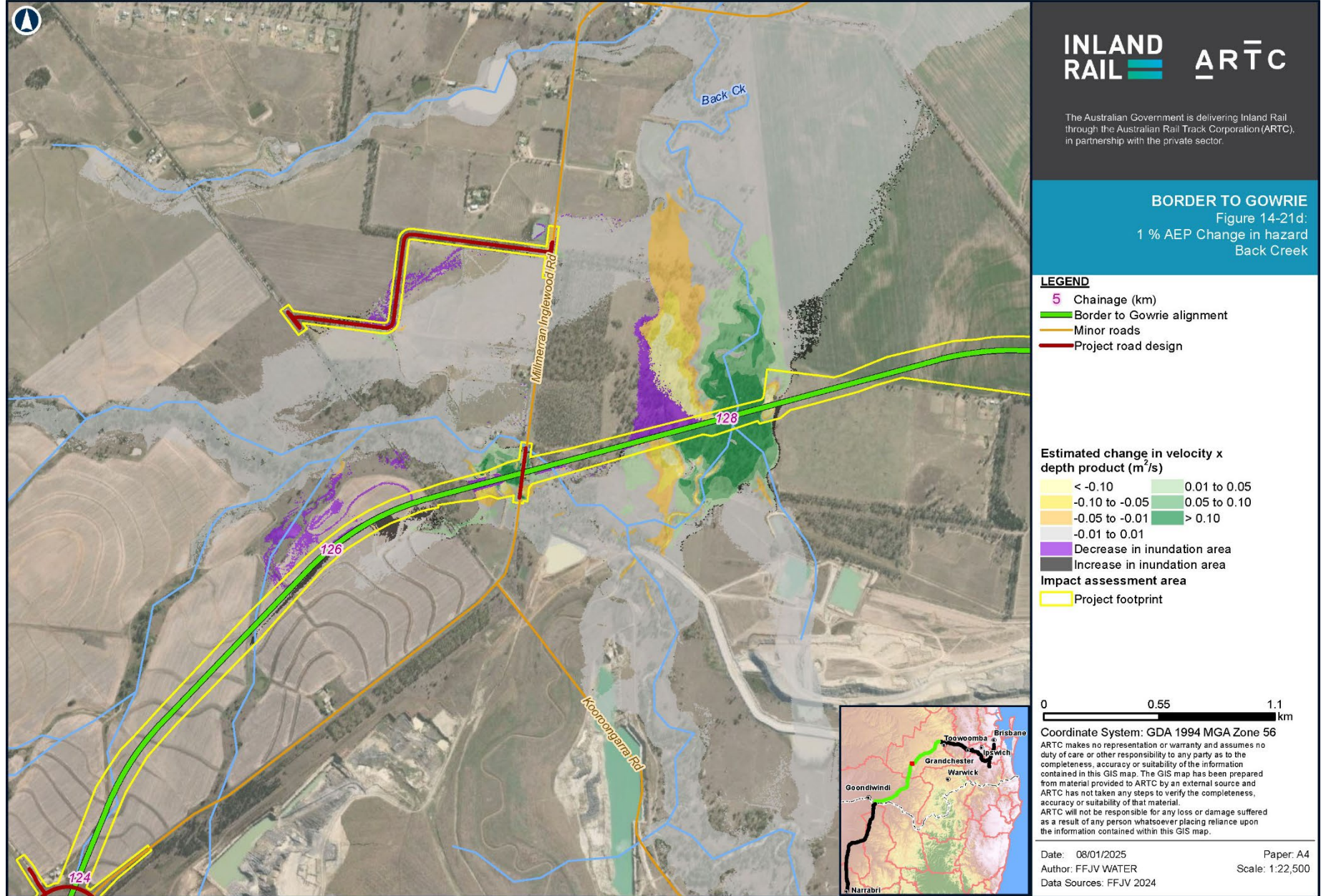
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

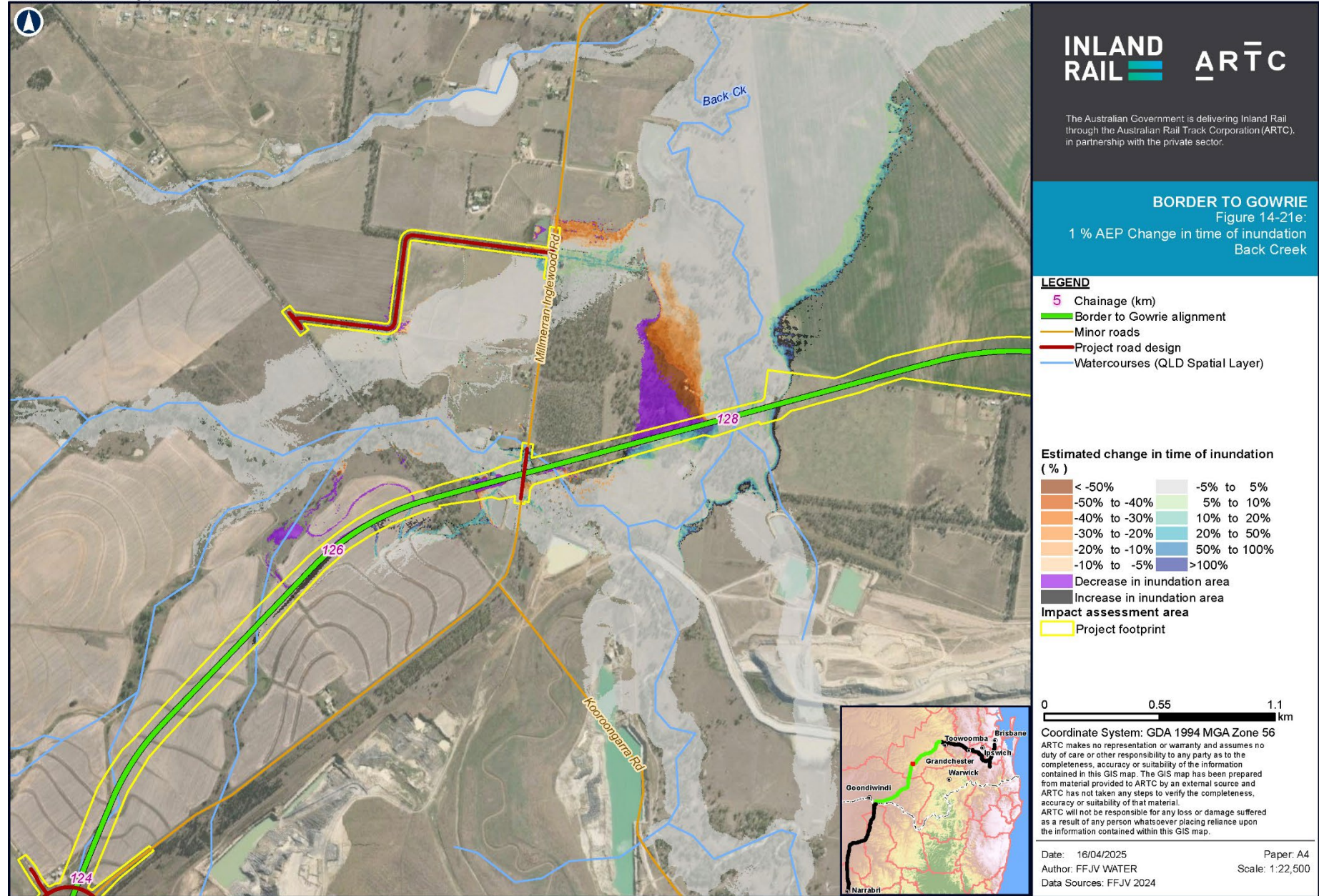
Notably, there are no predicted impacts on flood sensitive receptors due to the blockage assessment.











14.8.1.2.6 Nicol Creek

In the Nicol Creek floodplain, the Project's revised reference design includes:

- ▶ One bridge
- ▶ Four RCP locations (a total of 36 culvert cells).

Details of the floodplain structures required to convey Nicol Creek flood flows are presented in Table 14-71 and Table 14-72, with structure locations presented in Figure 14-22a. Figure 14-22a also presents the location of local catchment drainage structures.

TABLE 14-71 NICOL CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
104.39	310-BR11	Bridge	353.9	92.0

Table notes:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-72 NICOL CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ¹	Structure type	No. of culvert cells	Diameter (m)
104.94	C104.94	RCP	18	0.90
105.09	C105.09	RCP	6	0.90
105.11	C105.11	RCP	6	0.90
105.13	C105.13	RCP	6	0.90

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-22b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 9.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Nicol Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1 in 2,000 AEP event in the Nicol Creek floodplain.

Other infrastructure

No roads or rail have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1% AEP event in the Nicol Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 9.5.3).

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-22c for the 1% AEP event.

Private land outside the Project permanent footprint

One lot (Lot Plan 2RP197967) has been identified to be impacted by a maximum change in velocity of 1.17 m/s in the 1% AEP event. The increase in velocity can be attributed to a flood inundation extent increase and a newly flood-affected hydraulic model cell, resulting in a large velocity change within the cell.

Other infrastructure

No roads or rail have been identified as increasing in velocity above the flood impact objective targets for all events up to the 1% AEP in the Nicol Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 9.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the boundary of the Project permanent footprint.

Change in flood hazard

The potential change in hazard is quantified by assessing and comparing the velocity-depth product for the Existing Case and Developed Case with results presented in Figure 14-22d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in hazard in the Nicol Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

One lot (Lot Plan 2RP197967) has been identified to be impacted by a maximum increase in hazard of 27 per cent (from 0.13 m²/s to 0.17 m²/s) in the 1% AEP event. The increase in hazard can be attributed to the velocity increase identified in the above section.

Other infrastructure

No roads or rail have been identified to experience a change in peak velocity above the flood impact objective targets for all events up to the 1% AEP in the Nicol Creek floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all AEP events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 9.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-22e for the 1% AEP event.

Private land outside the Project permanent footprint

Two lots, Lot Plan 1RP197967 and 2RP197967, were identified as being impacted by some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. The maximum increase in time of inundation is approximately 3.55 hours and a 462 per cent increase on Lot Plan 1RP197967, with the total impacted area being 0.04 ha and 0.60 ha, respectively (approximately 1 per cent of total lot area). It should be noted that the above change is the peak only and does not necessarily occur across the whole impacted area. A maximum percentage change in time of inundation of 72.5 per cent and 0.4 hours occurs on Lot Plan 2RP197967. It is expected some degree of change in time of inundation occurs across 0.31 ha of the lot (less than 1 per cent of the total lot area).

Other infrastructure

No roads or rail have been identified to experience an increase in time of inundation above the flood impact objective targets for all events up to the 1% AEP event in the Nicol Creek floodplain.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 9.5.3).

Flood flow distribution

Maximum velocity-depth modelling results were used to create change in unit flow maps between Existing Case and Developed Case conditions to determine the change in flow distribution. Unit flow is a measure of discharge that is commonly used for assessing peak flow along cross-sections, or to identify the efficient flow corridors within a floodplain.

The presented flow distribution maps were filtered with a depth-velocity product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to identify main channels (i.e. high flow zones), and shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the change in flow distribution for Nicol Creek and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report– Volume 2.

- ▶ Minor flow decreases (upstream) and increases (downstream) are localised to cross-drainage infrastructure. This behaviour is expected due to the constriction of the flood way through the culvert and bridge openings. This is particularly evident for all flood events up to the 1% AEP event, where the Project alignment is not overtopped.
- ▶ While the Project alignment does impact flow conditions immediately upstream and downstream of the alignment, regional conditions remain relatively unchanged.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-73 outlines the changes in peak water levels greater than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event. Review of the modelled results and FIOs show there are no impacts above the flood impact objective target from extreme event flooding on flood sensitive receptors within the modelled Nicol Creek floodplain.

TABLE 14-73 NICOL CREEK: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
NIC_ID_12	Shed	-	0.01	+10	0.66	+190	2.07
NIC_ID_13	Shed	-	0.50	+20	1.17	+200	2.64
NIC_ID_14	Shed	-	-	+10	0.68	+110	2.22

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. During these extreme events the Project alignment is inundated at several locations. Table 14-74 outlines the overtopping locations and depths.

TABLE 14-74 NICOL CREEK: PROJECT ALIGNMENT—EXTREME EVENT OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
104.4	310-BR11	-	-	1.08
104.94	C104.94	-	0.17	1.42
105.09	C105.09	-	-	0.75
105.11	C105.11	-	-	0.50
105.13	C105.13	-	-	0.50

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and ‘damming’ effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Nicol Creek catchment area is 23.9 per cent.

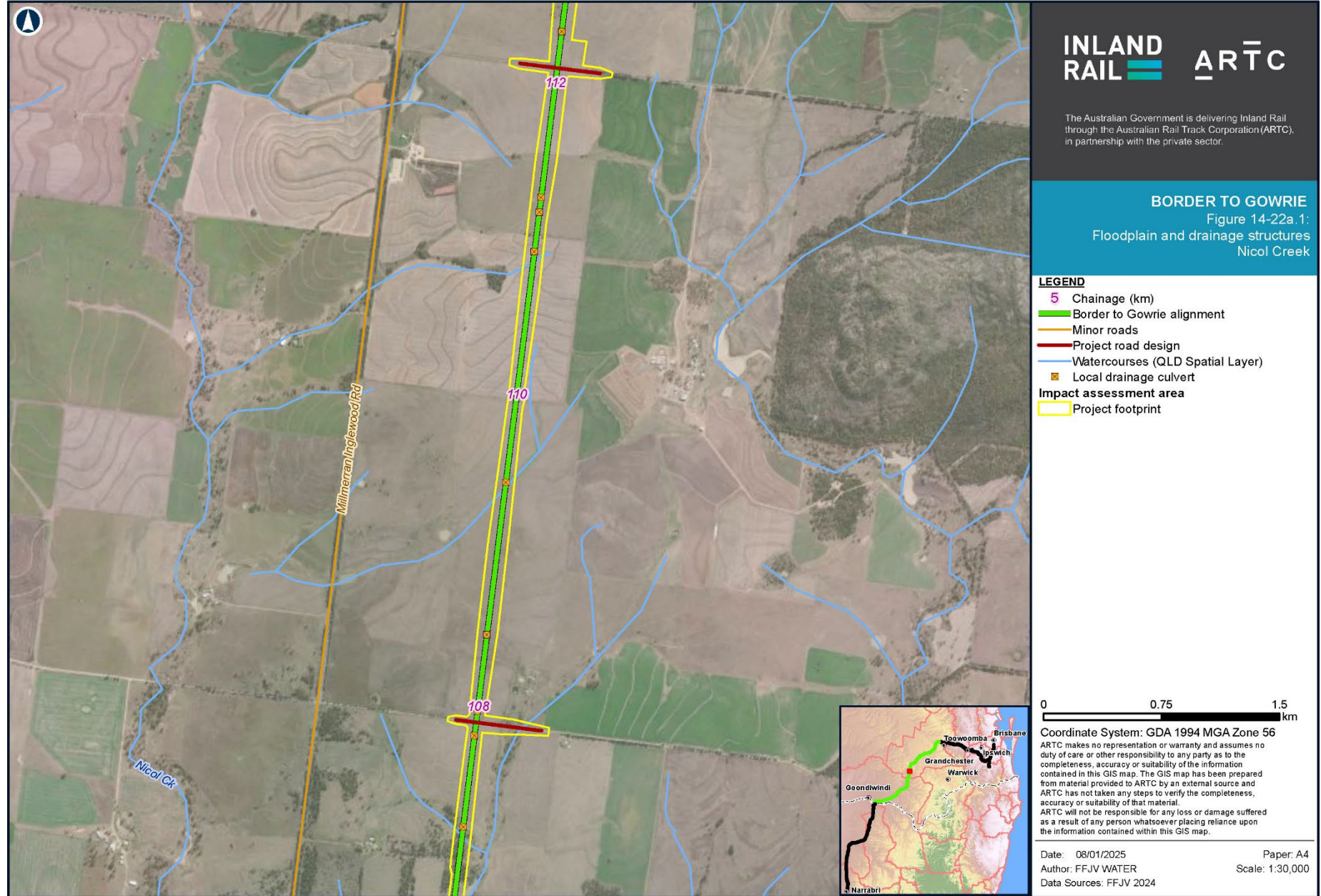
Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

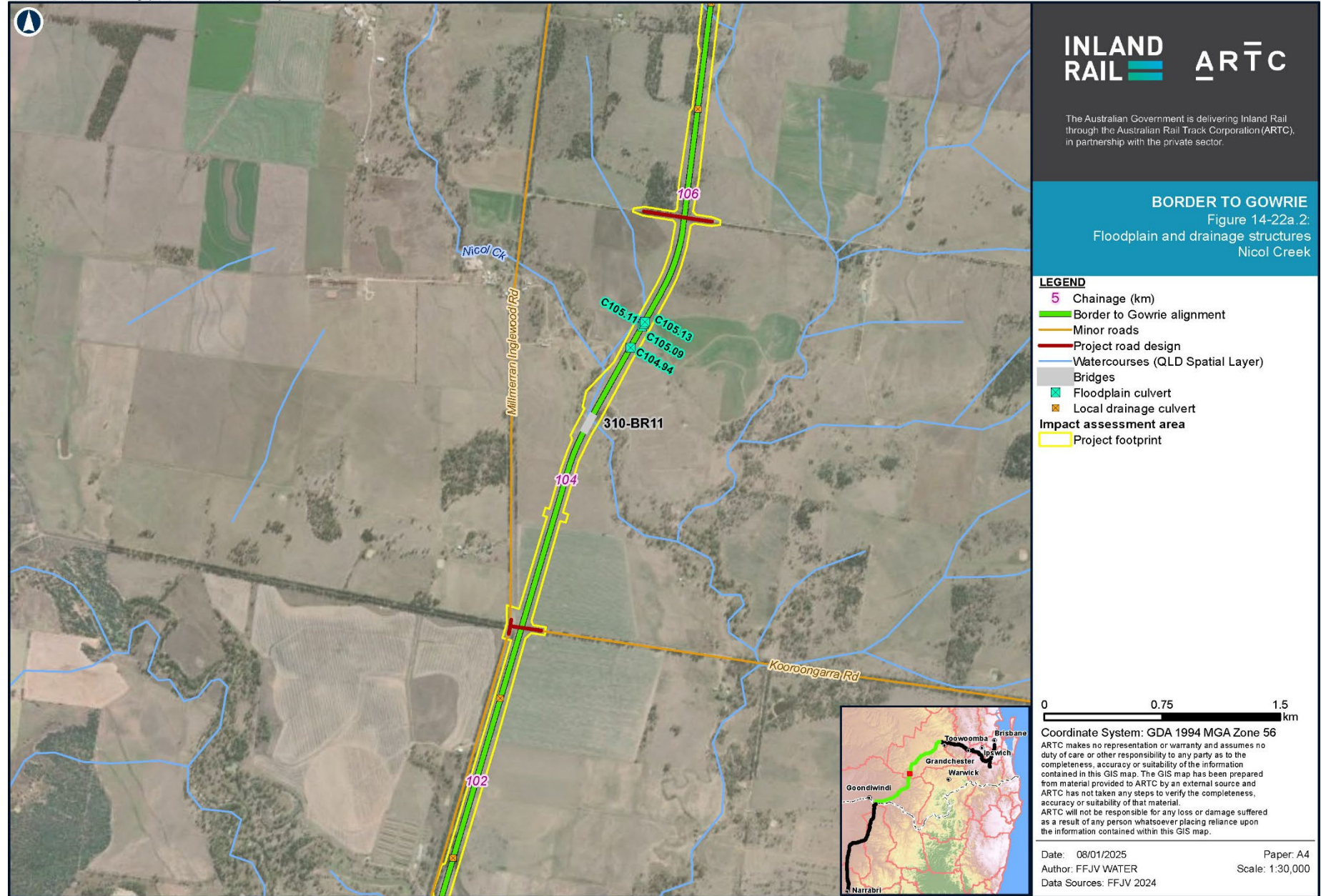
The climate change sensitivity result indicates that there are no predicted changes in peak water levels at flood sensitive receptors in the Nicol Creek modelled floodplain for the 1% AEP climate change event. The downstream extents of the climate change scenario are slightly larger than those under the 1% AEP event.

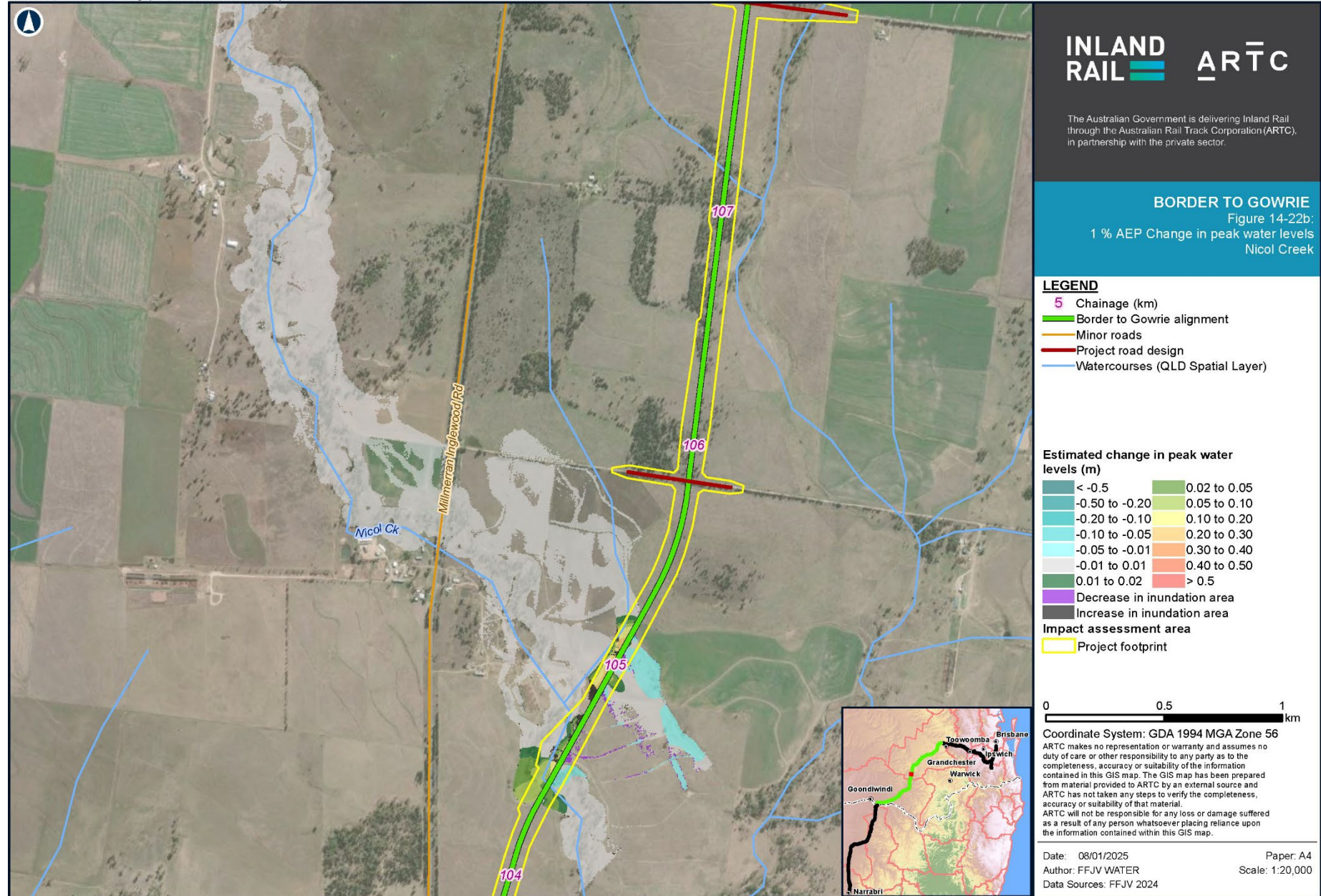
Blockage

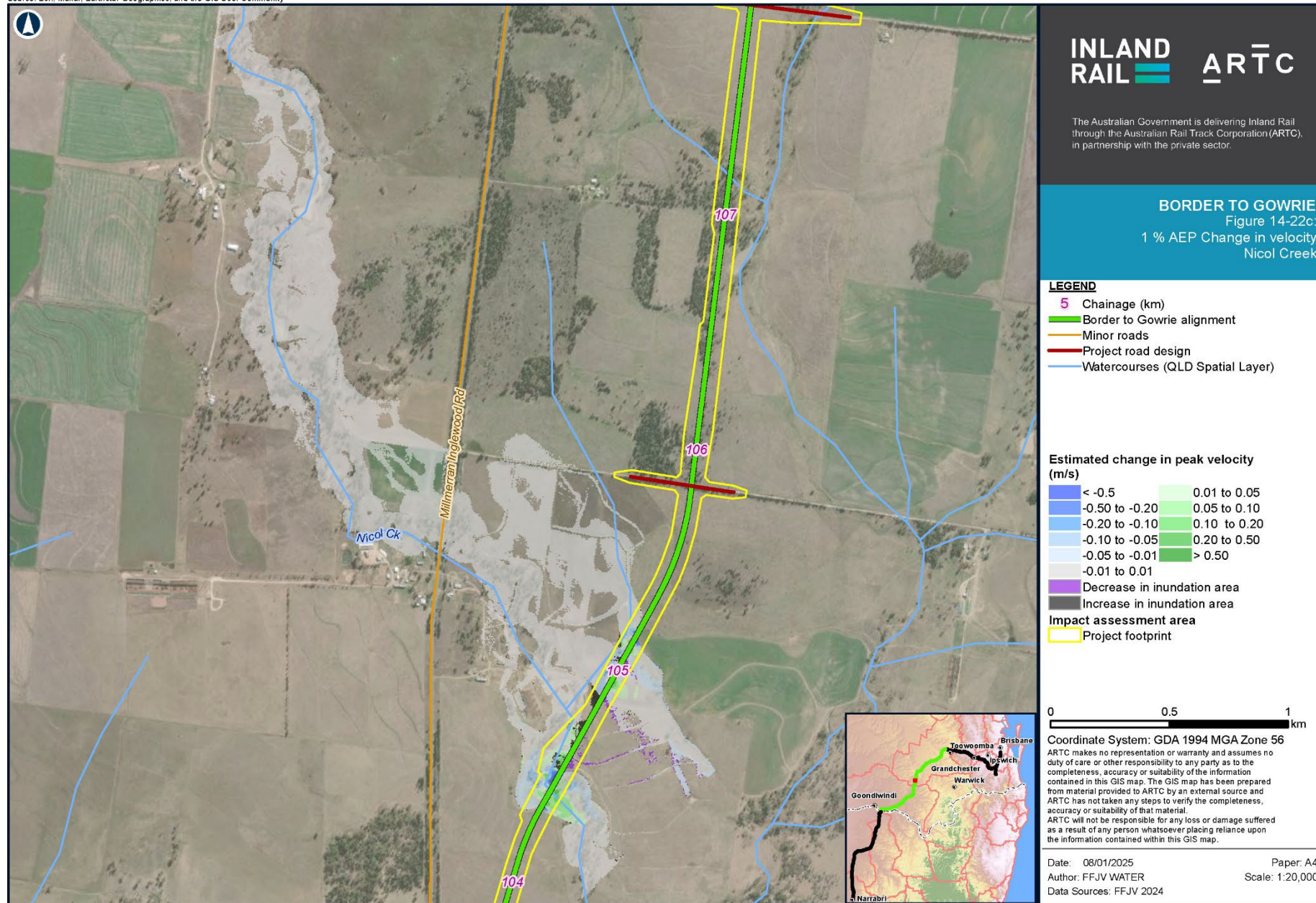
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

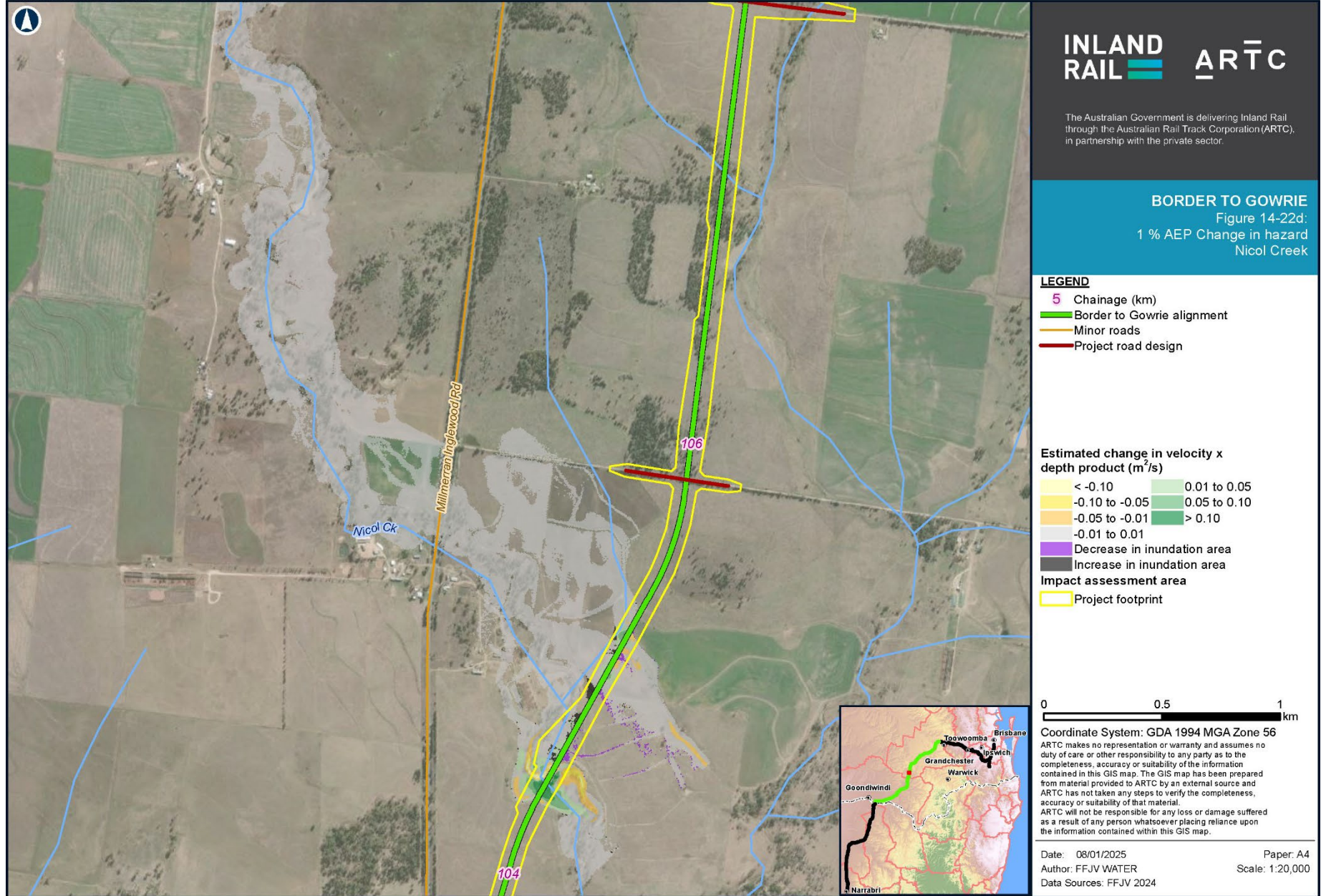
The blockage sensitivity results indicate there are no predicted changes in peak water levels for the 0 per cent and 50 per cent blockage scenarios at flood sensitive receptors in the 1% AEP event within the Nicol Creek modelled floodplain.

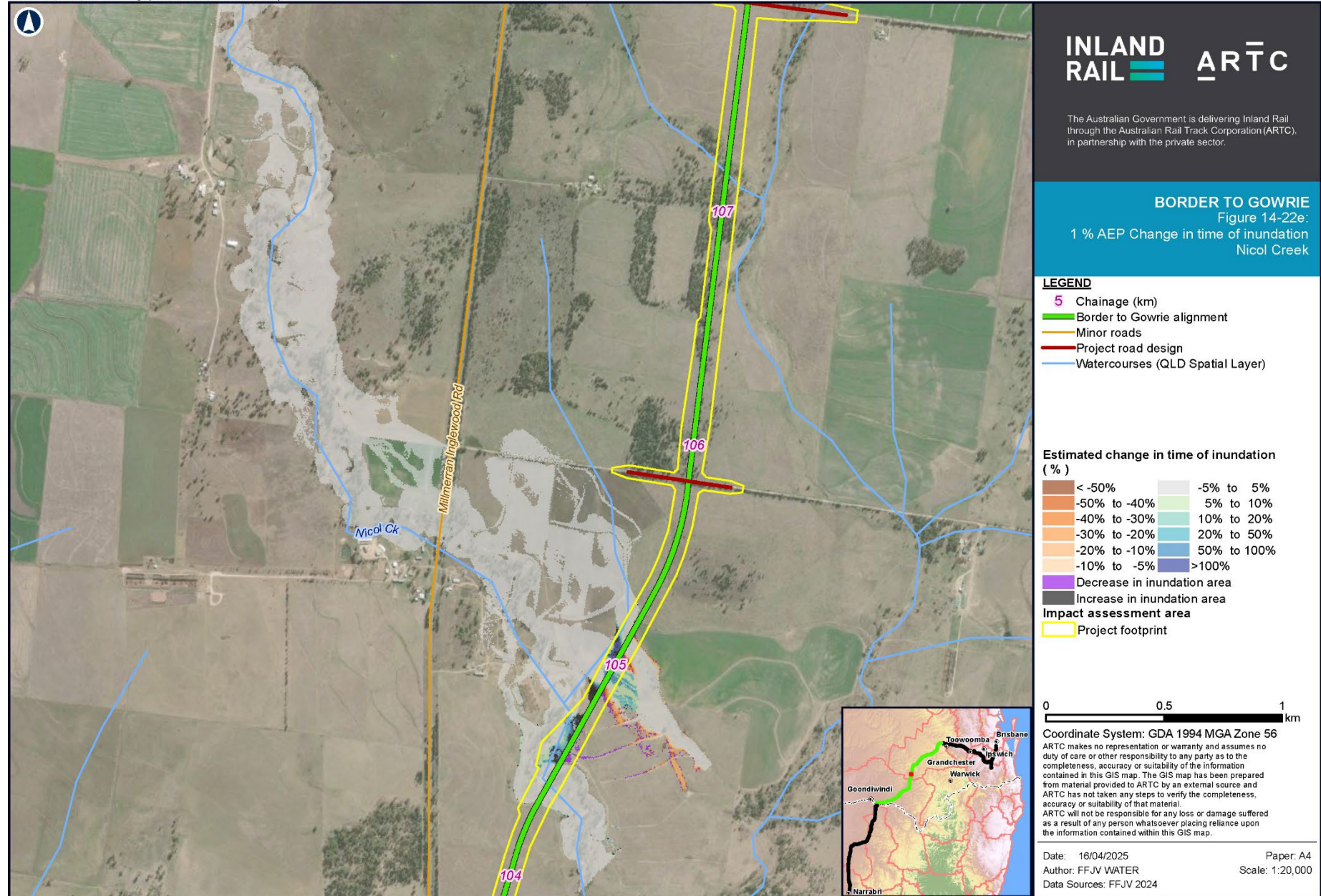












14.8.1.2.7 Bringalily Creek

In the Bringalily Creek floodplain, the Project's revised reference design includes:

- ▶ Three bridges
- ▶ Eight RCP locations (a total of 82 culvert cells).

Details of the floodplain structures required to convey Bringalily Creek flood flows are presented in Table 14-75 and Table 14-76, with structure locations presented in Figure 14-23a. Figure 14-23a also presents the location of catchment drainage structures.

TABLE 14-75 BRINGALILY CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
93.93	310-BR07 ²	Bridge	325.42	184
97.58	310-BR08	Bridge	332.79	299
100.39	310-BR10	Bridge	334.54	621

Table notes:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

2. Bridge 310-BR07 is included in the Native Dog Creek floodplain also

TABLE 14-76 BRINGALILY CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
97.29	C97.29	RCP	12	0.90
97.38	C97.38	RCP	12	0.90
97.84	C97.84	RCP	8	1.50
98.36	C98.36	RCP	10	0.90
99.37	C99.37	RCP	17	0.90
99.84	C99.84	RCP	14	0.90
99.77	C99.77	RCP	1	1.50
100.00	C100.00	RCP	8	1.50

Table notes:

1. For RCP height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-23b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 10.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Bringalily Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for one lot within the Bringalily Creek floodplain for all modelled events up to the 1 in 2,000 AEP event. The impacted lot, Lot Plan 107MH808, experiences a maximum change in peak water level of 490 mm in the 1% AEP event. Some degree of change in peak water level is expected to impact a maximum area of 0.02 ha (or less than 0.05 per cent of the total lot area). This change can be attributed to an increase in flood extent and newly flood-affected hydraulic model cell.

Other infrastructure

One State-controlled road, Millmerran-Inglewood Road, has been identified to experience a change in peak water levels across four individual segments. The maximum change in peak water level identified occurs in the road segment to the south of Heckles Road and is approximately 95 mm in the 1% AEP event. This change can be attributed to an increase in flood extent and a newly flood-affected hydraulic model cell.

No local public roads or existing rail infrastructure are expected to be impacted by an increase in peak water levels, up to the 1% AEP event, within the Bringalily Creek floodplain.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-23c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of eight lots (170MH808, 169MH786, 152MA3432, 1RP110474, 42MH18, a watercourse, 152MA3432 and 10MA3438) were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 42MH18 experiences the largest increase in velocity of 1.1 m/s in the 2% AEP event. Some order of change in velocity is expected to be experienced across 0.01 ha of the lot (less than 0.05 per cent of the total lot area) and can be attributed to a change in flood inundation extent and a newly flood-affected hydraulic model cell. Lot Plan 107MH808 experiences the largest percentage change in velocity with an increase of 64 per cent in the 1% AEP event (increasing from 0.50 m/s to 0.82 m/s). The following provides a summary of velocity changes identified across the impacted lots:

- ▶ One lot experiences a change in peak velocity greater than 1 m/s
- ▶ Three lots experience a change in peak velocity of between 0.5 m/s and 1.0 m/s
- ▶ Three lots experience a change in peak velocity of less than 0.1 m/s
- ▶ One lot experiences percentage increase in velocity only, of less than 25 per cent.

Other infrastructure

No State-controlled roads, local public roads or existing rail infrastructure have been identified to experience an increase in peak velocity above the flood impact objective targets for all modelled events up to the 1% AEP event in the Bringalily Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 10.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-23d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Bringalily Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of three lots (107MH808, 169MH786 and 1SP118699) were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Exceedances can be attributed to the Project's revised reference design constraining the existing flow regime and increasing velocities. The maximum increase in flood hazard is approximately 394 per cent (0.19 m²/s) in the 1% AEP event on Lot Plan 107MH808, with changes in hazard predicted across a total area of 4.08 ha (approximately 7 per cent of the total lot area). Lot Plan 169MH786 and 1SP118699 experience a percentage increase in hazard of 28.6 and 85 per cent in the 2% AEP event, respectively.

Other infrastructure

One segment of Millmerran-Inglewood Road (to the south of Heckles Road) experiences a maximum increase in hazard of 49 per cent (from 0.13 m/s to 0.19 m²/s) in the 2% AEP event. The increase in hazard can be attributed to the increase in peak water level with a total length of impact predicted to be 65 m in the 1% AEP event.

No local public roads or existing rail infrastructure have been identified to experience an increase in peak hazard above the flood impact objective targets for all modelled events up to the 1% AEP event in the Bringalily Creek floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 10.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-23e for the 1% AEP event.

Private land outside the Project permanent footprint

A total of seven lots (170MH808, 169MH786, 1SP118699, 152MA3432, 1RP110474, 42MH18 and 10MA3438) were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 107MH808 has been identified as experiencing the largest percentage increase in time of inundation of 236 per cent (increasing from 1.19 hours in the Existing Case to 3.98 hours in the Developed Case) and largest 'absolute' change of 2.93 hours. Of the remaining six lots impacted by a change in time of inundation, three experience a change greater than 30 per cent in time of inundation and the remaining three experience a change of less than 30 per cent.

Other infrastructure

Millmerran-Inglewood Road is the only State-controlled road impacted by an increase in time of inundation. A maximum change of 68 per cent (increasing from 0.6 hours to 1.01 hours) in the 1% AEP event has been identified.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 10.5.3).

Flood flow distribution

To determine the change in flow distribution maximum velocity-depth modelling results were used to produce change in unit flow maps between Existing and Developed Case conditions. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section, or to determine the effective flow corridors within a floodplain.

The presented flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to assist in identifying main channels (i.e. high flow zones) from shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the potential change in flow distribution for the Bringalily Creek floodplain and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

- ▶ The hydraulic results for Bringalily Creek show the primary change of flow conditions occurs at bridge BRI-08, and to a lesser extent at all culvert infrastructure for modelled events up to the 5% AEP event. This is mainly confined to the eastern side of the alignment which results in a positive increase in flow distribution.
- ▶ A consistent increase in unit flow is noted downstream of bridge 310-BR08, with localised increases and decreases occurring at culvert locations.
- ▶ Flow conditions remain largely unimpacted at bridge 310-BR10, up to the 1% AEP event, which spans the majority of the existing waterway, thus having minimal effect on existing flow conditions. In more extreme events (1 in 2,000, 1 in 10,000 AEP and PMF events), some positive change in flow distribution occurs on the eastern side of the Project alignment due to the interaction of flood waters with the design.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project, and may include further refinement of the bridge abutments, culvert skews, and additional surveys where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-77 outlines the changes in peak water levels greater than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event occur generally when there are already high flood depths, as would be expected under such a rare event. Review of the modelled results and FIOs show there are no impacts above the flood impact objective target from extreme event flooding on flood sensitive receptors within the modelled Bringalily Creek floodplain.

TABLE 14-77 BRINGALILY CREEK: SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
BRI_ID_1	Shed	-28	0.52	+55	1.18	+172	3.55
BRI_ID_2	House	+1	0.68	+71	1.35	+197	3.68
BRI_ID_3	Shed	-21	0.56	+75	1.17	+154	3.60
BRI_ID_4	Shed	-33	0.58	+59	1.22	+167	3.62
BRI_ID_9	House	-	0.06	+1	0.16	+35	2.43
BRI_ID_10	Shed	-	-	-	0.15	+35	2.26
BRI_ID_11	Shed	-	-	-	0.08	+35	1.93
BRI_ID_12	Shed	-	-	-	-	+34	1.68
BRI_ID_13	Shed	-	-	-	-	+36	2.12
BRI_ID_14	Shed	-	-	-	0.04	+36	1.82
BRI_ID_15	Shed	-	-	-	-	+42	1.90
BRI_ID_16	Shed	-	-	-	-	+47	1.71
BRI_ID_17	Shed	-	-	0	0.39	+13	2.40
BRI_ID_18	Shed	+16	0.79	+14	1.87	+32	4.67
BRI_ID_19	Shed	-	-	+60	0.31	+118	3.09
BRI_ID_25	Private access road	-	-	+30	0.35	+65	2.45

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. During these extreme events the Project alignment is inundated at several locations. Table 14-78 outlines the overtopping locations and depths.

TABLE 14-78 BRINGALILY CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
94.91	C94.91	-	0.16	2.65
95.07	C95.07	-	0.52	3.14
96.20	C96.20	-	-	2.49
97.01	C97.01	-	-	1.69
98.87	C98.87	-	-	1.26
99.37	C99.37	-	0.06	1.96
99.77	C99.77	-	-	2.18
99.84	C99.84	-	-	2.31
100.00	C100.00	-	-	2.35
100.6	310-BR10	-	0.50	3.21

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event, as the water level on both sides of the embankment is predicted to be similar.

Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Bringalily Creek catchment area is 23.9 per cent.

Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

Table 14-79 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the climate change scenario.

TABLE 14-79 BRINGALILY CREEK: SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1% AEP climate change event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
BRI_ID_18	Shed	+25	0.6

Table note:

1. Existing Case flood depth including climate change

The downstream extents of these impacts are similar to those under the 1% AEP event.

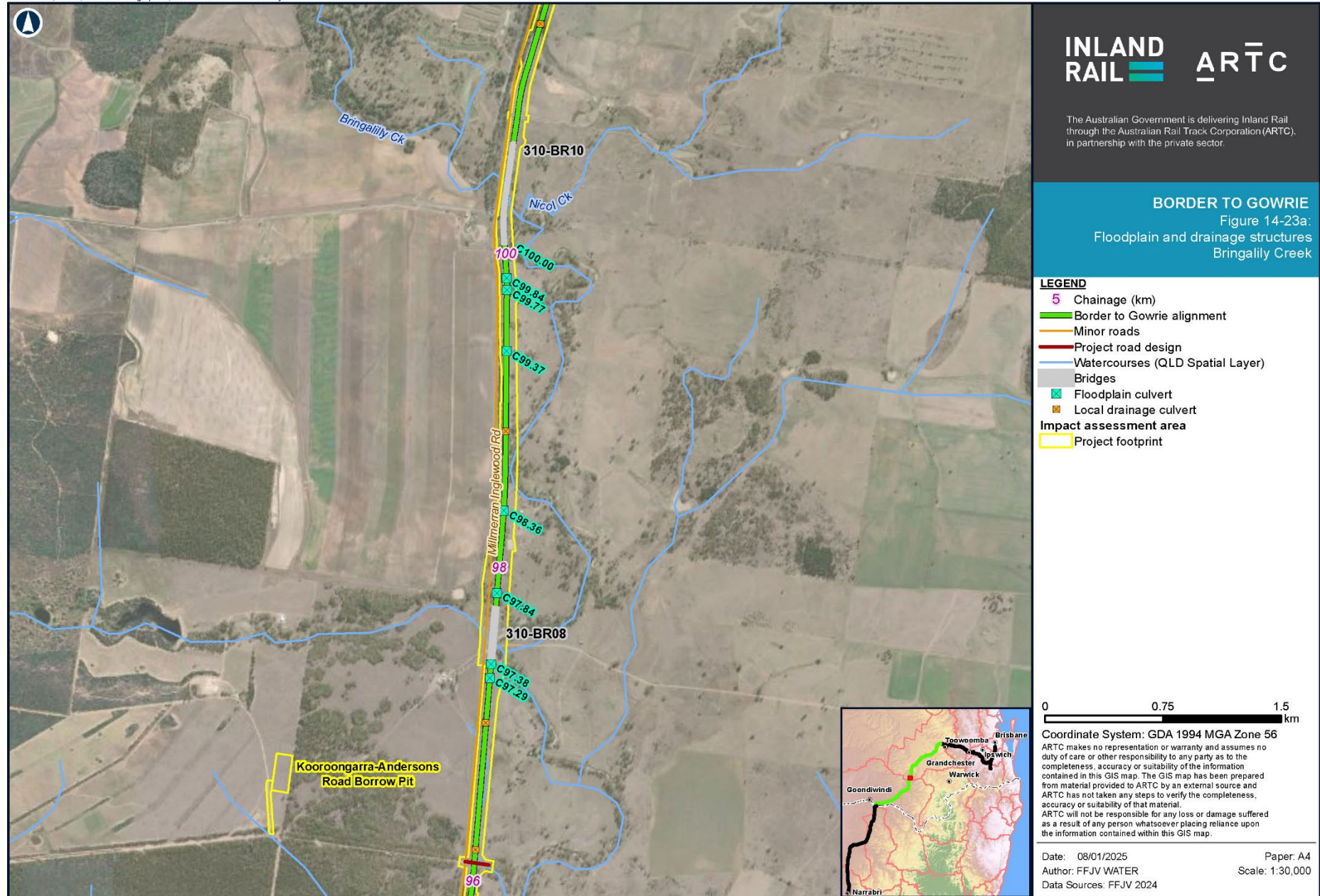
Blockage

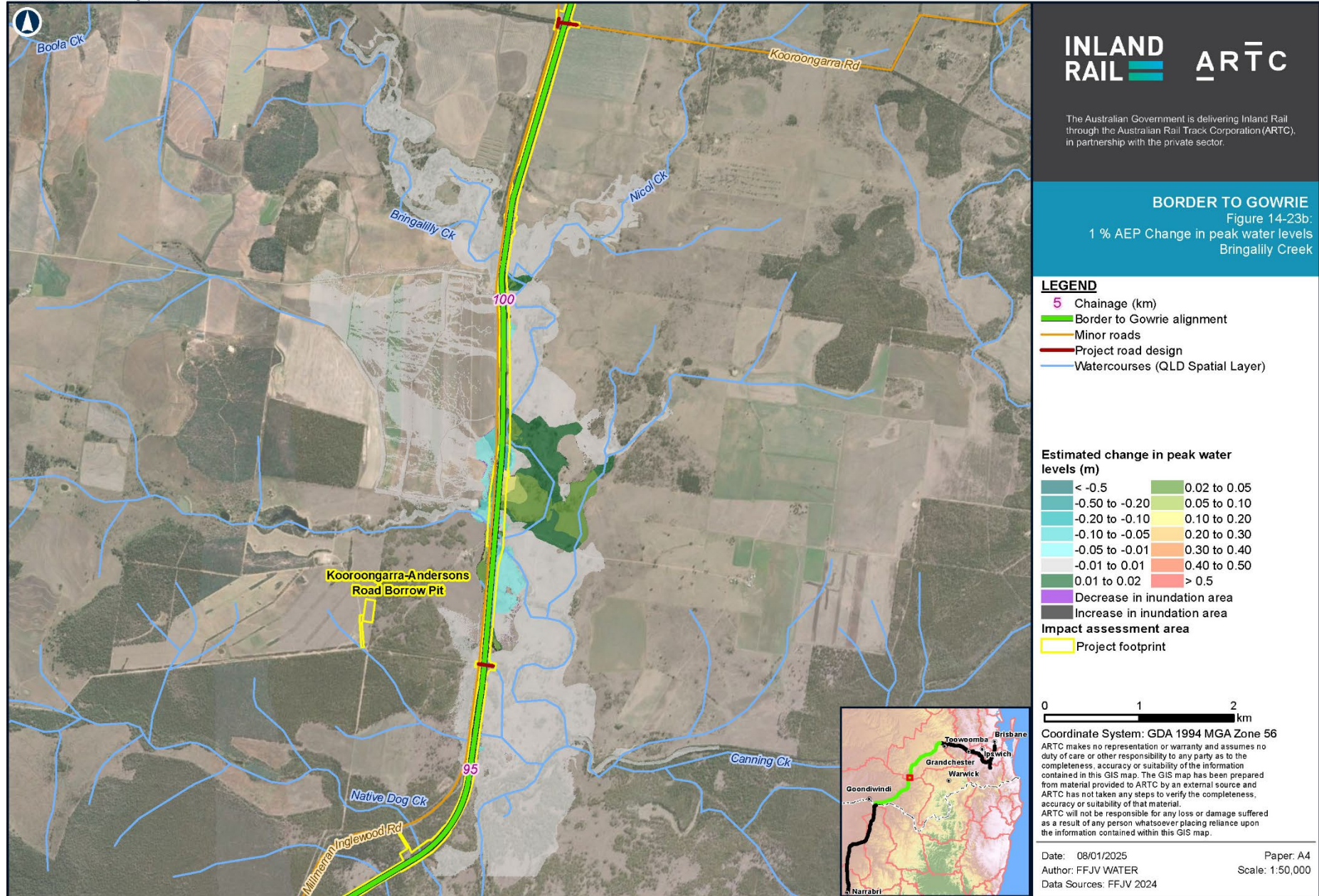
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

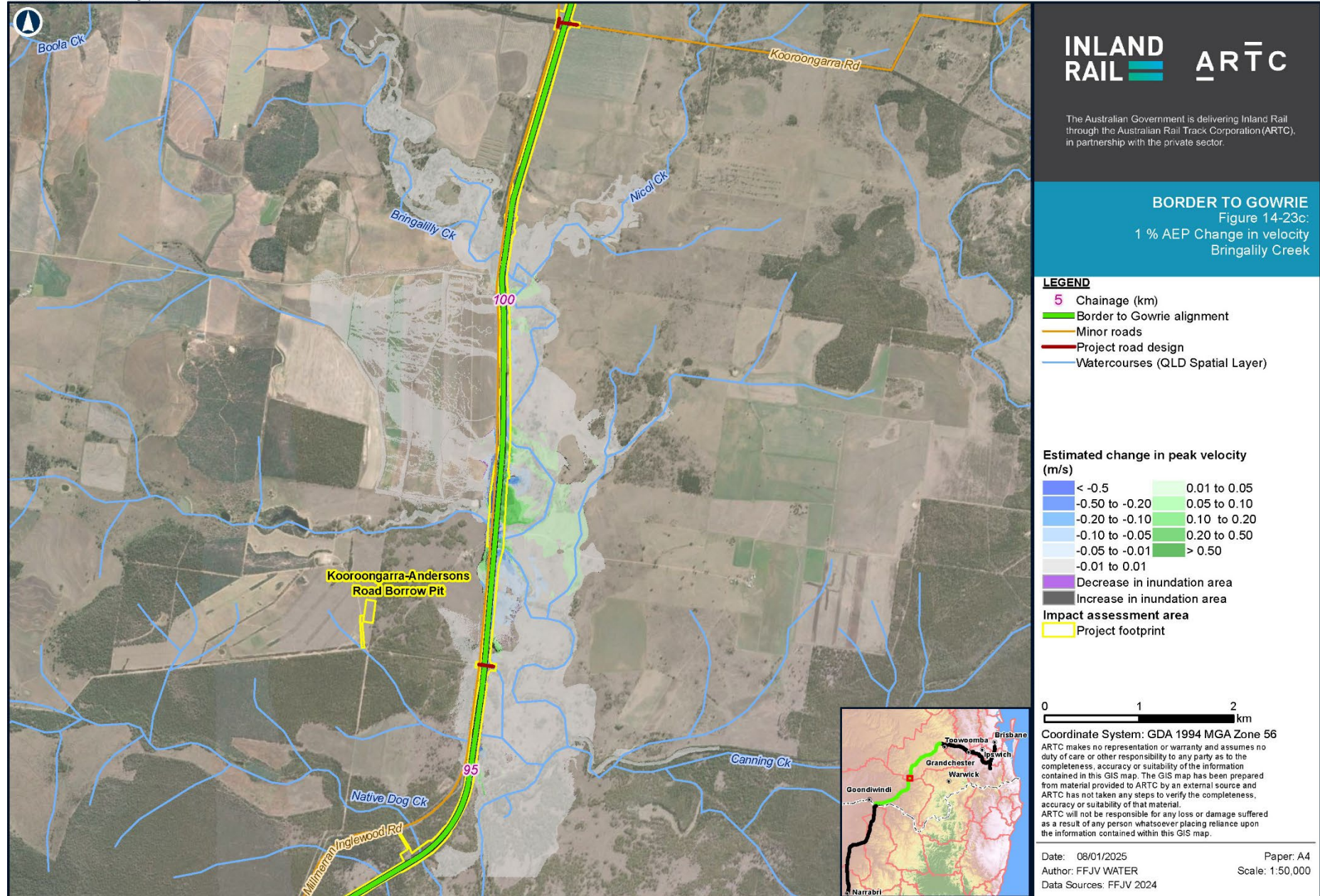
Table 14-80 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the 50 per cent blockage scenario (for a 1% AEP event).

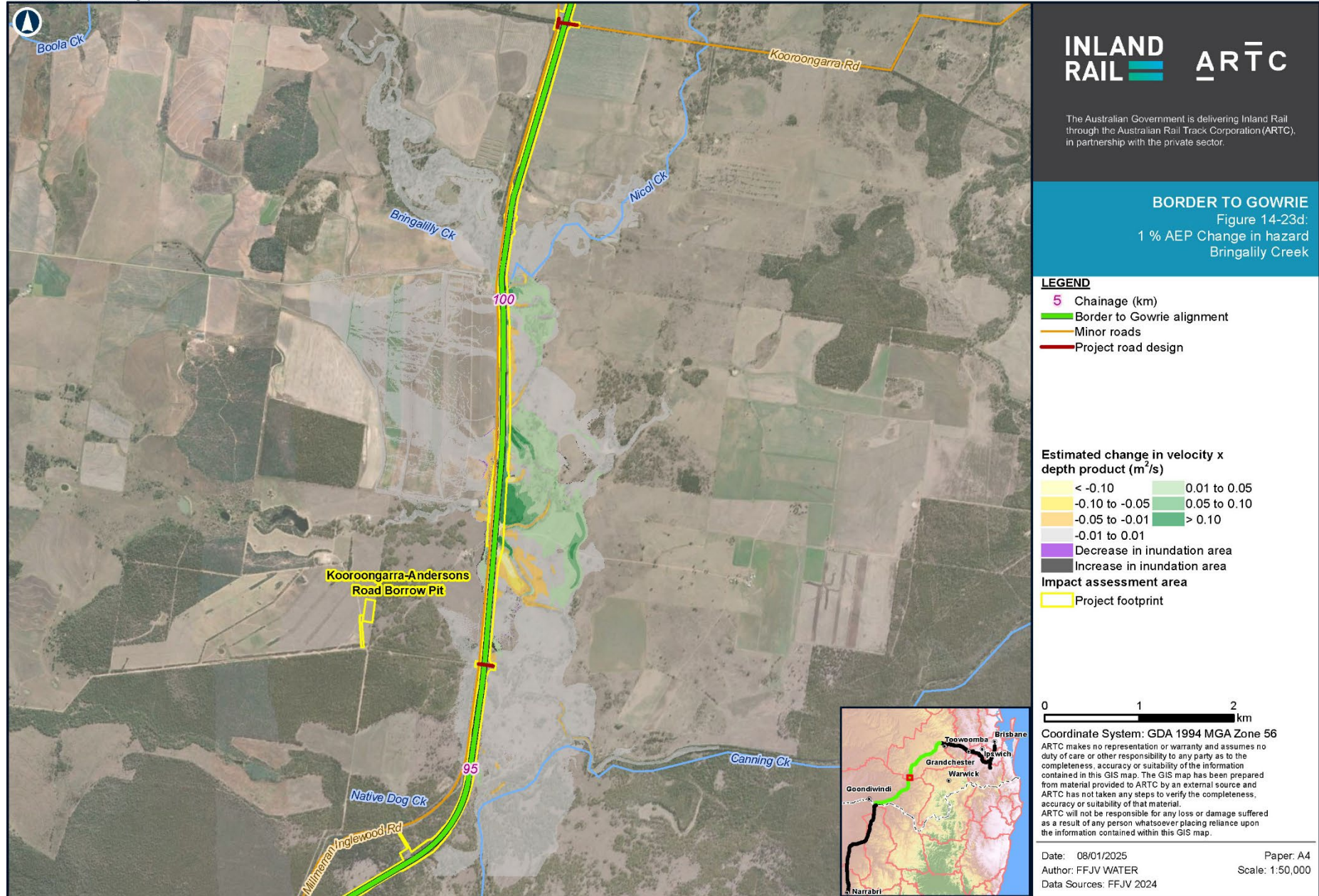
TABLE 14-80 BRINGALILY CREEK: SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD SENSITIVE RECEPTORS (1% AEP)

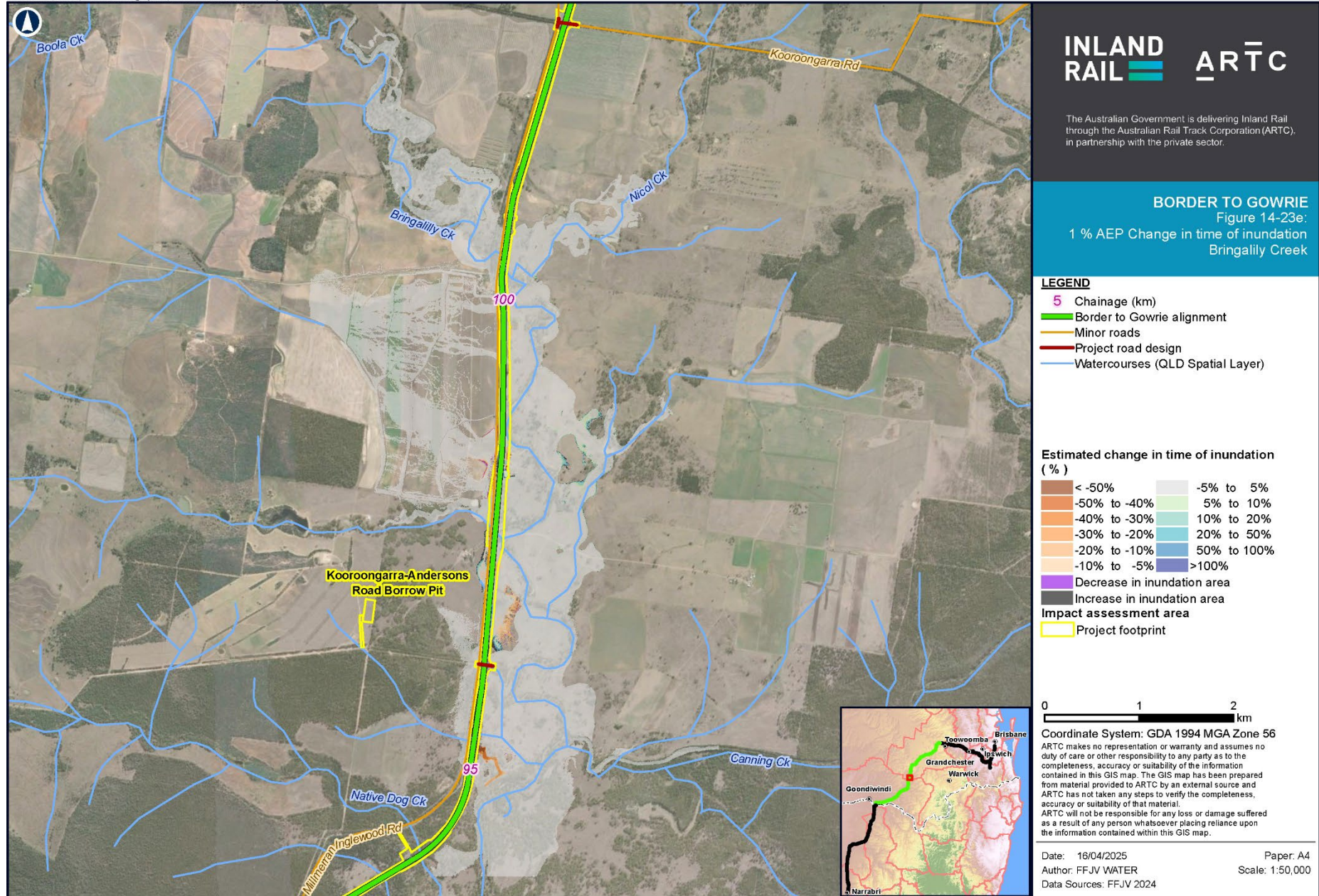
Flood sensitive receptor ID	Flood sensitive receptor type	Existing Case flood depth (m)	Change in peak water level (mm)
BRI_ID_18	Shed	0.4	+26











14.8.1.2.8 Native Dog Creek

In the Native Dog Creek floodplain, the Project's revised reference design includes one bridge.

Details of the floodplain structure required to convey Native Dog Creek flood flows are presented in Table 14-81. Figure 14-24a also presents the location of local catchment drainage structures.

TABLE 14-81 NATIVE DOG CREEK: FLOODPLAIN STRUCTURE LOCATION AND DETAIL

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (mAHD)	Bridge length (m)
93.93	310-BR07	Bridge	325.42	184

Change in peak water levels

Figure 14-24b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 11.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Native Dog Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1 in 2,000 AEP event in the Native Dog Creek floodplain.

Other infrastructure

No roads or rail have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1% AEP in the Native Dog Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 11.5.3).

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-24c for the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in velocity above the flood impact objective targets for all events up to the 1% AEP event in the Native Dog Creek floodplain.

Other infrastructure

No roads or rail have been identified to experience an increase in velocity above the flood impact objective targets for all events up to the 1% AEP event in the Native Dog Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 11.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-24d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in hazard in the Native Dog Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in hazard above the flood impact objective targets for all events up to the 1 in 2,000 AEP event in the Native Dog Creek floodplain.

Other infrastructure

No roads or rail have been identified to experience an increase in hazard above the flood impact objective targets for all events up to the 1% AEP in the Native Dog Creek floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 11.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Cases with results presented in Figure 14-24e for the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in time of inundation above the flood impact objective targets for all events up to the 1% AEP event in the Native Dog Creek floodplain.

Other infrastructure

No roads or rail have been identified to experience an increase in time of inundation above the flood impact objective targets for all events up to the 1% AEP in the Native Dog Creek floodplain.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 11.5.3).

Flood flow distribution

To determine the change in flow distribution velocity-depth product results were used to produce percentage change unit flow maps. Existing and developed flood results were used to calculate the percentage change in unit flow. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section or to determine the effective flow corridors within a floodplain.

Flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and is used to identify main channels (i.e. high flow zones), and shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the change in flow distribution for Native Dog Creek and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

- ▶ The hydraulic results for Native Dog Creek show negligible changes in global flow distribution patterns for all events up to and including the 1% AEP event.
- ▶ Some change occurs locally around the bridge opening to the south of the floodplain with some negative change occurring adjacent bridge abutments and an increase in flow distribution through the bridge opening in the 1 in 2,000 AEP and 1 in 10,000 AEP events.
- ▶ For the PMF event, unit flow increases around the bridge and local culvert structures located to the north, approximately 100 m. The increase in flow is balanced by a reduction in the larger floodplain to the southeast of the Project alignment.
- ▶ Local increases in unit flow (>20 per cent) are noted immediately upstream and downstream of the rail bridge, and culvert structures. This localised behaviour is expected as flood velocities increase through the cross-drainage infrastructure.
- ▶ Reduced overtopping during the PMF event causes a reduction in flow on the eastern/downstream side of the alignment.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional surveys where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Review of the modelled results and FIOs show there are no impacts from extreme event flooding on flood sensitive receptors within the Native Dog Creek floodplain.

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. Table 14-82 outlines the overtopping locations and depths. Some overtopping is experienced further north along the alignment from bridge 310-BR07 where structures are not currently proposed.

TABLE 14-82 NATIVE DOG CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
94.00	310-BR07	-	-	-

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and ‘damming’ effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Native Dog Creek catchment area is 23.9 per cent.

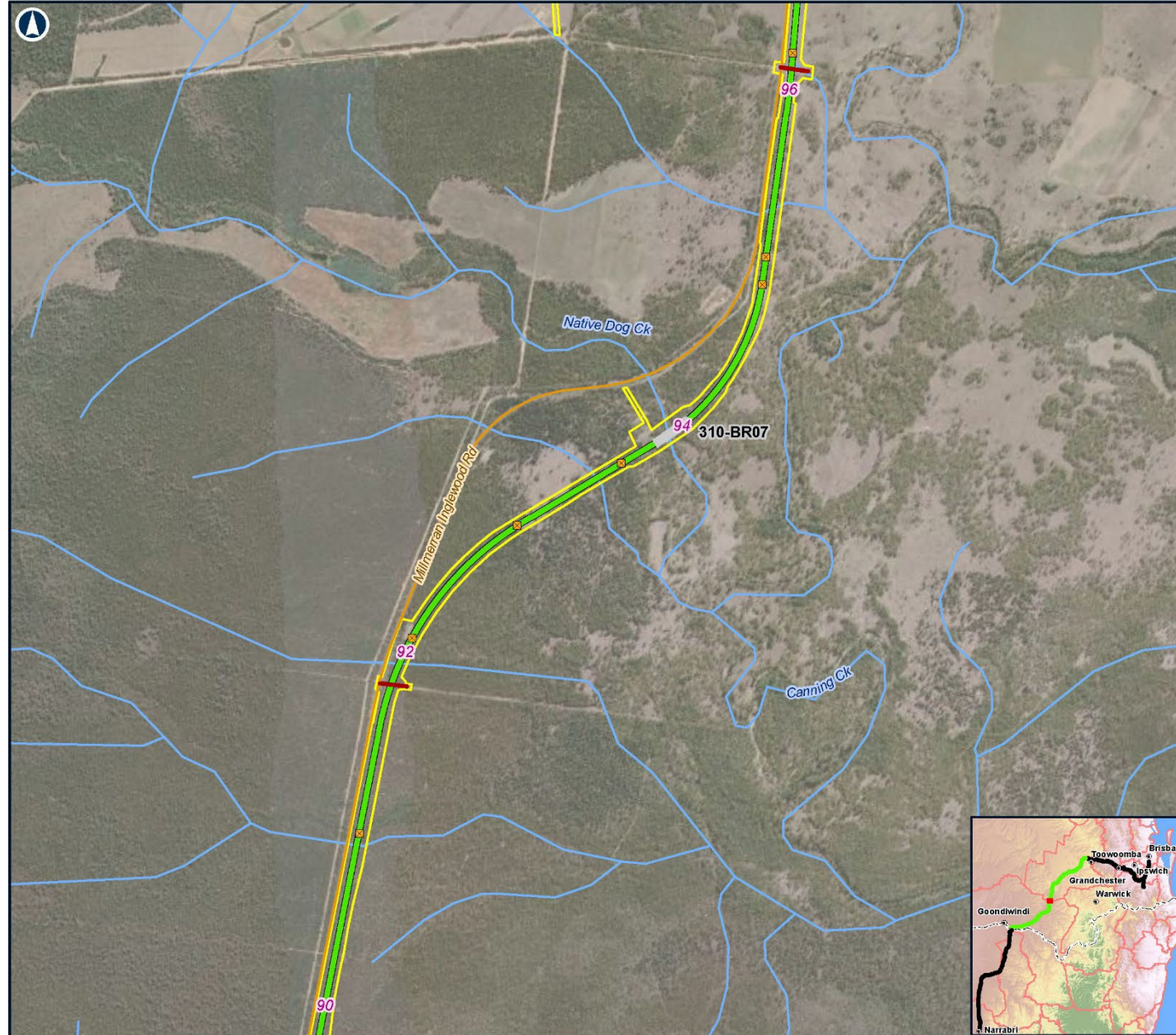
Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

The climate change sensitivity result indicates that there are no predicted changes in peak water levels at flood sensitive receptors in the Native Dog Creek modelled floodplain for the 1% AEP climate change event. The downstream extents of these impacts are similar to those under the 1% AEP event with a slight increase occurring.

Blockage

As previously stated, ARR 2019 guidelines are focused on the potential blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are multi-span large bridges and ARR 2019 notes that there are limited instances of multi-span bridges being observed with blockages similar to those seen at single-span bridges or culverts.

Therefore, a zero blockage factor was applied at the Native Dog Creek bridge. Additionally, there are no culverts in the Native Dog Creek floodplain, hence no sensitivity scenarios were conducted for blockage.



INLAND RAIL ARTC

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

BORDER TO GOWRIE Figure 14-24a: Floodplain and drainage structures Native Dog Creek

LEGEND

-  Chainage (km)
-  Border to Gowrie alignment
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Bridges
-  Local drainage culvert
-  Impact assessment area
-  Project footprint

0 0.75 1.5
km

Coordinate System: GDA 1994 MGA Zone 56

ARTC makes no representation or warranty and assumes no duty of care or other responsibility to any party as to the completeness, accuracy or suitability of the information contained in this GIS map. The GIS map has been prepared from material provided to ARTC by an external source and ARTC has not taken any steps to verify the completeness, accuracy or suitability of that material. ARTC will not be responsible for any loss or damage suffered as a result of any person whatsoever placing reliance upon the information contained within this GIS map.

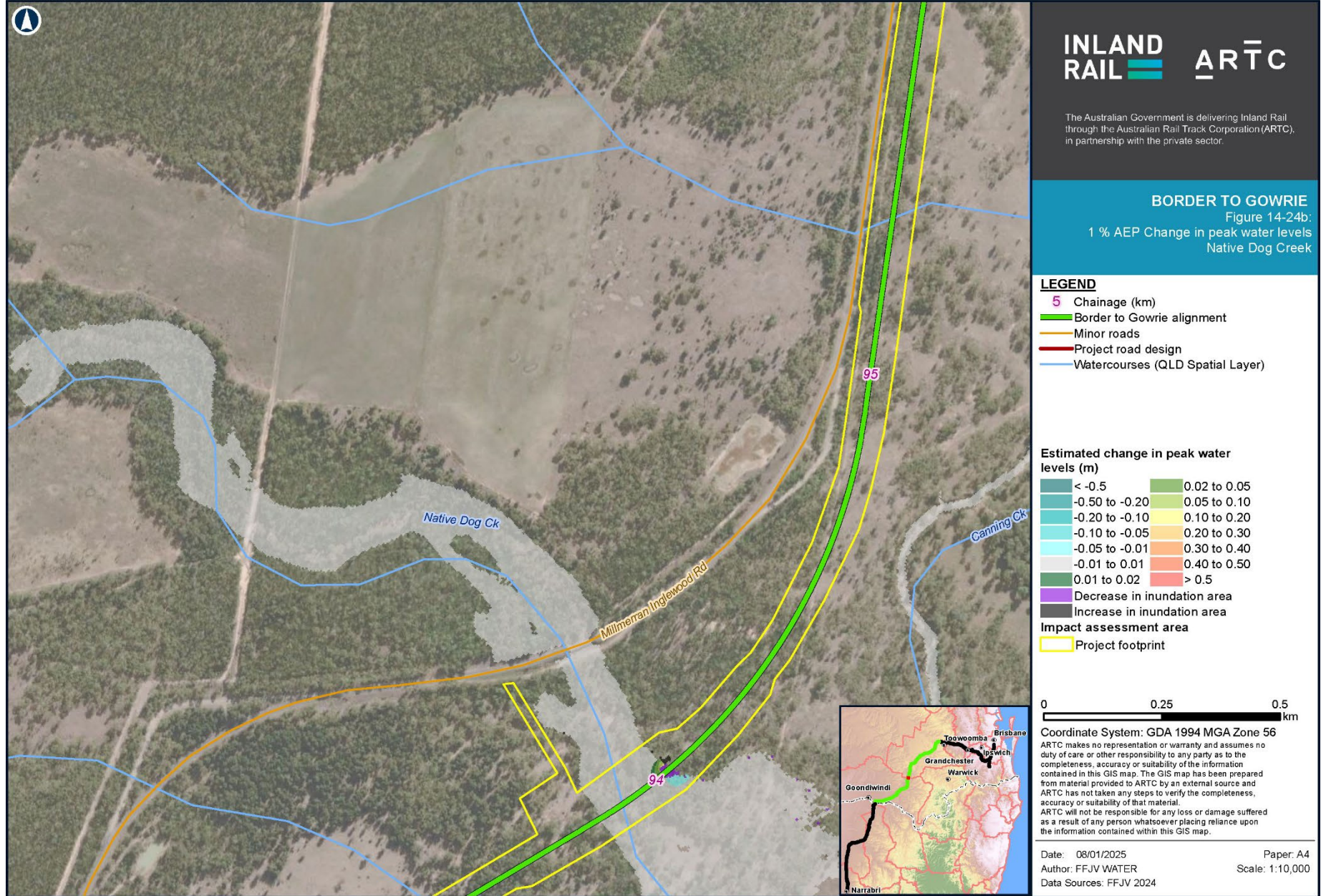
Date: 08/01/2025

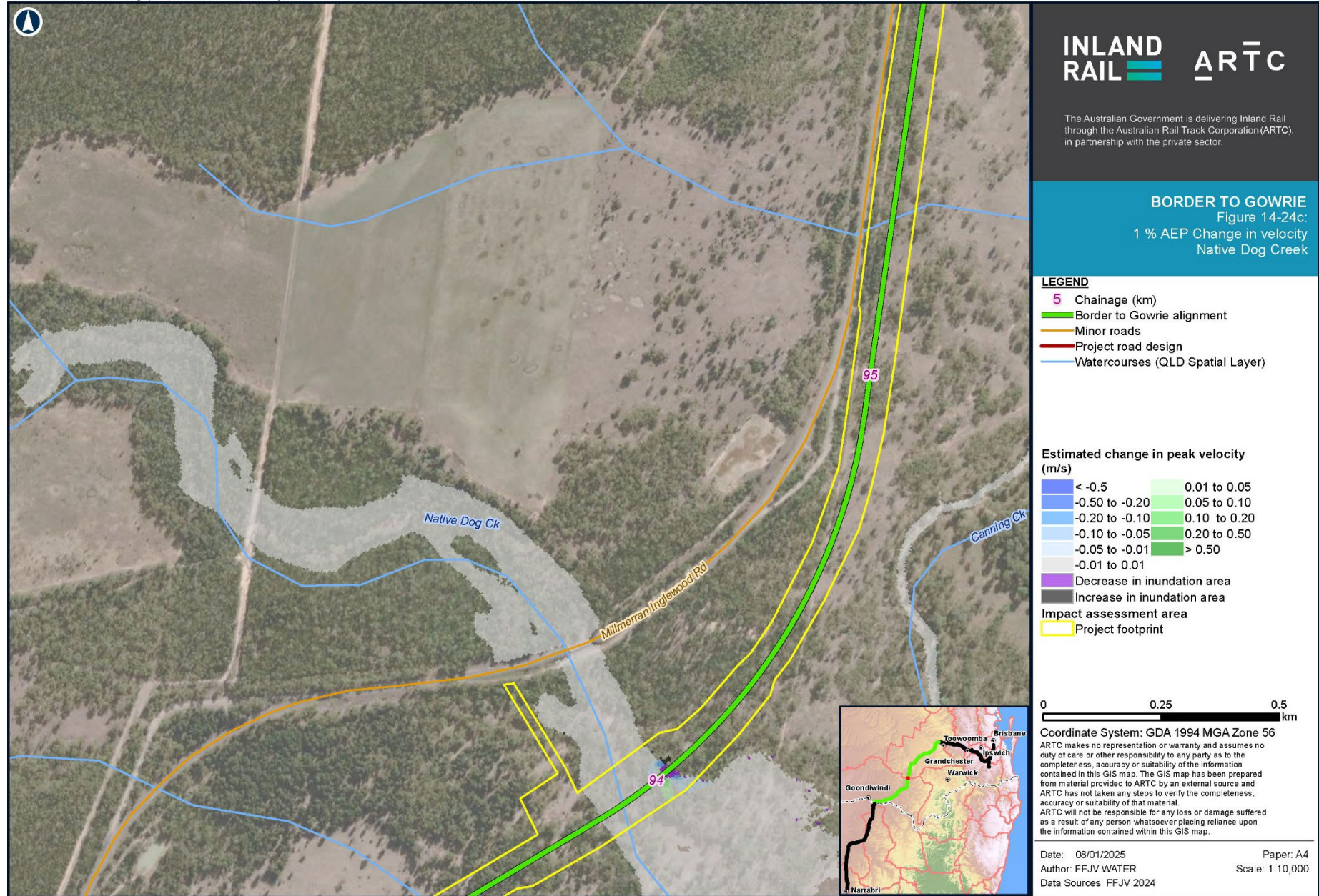
Author: FFJV WATER

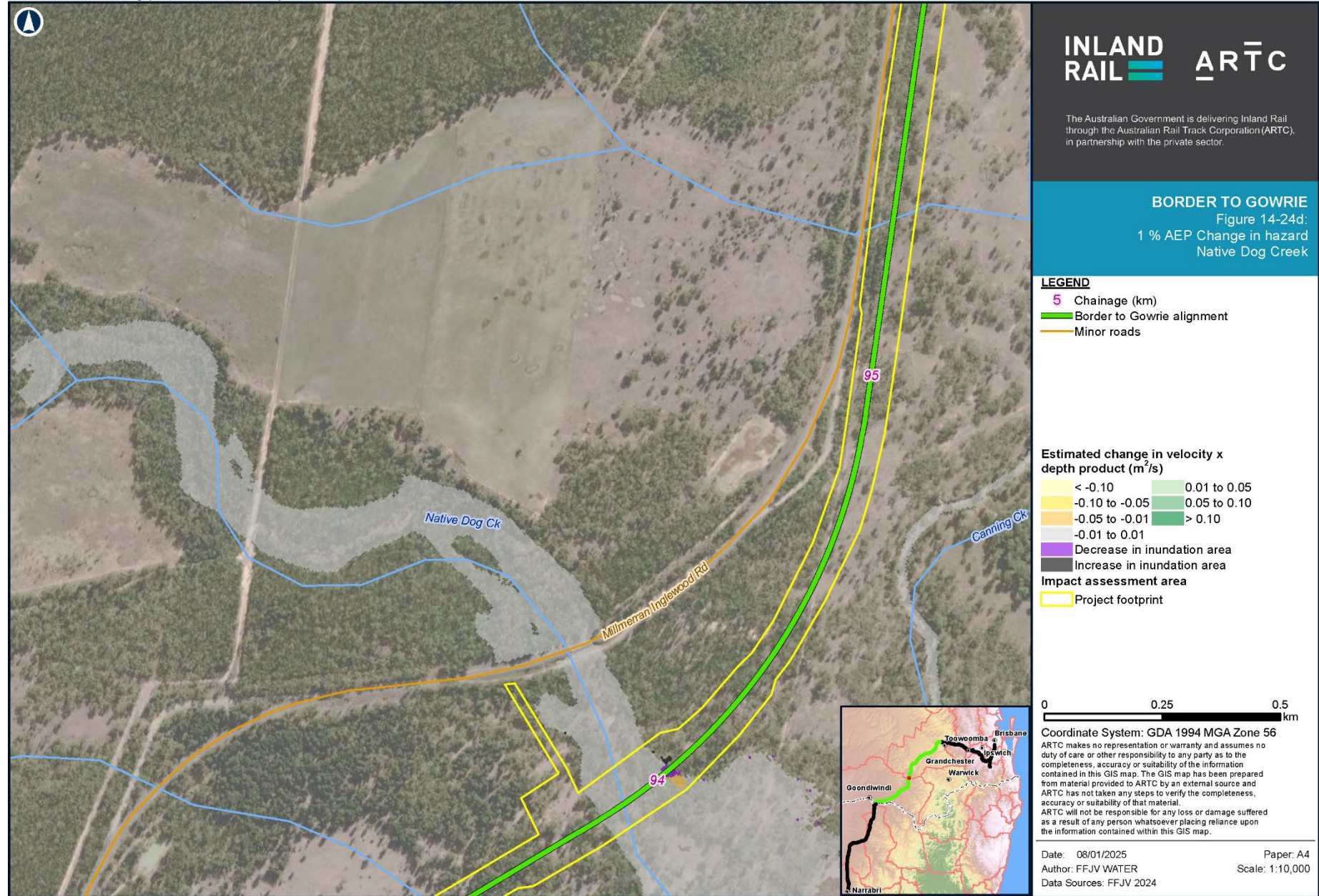
Data Sources: FFJV 2024

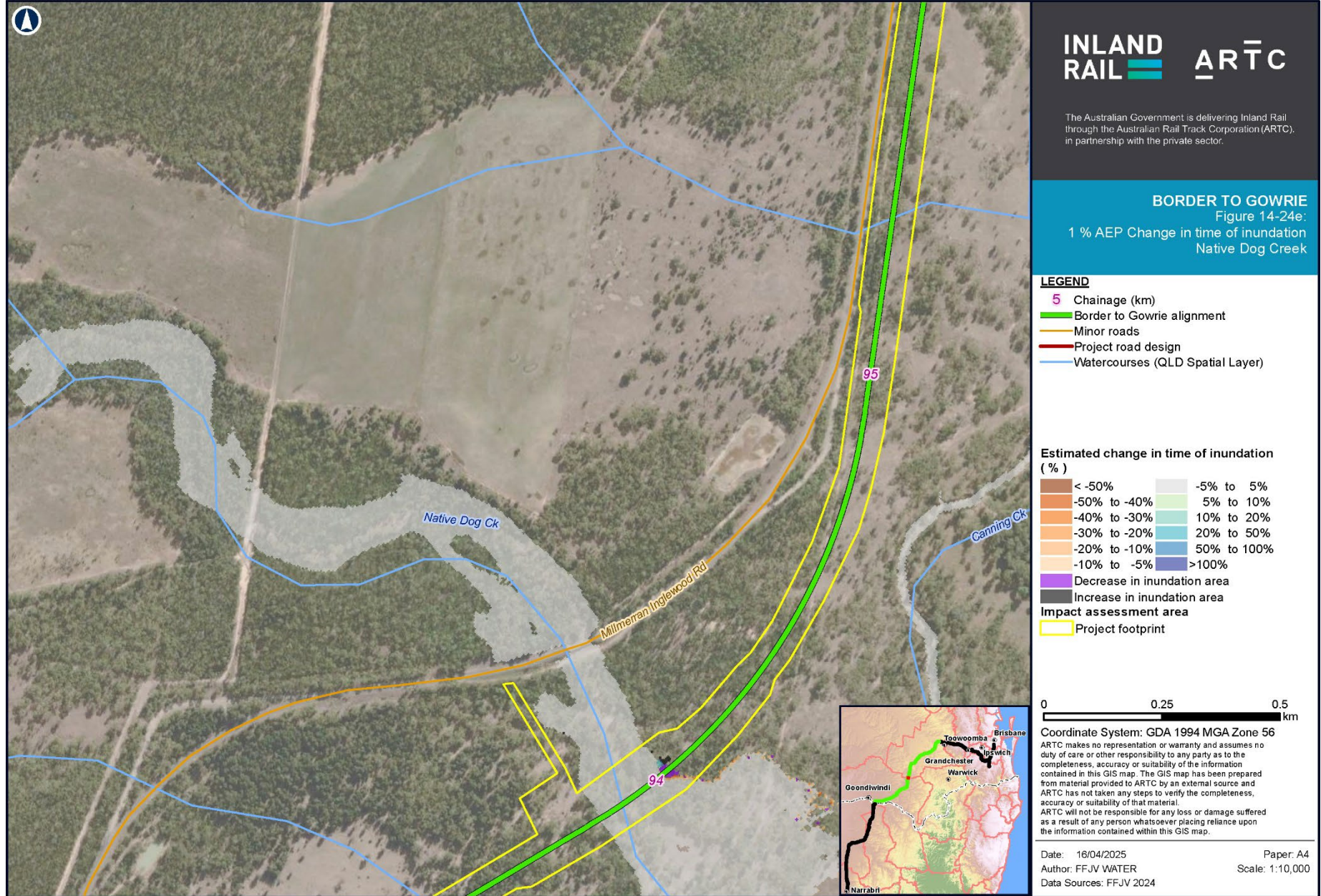
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Scale: 1:30,000









14.8.1.2.9 Cattle Creek

In the Cattle Creek floodplain, the Project's revised reference design includes:

- ▶ One bridge
- ▶ One RCP location (a total of six culvert cells)
- ▶ One RCBC location (a total of 15 culvert cells).

Details of the floodplain structures required to convey Cattle Creek flood flows are presented in Table 14-83 and Table 14-84, with structure locations presented in Figure 14-25a. Figure 14-25a also presents the location of local catchment drainage structures.

TABLE 14-83 CATTLE CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
88.28	310-BR06	Bridge	327.38	138

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-84 CATTLE CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
87.37	C87.37	RCP	6	2.10
87.19	C87.19	RCBC	15	2.40 x 1.80

Table notes:

1. For RCP height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-25b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 12.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event meet the flood impact objective targets (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Cattle Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1 in 2,000 AEP event in the Cattle Creek floodplain.

Other infrastructure

One unnamed local track is impacted by a maximum change in peak water level of 358 mm in the 1% AEP event. This change can be attributed to a change in flood extent and a newly flood-affected hydraulic model cell. In addition, this track experiences some change in peak water level for the 10%, 5% and 2% AEP events. Due to the proximity of this track to the Project alignment, this track will be closed, and the proposed Project alignment constructed over the top of this track. Therefore, the identified increase in water level is not considered an impact due to this road closure.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 12.5.3).

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-25c for the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in velocity above the flood impact objective targets for all events up to the 1% AEP in the Cattle Creek floodplain.

Other infrastructure

One unnamed local track is impacted by a maximum change in velocity of 25 per cent in the 2% AEP event and a change of 0.58 m/s in the 1% AEP event. Due to the proximity of this track to Project alignment, this track will be closed, and the proposed Project alignment constructed over the top of this track. Therefore, the identified increase in velocity is not considered an impact due to this road closure.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 12.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-25d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in hazard in the Cattle Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in hazard above the flood impact objective targets for all events up to the 1% AEP in the Cattle Creek floodplain.

Other infrastructure

One unnamed local track is impacted by a maximum change in hazard of 213 per cent (from 0.05 m²/s to 0.16 m²/s) in the 2% AEP event and a change of 176 per cent (from 0.08 m²/s to 0.21 m²/s) in the 1% AEP event. It is expected some change in hazard will occur across a length of 7.5 m in the 2% AEP and 15 m in the 1% AEP events. Due to the proximity of this track to Project alignment, this track will be closed, and the proposed Project alignment constructed over the top of this track. Therefore, the identified increase in hazard is not considered an impact due to this road closure.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 12.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-25e for the 1% AEP event.

Private land outside the Project permanent footprint

No lots have been identified to experience an increase in time of inundation above the flood impact objective targets for all events up to the 1% AEP event in the Cattle Creek floodplain.

Other infrastructure

One unnamed local track (two segments) is expected to be impacted by a maximum change in time of inundation of 2,707 per cent (0.05 hours to 1.51 hours) in the 2% AEP event and a change of 418 per cent (from 0.29 hours to 1.52 hours) in the 1% AEP event. It is expected some change in hazard will occur across a length of 12.5 m in the 2% AEP event and 17.5 m in the 1% AEP events for this unnamed track. Due to the proximity of this track to Project alignment, this track will be closed, and the proposed Project alignment constructed over the top of this track. Therefore, the identified increase in water level is not considered an impact due to this road closure.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 12.5.3).

Flood flow distribution

To determine the change in flow distribution velocity-depth product results were used to produce percentage change unit flow maps. Existing and developed flood results were used to calculate the percentage change in unit flow. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section or to determine the effective flow corridors within a floodplain.

Flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and is used to identify main channels (i.e. high flow zones), and shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the change in flow distribution for Cattle Creek and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

- ▶ For all events up to the 1% AEP flood, the hydraulic results demonstrate minimal impact to the existing flow patterns outside of the Project's permanent footprint.
- ▶ For the 1 in 2,000 AEP event, a minor reduction in unit flow is noted on the downstream side of the Project alignment.
- ▶ For the 1 in 10,000 AEP and PMF flood events, a unit flow increase is noted upstream of the alignment, and downstream of all cross-drainage structures (culvert 87.18 and C87.37). The increase in flow is a result of flood waters running parallel to the Project alignment due to limited overtopping/weir overflow.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises). Review of the modelled results and FIOs show there are no impacts from extreme event flooding on flood sensitive receptors within the Cattle Creek floodplain.

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. During these extreme events the Project alignment is inundated. Table 14-85 outlines the overtopping locations and estimated depths.

TABLE 14-85 CATTLE CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
87.18	C87.18	-	-	1.78
87.37	C87.37	-	0.18	1.09

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event, as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Cattle Creek catchment area is 23.9 per cent.

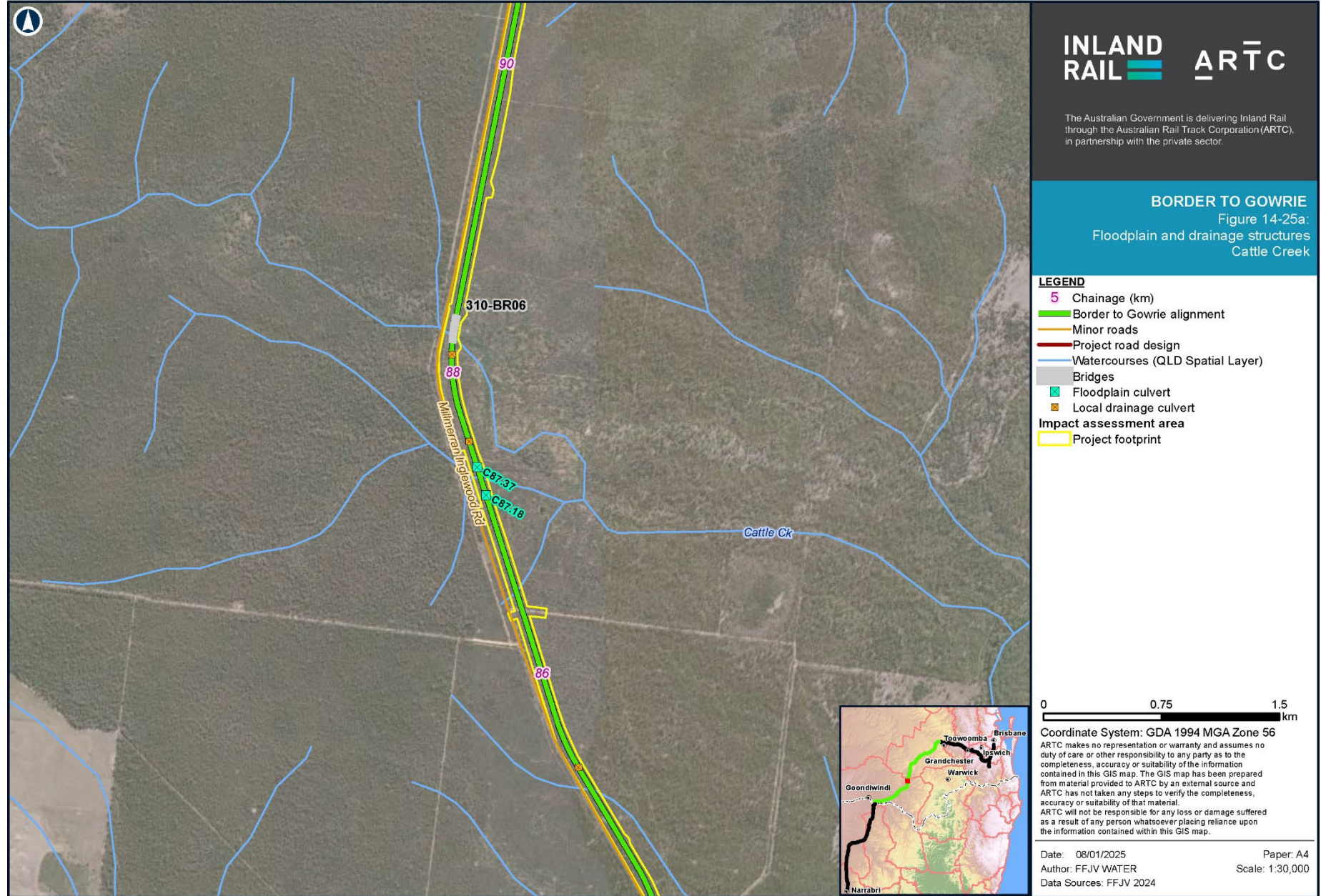
Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change. The inclusion of climate change slightly increases the change in peak water levels around the Project alignment. Climate change results in increased peak water levels of up to 0.3 m in the vicinity of the Project under the 1% AEP event.

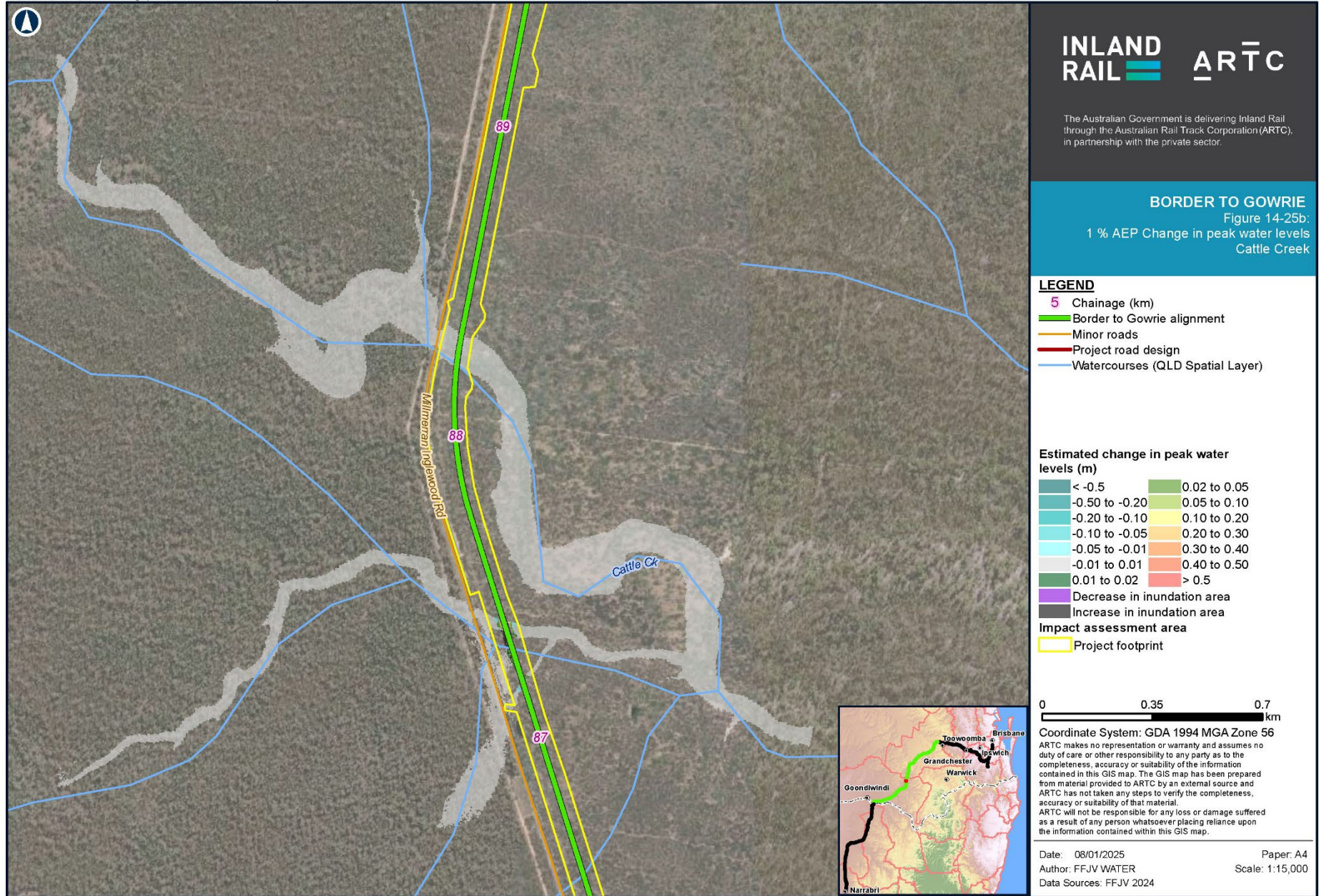
The Project formation level is higher than the 1% AEP climate change water levels. The climate change sensitivity result indicate there are no predicted changes in peak water levels at flood sensitive receptors in the Cattle Creek modelled floodplain for the 1% AEP climate change event. The downstream extents of these impacts are similar to those under the 1% AEP event.

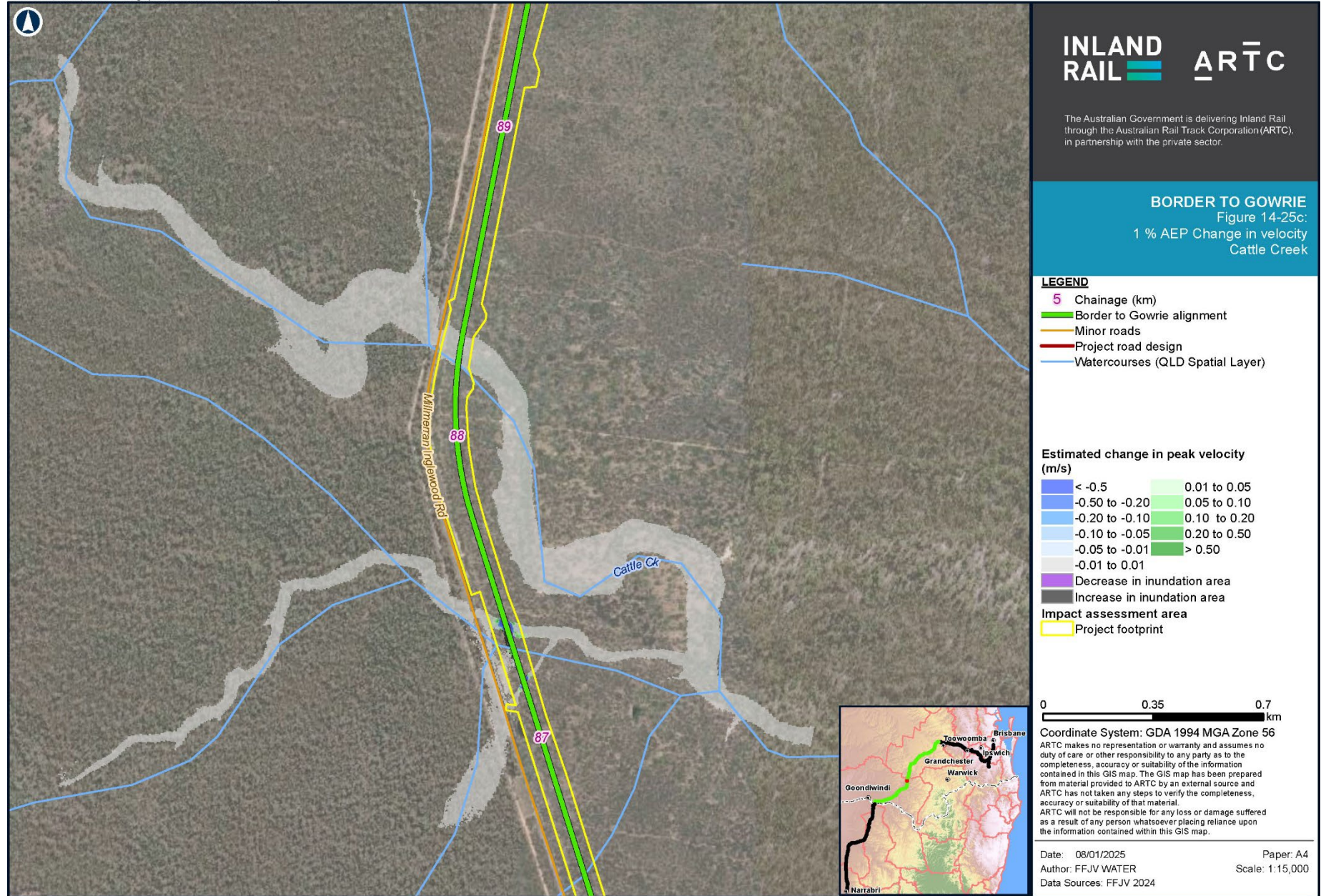
Blockage

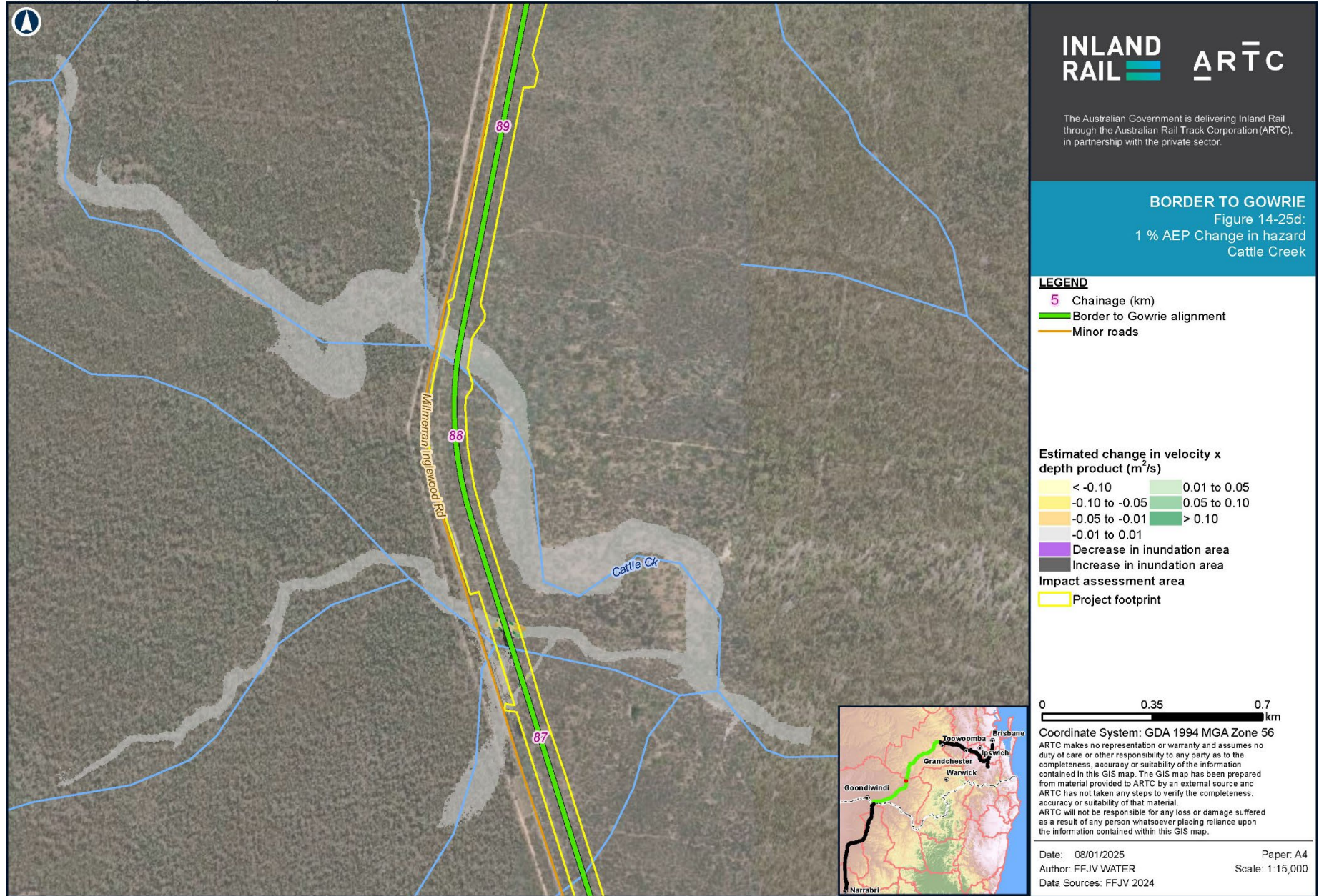
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

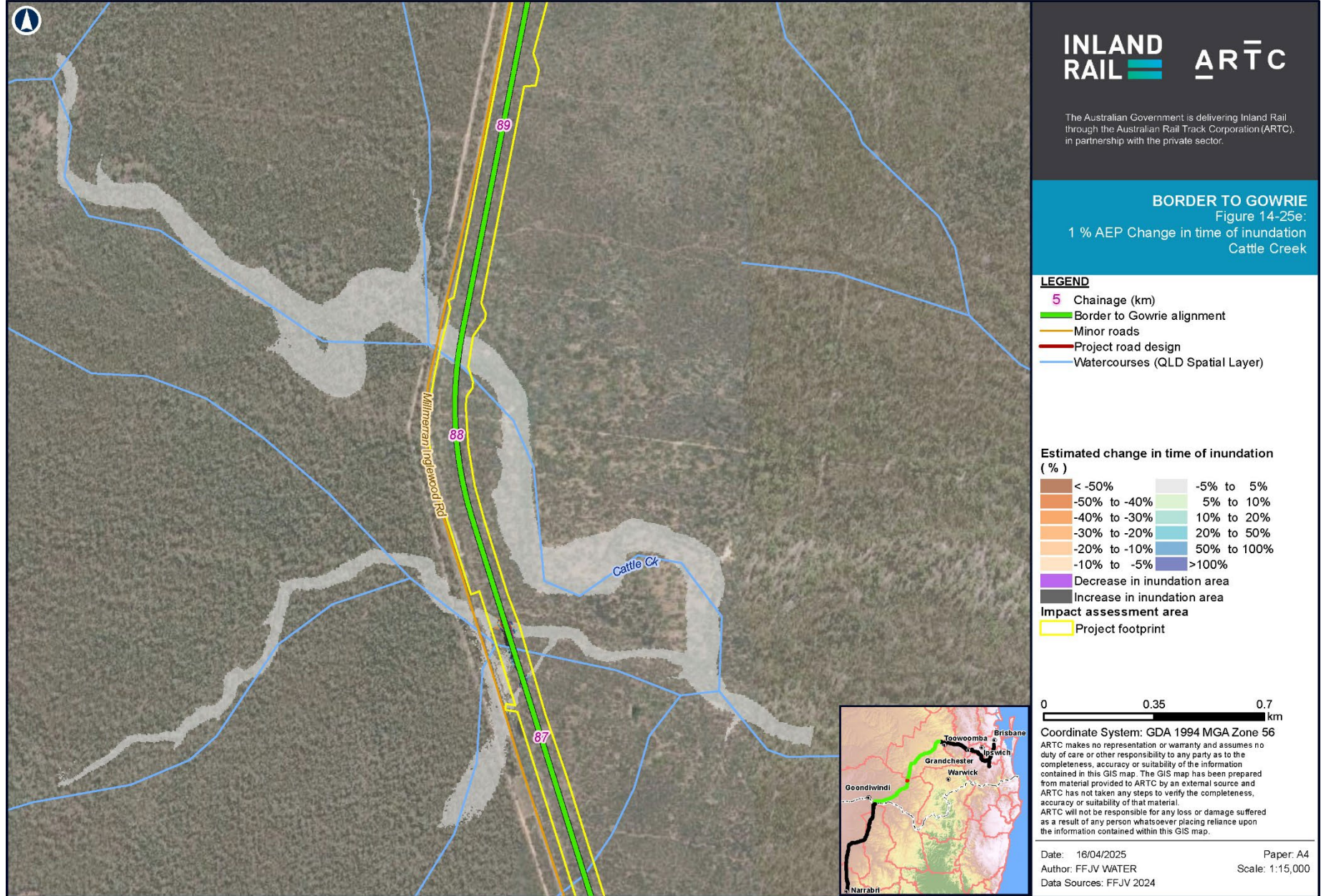
The blockage sensitivity results indicate there are no predicted changes in peak water levels at flood sensitive receptors for the 1% AEP 0 per cent and 50 per cent blockage scenarios in the Cattle Creek modelled floodplain.











14.8.1.2.10 Pariagara Creek

In the Pariagara Creek floodplain, the Project's revised reference design includes:

- ▶ One bridge
- ▶ Eighteen RCP locations (a total of 176 culvert cells)
- ▶ One RCBC locations (a total of eight culvert cells).

Details of the floodplain structures required to convey Pariagara Creek flood flows are presented in Table 14-86 and Table 14-87, with structure locations presented in Figure 14-26a. Figure 14-26a also presents the location of local catchment drainage structures.

TABLE 14-86 PARIAGARA CREEK: FLOODPLAIN STRUCTURE LOCATION AND DETAIL (BRIDGE)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
67.35	310-BR05	Bridge	285.31	345

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-87 PARIAGARA CREEK: FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
66.23	C66.23	RCBC	8	2.40 x 1.80
67.57	C67.57	RCP	8	1.20
67.64	C67.64	RCP	8	1.20
67.70	C67.70	RCP	8	1.20
67.83	C67.83	RCP	20	1.20
67.96	C67.96	RCP	20	1.20
68.09	C68.09	RCP	20	1.20
68.41	C68.41	RCP	20	1.20
68.76	C68.76	RCP	40	2.10
68.89	C68.89	RCP	2	1.20
69.02	C69.02	RCP	2	1.20
69.10	C69.10	RCP	2	1.20
69.14	C69.14	RCP	2	1.50
69.21	C69.21	RCP	2	1.80
69.28	C69.28	RCP	2	1.80
69.41	C69.41	RCP	5	1.80
69.54	C69.54	RCP	5	1.80
69.67	C69.67	RCP	5	1.80
69.80	C69.80	RCP	5	1.80

Table notes:

1. For RCP height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-26b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event meets the flood impact objective targets (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in peak water level in the Pariagara Creek floodplain for all modelled events up to the 1 in 2,000 AEP event.

Private land outside the Project permanent footprint

Potential change in peak water levels were identified for 15 lots within the Pariagara Creek floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 11 mm on Lot Plan 129MH95 to 0.90 m on Lot Plan 71MA3479. The large increases on Lot Plan 71MA3479 identified can be attributed to an increase in flood extent and newly flood-affected hydraulic model cells that impact an area of 0.75 ha (or less than 5.5 per cent of the total lot area). Ten of the 15 lots impacted by an increase in peak water levels can be attributed to an increase in flood extents and newly flood-affected model cells. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3.5) regarding these exceedances. A summary of peak water level changes on the 15 impacted lots is provided below:

- ▶ Eight lots were identified to be impacted by an increase in peak water level of between 0.5 m and 1 m (Section 14.8.1.2)
- ▶ Five lots were identified to be impacted by an increase in peak water level of between 0.1 m and 0.5 m
- ▶ Two lots were identified to be impacted by an increase in peak water level of less than 0.02 m.

Other infrastructure

One State-controlled road and eight local public roads (ten individual segments) are impacted by a change in peak water level. Millmerran-Inglewood Road is the only State-controlled road identified as being impacted by an increase in peak water levels, with a maximum change of 13 mm in the 5% AEP event. Approximately 30 m of Millmerran-Inglewood Road is expected to be impacted by some change in peak water levels due to the Project.

Of the eight local public roads (ten segments) impacted, an unnamed unsealed track shows the largest change in peak water levels of 228 mm in the 1% AEP event. Some degree of change in peak water levels is expected to occur across approximately 372.5 m. A summary of local public roads impacted by a change in peak water levels is detailed below:

- ▶ Four local roads experience change in peak water levels of greater than 100 mm
- ▶ Three local roads experience change in peak water levels of less than 100 mm
- ▶ One local road, Thornton Road, has three separate segments impacted with a varying degree of peak water level change. One segment experiences a peak change in water level of greater than 100 mm and two segments experience a peak change in water level of less than 100 mm.

No existing rail infrastructure have been identified to experience an increase in peak water level above the flood impact objective targets for all modelled events up to the 1% AEP event in the Pariagara Creek floodplain.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-26c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 15 lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 87MH16 experiences the largest increase in velocity of 2.08 m/s. Some order of change in velocity is expected to be experienced across 0.004 ha (less than 0.01 per cent of the total lot area) and can be attributed to a change in flood inundation extent and a newly flood-affected hydraulic model cell.

Nine of the 15 lots that experience a change in velocity above flood impact objective targets, experience both a percentage increase as well as an 'absolute' increase. It should be noted, six of the identified lots to experience a change in velocity have similar results and area to other lots identified, but differing Lot Plan numbers and land use. These lots need to be furthered investigated through consultation with landowners to confirm the correct Lot Plan numbers and end land use. A summary of peak velocity changes on the 15 impacted lots is provided below:

- ▶ Two lots experience an increase in peak velocity greater than 1.0 m/s
- ▶ Five lots experience an increase in peak velocity of between 0.5 m/s and 1.0 m/s
- ▶ Six lots experience an increase in peak velocity of less than 0.5 m/s
- ▶ Two lots experience only a percentage change in peak velocity of less than 72 per cent.

Other infrastructure

No State-controlled roads have been identified to experience a change in velocity due the presence of the Project.

Six local roads (eight segments) have been identified to experience a change in velocity due to the Project alignment. Thornton Road experiences velocity increases across three separate segments with the largest increase in velocity of 0.84 m/s (in the 2% AEP event) and a maximum percentage change of 122 per cent (in the 5% AEP event). Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3.3) regarding these exceedances.

A summary of peak velocity changes on the eight segments of the six local public roads is provided below:

- ▶ One local road experiences a change in velocity of greater than 0.5 m/s
- ▶ One local road experiences a change in velocity of between 0.1 m/s and 0.5 m/s
- ▶ Two local roads experience a change in velocity of between 0.05 m/s and 0.1 m/s
- ▶ Two local roads experience a change in velocity of less than 0.05 m/s.

No existing rail infrastructure have been identified to experience an increase in peak velocity above the flood impact objective targets for all modelled events up to the 1% AEP event in the Pariagara Creek floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities or a velocity exceedance above the flood impact objective target was identified for the particular soil type for each location, which was identified from published soil mapping.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-26d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Pariagara Creek floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of 12 lots were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Exceedances can be attributed to increased flow velocities and flood depths. The maximum increase for flood hazard is approximately 2,495 per cent increase (approximately 0.35 m²/s change from 0.01 m²/s to 0.37 m²/s) in the 1% AEP event on Lot Plan 87MH16. Some change in hazard is expected to occur across a total area of 0.05 ha on this lot in the 1% AEP event. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3.5) regarding these exceedances. A summary of peak hazard changes on the 12 lots impacted by a change in hazard is provided below:

- ▶ One lot experiences an increase in hazard of greater than 1,000 per cent
- ▶ Six lots experience an increase in hazard of 100 per cent to 500 per cent
- ▶ Two lots experience an increase in hazard of 50 per cent to 100 per cent
- ▶ Three lots experience an increase in hazard of less than 50 per cent.

Other infrastructure

No State-controlled roads have been identified to experience a change in hazard due the presence of the Project.

Five local roads (seven segments) have been identified to experience a change in hazard due to the Project alignment. One unnamed track experiences the largest increase in hazard of 125% (from 0.09 m²/s to 0.21 m²/s) in the 1% AEP event. A summary of peak hazard changes on the seven segments is provided below:

- ▶ One segment experiences a change in hazard of greater than 100 per cent
- ▶ One segment experiences a change in hazard of between 50 per cent and 100 per cent
- ▶ Two segments experience a change in hazard of between 20 per cent and 50 per cent
- ▶ Three segments experience a change in hazard of less than 20 per cent.

No existing rail infrastructure have been identified to experience an increase in peak hazard above the flood impact objective targets for all modelled events up to the 1% AEP event in the Pariagara Creek floodplain.

Figures showing the change in hazard presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3).

Change to time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-26e for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 25 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 87MH16 has been identified as experiencing the largest percentage increase in time of inundation of 455 per cent (increasing from 1.01 hours in the Existing Case to 5.62 hours in the Developed Case) in the 5% AEP event and an 'absolute' change of 9.08 hours in the 2% AEP event.

The large 'absolute' change can be attributed to a flood extent increase and a newly flood-affected hydraulic model cell. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3.5) regarding these exceedances.

A summary of peak time of inundation changes on the 25 lots is provided below:

- ▶ Nine lots experience a change in time of inundation of between 200 per cent and 500 per cent
- ▶ Four lots experience a change in time of inundation of 100 per cent and 200 per cent
- ▶ Five lots experience a change in time of inundation of 50 per cent and 100 per cent
- ▶ Seven lots experience a change in time of inundation of less than 50 per cent.

Other infrastructure

A total of 11 roads (State-controlled roads and local roads) are impacted by a change in time of inundation. One State-controlled road, Millmerran-Inglewood Road, experiences a maximum change in time of inundation of 70 per cent (increasing from 0.66 hours to 1.12 hours) with some degree of change expected on 5 m of the road. It should be noted the time of inundation of this segment of road is 5.48 hours in the Existing Case and, therefore, the above impact is considered negligible as the road is already submerged.

Nine local public roads (ten segments) are impacted by an increase in time of inundation for all modelled events up to the 1% AEP event. Sandy Creek Boundary Road experiences the largest increase in time of inundation of 194.2 per cent in the 5% AEP event. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Sections 13.5.3.2 and 13.5.3.3) regarding these exceedances.

A summary of peak time of inundation changes on the nine local roads is provided below:

- ▶ Three segments experience a change in time of inundation of greater than 100 per cent
- ▶ Four segments experience a change in time of inundation of between 50 per cent and 100 per cent
- ▶ Two segments experience a change in time of inundation of between 10 per cent and 20 per cent.

No existing rail infrastructure have been identified to experience an increase in peak time of inundation above the flood impact objective targets for all modelled events up to the 1% AEP event in the Pariagara Creek floodplain.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 13.5.3).

Flood flow distribution

To determine the change in flow distribution maximum velocity-depth modelling results were used to produce change in unit flow maps between Existing Case and Developed Case conditions. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section, or to determine the effective flow corridors within a floodplain.

The presented flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to assist in identifying main channels (i.e. high flow zones) from shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the potential change in flow distribution for the Pariagara Creek floodplain and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

- ▶ For all modelled events the results show increases and decreases in flow distribution upstream and downstream of the Project alignment, respectively.
- ▶ For events up to the 1% AEP, the majority of these changes occur in lower flow zones (<0.15 m³/s), resulting in a reduced flood risk.

- ▶ In the rarer events (1 in 2,000 AEP, 1 in 10,000 AEP and PMF events) a reduction in flow distribution can be seen on the downstream side of the Project alignment and positive change on the upstream side. Due to the presence of the Project alignment, flows are conveyed along the alignment to the west through the proposed bridge opening 310-BR05. This results in a positive change in flow distribution in the western portion of the Pariagara Creek floodplain.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project, and may include further refinement of the bridge abutments, culvert skews, and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

No increases in peak water levels greater than 10 mm at flood sensitive receptors for these extreme events are expected in the Pariagara Creek modelled floodplain. The risk of overtopping along the Project alignment has been assessed at each structure for the modelled extreme events. During these extreme events, the Project alignment is inundated at several locations. Table 14-88 outlines the overtopping locations and depths.

TABLE 14-88 PARIAGARA CREEK: PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
67.55	310-BR05	-	-	1.19
66.23	C66.23	-	-	0.25
67.57	C67.57	-	-	0.69
67.64	C67.64	-	-	0.60
67.70	C67.70	-	-	0.81
67.83	C67.83	-	-	0.92
67.96	C67.96	-	-	0.97
68.09	C68.09	-	-	0.79
68.41	C68.41	-	-	0.73
68.76	C68.76	-	-	0.84
68.89	C68.89	-	-	0.84
69.02	C69.02	-	-	0.99
69.10	C69.10	-	-	0.87
69.14	C69.14	-	-	1.00
69.21	C69.21	-	-	0.92
69.28	C69.28	-	-	0.99

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event, as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Pariagara Creek catchment area is 23.9 per cent.

Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change.

Due to no flood sensitive receptors being present with the hydraulic model domain, Table 14-89 outlines structures performance with Representative Concentration Pathways 8.5 climate change.

TABLE 14-89 PARIAGARA CREEK: SUMMARY OF CLIMATE CHANGE IMPACTS AT STRUCTURES

Structure ID	Structure type	1% AEP climate change event	
		Peak water level (m AHD)	Change in peak water level (mm)
C66.23	RCBC	285.61	+261
310-BR05	Bridge	285.50	+250
C67.57	RCP	285.58	+234
C67.64	RCP	285.67	+227
C67.70	RCP	285.73	+239
C67.83	RCP	285.83	+233
C67.96	RCP	285.93	+242
C68.09	RCP	286.04	+264
C68.41	RCP	286.59	+177
C68.76	RCP	287.12	+130
C68.89	RCP	287.28	+173
C69.02	RCP	287.44	+192
C69.10	RCP	287.48	+199
C69.14	RCP	287.51	+204
C69.21	RCP	287.54	+208
C69.28	RCP	287.55	+211
C69.41	RCP	287.57	+217
C69.54	RCP	287.58	+223
C69.67	RCP	287.60	+227
C69.80	RCP	287.61	+229

The downstream extents of these impacts are similar to those under the 1% AEP event.

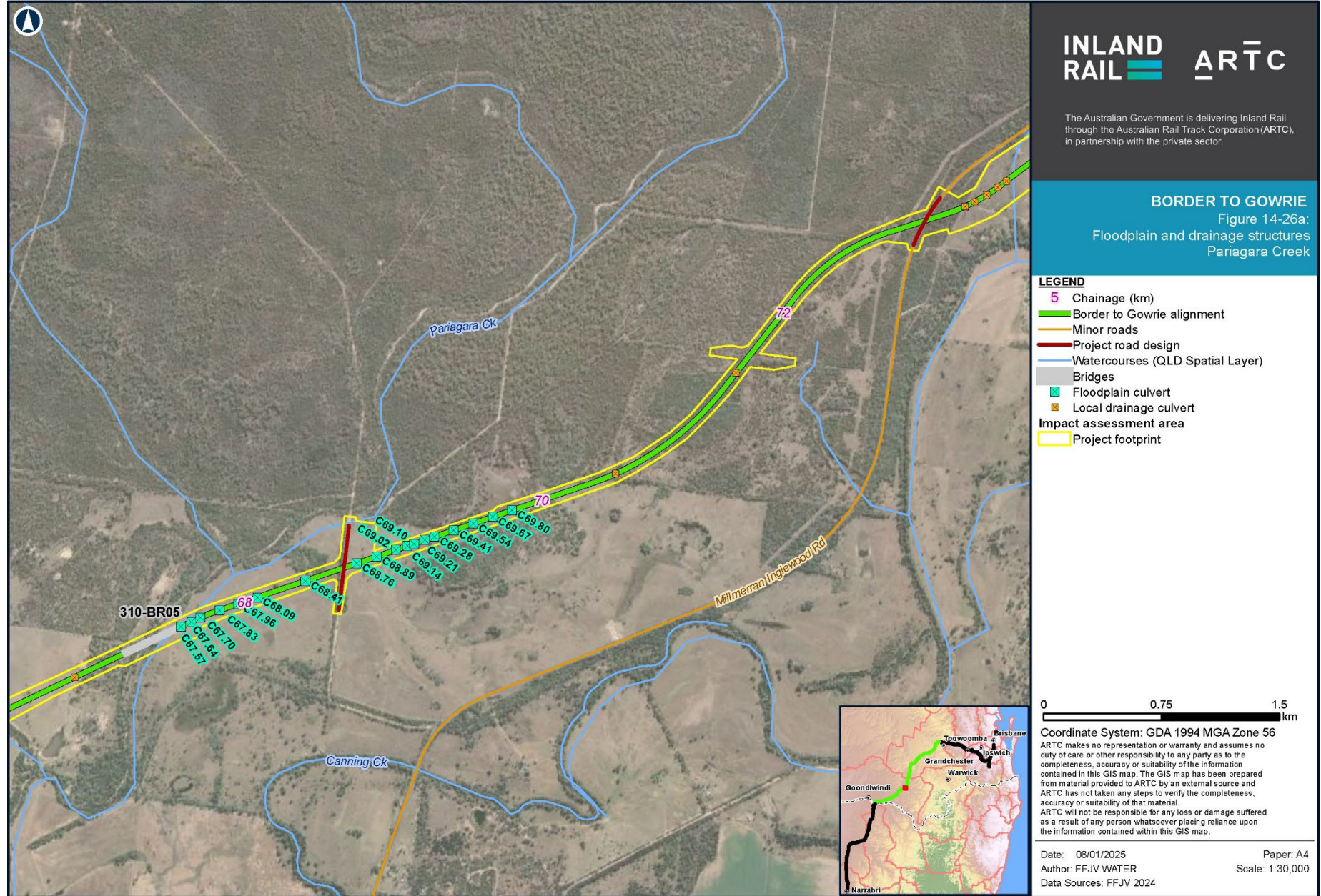
Blockage

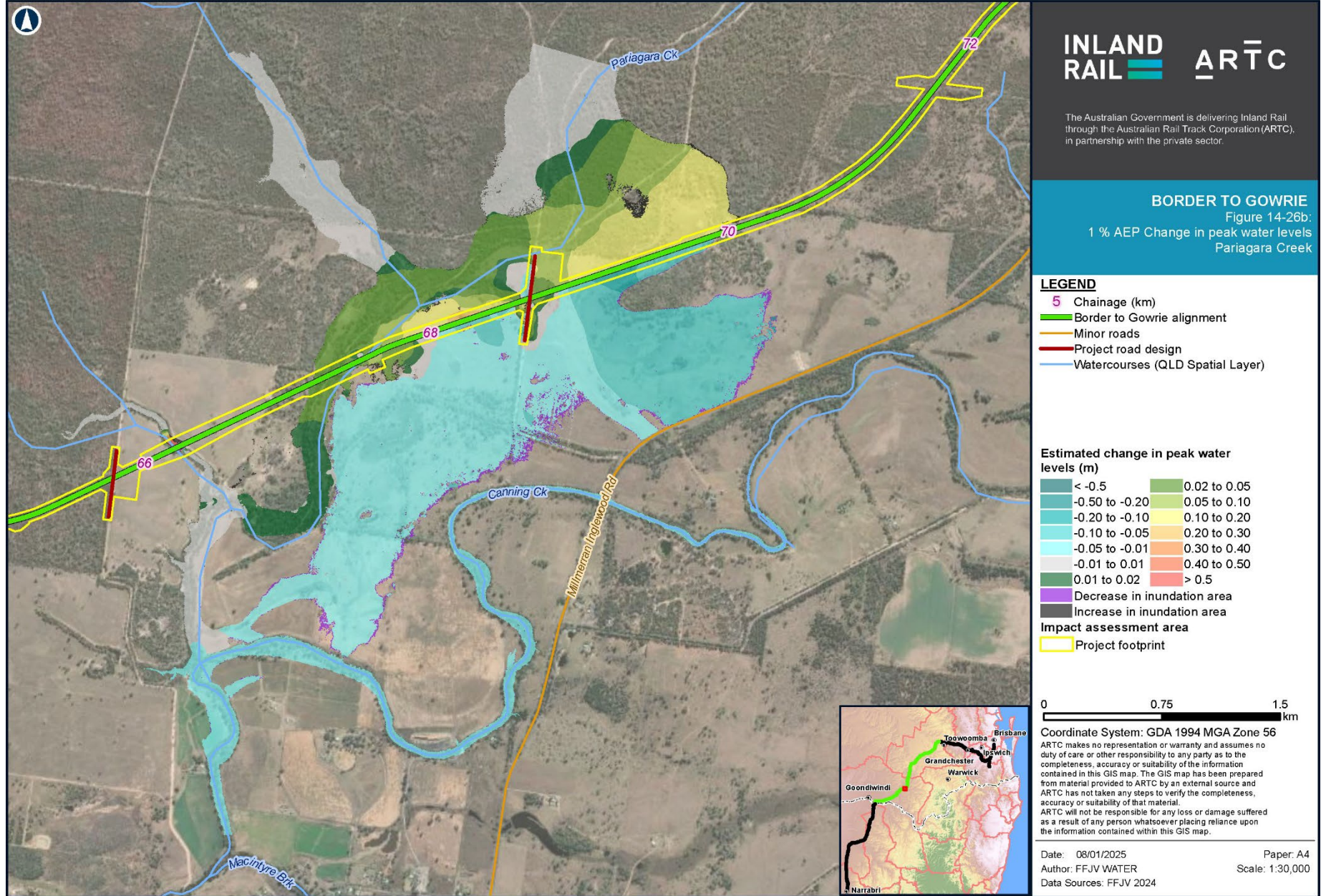
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

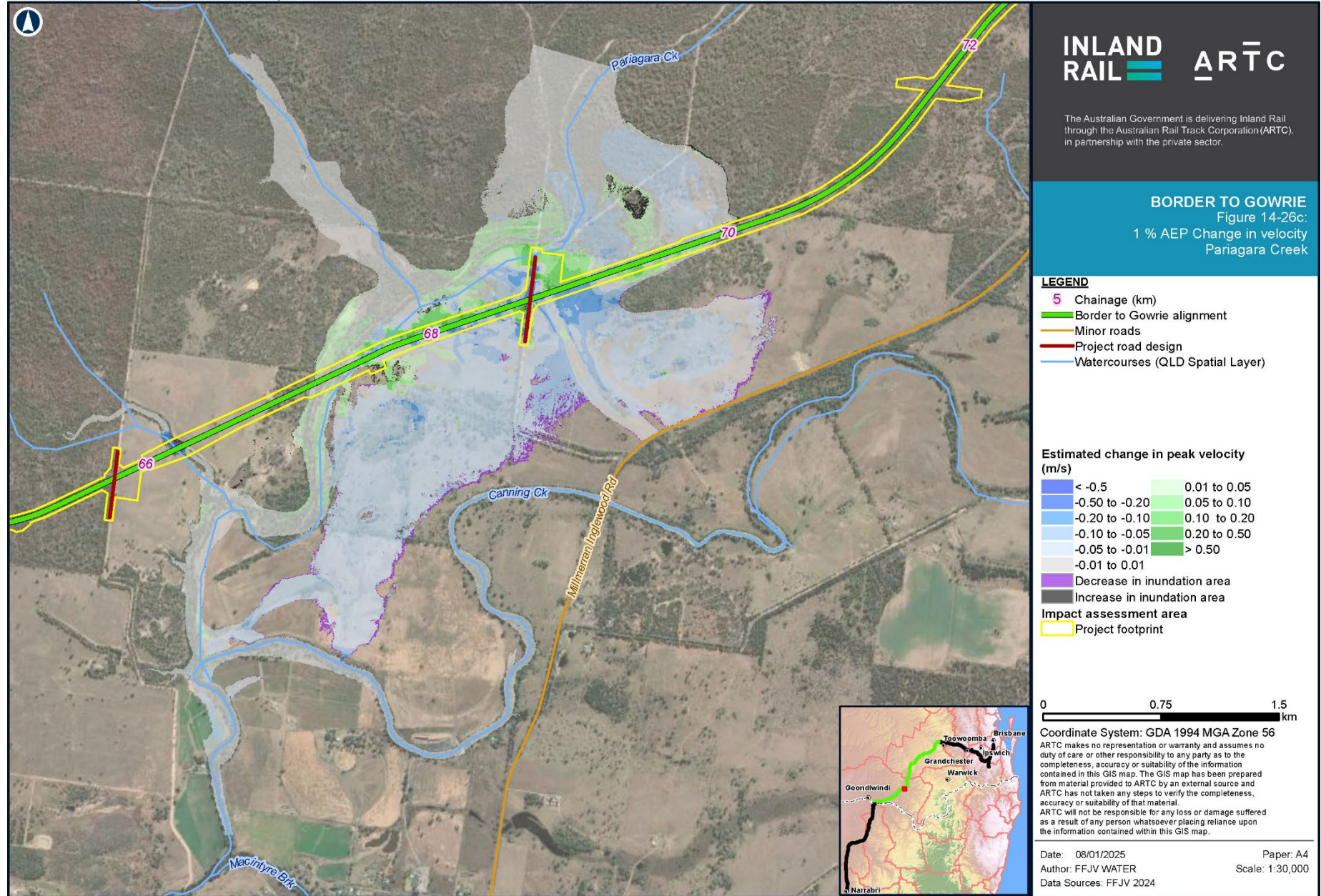
Due to no flood sensitive receptors being present with the hydraulic model domain, a sensitivity analysis was only completed on structures performance. Table 14-90 outlines the changes in peak water levels at structures for the 50 per cent blockage scenario (1% AEP).

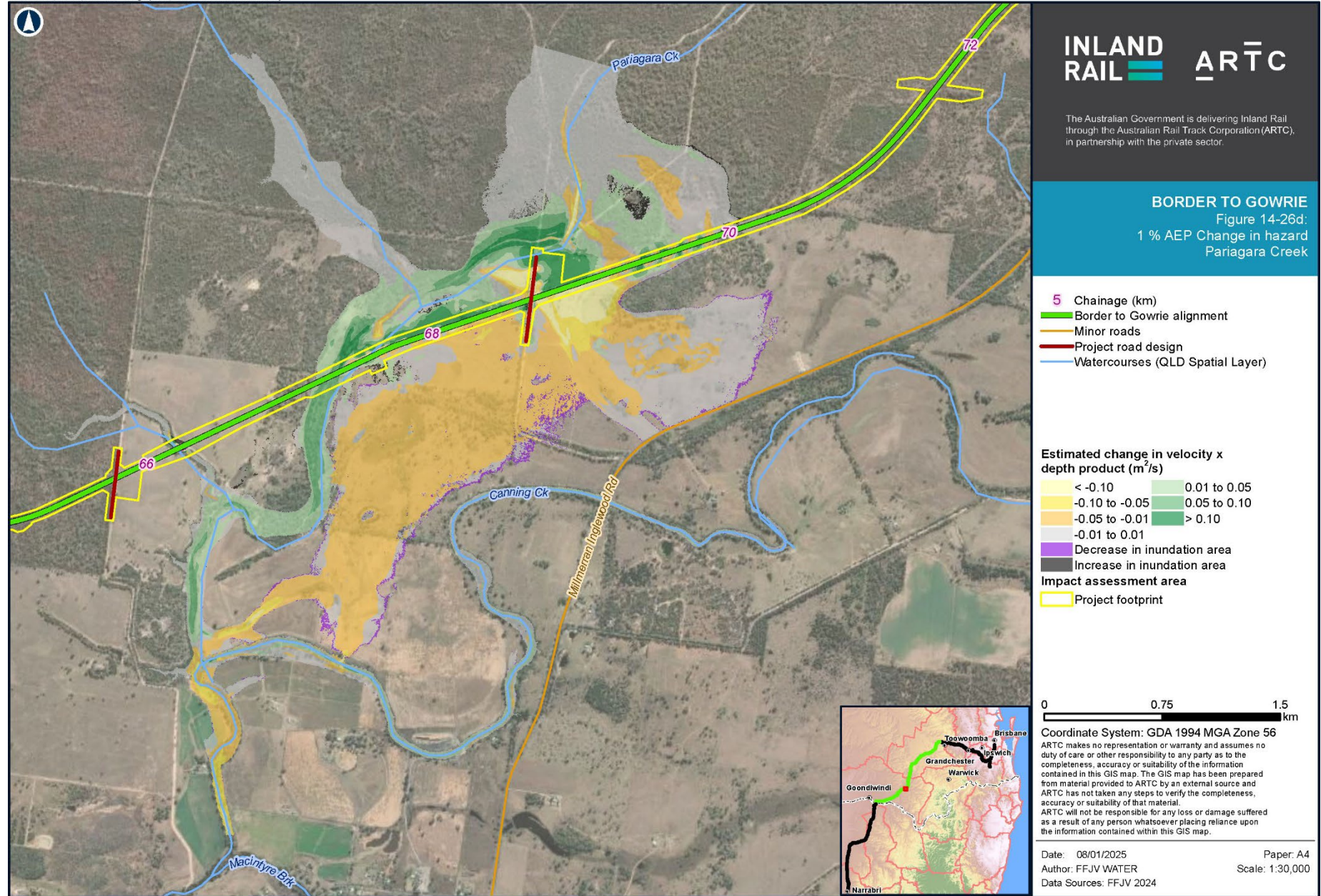
TABLE 14-90 PARIAGARA CREEK: SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT STRUCTURES (1% AEP)

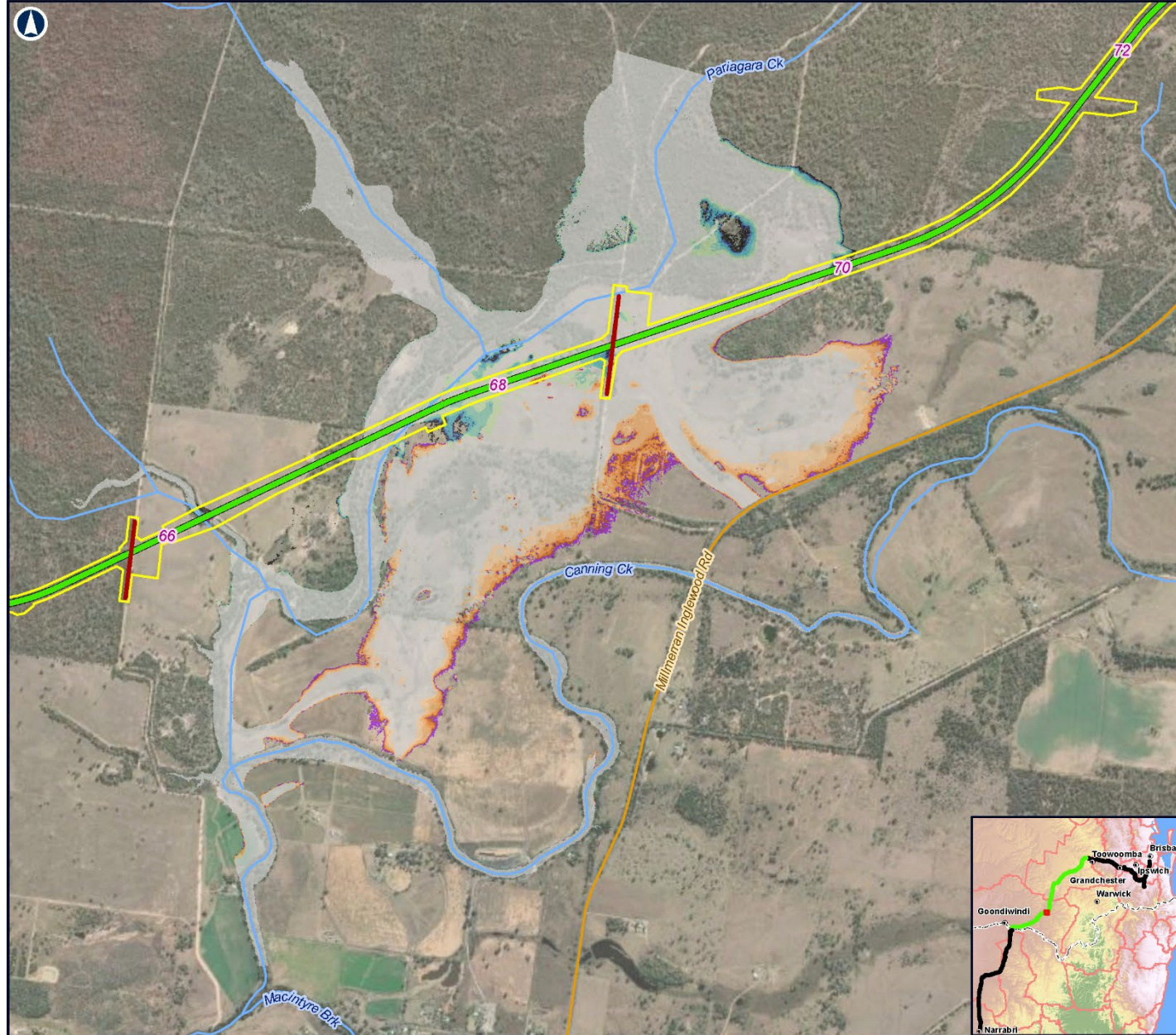
Structure ID	Structure type	50% blockage peak water level (m AHD)	Change in peak water level (mm)
C66.23	RCBC	285.92	+0.57
C67.57	RCP	287.13	+0.02
C67.64	RCP	285.35	+0.00
C67.70	RCP	285.45	+0.00
C67.83	RCP	285.50	+0.01
C67.96	RCP	285.61	+0.01
C68.09	RCP	285.70	+0.02
C68.41	RCP	285.80	+0.02
C68.76	RCP	287.00	+0.01
C68.89	RCP	287.13	+0.02
C69.02	RCP	287.27	+0.02
C69.10	RCP	287.31	+0.03
C69.14	RCP	287.34	+0.03
C69.21	RCP	287.36	+0.03
C69.28	RCP	287.37	+0.03
C69.41	RCP	287.38	+0.03
C69.54	RCP	287.40	+0.03
C69.67	RCP	287.41	+0.03
C69.80	RCP	287.42	+0.03











INLAND RAIL

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

BORDER TO GOWRIE

Figure 14-26e:
1 % AEP Change in time of inundation
Pariagara Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Project road design
- Watercourses (QLD Spatial Layer)

Estimated change in time of inundation (%)

- < -50%
- 50% to -40%
- 40% to -30%
- 30% to -20%
- 20% to -10%
- 10% to -5%
- 5% to 5%
- 5% to 10%
- 10% to 20%
- 20% to 50%
- 50% to 100%
- >100%
- Decrease in inundation area
- Increase in inundation area
- Impact assessment area
- Project footprint

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER
Data Sources: FFJV 2024

Paper: A4
Scale: 1:30,000

14.8.1.2.11 Macintyre Brook (Yelarbon to Inglewood)

The Project includes a section of the corridor running through Yelarbon. The design standard for the Project includes having a flood immunity of a 1% AEP flood event; to achieve this, the rail will be raised from the existing height. In this area, there are several waterway catchments that have potential to be affected by the raised alignment during flood events. The potential for changes in peak water levels from raising the rail embankment through Yelarbon, to provide flood immunity, is a key issue due to the large number and proximity of flood sensitive receptors to the Project alignment in Yelarbon that have the potential to be affected by changes in peak water levels. The flood-impact assessment has considered existing flooding, developed flood impacts and potential mitigation options.

Using a traditional approach (i.e. additional cross-drainage culverts) was not considered suitable through Yelarbon due to the cover requirements and interaction of the structures with the GrainCorp site. An assessment of the flows at Yelarbon was undertaken to determine the dominant flows for design consideration. Yelarbon experiences flooding from three main catchments: Macintyre Brook and Kippenbung Creek from the south, and Brigalow Creek from the north. The Brigalow Creek and Macintyre Brook flows have been considered in the flood assessment. The Macintyre Brook flows are larger than Kippenbung Creek and are expected to provide a worst-case assessment; therefore, the Kippenbung Creek catchment flows were not incorporated in the assessment.

The four key factors involved in mitigating the flooding impacts by the Project's revised reference design at Yelarbon are:

- ▶ Height of levee
- ▶ Extent of levee
- ▶ Location of levee
- ▶ Number of cross-drainage structures.

Several mitigation options involving different arrangements of the above factors were investigated. The flood mitigation assessment predicted that the most effective mitigation measure options include both raising of the existing town levee, to direct flow away from Yelarbon, combined with cross-drainage culverts (excluding the GrainCorp Silos section) to balance the flood across the rail.

A number of different levee extents and heights were assessed. The two extents that were investigated were 1.3 km (east levee only) and 1.8 km (east and west levee connected). For these two extents, raises between 200 mm and a 'Glass Wall Raise' of approximately 1.5 m were investigated. The investigation focused on the 1% AEP impacts to the Yelarbon Township and the trafficability of the Cunningham Highway, but also considered reducing impacts under more frequent events. The proposed levee extent and raise height is outlined in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

Additional works are proposed to the Cunningham Highway to tie in with the proposed levee where it crosses the highway and so that proposed flooding conditions remain consistent with existing conditions at the Cunningham Highway. The existing cross-drainage structure through the Cunningham Highway at Yelarbon will be maintained in the proposed works.

Proposed cross-drainage

In the Macintyre Brook floodplain, the Project's revised reference design includes:

- ▶ Two bridges across minor tributaries of the Macintyre Brook (at Bybera Road and Cremascos Road)
- ▶ 23 RCP locations (a total of 563 culvert cells)
- ▶ 13 RCBC locations (a total of 174 culvert cells).

Noise barriers were incorporated into the hydraulic model through Yelarbon from approximately Wondalli Street to the west and East Sawmill Street to the east of town. The noise barriers have been hydraulically modelled as impermeable barriers 4 m high on the top of the formation.

Details of the floodplain structures required to convey Macintyre Brook flood flows are presented in Table 14-91 and Table 14-92, with structure locations presented in Figure 14-27a. Figure 14-27a also presents the location of local catchment drainage structures.

TABLE 14-91 MACINTYRE BROOK (YELARBON TO INGLEWOOD): FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)²

Approximate chainage (km)	Bridge design ID1	Structure name	Soffit level (m AHD)	Bridge length (m)
55.45	310-BR04	Bridge at Bybera Road	286.96	207
52.48	310-BR03	Bridge at Cremascos Road	276.02	207

Table notes:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

2. Separate localised flood models were developed to determine required bridge sizes at Bybera Road and Cremascos Road

TABLE 14-92 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—FLOODPLAIN STRUCTURE DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
25.19	C25.19	RCBC	6	1.20 x 0.60
25.46	C25.46	RCP	21	0.90
25.50	C25.50	RCBC	8	2.40 x 0.90
25.80	C25.80	RCBC	24	2.40 x 0.90
25.87	C25.87	RCBC	24	2.40 x 0.90
25.95	C25.95	RCBC	1	3.00 x 0.50
25.97	C25.97	RCBC	1	3.00 x 0.50
26.05	C26.05	RCBC	1	1.20 x 0.30
27.05	C27.05	RCBC	15	1.50 x 1.20
27.15	C27.15	RCBC	15	1.50 x 1.20
27.24	C27.24	RCBC	25	1.50 x 1.20
27.33	C27.33	RCBC	25	1.50 x 1.20
27.42	C27.42	RCBC	20	1.50 x 1.20
42.87	C42.87	RCP	15	0.90
43.02	C43.02	RCP	15	1.20
43.09	C43.09	RCP	30	1.20
43.16	C43.16	RCBC	9	3.00 x 1.80
43.35	C43.35	RCP	45	1.20
43.56	C43.56	RCP	10	1.20
43.66	C43.66	RCP	15	1.20
43.77	C43.77	RCP	15	1.20
43.86	C43.86	RCP	15	1.20
43.97	C43.97	RCP	15	1.20
44.32	C44.32	RCP	15	1.20
44.67	C44.67	RCP	15	1.20
44.78	C44.78	RCP	30	0.90
44.88	C44.88	RCP	30	0.90
44.96	C44.96	RCP	15	0.90
45.01	C45.01	RCP	35	0.90
45.10	C45.10	RCP	30	0.90
45.24	C45.24	RCP	35	0.90
45.30	C45.30	RCP	35	0.90
45.40	C45.40	RCP	40	0.90
45.45	C45.45	RCP	40	0.90
45.53	C45.53	RCP	40	0.90
45.64	C45.64	RCP	7	0.90

Table notes:

1. For RCP, height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

Change in peak water levels

Figure 14-27b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events).

Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event meet the flood impact objective targets (Section 14.6.3.3).

Flood impacts at sensitive receptors

Table 14-93 presents the change in peak water levels up to the 1 in 2,000 AEP event where the change in peak water levels lie outside the FIOs.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the FIOs (Section 14.6.3.3).

TABLE 14-93 MACINTYRE BROOK (YELARBON TO INGLEWOOD): CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Flood sensitive receptor ID	Flood sensitive receptor type	Approximate chainage (km)	FIOs up to the 1% AEP event	FIOs up to the 1 in 2,000 AEP event	Maximum increase in peak water level up to the 1% AEP event (mm)	Maximum increase in peak water level up to the 1 in 2,000 AEP event (mm)
MCB_ID_241	House	26.2	< 10 mm	<250 mm	+20	-
MCB_ID_242	House	26.2	< 10 mm	<250 mm	+2 ¹	-
MCB_ID_243	House	26.2	< 10 mm	<250 mm	+99	-
MCB_ID_278	House	26.1	< 10 mm	<250 mm	+20	-
MCB_ID_420	House	26.1	< 10 mm	<250 mm	+31	-
MCB_ID_426	House	26.1	< 10 mm	<250 mm	+17	-
MCB_ID_469	House	26.2	< 10 mm	<250 mm	+1 ¹	-
MCB_ID_507	House	25.8	< 10 mm	<250 mm	+36 ¹	-
MCB_ID_508	Shed	25.8	<100 mm	<250 mm	+18 ¹	-
MCB_ID_509	House	25.8	< 10 mm	<250 mm	+28	-
MCB_ID_510	House	25.8	< 10 mm	<250 mm	+29	-
MCB_ID_519	Shed	25.8	<100 mm	<250 mm	-	+103 ¹
MCB_ID_583	Shed	17.2	<100 mm	<250 mm	-	+548
MCB_ID_584	House	15.3	< 10 mm	<250 mm	-	+548
MCB_ID_585	Shed	15.3	<100 mm	<250 mm	-	+512
MCB_ID_586	Shed	15.3	<100 mm	<250 mm	-	+480
MCB_ID_587	Shed	15.3	<100 mm	<250 mm	-	+398
MCB_ID_588	Shed	15.3	<100 mm	<250 mm	-	+421
MCB_ID_604	House	28.2	< 10 mm	<250 mm	+13	-

Table note:

1 Newly flood-affected flood sensitive receptor in the Developed Case, 1% AEP climate change event

Private land outside the Project permanent footprint

Potential changes in peak water level were identified for 61 lots within the Macintyre Brook floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 17 mm on Lot Plan 2Y56919 (in the 5% AEP event) to 483 mm on Lot Plan 021G6771 in the 1 in 2,000 AEP event. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4.5) regarding these exceedances.

32 of the 61 lots impacted by an increase in peak water levels are identified to only exceed in the 1 in 2,000 AEP event due to the land use criteria of Vacant–Large House site which has had a maximum change in peak water level target of 250 mm applied. The flood impact objective target of 250 mm afflux in the 1 in 2,000 AEP event applies to ‘existing habitable dwellings’. A review of aerial imagery does not show any existing dwellings on this lot, but the conservative approach of applying the 250 mm target on these lots has been taken due to the future potential of the lot being developed. Further justification of the exceedance is provided below. These generally experience an increase in peak water level of between 100 mm to 500 mm. A summary of peak water level changes on the 61 impacted lots is provided below:

- ▶ 46 lots recorded an increase in peak water level of between 100 mm and 500 mm
- ▶ Three lots recorded an increase in peak water level of between 50 mm and 100 mm
- ▶ 12 lots recorded an increase in peak water level of between 10 mm and 50 mm.

Other infrastructure

A total of five State-controlled roads (15 individual segments) and 23 local public roads (33 individual segments) are impacted by a change in peak water level. Of the State-controlled roads impacted Wondalli Street has been identified as experiencing the largest increase in peak water levels of 636 mm in the 1% AEP event. This portion of road is subject to a change in design due to the Project and therefore exceedances will be investigated further during detailed design stage to mitigate these. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Sections 14.5.4.2 and 14.5.4.3) regarding these exceedances.

A summary of the five impacted State-controlled roads is below:

- ▶ Taloom Street experiences a maximum change in peak water level of 487 mm in the 2% AEP event
- ▶ Wondalli Street experiences a maximum change in peak water level of 636 mm in the 1% AEP event
- ▶ The Cunningham Highway experiences a maximum change in peak water level of 280 mm in the 1% AEP event
- ▶ Yelarbon-Keetah Road experiences a maximum change in peak water level of 306 mm in the 1% AEP event
- ▶ Kildonan Road experiences a maximum change in peak water level of 199 mm in the 1% AEP event.

Of the 23 local public roads (33 segments) impacted, Railway Parade shows the largest change in peak water level of 607 mm in the 1% AEP event. A summary of local public roads impacted by a change in peak water levels is detailed below:

- ▶ One local road experiences a change in peak water level of between 500 mm and 600 mm
- ▶ One local road experiences a change in peak water level of between 300 mm and 500 mm
- ▶ Seven local roads experience a change in peak water level of between 100 mm and 300 mm
- ▶ Six local roads experience a change in peak water level of between 50 mm and 100 mm
- ▶ Eight local roads experience a change in peak water level of between 10 mm and 50 mm.

Three existing rail lines (seven segments) experience a change in peak water level, with the Toowoomba to Thallon segment experiencing a change of 352 mm in the 5% AEP event.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-27c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 28 lots were identified as being impacted to by a change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 60MA3454 experiences the largest increase in velocity of 1.29 m/s. Lot Plan 11RP226715 experiences the largest percentage change in velocity of 49 per cent in the 1% AEP event (increasing from 0.51 m/s to 0.76 m/s). Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4.5) regarding these exceedances.

A summary of peak velocity changes on the 28 impacted lots is provided below:

- ▶ One lot experiences an increase in peak velocity greater than 1.0 m/s
- ▶ One lot experiences an increase in peak velocity of 0.5 m/s to 1.0 m/s
- ▶ Eight lots experience an increase in peak velocity of between 0.1 m/s and 0.5 m/s
- ▶ Seventeen lots experience an increase in peak velocity of less than 0.1 m/s
- ▶ One lot only experiences a maximum percentage increase of less than 50 per cent.

Other infrastructure

No State-controlled roads have been identified to experience a change in velocity due the presence of the Project.

Five local roads (eight segments) (Thorton Road and five unnamed roads) have been identified to experience a change in velocity due to the Project alignment. An unnamed road experiences the largest change in velocity of 0.52 m/s in the 2% AEP increasing from 0.15 m/s to 0.67 m/s. A summary of peak velocity changes on the five local public roads is provided below:

- ▶ One local road experiences an increase in peak velocity greater than 0.5 m/s
- ▶ Two local roads experience an increase in peak velocity of between 0.1 m/s and 0.5 m/s
- ▶ Two local roads experience an increase in peak velocity of less than 0.1 m/s.

Two segments of existing rail infrastructure are impacted by an increase in peak velocity, with the Toowoomba to Thallon segment experiencing the largest change of 18.79 per cent and 0.09 m/s.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-27d for the 1% AEP event.

Flood impacts at sensitive receptors

Table 14-94 presents the change in peak hazard up to the 1% AEP event where the change in peak hazard lies outside the FIOs.

TABLE 14-94 MACINTYRE BROOK (YELARBON TO INGLEWOOD): CHANGE IN HAZARD OUTSIDE FLOOD IMPACT OBJECTIVES

Flood sensitive receptor ID	Flood sensitive receptor type	Approximate chainage (km)	FIOs up to the 1% AEP event	Maximum increase in peak hazard up to the 1% AEP event (%)
MCB_ID_505	Shed	25.8	< 10%	+15
MCB_ID_511	Shed	26.8	< 10%	+18

Private land outside the Project permanent footprint

A total of 28 lots were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. The maximum increase for flood hazard is approximately 226 per cent (0.12 m²/s change from 0.05 m²/s to 0.17 m²/s) in the 1% AEP event on Lot Plan 27SP2111998. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4.5) regarding these exceedances.

A summary of changes on the 28 lots impacted by a change in hazard is provided below:

- ▶ One lot experiences an increase in hazard of greater than 200 per cent
- ▶ Three lots experience an increase in hazard of between 100 per cent and 200 per cent

- ▶ Six lots experience an increase in hazard of between 50 per cent and 100 per cent
- ▶ Eighteen lots experience an increase in hazard of between 10 per cent and 50 per cent.

Other infrastructure

A total of three State-controlled roads (four individual segments) and 13 local public roads (18 individual segments) are impacted by a change in peak water level. Of the State-controlled roads impacted, Wondalli Street has been identified as experiencing the largest increase in hazard of 36,517 per cent (0.22 m²/s) increasing from 0.00 m²/s to 0.22 m²/s in the 1% AEP event. This portion of road is subject to a change in design due to the Project and therefore exceedances will be investigated further during detailed design stage to mitigate these. The three impacted State-controlled roads are:

- ▶ The Cunningham Highway experiences a maximum change in hazard of 106 per cent (0.08 m²/s) in the 2% AEP event
- ▶ Wondalli Street experiences a maximum change in hazard of 36,517 per cent (0.22 m²/s) in the 1% AEP event
- ▶ Yelarbon-Keetah Road experiences a maximum change in hazard of 13 per cent (0.01 m²/s) in the 1% AEP event.

Thirteen local roads (18 segments) have been identified to experience a change in hazard due to the Project alignment. Railway Parade experiences the largest increase in hazard of 19,592 per cent (from 0.00 m²/s to 0.15 m²/s) in the 1% AEP event. Which can be attributed to the Existing Case result being extremely small with an increase to a small hazard result in the Developed Case.

A summary of peak hazard changes on the 13 local roads is provided below:

- ▶ One local road experiences a change in hazard of greater than 1,000 per cent
- ▶ Two local roads experience a change in hazard of between 100 per cent and 500 per cent
- ▶ Two local roads experience a change in hazard of between 50 per cent and 100 per cent
- ▶ Eight local roads experience a change in hazard of between 10 per cent and 50 per cent.

Two sections (three segments) of existing rail infrastructure are impacted by a change in peak hazard, with the Whetstone Siding and the Toowoomba to Thallon lines both experiencing a peak change of 26 per cent in the 1% AEP event.

Figures showing the change in hazard presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-27e for the 1% AEP event.

Private land outside the Project permanent footprint

A total of 117 lots were identified as being impacted by a change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 2MH784 has been identified as experiencing the largest percentage increase in time of inundation of 1,620 per cent (increasing from 1.09 hours in the Existing Case to 18.71 hours in the Developed Case) in the 5% AEP event.

The largest 'absolute' change of 35.39 hours in the 1% AEP event has been identified on Lot Plan 89SP140808 and can be attributed a flood extent increase and a newly flood-affected hydraulic model cell (Section 14.8.1.2). Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4.5) regarding these exceedances.

A summary of peak time of inundation changes on the 117 lots is provided below:

- ▶ Three lots experience a change in time of inundation of greater than 1,000 per cent
- ▶ Four lots experience a change in time of inundation of between 500 per cent and 1,000 per cent
- ▶ 35 lots experience a change in time of inundation of between 100 per cent and 500 per cent
- ▶ 27 lots experience a change in time of inundation of between 50 per cent and 100 per cent
- ▶ 46 lots experience a change in time of inundation of between 10 per cent and 50 per cent
- ▶ Two lots experience an 'absolute' change only.

Other infrastructure

A total of 29 roads (State-controlled and local roads) are impacted by a change in time of inundation. Five State-controlled roads are identified as impacted with Wondalli Street recording the largest impact of 2,032 per cent in change in time of inundation (increasing from 1.47 hours to 31.3 hours). This segment of road is proposed to be upgraded as part of the Project's revised reference design and therefore this exceedance will be reviewed further in detailed design. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Sections 14.5.4.2 and 14.5.4.3) regarding these exceedances.

A summary of impacts on State-controlled roads is provided below:

- ▶ Taloom Street experiences a peak change in time of inundation of 918 per cent (13.78 hours)
- ▶ Wondalli Street experiences a peak change in time of inundation of 2,032 per cent (29.83 hours)
- ▶ The Cunningham Highway experiences a peak change in time of inundation of 157 per cent (3.23 hours)
- ▶ Yelarbon-Keetah Road experiences a peak change in time of inundation of 45 per cent (2.26 hours)
- ▶ Desert Creek Road experiences a peak change in time of inundation of 69 per cent (0.01 hours).

Twenty-four local public roads are impacted by an increase in time of inundation for all modelled events up to the 1% AEP event. Kera Street experiences the largest increase in time of inundation of 4,506 per cent (39.5 hours) in the 10% AEP event and be attributed to a change in road alignment due to the Project. A summary of peak time of inundation changes on the 24 local roads is provided below:

- ▶ Two local roads experience a change in time of inundation of greater than 1,000 per cent
- ▶ One local road experiences a change in time of inundation of between 500 per cent and 1,000 per cent
- ▶ Seven local roads experience a change in time of inundation of between 100 per cent and 500 per cent
- ▶ Two local roads experience a change in time of inundation of between 50 per cent and 100 per cent
- ▶ Twelve local roads experience a change in time of inundation of between 10 per cent to 50 per cent.

Three sections of existing rail infrastructure are impacted by a change in time of inundation with a summary of results below:

- ▶ Toowoomba to Thallon segment experiences a peak change in time of inundation of 1,057 per cent (31.46 hours)
- ▶ Yelarbon Yard experiences a peak change in time of inundation of 122 per cent (2.85 hours)
- ▶ Whetstone Siding experiences a peak change in time of inundation of 1,057 per cent (31.46 hours).

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.4).

Flood flow distribution

To determine the change in flow distribution, maximum velocity-depth grids were used to produce change in unit flow maps between existing and design conditions. Unit flow is the measure of discharge (i.e. velocity-depth product) and is often used for assessing peak flow along a cross-section, or to determine the effective flow corridors within a floodplain.

The presented flow distribution maps were filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to assist in identifying main channels (i.e. high flow zones) from shallow lower flood zones (i.e. outer extents of the flood surface).

The following points summarise the potential change in flow distribution for Macintyre Brook at Cremascos Road floodplain and should be considered in conjunction with flow distribution figures supplied in Appendix T2: Hydrology and Flooding Technical Report – Volume 2.

- ▶ Negligible change in flow distribution patterns for all events up to and including 1 in 2,000 AEP event
- ▶ Within the higher flow zones (>0.15 m³/s/m), minimal changes are observed up to and including the 1 in 2,000 AEP event
- ▶ The majority of changes occurs within the Macintyre Brook, with a 2 per cent to 5 per cent increase
- ▶ Some positive and negative change is observed directly adjoined the Cremascos Road bridge crossing in the 1 in 10,000 AEP event with this propagating upstream and downstream in the PMF event.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project and may include further refinement of the bridge abutments and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-95 outlines the changes in peak water levels greater than 10 mm at flood sensitive receptors for these extreme events. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event.

TABLE 14-95 MACINTYRE BROOK (YELARBON TO INGLEWOOD): SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
MCB_ID_519	Shed	103 ¹	-	144 ¹	0.42	55 ¹	2.36
MCB_ID_583	Shed	548	0.36	486	0.61	274	1.39
MCB_ID_584	House	548	0.36	599	0.56	520	0.95
MCB_ID_585	Shed	512	0.45	550	0.67	473	1.09
MCB_ID_586	Shed	480	0.36	500	0.57	419	0.98
MCB_ID_587	Shed	398	0.35	412	0.57	341	0.99
MCB_ID_588	Shed	421	0.57	440	0.80	369	1.22

Table note:

1. Newly flood-affected flood sensitive receptor in the Developed Case

The risk of overtopping along the Project alignment has been assessed at structures for the modelled extreme events. During these extreme events, the Project alignment is inundated at several locations. Table 14-96 outlines the overtopping locations and depths.

TABLE 14-96 MACINTYRE BROOK (YELARBON TO INGLEWOOD): PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP overtopping depth (m)	1 in 10,000 AEP overtopping depth (m)	PMF overtopping depth (m)
25.19	C25.19	-	-	1.55
25.46	C.25.46	-	0.02	1.69
25.50	C.25.50	-	-	1.68
25.80	C25.80	-	0.42	2.25
25.87	C25.87	-	0.10	1.95
25.95	C25.95	-	0.35	2.27
25.97	C25.97	-	0.18	2.09
26.05	C26.05	-	0.07	2.00
27.05	C27.05	-	0.26	1.99
27.15	C27.15	-	0.71	2.41
27.24	C27.24	0.28	0.70	2.45
27.33	C27.33	-	0.23	1.89
27.42	C27.42	-	-	1.52
42.87	C42.87	0.23	0.90	4.86
43.02	C43.02	0.22	0.90	4.87
43.09	C43.09	0.13	0.91	4.90
43.16	C43.16	0.28	0.97	4.94

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP overtopping depth (m)	1 in 10,000 AEP overtopping depth (m)	PMF overtopping depth (m)
43.35	C43.35	0.22	0.96	4.95
43.56	C43.56	0.57	1.39	5.38
43.66	C43.66	0.23	1.01	5.00
43.77	C43.77	0.23	1.03	5.01
43.86	C43.86	0.32	1.13	5.11
43.97	C43.97	0.31	1.11	5.08
44.32	C44.32	0.50	1.33	5.30
44.67	C44.67	0.39	1.23	5.19
44.78	C44.78	0.23	1.11	5.11
44.88	C44.88	0.23	1.03	5.03
44.96	C44.96	0.15	1.00	5.04
45.01	C45.01	0.25	0.98	4.97
45.10	C45.10	0.18	0.86	4.84
45.24	C45.24	0.15	0.80	4.76
45.30	C45.30	0.08	0.72	4.66
45.40	C45.40	-	0.47	4.56
45.45	C45.45	-	0.41	4.42
45.53	C45.53	-	0.39	4.36
45.64	C45.64	0.10	0.69	4.38

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are, therefore, not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. Further details of embankment overtopping failure risk can be found in Section 14.8.1.2.14.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Macintyre Brook catchment area is 23 per cent.

Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change. The inclusion of climate change slightly increases the change in peak water levels around the Project alignment. Climate change results in increased peak water levels of up to 0.4 m in the vicinity of the Project under the 1% AEP event. The Project formation level is higher than the 1% AEP climate change water levels.

Table 14-97 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the climate change scenario.

TABLE 14-97 MACINTYRE BROOK (YELARBON TO INGLEWOOD): SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1% AEP climate change event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
MCB_ID_75	House	+11	1.06
MCB_ID_76	House	+11	0.40
MCB_ID_82	House	+36	1.26
MCB_ID_83	House	+18	1.22
MCB_ID_228	House	+103	0.69
MCB_ID_229	Shed	+112	0.35
MCB_ID_231	Commercial	+40	0.54

Flood sensitive receptor

1% AEP climate change event

ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
MCB_ID_241	House	+23	0.25
MCB_ID_242	House	+18	0.16
MCB_ID_243	House	+25	0.34
MCB_ID_274	House	+39	0.82
MCB_ID_278	House	+31	0.31
MCB_ID_321	Commercial	+20	0.86
MCB_ID_322	Commercial	+37	0.72
MCB_ID_324	House	+38	1.12
MCB_ID_325	House	+12	0.77
MCB_ID_326	House	+15	0.72
MCB_ID_327	House	+27	0.76
MCB_ID_328	House	+36	0.90
MCB_ID_330	Commercial	+70	0.18
MCB_ID_332	Commercial	+83	0.81
MCB_ID_333	Commercial	+86	0.87
MCB_ID_335	House	+90	0.83
MCB_ID_337	House	+94	0.71
MCB_ID_338	House	+95	0.77
MCB_ID_339	House	+94	0.68
MCB_ID_341	Commercial	+93	0.78
MCB_ID_343	House	+76	0.95
MCB_ID_345	House	+78	0.89
MCB_ID_346	House	+35	1.16
MCB_ID_347	House	+35	1.19
MCB_ID_349	House	+34	1.24
MCB_ID_352	House	+34	1.17
MCB_ID_353	House	+35	1.05
MCB_ID_355	House	+40	1.32
MCB_ID_359	House	+45	1.38
MCB_ID_360	House	+53	1.14
MCB_ID_361	House	+81	1.30
MCB_ID_363	House	+84	1.17
MCB_ID_365	House	+86	1.20
MCB_ID_367	House	+86	1.17
MCB_ID_369	Commercial	+29	1.05
MCB_ID_370	House	+34	1.20
MCB_ID_374	House	+39	1.12
MCB_ID_381	House	+35	0.86
MCB_ID_382	House	+37	0.64
MCB_ID_384	House	+39	0.74
MCB_ID_394	House	+30	1.05
MCB_ID_395	House	+31	1.12
MCB_ID_397	House	+31	1.22
MCB_ID_401	House	+34	0.98
MCB_ID_414	House	+43	0.82

Flood sensitive receptor

1% AEP climate change event

ID	Type	Change in peak water level (mm)	Existing Case flood depth ¹ (m)
MCB_ID_415	House	+39	0.73
MCB_ID_416	House	+37	0.92
MCB_ID_420	House	+38	0.46
MCB_ID_423	House	+42	0.58
MCB_ID_424	House	+36	0.40
MCB_ID_426	House	+22	0.46
MCB_ID_453	House	+31	1.04
MCB_ID_457	House	+55	1.17
MCB_ID_465	Shed	+111	0.48
MCB_ID_469	House	+28	0.37
MCB_ID_470	House	+58	0.40
MCB_ID_472	House	+105	0.35
MCB_ID_474	House	+121	0.40
MCB_ID_475	House	+137	0.44
MCB_ID_476	Shed	+125	0.28
MCB_ID_477	House	+105	0.38
MCB_ID_478	House	+100	0.47
MCB_ID_479	House	+86	0.38
MCB_ID_480	House	+71	0.32
MCB_ID_481	House	+49	0.40
MCB_ID_482	House	+40	0.43
MCB_ID_483	House	+28	0.52
MCB_ID_484	House	+28	0.46
MCB_ID_494	Electrical Interchange	+106	0.56
MCB_ID_527	Shed	+101	0.83
MCB_ID_528	Shed	+101	0.63
MCB_ID_544	Shed	+114	0.42
MCB_ID_575	House	+35	0.72

Table note:

1. Existing Case flood depth including climate change

The downstream extents of these impacts are similar to those under the 1% AEP event.

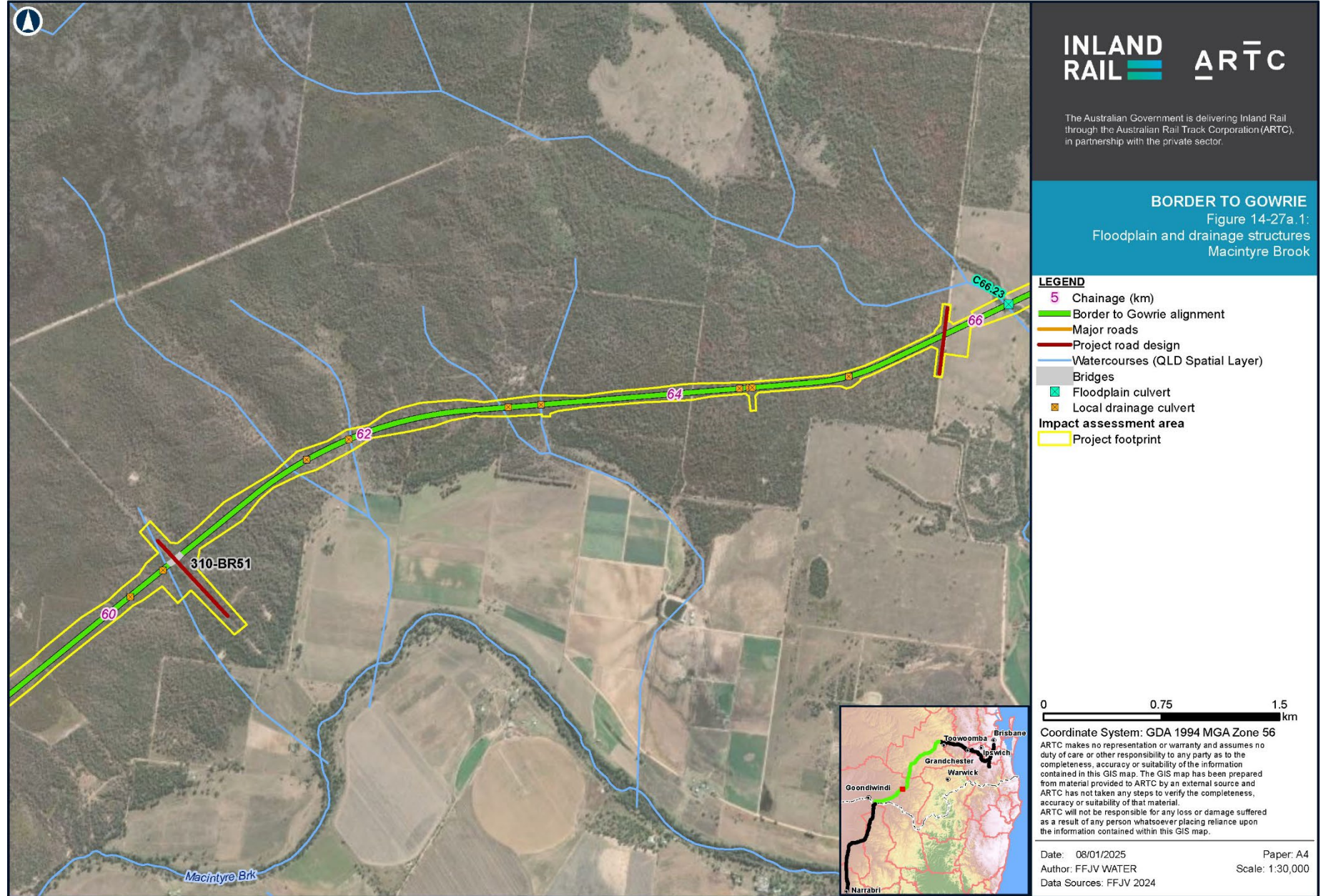
Blockage

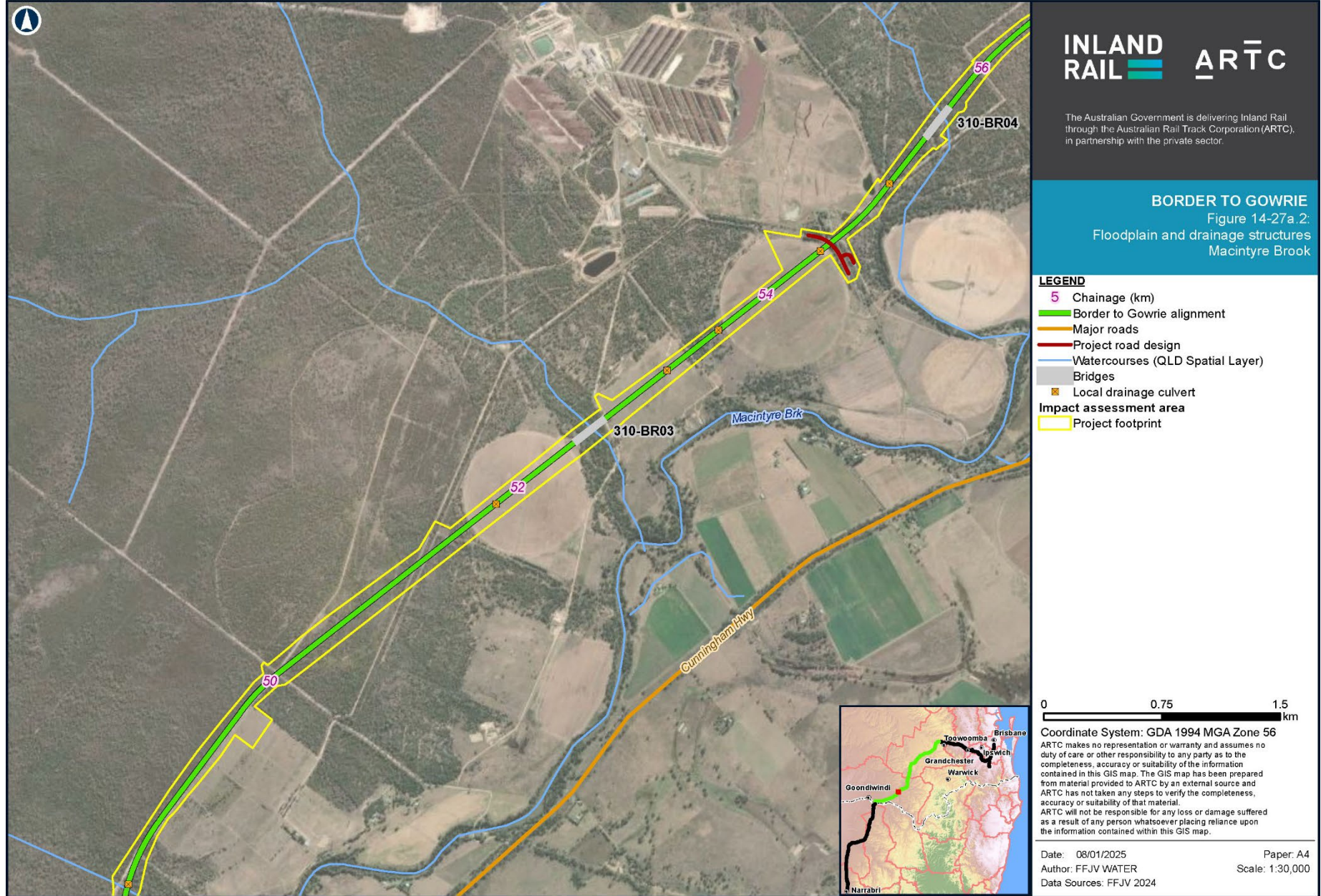
Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 14.5.6.2) and Appendix T2: Hydrology and Flooding Technical Report–Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

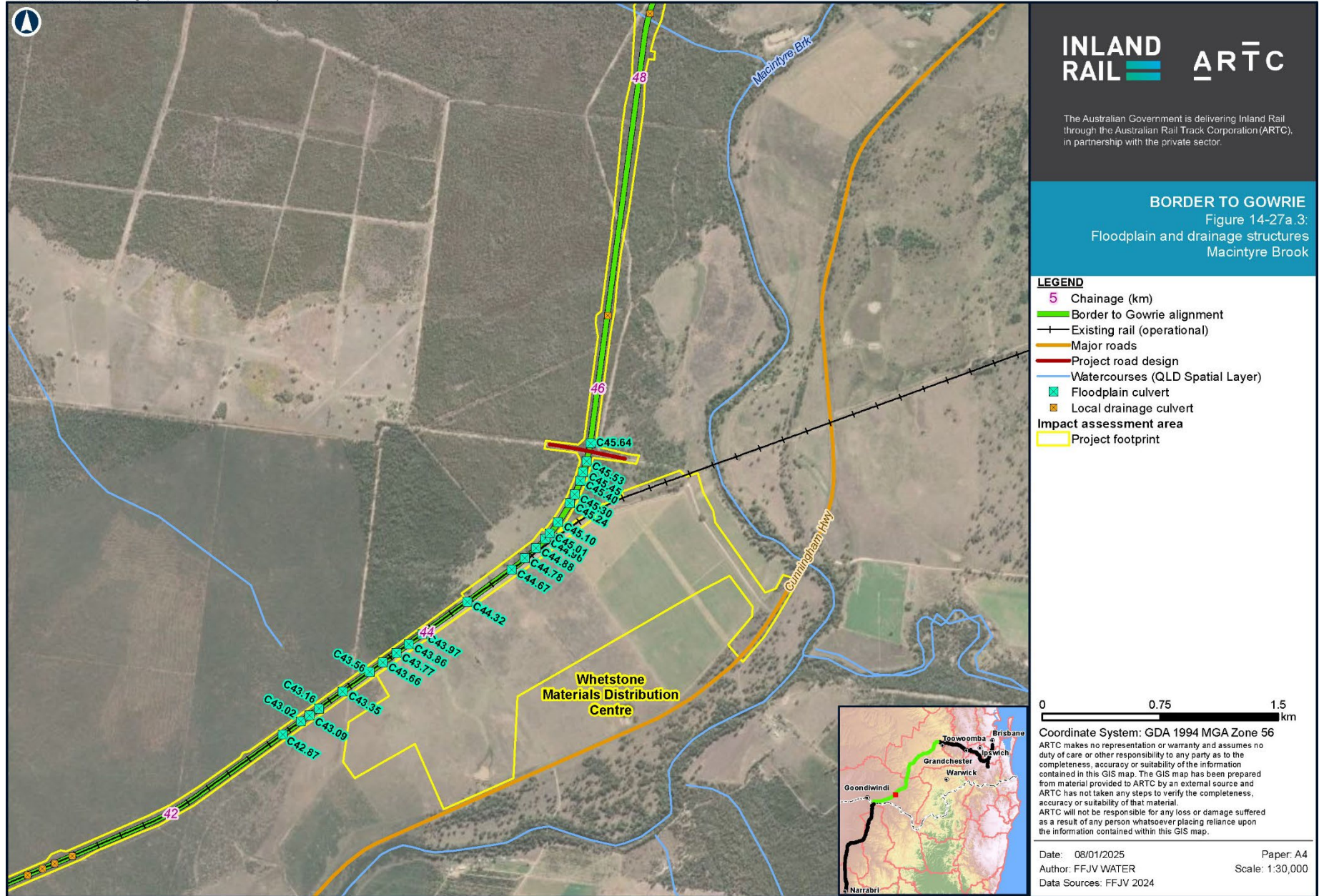
Table 14-98 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the 50 per cent blockage scenario (1% AEP).

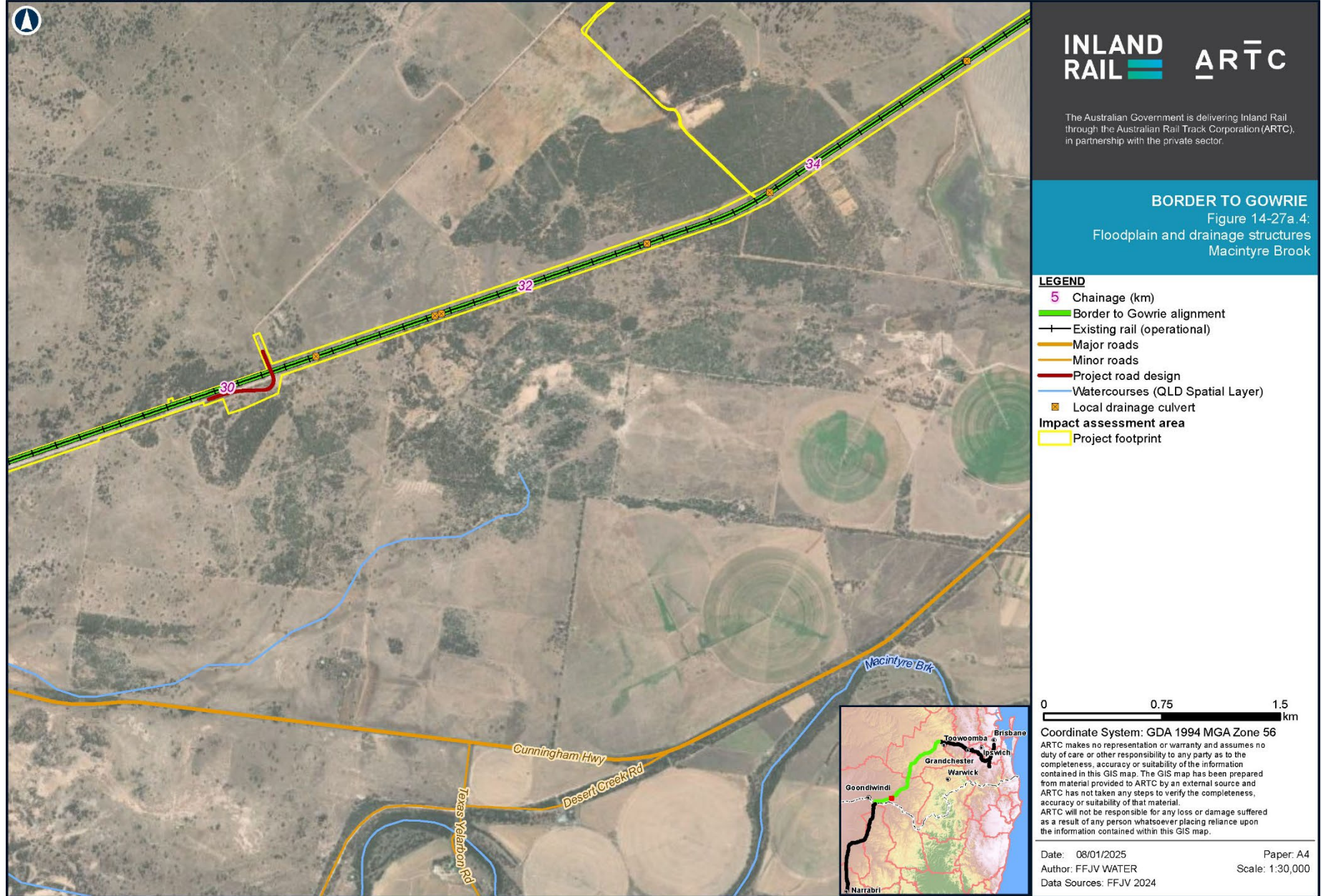
TABLE 14-98 MACINTYRE BROOK (YELARBON TO INGLEWOOD): SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD SENSITIVE RECEPTORS (1% AEP)

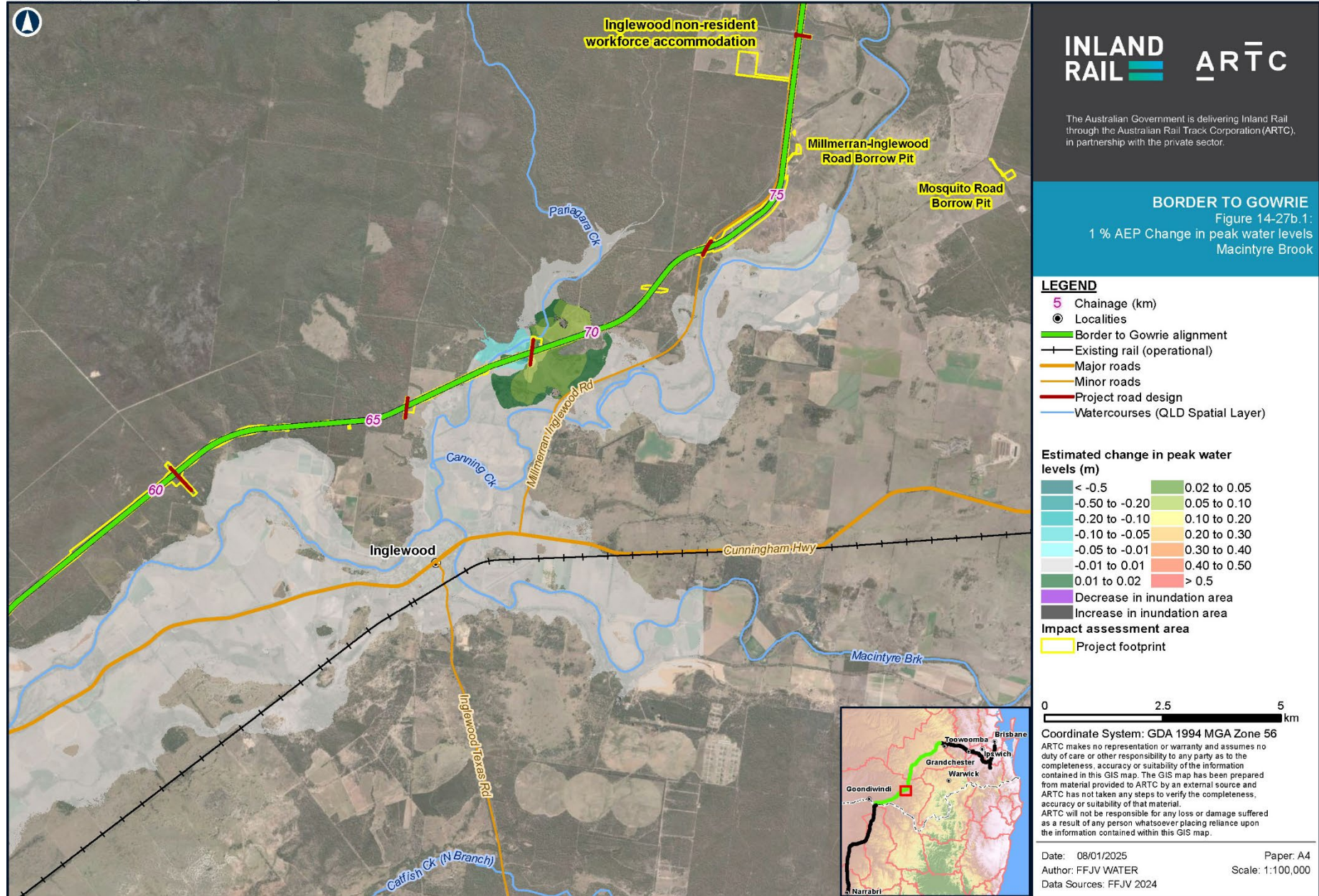
Flood sensitive receptor ID	Flood sensitive receptor type	Existing Case flood depth (m)	Change in peak water level (mm)
MCB_ID_278	House	0.00	+22
MCB_ID_420	House	0.00	+32
MCB_ID_426	House	0.15	+16

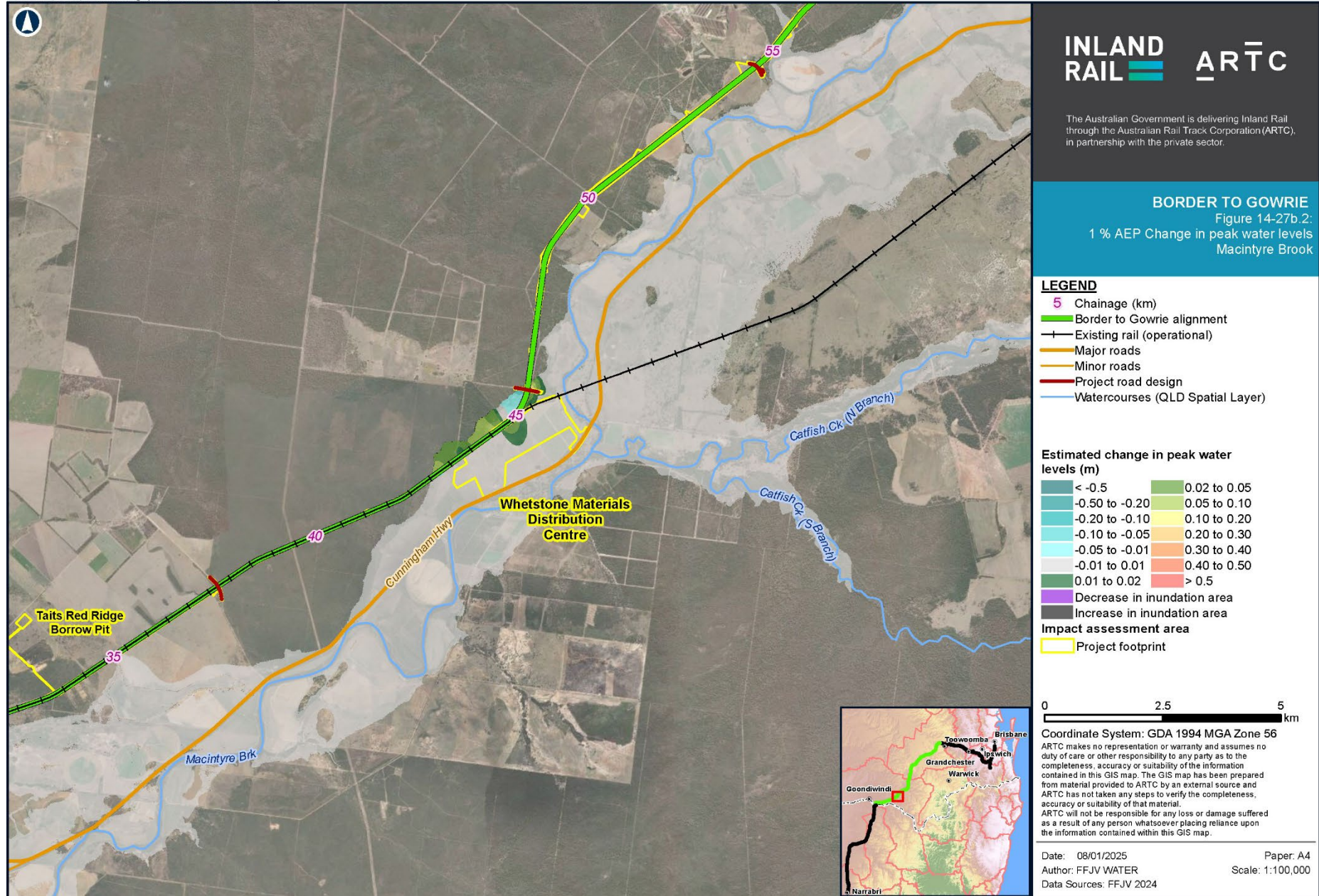


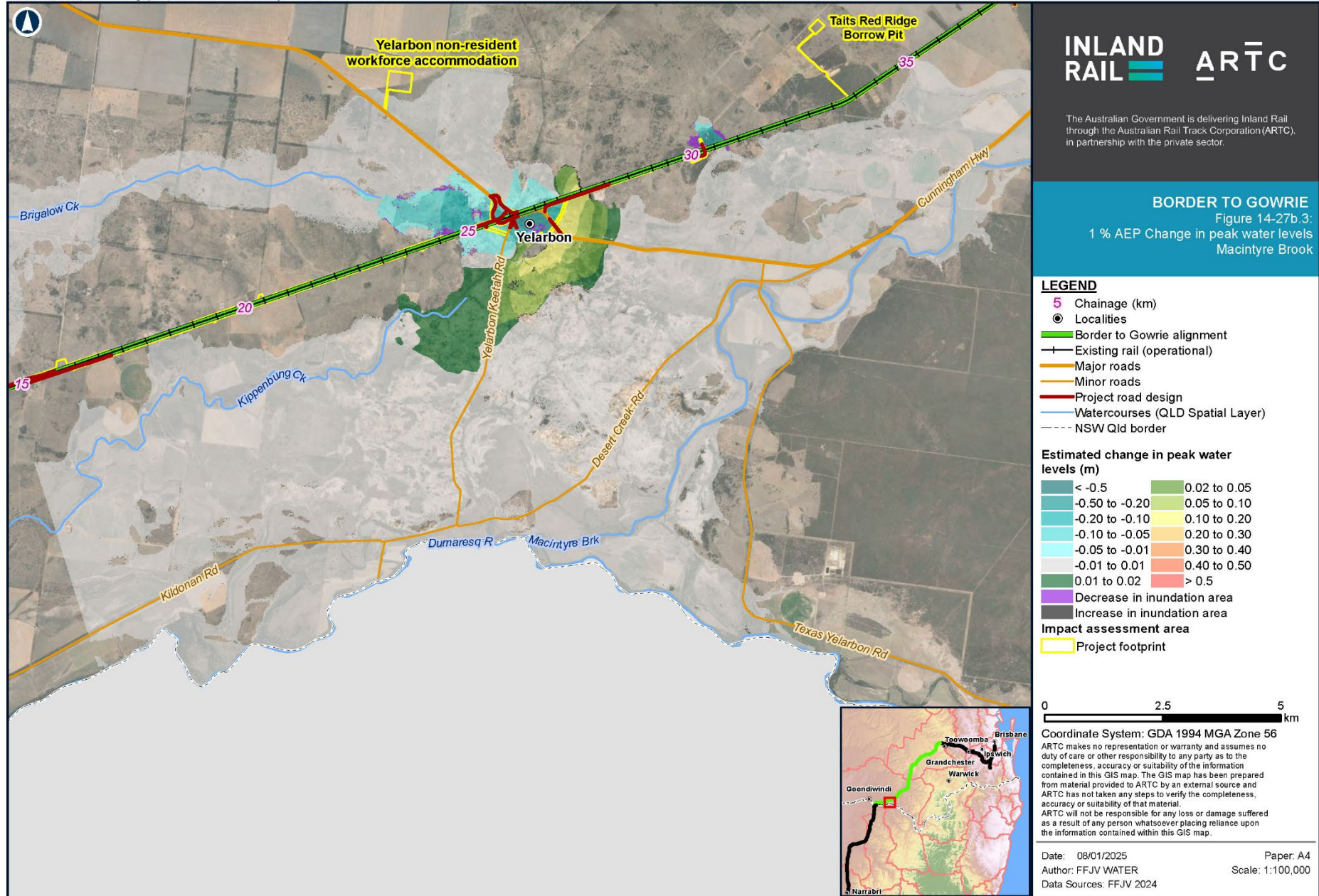


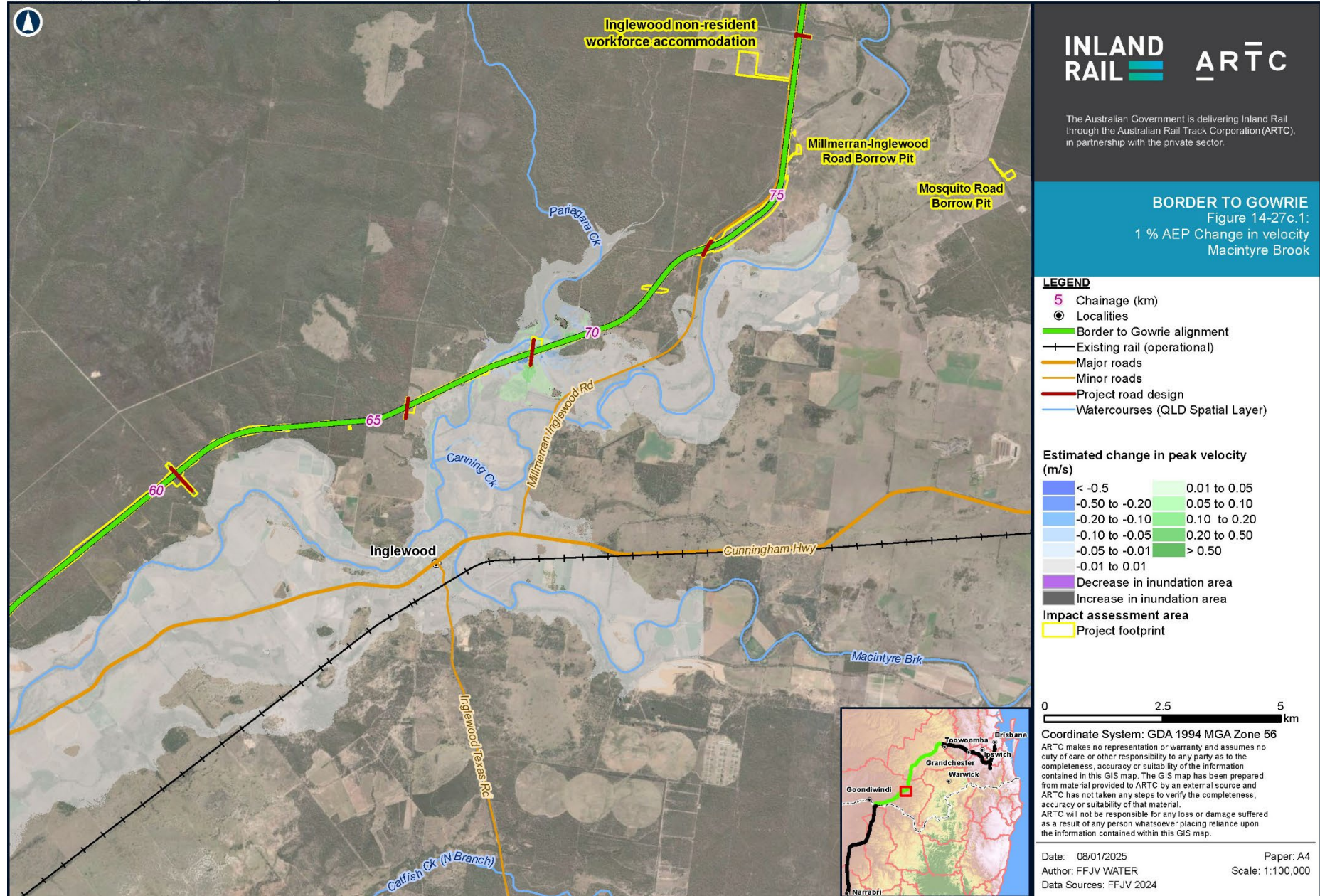


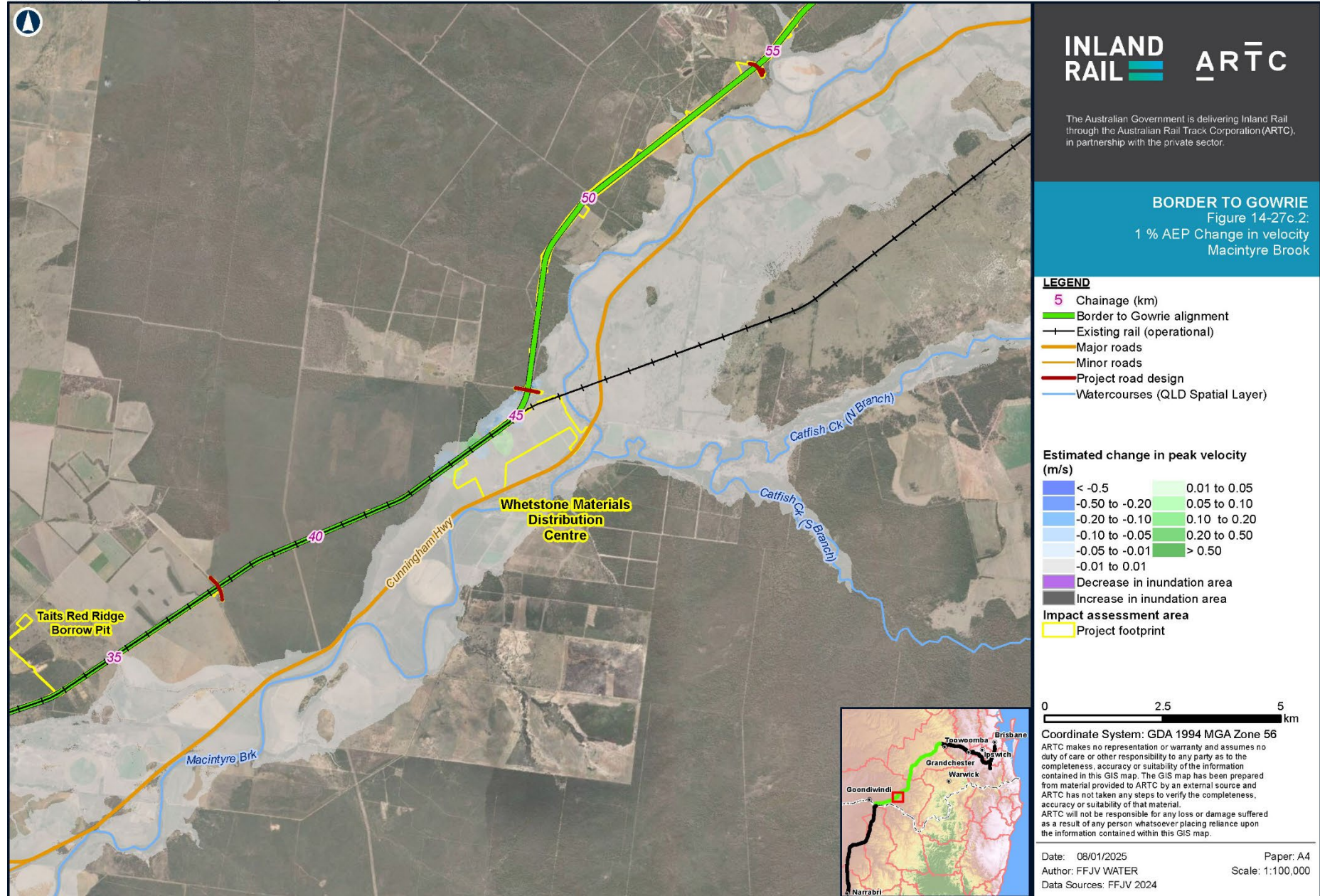


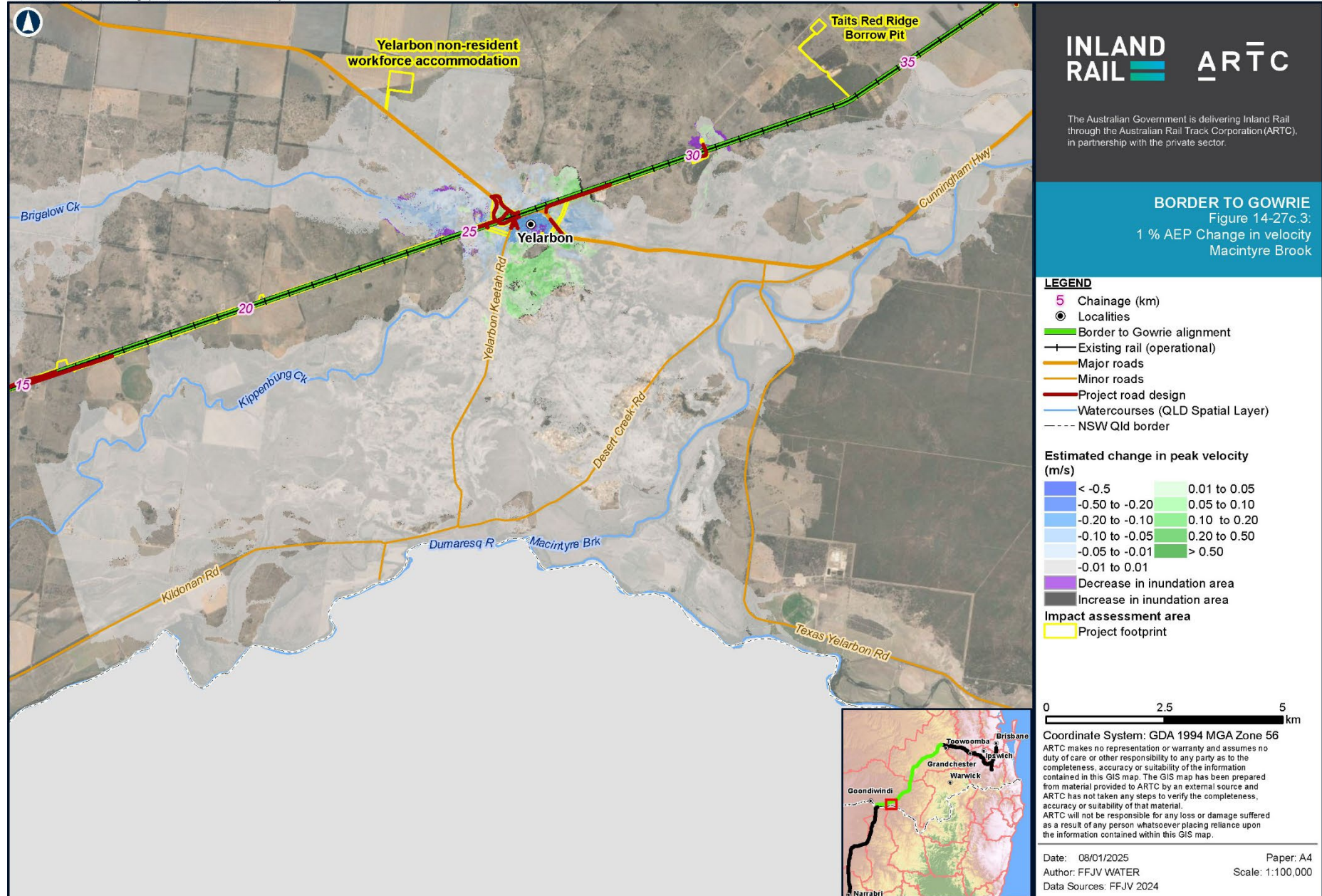


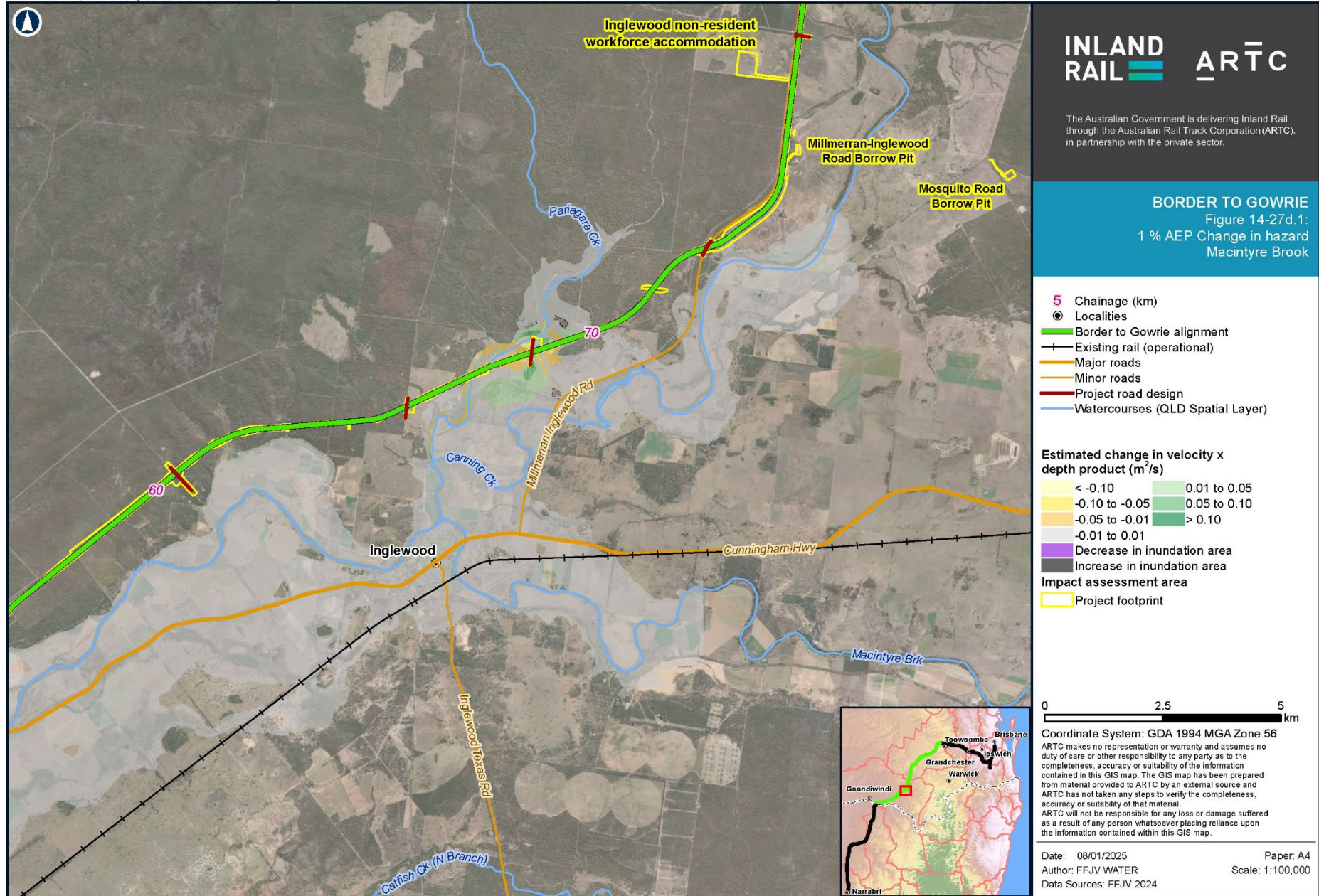


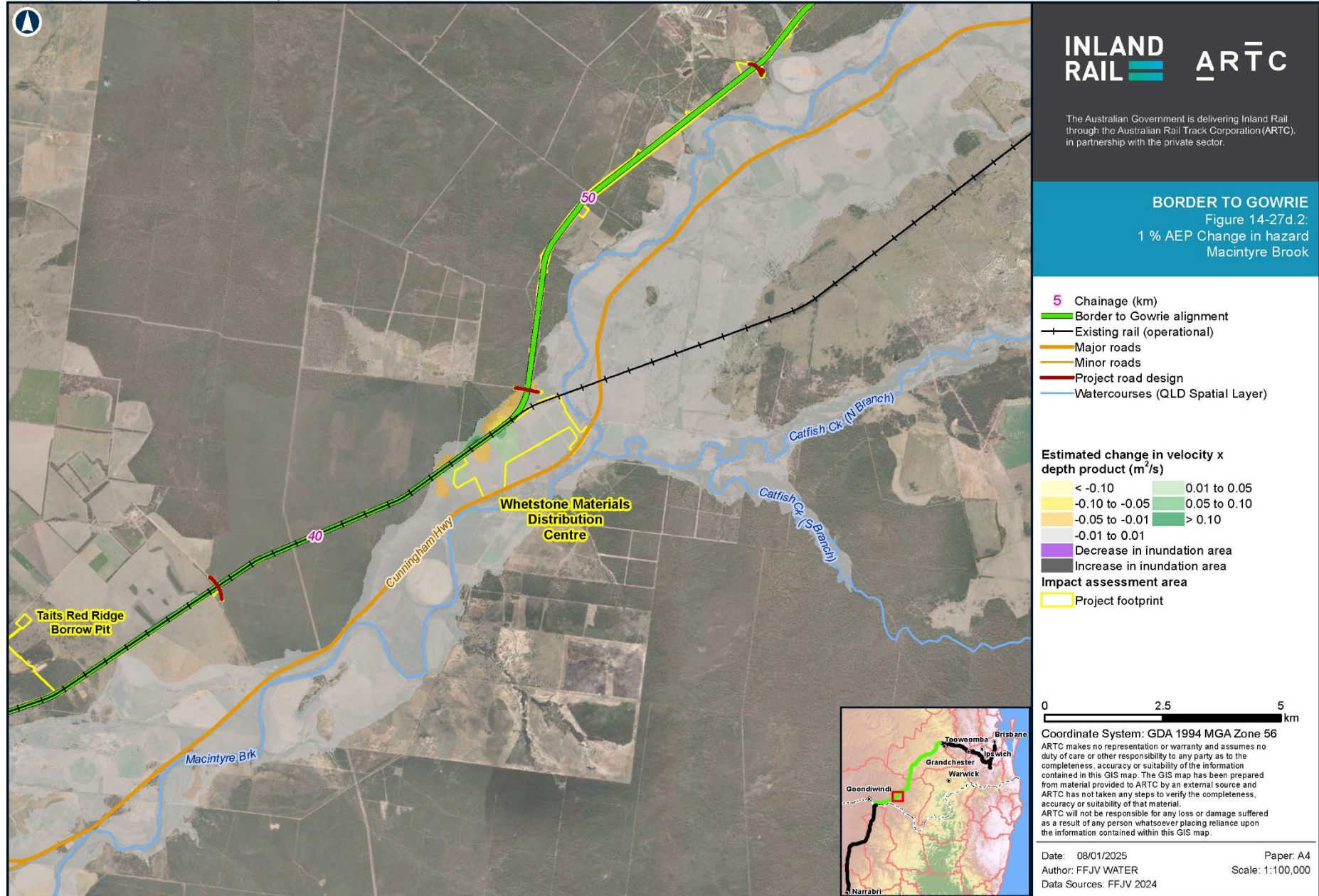


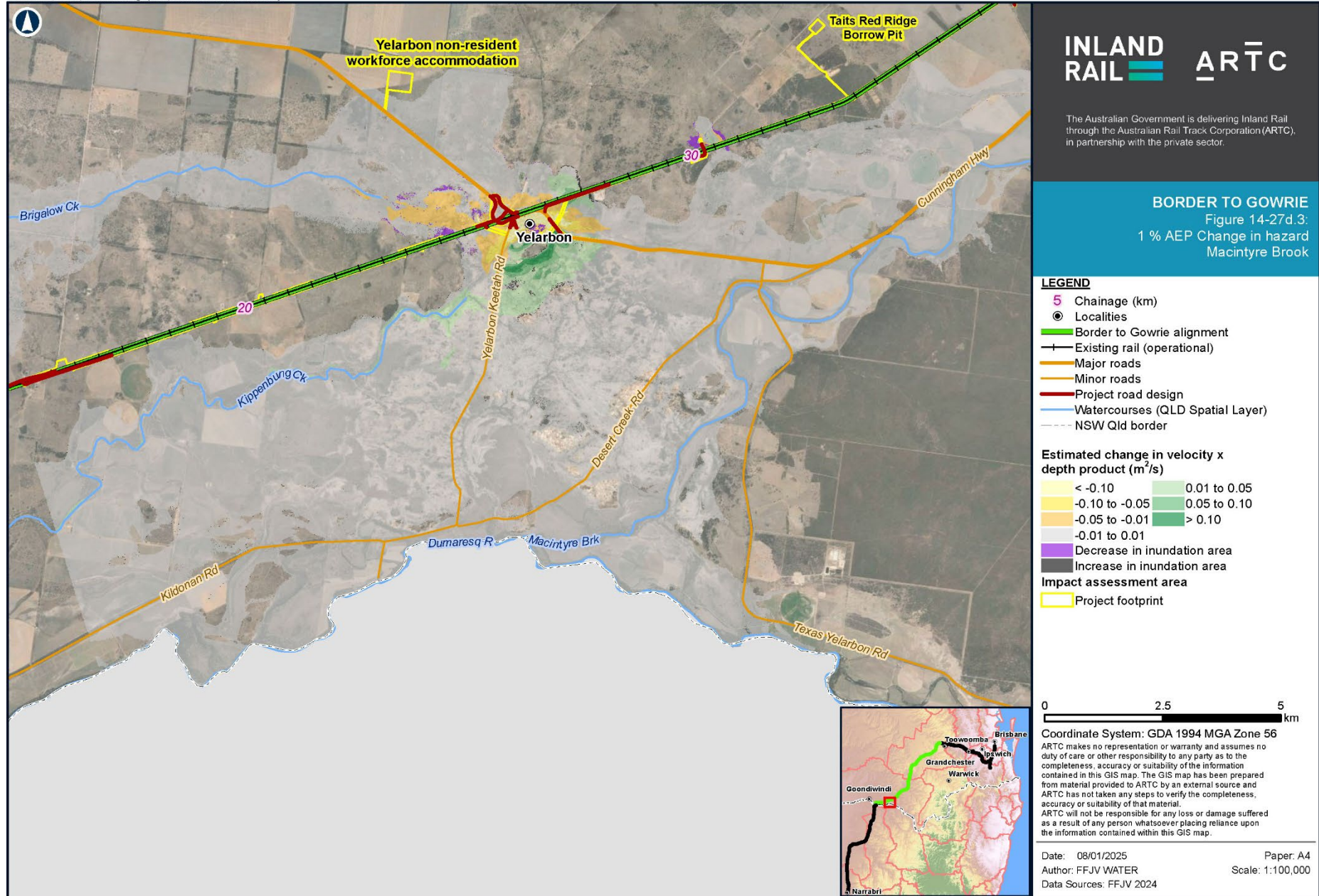


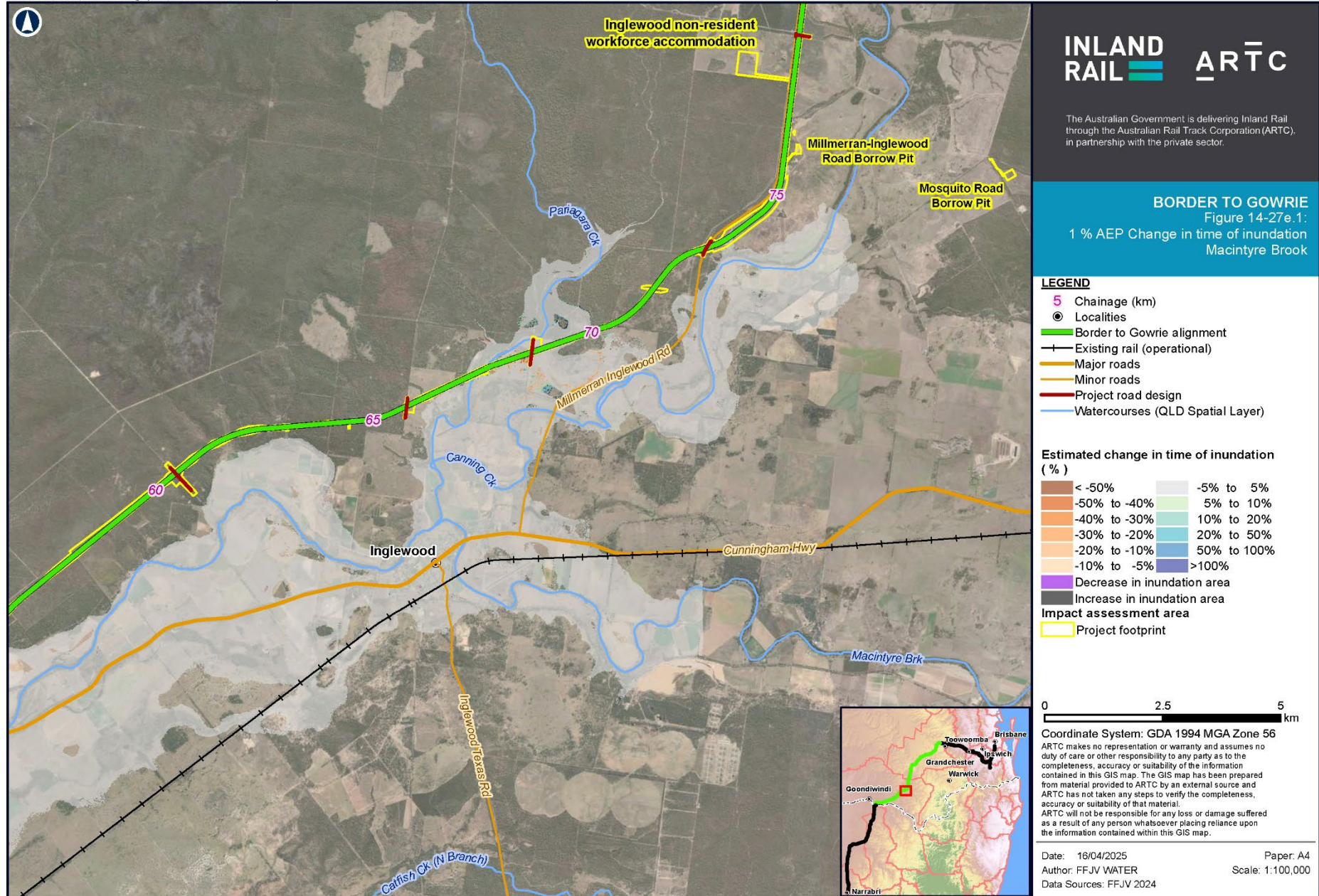


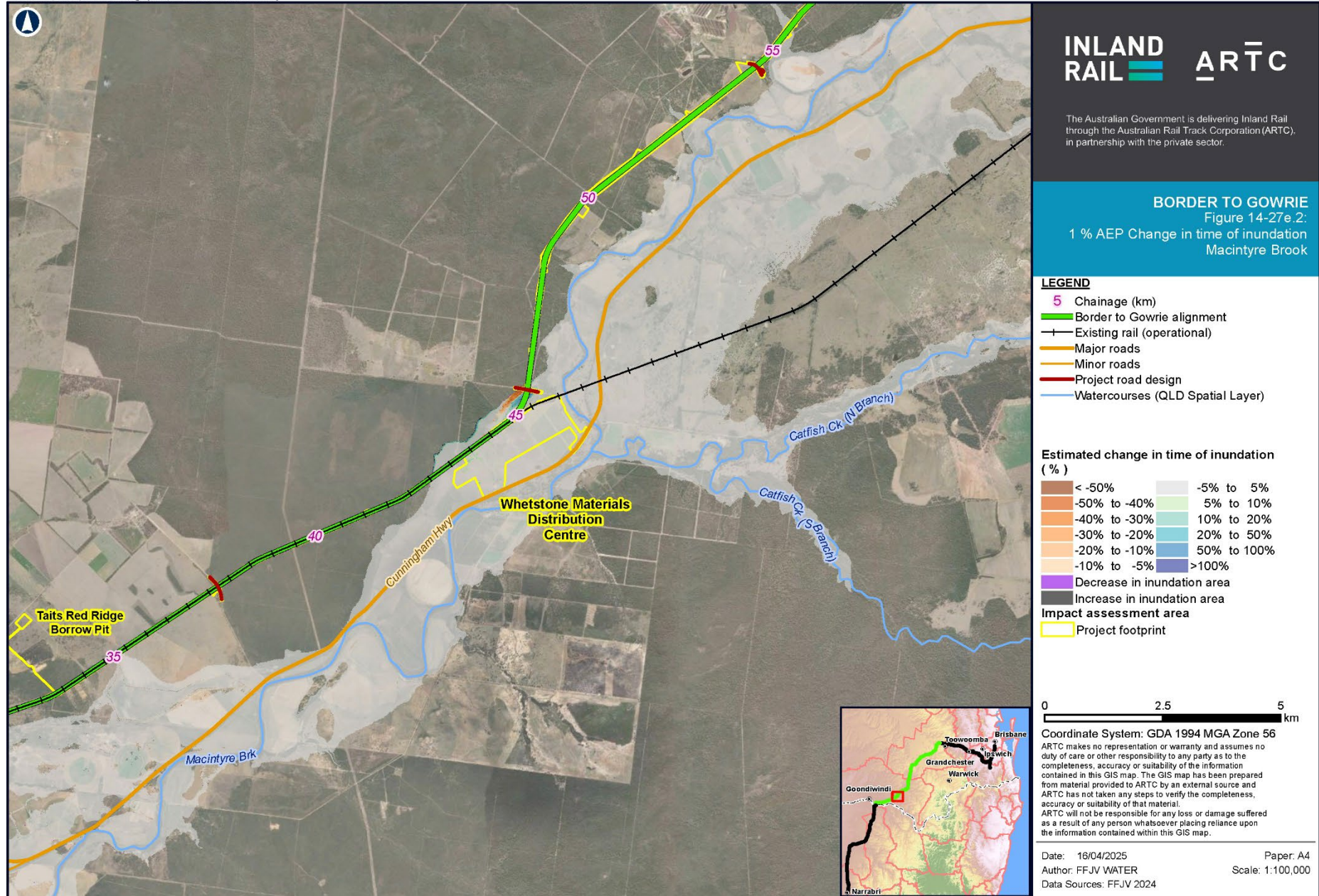


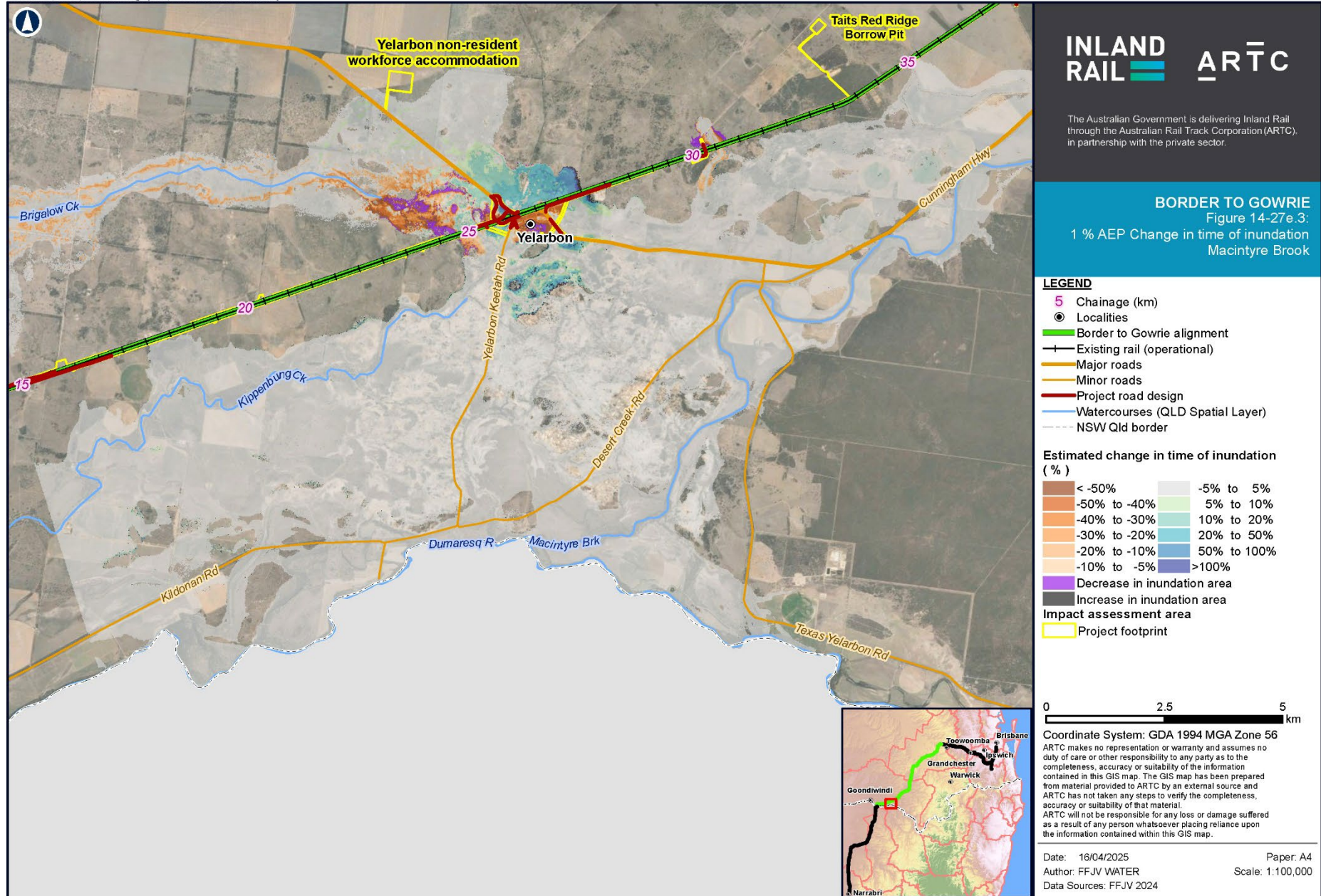












14.8.1.2.12 Macintyre River

Major floodplain structures for the Inland Rail within the Macintyre River floodplain are located within NSW, in the adjoining North Star to NSW/QLD Border project.

In the Macintyre River floodplain north of the NSW/QLD border, the Project's revised reference design includes:

- ▶ Three bridges
- ▶ Four RCP locations (a total of 50 culvert cells).

Details of the floodplain structures required to convey Macintyre River flood flows are presented in Table 14-99 and Table 14-100, with structure locations presented in Figure 14-28a. Figure 14-28a also presents the location of local catchment drainage structures.

TABLE 14-99 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER): FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID ¹	Structure type	Soffit level (m AHD)	Bridge length (m)
30.63 (NS2B)	270-BR11	Bridge	230.00	1,748
31.52 (NS2B)	270-BR12	Bridge	227.46	140
32.56 (NS2B)	270-BR13	Bridge	225.71	546

Table note:

1. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B)

TABLE 14-100 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER): FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID ²	Structure type	No. of culvert cells	Diameter/width x height (m) ¹
31.26 (NS2B)	C31.26	RCP	10	1.80
31.32 (NS2B)	C31.32	RCP	10	1.80
31.87 (NS2B)	C31.87	RCP	15	0.90
32.00 (NS2B)	C32.00	RCP	15	0.90

Table notes:

1. For RCP height equals diameter

2. See Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report – Volume 1 (Appendix B)

Change in peak water levels

Figure 14-28b presents the potential change in peak water levels under the 1% AEP event and the following sections detail predicted impacts above the flood impact objective targets. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events).

Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 17.5.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area predicted to be impacted by changes in peak water levels on the Macintyre River floodplain north of the NSW/QLD border for events up to the 1% AEP.

Under the 1 in 2000 AEP event there are four habitable or commercial buildings with predicted afflux above 250 mm, and one newly flood-affected flood sensitive receptor. Table 14-101 provides a summary of the flood sensitive receptors where exceedances are predicted above the flood impact objective target for all events up to and including the 1 in 2000 AEP event.

TABLE 14-101 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER): CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Flood sensitive receptor ID	Flood sensitive receptor type	Approximate chainage (km)	FIOs for 1 in 2,000 AEP event	Maximum increase in peak water level (mm)	Comment
MCR_ID_41	Shed	32.25 (NS2B)	≤ 250 mm	+373	Existing 1 in 2,000 AEP flood depth: 1.64 m
MCR_ID_46	House	36.20 (NS2B)	≤ 250 mm	+502 ¹	Existing 1 in 2,000 AEP flood depth: 0.00 m
MCR_ID_44	Stock yards	34.50 (NS2B)	≤ 250 mm	+415	Existing 1 in 2,000 AEP flood depth: 0.19 m
MCR_ID_98	House	2.00	≤ 250 mm	+33 ¹	Existing 1 in 2,000 AEP flood depth: 0.00m

Table note:

1. Newly flood-affected flood sensitive receptor in the Developed Case

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for ten lots within the Macintyre River floodplain for all modelled events up to the 1 in 2,000 AEP event. Peak changes in water level ranged from 10 mm on Lot Plan 1AP22566 to 2.55 m on Lot Plan 484SP119198. The large increases identified can be attributed to newly flood-affected hydraulic model cells and with some degree of change expected across an area of 12.4 ha (or less than 49 per cent of the total lot area).

Of the ten lots identified, seven are impacted due to the change in flood extent and identified due to newly flood-affected model cells. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report – Volume 1 (Section 17.5.3.5) regarding these exceedances.

The below provides a summary of impacted lots:

- ▶ One lot experiences a change in peak water level greater than 1 m
- ▶ Five lots experience a change in peak water level between 0.5 m and 1 m
- ▶ Three lots experience a change in peak water level of between 0.1 m and 0.5 m
- ▶ One lots experiences a change in peak water level of less 0.1 m.

Other infrastructure

No roads or rail have been identified to experience an increase in peak water levels above the flood impact objective targets for all events up to the 1% AEP in the Macintyre River floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 17.5.3).

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case with results presented in Figure 14-28c for the 1% AEP event.

Private land outside the Project permanent footprint

A total of four lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 14SP127017 experiences the largest increase in velocity of 1.1 m/s in the 2% AEP event. Change in velocity is expected to be experienced across 0.02 ha (less than 1 per cent of the total lot area) and can be attributed to a change in flood inundation extent and a newly flood-affected hydraulic model cell. Lot Plans 52SP131989, 1RP49163 and 39MH796 all experience an increase in velocity of between virtually zero to 0.28 m/s.

Other infrastructure

No roads or rail have been identified to experience an increase in velocity above the flood impact objective targets for all events up to the 1% AEP in the Macintyre River floodplain.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 17.5.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case with results presented in Figure 14-28d for the 1% AEP event.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Macintyre River floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of three lots, 37MH878, 2SP142352 and 39MH796, were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. The maximum increase for flood hazard is approximately 8,180 per cent (increasing from 0.002 m²/s to 0.15 m²/s) on Lot Plan 37MH878, with changes in hazard predicted across a total area of 1.27 ha (approximately 1.4 per cent of the total lot area).

Of the remaining lots impacted, Lot Plan 2SP142352 experiences a maximum change of 3,136 per cent (increasing from 0.015 to 0.497 m²/s) in the 1% AEP event and Lot Plan 39MH796 experiences an increase of 67.3 per cent in hazard (from 0.602 m²/s to 1.007 m²/s) in the 1% AEP event. Both lots can expect some increase in hazard across approximately 1 per cent or less of their total lot area.

Other infrastructure

No roads or rail have been identified to experience an increase in hazard above the flood impact objective targets for all events up to the 1% AEP in the Macintyre River floodplain.

Figures showing the change in hazard are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 17.5.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case with results presented in Figure 14-28e for the 1% AEP event.

Private land outside the Project permanent footprint

Change in time of inundation is the primary exceedance category on lot for the Macintyre River floodplain. A total of 16 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 1RP49163 has been identified as experiencing the largest percentage increase in time of inundation of 334 per cent in the 2% AEP event and 4.53 hour increase in the 5% AEP event. Some change in time of inundation can be expected to be experienced across a total area of 2.60 ha (or 1.5 per cent of the total lot area). Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 17.5.3.5) regarding these exceedances.

Of the remaining 15 lots:

- ▶ Ten lots experience a change in time of inundation of between 100 per cent and 300 per cent
- ▶ Two lots experience a change in time of inundation of between 50 per cent and 100 per cent
- ▶ Three lots experience a change in time of inundation of less than 50 per cent.

Other infrastructure

No roads or rail have been identified to experience an increase in time of inundation above the flood impact objective targets for all events up to the 1% AEP in the Macintyre River floodplain.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report—Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report—Volume 1 (Section 17.5.3).

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage north of the NSW/QLD border with significant floodplain structures included to maintain or improve the existing flood regime. Table 14-102 presents the flows for the Bogabilla Gauge 'Section 1' as defined by the Floodplain Management Plan for the Borders River Valley Floodplain.

The Floodplain Management Plan for the Borders River Valley Floodplain requires that there is no more than a 5 per cent change in flow distribution between the Existing Case and Developed Case (noting the Developed Case includes the proposed Project alignment and associated works). As can be seen the percentage changes values are all less than the 5 per cent target, with the majority around 0 per cent to 2.5 per cent. It is noted that this assessment was undertaken on peak flows and that consideration of volume is likely to result in closer volumes between the Existing Case and Developed Case. Refer to Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 17.5.3.6) for locations of 'Section 1' and its individual segments.

TABLE 14-102 PEAK FLOW VARIATION ASSESSMENT ALONG SECTION 1

Segment of Section 1	Floodplain Management Plan for the Borders River Valley Floodplain levees and validated 1976 flows	
	Existing Case flows (m ³ /s)	Developed Case flows (m ³ /s) and % Change
DPIE_100	402	406 (1%)
DPIE_101	2,228	2,193 (-2%)
DPIE_102	3,362	3,366 (0%)
DPIE_103	193	195 (1%)
DPIE_104	380	386 (1%)
DPIE_105	121	124 (2.5%)

In addition to the above, flow distribution mapping was produced for all events up to the PMF. To determine the change in flow distribution the maximum depth-velocity product results were used to produce change in unit flow maps between existing and design conditions. Unit flow is the measure of discharge (i.e. depth-velocity product) and is often used for assessing peak flow along a cross-section, or to determine the effective flow corridors within a floodplain.

The presented flow distribution maps were filtered with a depth-velocity product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to assist in identifying main channels (i.e. high flow zones) from shallow lower flood zones (i.e. outer extents of the flood surface). Flow distribution mapping can be found in Appendix T2: Hydrology and Flooding Technical Report–Volume 2.

Ongoing mitigation measures to reduce changes in flow distribution are likely to occur during future design stages of the Project, and may include further refinement of the bridge abutments, culvert skews, and additional survey where necessary.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Mapping for the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events can be found at the **Online Digital Platform**.

In accordance with the FIOs, flood sensitive receptors are considered impacted by extreme flood events if the change in water level is greater than 250 mm in the 1 in 2,000 AEP event, subject to the receptor classification (i.e. at existing habitable dwellings and/or commercial and industrial buildings/premises).

Table 14-103 outlines the changes in peak water levels greater than 10 mm at flood sensitive receptors for these extreme events north of the NSW/QLD border. The existing depth of flooding is also detailed and as shown, the larger impacts that occur under the PMF event generally occur when there are already high flood depths, as would be expected under such a rare event.

TABLE 14-103 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER): SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
MCR_ID_31	Centre pivot irrigation	+55	1.25	+85	2.14	+96	3.87
MCR_ID_32	Centre pivot irrigation	+52	1.34	+84	2.25	+89	4.01
MCR_ID_36	River pump station	+58	3.28	+85	4.15	+102	5.83
MCR_ID_40	Stockyards	-69	2.15	-83	3.19	-34	5.00
MCR_ID_41	Sheds	+373	1.64	+511	2.66	+358	4.44
MCR_ID_42	Rainbow Reserve	+58	0.50	+96	1.47	+92	3.28
MCR_ID_43	Additional development constructed	+152	0.17	+850	0.87	+254	2.69
MCR_ID_44	Stockyards	+415	0.19	+1116	1.42	+280	3.36
MCR_ID_46	House	+502	-	+111	0.81	+4	2.57
MCR_ID_49	Grazing	+119	1.91	+224	2.99	+205	4.86
MCR_ID_50	Quarry access	+66	1.10	+142	2.33	+141	4.43
MCR_ID_98	House	+33	-	+211	0.10	+71	0.75
MCR_ID_104	House	+75	1.79	+88	2.74	+81	4.50
MCR_ID_105	House	+80	1.71	+93	2.73	+86	4.56
MCR_ID_106	Shed	+79	2.38	+91	3.37	+84	5.18
MCR_ID_108	Sheds commercial	+74	0.47	+92	1.45	+89	3.26
MCR_ID_110	House	Dry	0.65	-421	1.35	-119	2.59
MCR_ID_111	House	+243	1.06	+367	1.85	+221	3.20
MCR_ID_112	House	Dry	0.50	-362	1.24	-36	2.52
MCR_ID_115	House	+71	0.80	+91	1.75	+89	3.55
MCR_ID_118	Sheds	+67	1.85	+89	2.72	+97	4.42
MCR_ID_119	House	Dry	0.68	-369	1.42	-46	2.70
MCR_ID_120	Shed	+176	1.64	+243	2.56	+135	4.18
MCR_ID_123	House	+109	0.39	+158	1.61	+114	3.64
MCR_ID_124	Commercial	-	-	+517		+135	0.46
MCR_ID_125	House	-	-	-98	0.30	+57	1.61
MCR_ID_126	House	+14	2.87	+42	4.03	+96	6.04
MCR_ID_127	Water tanks	+14	1.72	+41	2.88	+96	4.90
MCR_ID_128	House	+5	1.39	+28	2.59	+82	4.83
MCR_ID_129	House	+5	1.39	+28	2.58	+82	4.82
MCR_ID_130	House	+5	1.13	+27	2.32	+81	4.55
MCR_ID_131	Shed	+6	1.26	+28	2.45	+83	4.67
MCR_ID_132	House	-	2.56	+6	3.65	+41	5.86
MCR_ID_133	Shed	-	2.24	+5	3.34	+40	5.54
MCR_ID_134	Shed	-	2.47	+7	3.55	+43	5.75

The risk of overtopping along the Project alignment has been assessed for the modelled extreme events. During these extreme events the Project alignment is inundated above formation in the 1 in 10,000 AEP and PMF event. Table 14-104 outlines the overtopping locations and depths.

TABLE 14-104 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER): PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km) ¹	Structure ID	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
31.52	310-BR12	-	-	1.23
31.87	C31.87	-	0.44	2.01
32.00	C32.0	-	0.41	1.90

Table note:

1. The length of Project alignment overtopped around these areas varies between events

Under these rare events, in most sections, the bridge structures and culverts allow adequate passage of flow during the flood events and 'damming' effects are, therefore, not expected to occur. In addition, in these areas, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events.

At approximately Ch 32 km and Ch 36 km, the alignment experiences the increase in peak water levels upstream of the proposal alignment in the PMF event. During detailed design, mitigation measures to refine the design and to address the risks to the embankment and rail infrastructure as well as downstream lots will be investigated further. If required, this may include engineering solutions to increase the strength and resilience of the rail embankment in this specific location, thereby mitigating the flood risk impact to both the asset and the adjacent floodplains.

Climate change

The potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment due to climate change has been assessed, using the methodology described in Section 14.8.1.2.2. The increased rainfall intensity associated with Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario across the Macintyre River catchment area is 25 per cent.

Appendix T2: Hydrology and Flooding Technical Report—Volume 2 presents the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change. The inclusion of climate change slightly increases the change in peak water levels around the Project alignment. Climate change results in increased peak water levels of up to 0.2 m in the vicinity of the Project under the 1% AEP event. The Project formation level is higher than the 1% AEP climate change water levels. The downstream extents of these impacts are similar to those under the 1% AEP event.

Table 14-105 outlines the increases in peak water levels greater than 10 mm at flood sensitive receptors for the climate change scenario north of the NSW/QLD border.

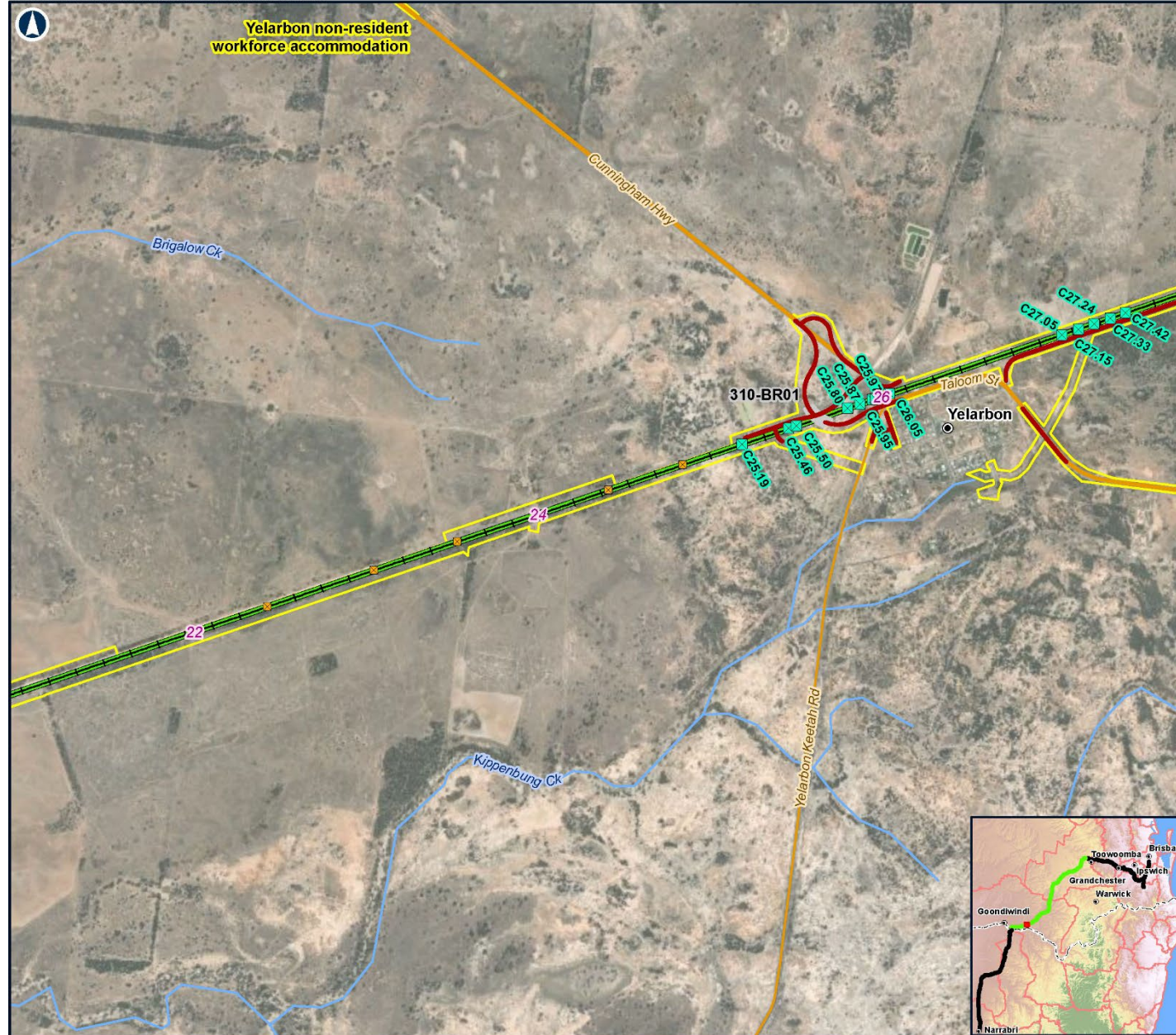
TABLE 14-105 MACINTYRE RIVER: SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor		1% AEP climate change event	
ID	Type	Change in peak water level (mm)	Existing Case flood depth (m)
MCR_ID_41	Sheds	+186	0.69

Blockage

Blockage of drainage structures has been assessed using the methodology described in Section 14.8.1.2.2. Appendix T2: Hydrology and Flooding Technical Report—Volume 2 presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

The blockage sensitivity results indicate there are no predicted changes greater than 10 mm in peak water levels at flood sensitive receptors for the 1% AEP, zero per cent and 50 per cent blockage scenarios in the Macintyre River modelled floodplain north of the NSW/QLD border.



INLAND RAIL ARTC

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BORDER TO GOWRIE

Figure 14-28a.1:
Floodplain and drainage structures
Macintyre River

LEGEND

-  Chainage (km)
-  Localities
-  Border to Gowrie alignment
-  Existing rail (operational)
-  Major roads
-  Minor roads
-  Project road design
-  Watercourses (QLD Spatial Layer)
-  Bridges
-  Floodplain culvert
-  Local drainage culvert
-  Impact assessment area
-  Project footprint

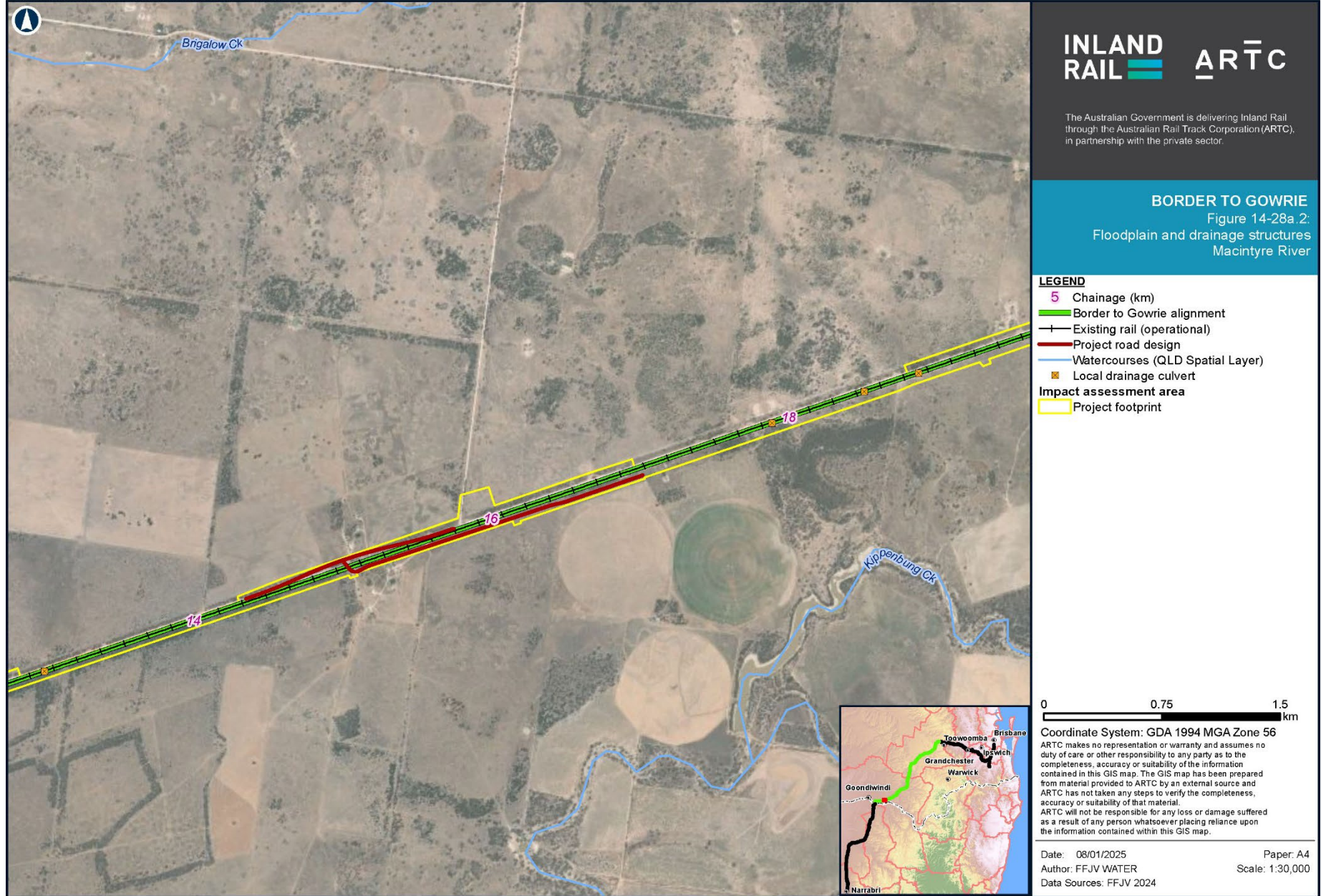
0 0.75 1.5
km

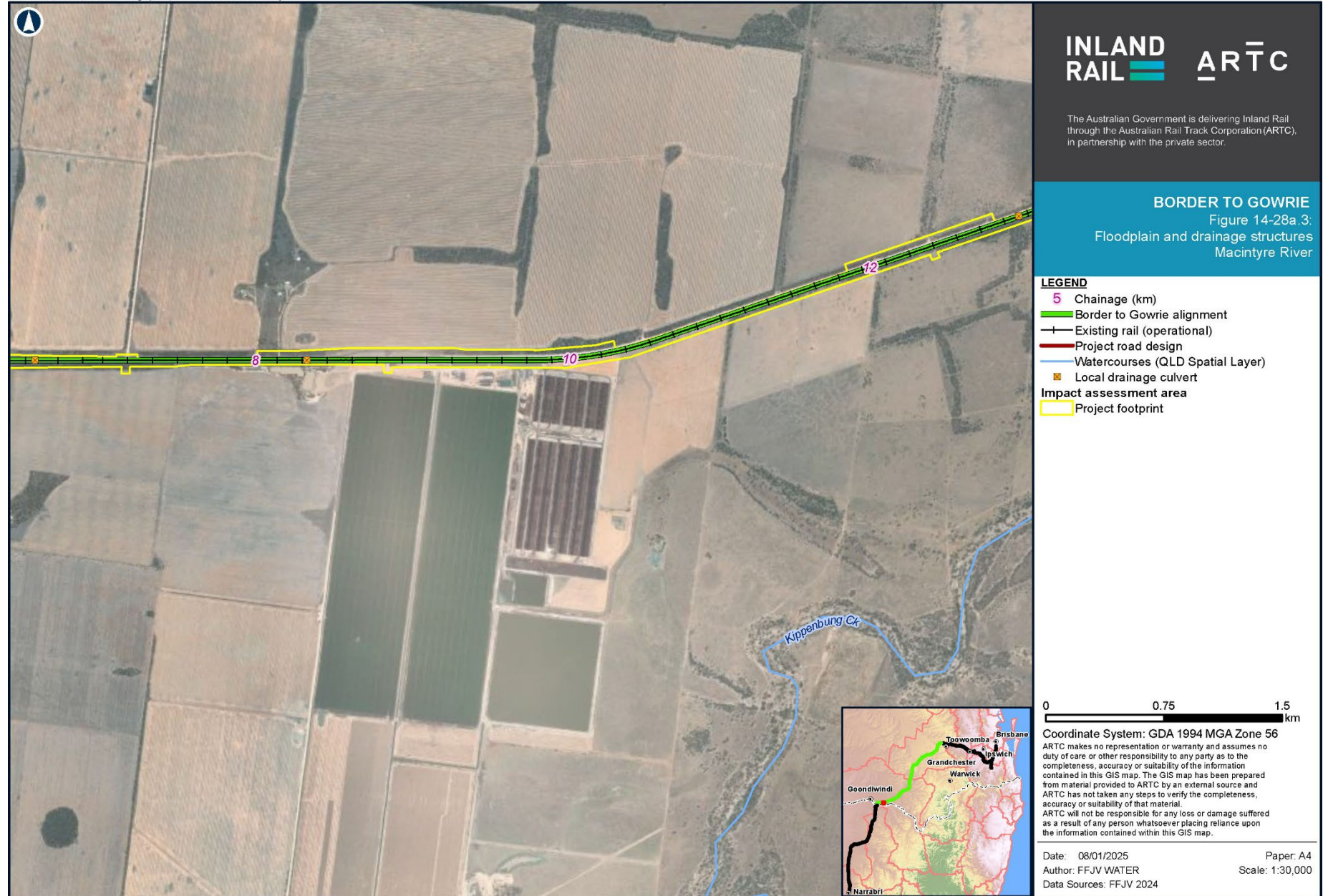
Coordinate System: GDA 1994 MGA Zone 56

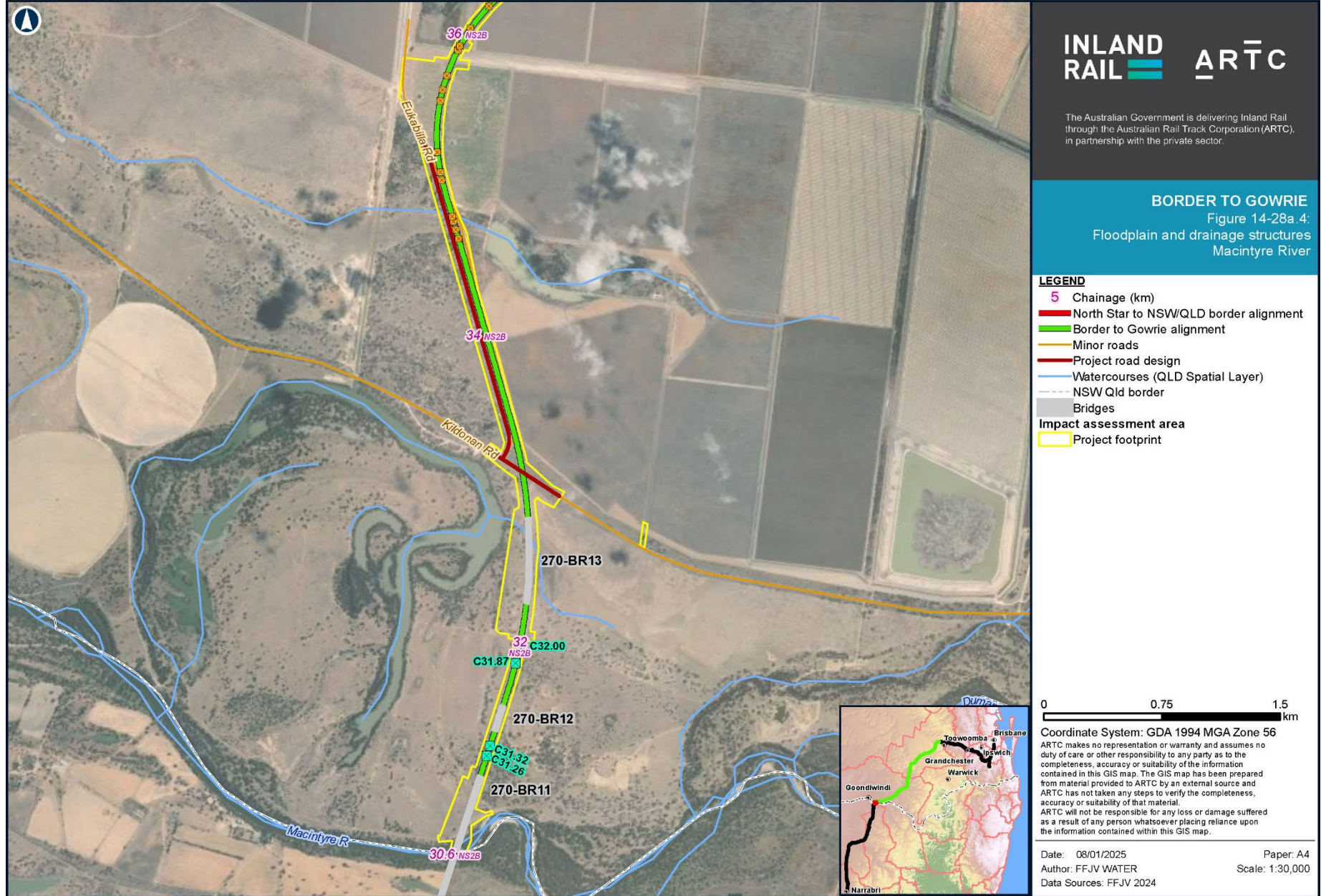
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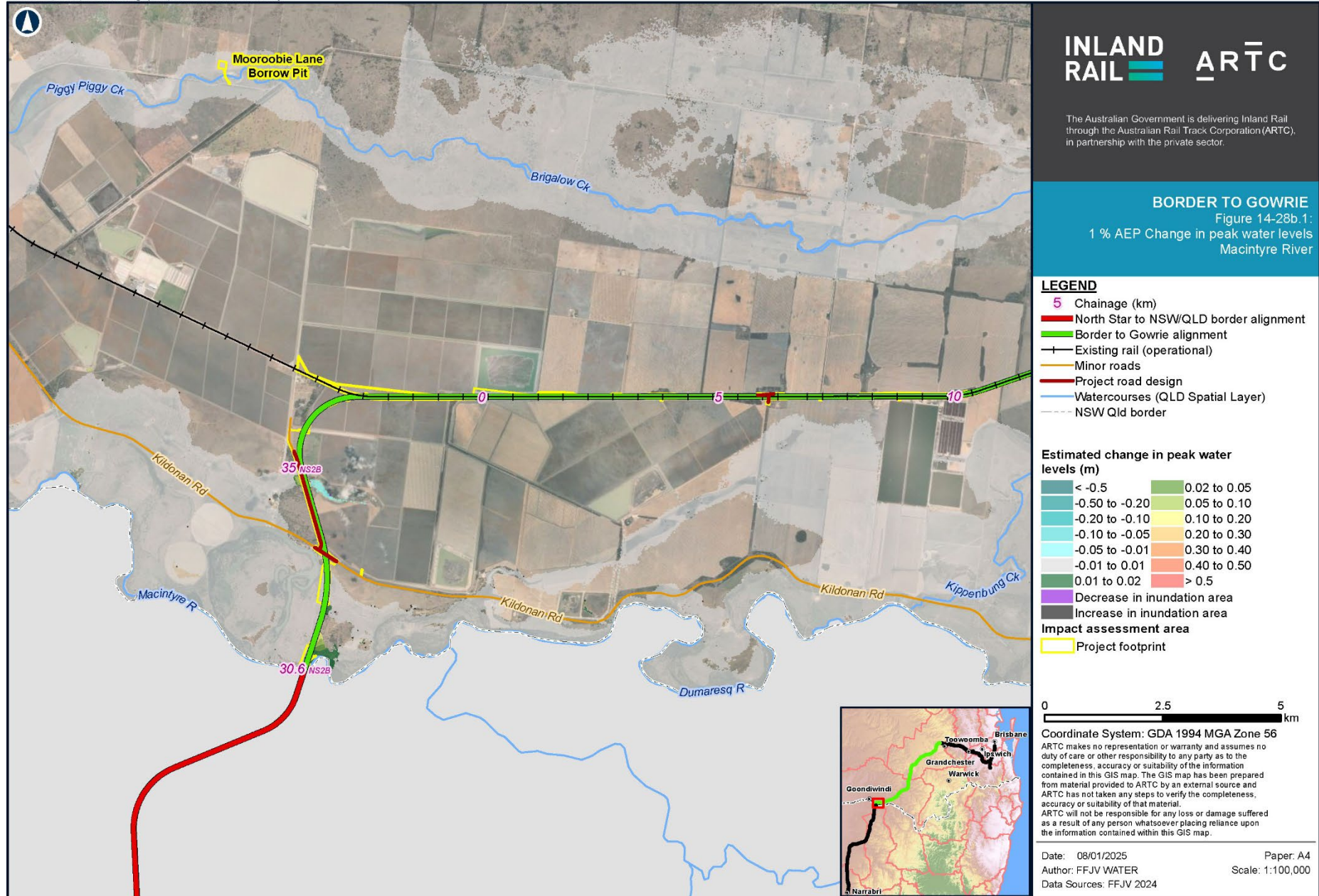
Date: 08/01/2025
Author: FFJV WATER
Data Sources: FFJV 2024

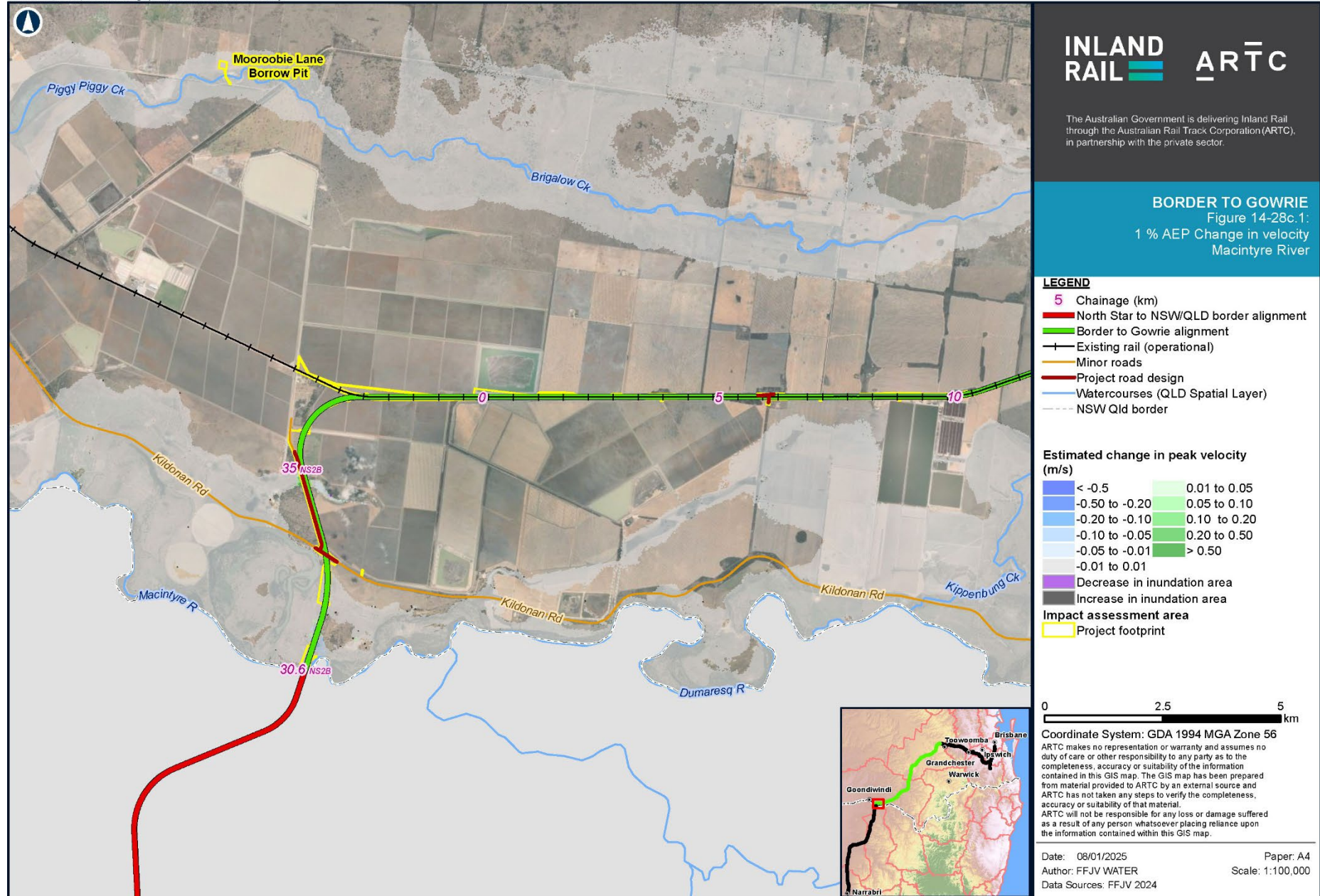
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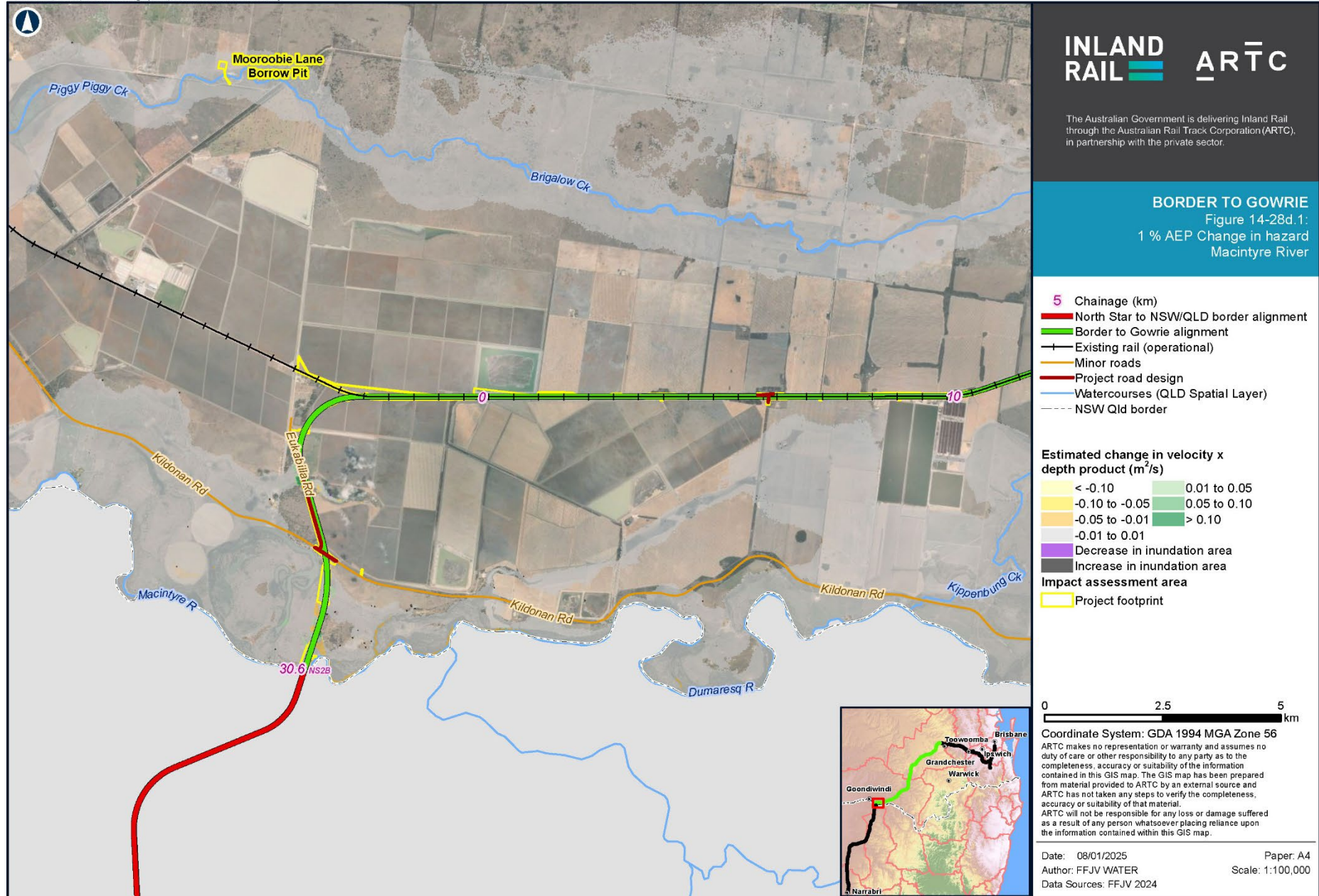


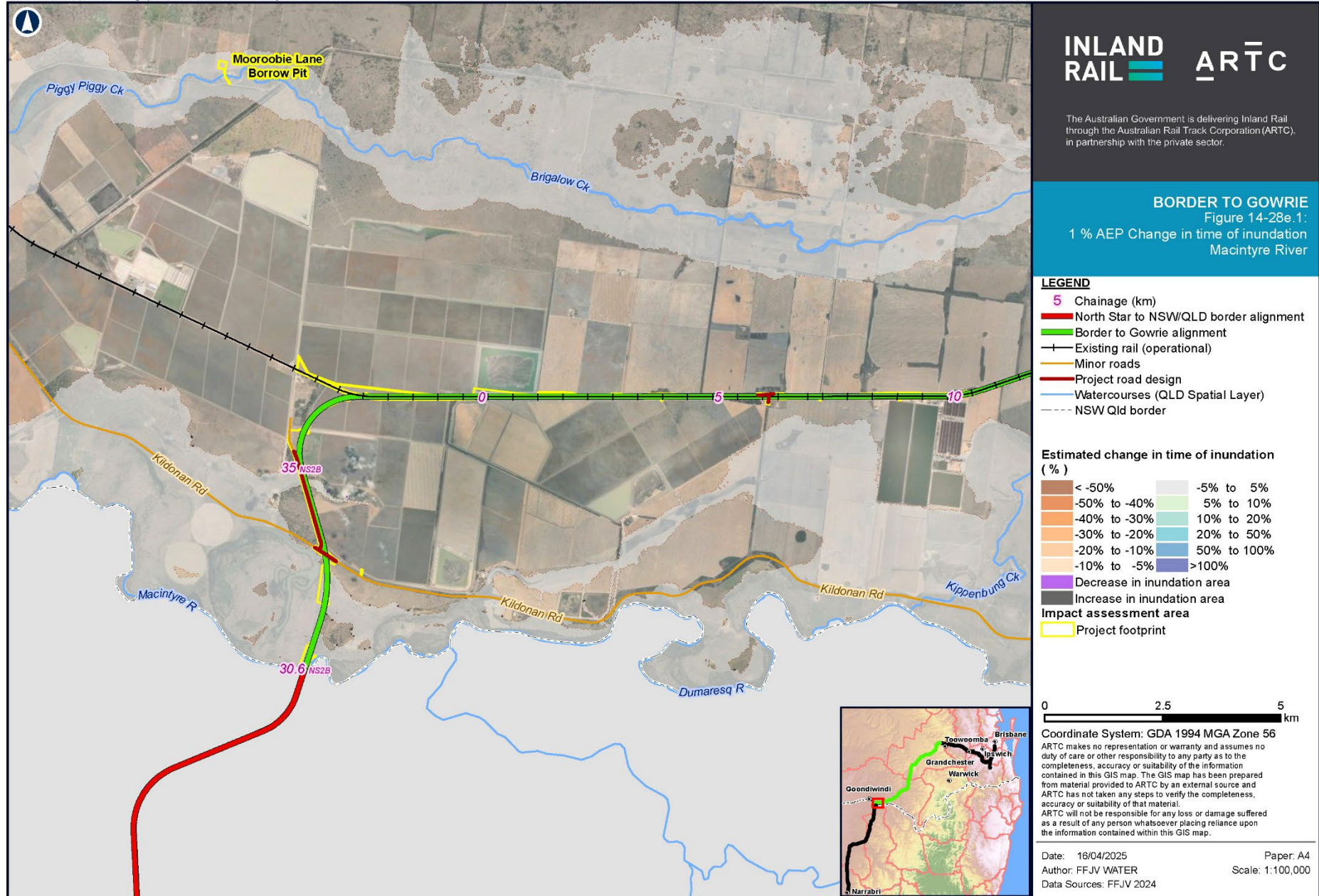












14.8.1.2.13 Local drainage catchments

In the local drainage catchments, the revised reference design includes:

- ▶ 74 RCP locations (a total of 527 culvert cells)
- ▶ 101 RCBC locations (a total of 891 culvert cells)
- ▶ One waterway bridge (310-BR42)
- ▶ Five rail-over-road bridges that also convey flood flows in large events (310-BR28, 310-BR29, 310-BR30, 310-BR40 and 310-BR51).

Details of the bridge structures required to convey local drainage flood flows are presented in Table 14-106. Details of local drainage culverts can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B).

TABLE 14-106 LOCAL DRAINAGE—STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Bridge name	Soffit level (m AHD)	Bridge length (m)
60.51	310-BR51	Bybera Road rail bridge	308.59	75
115.49	310-BR28	Millmerran Inglewood Road rail bridge #2	456.88	75
162.49	310-BR29	Yarranlea Road rail bridge	433.16	69
172.19	310-BR30	Oakey Pittsworth Road rail bridge	513.94	69
173.68	310-BR40	Lochaber Road rail bridge	528.95	75
184.83	310-BR42	Biddeston Southbrook Road rail bridge	530.43	144

Change in peak water levels

The following sections detail potential impacts above the flood impact objective targets for the change in peak water level. Analysis of the 20%, 10%, 5%, 2% and 1% AEP events was undertaken and figures showing the change in peak water levels are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3). Except for the identified locations, the change in peak water levels for modelled events up to the 1% AEP event complies with the FIOs (Section 14.6.3.3).

Flood impacts at sensitive receptors

Table 14-107 presents the change in peak water levels up to the 1 in 2,000 AEP event where the change in peak water levels lie outside the FIOs.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the FIOs (Section 14.6.3.3).

TABLE 14-107 LOCAL DRAINAGE CATCHMENTS—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Flood sensitive receptor ID	Flood sensitive receptor type	Approximate chainage (km)	FIOs up to the 1% AEP event	FIOs up to the 1 in 2,000 AEP event	Maximum increase in peak water level up to the 1% AEP event (mm)	Maximum increase in peak water level up to the 1 in 2,000 AEP event (mm)
CON_ID_392	Shed	161.7	< 100 mm	<250 mm	-	+9 ¹
GC6_ID_3	House	173.8	< 10 mm	<250 mm	-	+2 ¹

Table note:

1. Newly flood-affected flood sensitive receptor in the Developed Case

Private land outside the Project permanent footprint

Potential change in peak water level exceedances were identified for 61 lots within the local drainage modelled extents for all modelled events up to the 1 in 2,000 AEP event. Peak changes ranged from 11 mm on Lot Plan 33K5781 (in the 10% AEP event) to 2.10 m on Lot Plan 86MH675 and 79FTY1967 in the 10% AEP event. The large increases on Lot Plan 86MH675 and 79FTY1967 can be attributed to an increase in flood extent and newly flood-affected hydraulic model cells. A review of Lot Plan 86MH675 and 79FTY1967 indicates these are identical lots with different land use types. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.5) regarding these exceedances.

A summary of peak water level changes on the 61 impacted properties is provided below:

- ▶ Nine lots experience a maximum increase in peak water level greater than 1 m
- ▶ 16 lots experience a maximum increase in peak water level of between 500 mm and 1 m
- ▶ 22 lots experience a maximum increase in peak water level of between 100 mm and 500 mm
- ▶ 10 lots experience a maximum increase in peak water level of between 50 mm and 100 mm
- ▶ Four lots recorded an increase in peak water level of between 10 and 50 mm.

Other infrastructure

A total of five State-controlled roads (21 individual segments) and 34 local public roads (63 individual segments) are impacted by a change in peak water level. A full list of impacted roads can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Sections 18.6.3.2 and 18.6.3.3). Of the State-controlled roads impacted, Millmerran-Inglewood Road has been identified as experiencing the largest increase in peak water levels of 261 mm in the 1% AEP event. This portion of road is subject to increase in flood extent and a newly flood-affected hydraulic model cell. Millmerran-Inglewood Road experiences the most change of the State-controlled roads with 13 segments experiencing an increase in peak water levels. A summary of the five impacted State-controlled roads is below:

- ▶ The Cunningham Highway experiences a maximum change in peak water level of 172 mm in the 1% AEP event
- ▶ Yelarbon-Keetah Road experiences a maximum change in peak water level of 162 mm in the 2% AEP event
- ▶ Millmerran-Inglewood Road experiences a maximum change in peak water level of 261 mm in the 1% AEP event
- ▶ Oakey-Pittsworth Road experiences a maximum change in peak water level of 79 mm in the 1% AEP event
- ▶ Toowoomba-Cecil Plains Road experiences a maximum change in peak water level of 91 mm in the 2% AEP event.

Of the 34 local public roads (63 segments) impacted, Draper Road experiences the largest change in peak water level of 2.16 m in the 1% AEP event. A summary of local public roads impacted by a change in peak water levels is detailed below:

- ▶ One local road experiences a change in peak water level of greater than 1 m
- ▶ 18 local roads experience a change in peak water level of between 100 mm and 500 mm
- ▶ Five local roads experience a change in peak water level of between 50 mm and 100 mm
- ▶ 10 local roads experience a change in peak water level of between 10 mm and 50 mm.

Two existing rail lines experience a change in peak water level, with the Toowoomba to Thallon segment experiencing a change of 62 mm in the 1% AEP event.

Change in velocities

The potential change in velocity is quantified by assessing and comparing the velocity for the Existing Case and Developed Case.

Private land outside the Project permanent footprint

A total of 128 lots were identified as being impacted to some degree of change in velocity above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 79FTY1967 experiences the largest increase in velocity of 3.1 m/s. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.5) regarding these exceedances.

A summary of lots impacted by a change in velocity is provided below:

- ▶ Three lots experience a change in velocity greater than 2 m/s
- ▶ 39 lots experience a change in velocity of between 1 m/s and 2 m/s
- ▶ 40 lots experience a change in velocity of between 0.5 m/s and 1 m/s
- ▶ 45 lots experience a change in velocity less than 0.5 m/s
- ▶ One lot experiences a percentage change in velocity only.

Other infrastructure

Two State-controlled roads have been identified to experience a change in velocity due the presence of the Project. The Cunningham Highway is identified as experiencing a 21 per cent change in velocity (1.6 m/s to 2.0 m/s) and Oakey-Pittsworth Road is expected to experience a 58 per cent increase in peak velocity and an 'absolute' change of 0.63 m/s.

Twenty-two local roads (26 segments) have been identified to experience a change in velocity due to the Project alignment. An unnamed road experiences the largest change in velocity of 1.48 m/s in the 20% AEP event and can be attributed to a change in flood extent and newly flood-affected hydraulic model cell. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.3) regarding these exceedances.

A summary of peak velocity changes on the 22 local public roads is provided below:

- ▶ Two local roads experience an increase in peak velocity greater than 1 m/s
- ▶ Four local roads experience an increase in peak velocity of between 0.5 m/s and 1 m/s
- ▶ Three local roads experience an increase in peak velocity of between 0.1 m/s and 0.5 m/s
- ▶ 13 local roads experience an increase in peak velocity of less than 0.1 m/s.

No existing rail infrastructure is expected to be impacted by a change in velocity.

Figures showing the change in velocity are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3).

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Guide to Road Design Part 5B: Drainage–Open Channels, Culverts and Floodways* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping or a velocity exceedance above the flood impact objective target was identified at the Project corridor boundary.

Change in flood hazard

The potential change in hazard (i.e. velocity-depth product) is quantified by assessing and comparing the hazard for the Existing Case and Developed Case.

Flood impacts at sensitive receptors

Based on the available aerial imagery, no buildings or critical infrastructure are located within the area impacted by change in flood hazard in the Macintyre River floodplain for all modelled events up to the 1% AEP event.

Private land outside the Project permanent footprint

A total of 84 lots were identified as being impacted to some degree of change in hazard above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. The maximum increase for flood hazard is approximately 0.45 m²/s (from 0.00 to 0.45 m²/s) on Lot Plan 9MH365. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.5) regarding these exceedances.

A summary of peak hazard changes on the 84 lots impacted by a change in hazard is provided below:

- ▶ 17 lots experience a change in hazard of greater than 1,000 per cent
- ▶ Three lots experience a change in hazard of between 500 per cent and 1,000 per cent
- ▶ 30 lots experience a change in hazard of between 100 per cent and 500 per cent
- ▶ 12 lots experience a change in hazard of between 50 per cent and 100 per cent
- ▶ 22 lots experience a change in hazard of between 100 per cent and 50 per cent.

Other infrastructure

A total of three State-controlled roads (five individual segments) and 11 local public roads (13 individual segments) are impacted by a change in peak hazard. Of the State-controlled roads impacted, Millmerran-Inglewood Road has been identified as experiencing the largest increase in peak hazard of 204 per cent (0.11 m²/s) increasing from 0.05 m²/s to 0.160 m²/s in the 1% AEP event. A summary of the three impacted State-controlled roads is below:

- ▶ The Cunningham Highway experiences a maximum change in hazard of 63 per cent (0.11 m²/s) in the 5% AEP event
- ▶ Millmerran-Inglewood Road experiences a maximum change in hazard of 204 per cent (0.11 m²/s) in the 1% AEP event
- ▶ Oakey-Pittsworth Road experiences a maximum change in hazard of 100 per cent (0.09 m²/s) in the 10% AEP event.

Eleven local roads (13 segments) have been identified to experience a change in hazard due to the Project alignment. Yelarbon Kurumbul has been identified as experiencing the largest increase in peak hazard of 25,977 per cent (0.20 m²/s) increasing from 0.00 m²/s to 0.20 m²/s in the 5% AEP event which can be attributed to the Existing Case result being extremely small with an increase to a small hazard result in the Developed Case. A summary of peak hazard changes on the 11 local roads is provided below:

- ▶ One local road experiences a change in hazard of greater than 1,000 per cent
- ▶ One local road experiences a change in hazard of between 500 per cent and 1,000 per cent
- ▶ One local road experiences a change in hazard of between 100 per cent and 500 per cent
- ▶ Three local roads experience a change in hazard of between 50 per cent and 100 per cent
- ▶ Five local roads experience a change in hazard of between 10 per cent and 50 per cent.

No existing rail infrastructure is expected to be impacted by a change in peak hazard.

Figures showing the change in hazard presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3).

Change in time of inundation

The potential change in time of inundation is quantified by assessing and comparing the time of inundation for the Existing Case and Developed Case.

Private land outside the Project permanent footprint

A total of 154 lots were identified as being impacted to some degree of change in time of inundation above the flood impact objective targets for the 20%, 10%, 5%, 2% and 1% AEP events. Of these, Lot Plan 8MH160 has been identified as experiencing the largest percentage increase in time of inundation of 540 per cent (increasing from 1.0 hours in the Existing Case to 6.5 hours in the Developed Case) in the 1% AEP event. The largest 'absolute' change of 6.5 hours has been identified on Lot Plan 413SP119197. Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.5) regarding these exceedances.

A summary of time of inundation changes on the 154 lots is provided below:

- ▶ One lot experiences an increase in time of inundation of greater than 500 per cent
- ▶ 56 lots experience an increase in time of inundation of between 100 per cent and 500 per cent
- ▶ 33 lots experience an increase in time of inundation of between 50 per cent and 100 per cent
- ▶ 49 lots experience an increase in time of inundation of between 10 per cent and 50 per cent
- ▶ 15 lots only experience an 'absolute' change in time of inundation.

Other infrastructure

A total of 48 roads (State-controlled and local roads) are impacted by a change in time of inundation. Six State-controlled roads are identified as impacted with the Cunningham Highway recording the largest impact of 876 per cent change in time of inundation (increasing from 0.01 hours to 0.09 hours). Additional information can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3.2 and Section 18.6.3.3) regarding these exceedances.

A summary of impacts on State-controlled roads is provided below:

- ▶ Oakey-Pittsworth Road experiences a peak change in time of inundation of 34 per cent (0.14 hours)
- ▶ Millmerran-Inglewood Road experiences a peak change in time of inundation of 799 per cent (0.51 hours)
- ▶ The Cunningham Highway experiences a peak change in time of inundation of 876 per cent (0.08 hours)
- ▶ Yelarbon-Keetah Road experiences a peak change in time of inundation of 713 per cent (0.05 hours)
- ▶ The Gore Highway experiences a peak change in time of inundation of 16 per cent (0.04 hours)
- ▶ Toowoomba-Cecil Plains Road experiences a peak change in time of inundation of 200 per cent (0.22 hours).

A total of 42 local public roads are impacted by an increase in time of inundation for all modelled events up to the 1% AEP event. Longhurst Road experiences the largest increase in time of inundation of 2,323 per cent (0.71 hours) in the 1% AEP event. A summary of time of inundation changes on the 42 local roads is provided below:

- ▶ Five local roads experience a change in time of inundation of greater than 1,000 per cent
- ▶ Four local road experiences a change in time of inundation of between 500 per cent and 1,000 per cent
- ▶ Eight local roads experience a change in time of inundation of between 100 per cent and 500 per cent
- ▶ Five local roads experience a change in time of inundation of between 50 per cent and 100 per cent
- ▶ 20 local roads experience a change in time of inundation of between 10 per cent to 50 per cent.

No existing rail infrastructure is expected to be impacted by a change in peak time of inundation.

Figures showing the change in time of inundation are presented in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (for 20% and 1% AEP events only) and the **Online Digital Platform** (for all events). Further information of exceedances can be found in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 18.6.3).

Flood flow distribution

To estimate the change in flow distribution, the maximum velocity-depth product modelling results were used to identify a change in unit flow between Existing Case and Developed Case conditions. Unit flow is a measure of discharge that is commonly used for assessing peak flow along cross-sections, or to identify the efficient flow corridors within a flow path.

The estimated flow distribution was filtered with a velocity-depth product cut-off of 0.15 m²/s. The cut-off is in line with flood impact objective requirements and was used to differentiate main channels (i.e. high flow zones) from shallow sheet flows (the assumed threshold for shallow sheet flow is 0.15 m²/s).

General observations with respect to the impact of the Project on the flow distribution within local catchments include:

- ▶ The raised rail embankment restricts runoff overtopping and encourages ponding, causing an increased flow distribution impact upstream of the proposed rail embankment
- ▶ The improved conveyance of the proposed culverts to cater for rare events reduces flow distribution impact at culverts upstream during more frequent events
- ▶ The concentrated runoff at the culvert outlets increased flow distribution impact at culverts downstream.

A summary of flood flow distribution changes in local catchments is detailed in Table 14-108.

TABLE 14-108 LOCAL CATCHMENT FLOOD FLOW DISTRIBUTION CHANGE

Chainage	Flood flow distribution change
33.30 km (NS2B) to 37.10 km (NS2B)	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Moderate flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Three farm dams are impacted due to flow redistribution.
4.80 km to 33.60 km	Small to moderate flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Localised larger flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. 14 farm dams are impacted due to flow redistribution.
33.00 km to 55.30 km	Small to medium flow distribution impacts (less than $\pm 15\%$) were observed in all modelled events up to a 1% AEP event. Localised larger flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. One farm dam is impacted due to flow redistribution.
56.10 km to 67.60 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Four farm dams are impacted due to flow redistribution.
70.18 km to 86.10 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Localised larger flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Eight farm dams are impacted due to flow redistribution.
86.50 km to 93.70 km	Moderate flow distribution impacts (less than $\pm 20\%$) were observed in all modelled events up to a 1% AEP event. Similarly, moderate flow distribution impacts (less than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. One farm dam is impacted due to flow redistribution.
94.30 km to 103.80 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Localised larger flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Three farm dams are impacted due to flow redistribution.
104.30 km to 116.20 km	Moderate flow distribution impacts (less than $\pm 20\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. 15 farm dams are impacted due to flow redistribution.

Chainage	Flood flow distribution change
115.10 km to 127.00 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Seven farm dams are impacted due to flow redistribution.
128.20 km to 138.20 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP events. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. One farm dam is impacted due to flow redistribution.
152.10 km to 165.80 km	Small flow distribution impacts less than $\pm 5\%$) were observed in all modelled events up to a 1% AEP event. Medium localised flow distribution impacts (greater than $\pm 10\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Four farm dams are impacted due to flow redistribution.
166.70 km to 174.50 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Four farm dams are impacted due to flow redistribution.
176.30 km to 188.00 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths. Four farm dams are impacted due to flow redistribution.
186.25 km to 196.37 km	Small to medium flow distribution impacts (less than $\pm 10\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths.
198.95 km to 202.25 km	Medium flow distribution impacts (less than $\pm 15\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths.
205.40 km to 208.20 km	Small flow distribution impacts (less than $\pm 5\%$) were observed in all modelled events up to a 1% AEP event. Larger localised flow distribution impacts (greater than $\pm 20\%$) were observed in the vicinity of culvert inlets/outlets and along the main flow paths.

14.8.1.2.14 Embankment overtopping failure risk assessment

An assessment was undertaken to determine the potential risk, and associated impacts of a rail embankment collapse during extreme flood events. The outcomes of this assessment are reported in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 21).

Overtopping flow is the key factor in most potential failure modes caused by floods. Most embankments are unlikely to withstand sustained overtopping by 300 mm to 600 mm without a high probability of failure. The likelihood of failure depends on factors such as the depth and duration of overtopping, the strength and erodibility of the materials, and various other factors.

The potential risk to life due to overtopping flood failure of an embankment is related to:

- ▶ The location of flood sensitive receptors including places of permanent and temporary occupation (e.g. dwellings, commercial buildings, sheds) relative to the potential breach location
- ▶ The number of occupants expected at each flood sensitive receptors
- ▶ The severity of flooding experienced under flood conditions prior to failure of the embankment
- ▶ The flood characteristics experienced at flood sensitive receptor locations resulting from embankment failure.

It is important to note that for an overtopping failure event, there may be extensive floodplain inundation prior to the failure occurring. In this instance, there could be occupants who have already been significantly affected by pre-failure flooding and, consequently, who could be considered to no longer remain in the flood zone.

An example of this would be people who have been subjected to significant flood depth and flood velocity, or people who are within an area covered by an emergency management plan that requires them to leave the area (Australian National Committee on Large Dam, 2012). This sentiment is also reflected in the Queensland *Guidelines for failure impact assessment of water dams* (Department of Natural Resources, Mines and Energy, 2018), where flood sensitive receptors do not contribute to the number of persons at risk if they experience flood depths ≥ 300 mm over a building's plinth in the no-failure flood event.

The methodology employed to assess the risk to life due to embankment overtopping included the following steps: hydraulic modelling of extreme flood events, creation of a GIS database of places of occupation, determination of risk of overtopping based on depth, mapping of areas at risk of overtopping failure, identification and mapping of receptors likely to be impacted by flood inundation in the event of an embankment failure, assessment of peak water level differentials across the embankment and a slope stability assessment of the embankment in critical areas.

The results of the risk assessment for the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF flood events are illustrated in Appendix T2: Hydrology and Flooding Technical Report–Volume 2 (Figures R1-1 to R4-11). These maps illustrate that, based on the rarity of these flood events, the number of potentially impacted receptors located downstream of each of the identified embankment breach locations, the slope stability assessment exceeding the target factor of safety, and in consideration of the minor hydrostatic pressure differentials expected across the embankment during significant flood events, the potential risk to life due to overtopping failure of an embankment is considered to be low.

14.8.1.2.15 Emergency access route assessment

Consultation with the Local Disaster Management Group (LDMG) in each local government area was undertaken to determine current and planned evacuation routes during flood events, and an impact assessment was conducted on these routes based on the feedback received from councils. For TRC, 32 potential evacuation centres (in the planning stage) were identified within the Local Government Area. For GRC, three potential evacuation centres were identified. The selection and use during an emergency are dependent on the range of factors including the type and scale of disaster.

Key localities within the vicinity of the Project identified by TRC and GRC LDMGs are summarised in Table 14-109, including nominated evacuation mechanisms and potential evacuation centres for these localities.

TABLE 14-109 EVACUATION CENTRES ALONG THE PROJECT ALIGNMENT

Location	Commentary
Millmerran, Pampas and surrounding localities	Three potential evacuation centres exist based in the Millmerran township. Due to riverine flooding cutting the Gore Highway at Centenary Bridge (Condamine River) and surrounding lower-level roads, localities to the east of this would need to be directed to potential evacuation centres back towards Toowoomba.
Brookstead	One potential evacuation centre is located in this vicinity.
Pittsworth	Two potential evacuation centres is located in the township.
Southbrook	No evacuation centres are present in the township. Evacuation to Pittsworth or Toowoomba would be required.
Wellcamp	No evacuation centres are present in the area. Evacuation to Toowoomba would be required.
Gowrie Junction	One evacuation centre is present within the area.
Gowrie Mountain	Impact to the Warrego Highway may have an impact on evacuations from the western localities into Toowoomba.
Goondiwindi Evacuation Centre ¹	One evacuation centre is located at the Goondiwindi Showgrounds, at 323 Boundary Road, Goondiwindi, and is advertised to the public as the primary evacuation centre site.
Inglewood Assembly Point ¹	One evacuation centre is located at the Inglewood Landfill Facility, off Inglewood-Texas Road, Inglewood. This is a new site to that was used in the flood event of 2021.
Texas Evacuation Centre ¹	One evacuation centre is located at the Texas Sport Complex, off Middleton Street, Texas, and is advertised to the public as the primary evacuation centre site.

Table note:

1. Due to the terrain and nature of the GRC area, most flooding is caused by riverine flooding rather than flash flooding and, as a result of this, most of its centres can be completely isolated by road for periods during floods. Although the state road network is very important for access at all times, part of the Kildonan Road and the Yelarbon-Kurumbul Road provide an important access route to Goondiwindi at times during floods.

A review of the State-controlled roads in the areas of evacuation centres was completed and a flood impact assessment was conducted to determine the potential effects of the Project on these routes. The review identified a large number of segments of State-controlled roads, especially within the Macintyre Brook and Condamine River floodplains, currently having low immunity with trafficability limited under the Existing Case scenario. The impact assessment was completed against the FIOs and some flood impact objective exceedances were identified for the roads in the area. The impact assessment is reported in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 19) with a summary provided below.

Millmerran and Pampas

The flood impact objective assessment identified potential impacts to the Gore Highway, Millmerran-Inglewood Road, Millmerran-Leyburn Road and Pampas-Horrane Road. Access to Millmerran from the south is generally via Millmerran-Inglewood Road which is subject to exceedances in both regional and local flooding. Millmerran-Inglewood Road experiences flooding within the vicinity of Bringalily Creek and Back Creek catchments and generally has low-immunity in the Existing Case scenario. The majority of exceedances along Millmerran-Inglewood Road are due to an increase in duration of inundation.

Access to Millmerran from the northeast is generally via the Gore Highway. The Gore Highway is impacted by flooding from both Back Creek and Condamine River in the Existing Case scenario and has low existing immunity across the Condamine floodplain. Some exceedances of the FIOs are experienced on the Gore Highway due to the presence of the Project and are generally related to afflux and change in duration of inundation. In instances where the Gore Highway is inaccessible due to flooding, evacuation of residents from Pampas should be strongly considered to mitigate isolation due to flooding from both the Main Branch and North Branch of the Condamine River.

Although some impact to State-controlled roads due to the Project occurs within the vicinity of the Millmerran and Pampas, existing road infrastructure currently has low immunity and is flooded during the Existing Case. It is not anticipated that the flood impact objective exceedances identified will affect the trafficability of the road network within this region, as generally the road network as a whole experiences access issues due to other low lying areas (away from the Project alignment) preventing access.

Brookstead

Generally, access to Brookstead from the north (via Brookstead-Norwin Road) and east (via the Gore Highway) is not impacted due to the presence of the Project. A potential impact occurs to the Gore Highway to the south of Brookstead due to flooding from the North Branch of the Condamine River.

Southbrook

Access along the Gore Highway from Pittsworth to Southbrook is not impacted due to the Project. To the north of Southbrook, some afflux (up to 11 mm) and an increase in duration of inundation (a 15.5 per cent increase) may be experienced on the highway due to the presence of the Project. Although this does technically exceed the flood impact objective target, the impacted length of 2.5 m and 5 m, respectively, as well as the magnitude of the impacts, are considered negligible. Further consultation with road managers in this area will be undertaken during the detailed design regarding this exceedance.

Oakey-Pittsworth Road is impacted due to the presence of the Project alignment, adjacent to the intersection with the Gore Highway. Afflux is experienced on this segment of road up to a maximum of 79 mm in the 1% AEP event, across a length of approximately 115 m. A maximum velocity increase of 0.63 m/s is experienced in this same location. This segment of road is proposed to be upgraded as part of the Project and likely the cause of change from the Existing Case. Further optimisation of this design will be undertaken as part of detailed design to minimise impacts on the existing trafficability of the road.

Wellcamp

The flood impact objective assessment of the Project's permanent footprint has demonstrated that some exceedance of the FIOs occurs along Toowoomba-Cecil Plains Road in both regional and local flooding. Afflux, change in duration of inundation, change in velocity and change in hazard impacts are all recorded within the same stretch of road. These exceedances are generally confined to the regional flood event, with afflux and change in duration of inundation exceedances also occurring in the local flood event. Impact on Toowoomba-Cecil Plains Road may further constrain access from the west heading towards Toowoomba, although this section of road, as stated above, currently has low flood immunity in the Existing Case scenario.

Gowrie Mountain

Flood impact objective exceedances occur on the eastbound lane within the vicinity of the Project alignment and, as stated above, this is likely due to the misrepresentation of the eastbound lane within the utilised LiDAR. Two other locations demonstrate exceedances along the Warrego Highway both of which occur on the westbound lane. A review of these exceedances shows up to a maximum of 51 mm of afflux occurring within the proximity of the Project alignment and an 11 per cent increase in duration of inundation, approximately 1 km to the east of the Project alignment crossing. A review of the extent of impact shows approximately 6 m of road segment is impacted by increased afflux and 2 m of road segment impacted by the increase of time of inundation.

Gowrie Junction

No impacts to State-controlled roads within the vicinity of Gowrie Junction were identified due to the Project.

Goondiwindi and Yelarbon

The flood impact assessment results show that, due to the low immunity of roads around the Goondiwindi and Yelarbon area, some impacts result due to the introduction of the Project. Generally, most flood impact objective exceedances identified related to regional flooding are afflux and change in duration of inundation, with some increase in hazard identified on the Cunningham Highway. Local flooding mainly impacts Yelarbon-Kurumbul Road which can be attributed to the maturity of the cross-drainage design and lack of existing survey data in this area. Further work will be undertaken in detailed design to reduce these exceedances through use of additional survey information and consultation with QR to identify further existing infrastructure under the rail line.

Inglewood

The flood impact assessment identified potential impacts to Millmerran-Inglewood Road and the Cunningham Highway. Generally, flood impact objective exceedances recorded are related to afflux and range from 10 mm to 60 mm. It is anticipated through cross-drainage optimisation, that these impacts can be further reduced in detailed design.

14.8.2 Potential impacts–geomorphology

Changes to existing condition processes may lead to potential impacts. Watercourse and floodplain geomorphic processes are listed in Section 14.7.8.4 and Appendix H: Geomorphology Report. The impact assessment has been undertaken to identify further work requirements and inform mitigation and management measures relevant to future project stages to maintain Existing Case geomorphological processes where practical or minimise change to allow to the processes to continue to function in the future. This assessment considers all geomorphic processes; however, it is not an assessment of ETV. Erosion threshold velocity-based design aims to inform and guide erosion protection strategies for the Project. These strategies will reduce a watercourse's ability to transport its own sediment, leading to aggradation and reduced flood capacity.

Existing geomorphic processes are described in Sections 14.7.8.4 and 14.7.8.7. In summary, potential impacts throughout Project stages include changes to the following:

- | | |
|---------------------------|----------------------------|
| ▶ Watercourse | ▶ Floodplains |
| ▶ erosion | ▶ erosion |
| ▶ deposition | ▶ deposition |
| ▶ channel type change | ▶ floodplain connectivity. |
| ▶ channel planform change | |

Floodplain processes may be impacted by the Project alignment where connectivity to the main channel/s is reduced or disconnected. This may occur in areas with no cross-drainage included in the revised reference design where the Project alignment sidles along the edge of a floodplain (e.g. floodplain sidling), effectively forming a barrier between parts of the geomorphic floodplain and main channel/s.

The geomorphology impact assessment has been undertaken on the greatest area of potential change along watercourses and floodplains due to the Project even though this often occurs within the Project footprint. This is because impacts in fluvial systems can have downstream and upstream implications, for example sediment eroded from within the Project permanent footprint would be transported and deposited outside of the study area.

Local opportunities for watercourse or floodplain enhancement opportunities have been noted where they have been identified, while taking into consideration that remediation typically requires a catchment wide approach, which is outside the Project's influence and control.

14.8.2.1 Pre-construction and early works activities, and construction works potential impacts

This period involves the greatest level of ground disturbance, and has the potential to lead to environmental impacts, including:

- ▶ Increased erosion due to vegetation clearance of sites, access tracks construction, disturbance of the soil surface and the creation of infiltration and erosion pathways (This can include when infrastructure is only partially built, as there can be a potential combination of flow being concentrated, the presence of bare/disturbed soils, and the possibility that scour protection or other mitigation measures may not yet be fully in place.
- ▶ Increased deposition due to increased erosion or improperly designed site layout or storage areas leading to potential blockage of drainage pathways or channel aggregation.
- ▶ Channel planform change due to potential redirection of flow.
- ▶ Changes to channel types due to potential redirection of flow and or flow concentration.

14.8.2.2 Commissioning and operations stage potential impacts

Commissioning and operations stage potential impacts were assessed for all watercourses included in the sub-reach assessment and all geomorphic floodplains.

Watercourses not included in the sub-reach assessment have so little evidence of active fluvial geomorphology that they typically have no channel form where they cross the Project alignment. These watercourses were assessed under the hydrology and flooding EIS aspect against the FIOs, and any exceedances were noted and mitigation options identified within Appendix T1: Hydrology and Flooding Technical Report–Volume 1. The mitigations were reviewed by a geomorphologist.

Criteria to assess for potential impacts to the fluvial geomorphic environment are included in Table 14-5 and Table 14-6. Meeting the criteria to assess for potential change does not mean that impacts may occur. Where the criteria was met, the potential for an impact to occur was assessed taking into consideration:

- ▶ The revised reference design (including scour protection and rehabilitation, as per Chapter 5: Project Description).
 - ▶ For example, if increased flow velocity was identified as a potential impact, but it was limited to the length of the scour protection, it was considered a minor consequence. If potential increased flow velocities extended beyond the scour protection, an assessment of consequence was made based on the flow velocity beyond the scour protection, baseline conditions and Existing Case sensitivity to change.
 - ▶ Based on review of the hydraulic difference models, geomorphic impacts will reduce to undetectable by 100 m upstream and 100 m downstream of the Project alignment, with the highest impacts at the culvert outlet (Figure 14-29a) typically within the area the scour protection measures will be located.
- ▶ Geomorphic baseline conditions, including processes at the site.
 - ▶ For example, deposition is unlikely to be a potential impact at the site, as even if design flow velocities are reduced, there is no evidence of bedload.
- ▶ The amount, type and location of potential change.
 - ▶ For example, a design culvert may be in an area of a floodplain with below average Existing Case velocities relative to the rest of the floodplain and show a greater apparent increase in design flow velocities. Where design flow velocities at this culvert are consistent with Existing Case flow velocities elsewhere on the floodplain, they are unlikely to result in elevated erosion potential.
 - ▶ Conversely, a channel may be showing signs of erosion under Existing Case conditions, with a high sensitivity to change. In this case even a small increase in design flow velocity would be likely to increase the erosion potential.

Potential impacts to watercourses

Commissioning and operations stage potential impacts were assessed for 85 watercourse and are summarised in Table 14-110 by infrastructure type, including:

- ▶ Design bridges, 21 watercourses
- ▶ Design culverts, 55 watercourses
- ▶ Diversion, three watercourses at two diversions
- ▶ Design cut, three watercourses
- ▶ No design cross-drainage, three watercourses.

Two sites with sub-reach assessments were assessed under the floodplain category as they are flood channels/basins: the Condamine South Branch and Condamine anabranch.

The most common potential impact is planforms change; this is largely driven by design bridge abutments that are very close to or within a channel, and design culverts not aligned to flow. Erosion and 'channel type change' potential impacts were identified at 18 watercourses where scour protection in the revised reference design was not assessed as sufficient to mitigate for increased erosion potential or was not present. The criteria to assess for deposition potential was triggered the most, at 61 of the 85 watercourses; however, as the majority of the Project watercourses have washslope or non-channelised valley floor channel types with no evidence for bedload, deposition was only identified as a potential impact at 13 watercourses.

TABLE 14-110 SUMMARY OF COMMISSIONING AND OPERATIONS STAGE POTENTIAL IMPACTS FOR WATERCOURSES, INCLUDING THE NUMBER OF WATERCOURSES THAT MET IMPACT ASSESSMENT CRITERIA (GEOMORPHOLOGY TECHNICAL REPORT)

Design infrastructure Potential impact category	Number of channels	Number of channels by potential impact (# of channels that met impact assessment criteria)			
		Erosion	Deposition	Planform change	Channel type change
Bridges					
1. No encroachment	1	0 (0)	0 (0)	0 (0)	0 (0)
2. Floodplain encroachment by one/both abutments	8	2 (2)	0 (3)	0 (0)	0 (0)
3. Floodplain encroachment/sidling by one/both abutments	4	0 (0)	0 (0)	0 (0)	0 (0)
4. Floodplain encroachment by abutment up to channel edge	4	0 (2)	0 (2)	4 (4)	4 (4)
5. Watercourse encroachment by one/both abutments	4	1 (1)	0 (2)	4 (4)	4 (4)
Culverts					
1. Within 10% of existing flow	2	0 (1)	0 (0)	0 (0)	0 (0)
2. Upstream within 10% of existing flow, downstream decrease	4	0 (1)	2 (4)	3 (3)	0 (0)
3. Upstream within 10% of existing flow, downstream increase	1	1 (1)	0 (0)	1 (1)	1 (1)
4. Upstream decrease, downstream within 10% of existing flow	12	1 (5)	2 (12)	5 (5)	0 (0)
5. Upstream increase, downstream within 10% of existing flow	2	2 (2)	0 (1)	1 (1)	2 (2)
6. Upstream decrease in flow, downstream increase	15	1 (15)	1 (15)	9 (9)	1 (14)
7. Upstream and downstream decrease	15	0 (0)	4 (15)	7 (7)	0 (0)
8. Upstream and downstream increase	4	4 (4)	0 (0)	2 (2)	4 (4)
Diversions					
Upstream decrease in flow, downstream increase	3	3 (3)	1 (1)	2 (2)	2 (2)
Cut					
Upstream decrease in flow, downstream increase	3	0 (3)	0 (3)	0 (0)	0 (0)
No cross drainage					
Redirected flow path	3	3 (3)	3 (3)	3 (3)	0 (0)
TOTAL	85	18 (43)	13 (61)	41 (41)	18 (31)

Potential impacts to watercourses from bridges

The potential impacts of bridges on watercourses that met impact assessment criteria and risk outcomes are summarised by watercourse in Table 14-112 and Table 14-113. Potential impacts of bridge piers have not been included in this assessment. Potential impact categories, which group similar types of effects in increasing consequence comprise:

- ▶ No encroachment–no impacts
 - ▶ bridge embankments do not intersect the flow up to and including the 1% AEP (1 in 100 year) event
- ▶ Floodplain encroachment by one/both abutments (Figure 14-29b)
 - ▶ bridge does not intersect flow during the bankfull event
 - ▶ during a 1% AEP event the floodplain at the bridge site is encroached by one or both abutments.
- ▶ Floodplain encroachment/sidling by one/both abutments
 - ▶ bridge does not intersect flow during the bankfull event
 - ▶ during a 1% AEP event an encroaching embankment faces flow redirection along its edge.

- ▶ Floodplain encroachment by abutment up to channel edge (Figure 14-29c)
 - ▶ during a 1% AEP event a floodplain encroaching embankment reaches the edge of a channel without encroaching the channel itself.
- ▶ Watercourse encroachment by abutment (Figure 14-29d)
 - ▶ during a 1% AEP event an embankment encroaches up to and on to a watercourse.

Due to the mitigation measures allowed for in the revised reference design, most of the potential consequences of bridges on the fluvial geomorphic environment are 'not significant' to 'minor'. Higher potential consequences occur where the revised reference design bridge abutment extends up to the channel edge or into a channel. With the proposed mitigation measures developed for future stages, including the setback of embankments from the channels, these sites all reduce to low-risk.

Potential impacts to watercourses from culverts

The potential impacts of culverts on watercourses that met impact assessment criteria and risk outcomes are summarised by watercourse in Table 14-114 and Table 14-115. Potential impact categories, which group similar types of effects comprise:

- ▶ Within 10% of existing flow—impacts unlikely
- ▶ Upstream within 10% of existing flow, downstream decrease
- ▶ Upstream within 10% of existing flow, downstream increase
- ▶ Upstream decrease, downstream within 10% of existing flow
- ▶ Upstream increase, downstream within 10% of existing flow
- ▶ Upstream decrease in flow, downstream increase
- ▶ Upstream and downstream decrease
- ▶ Upstream and downstream increase.

Where culverts are not aligned to watercourse, example shown in Figure 14-29e and Figure 14-29f) they can concentrate flow to the edge of the channel or even outside of the channel on the floodplain, potentially changing channel planform. This was the most common potential impact for watercourses with culverts. Culvert alignment to watercourse is noted in Appendix H: Geomorphology Report (see Appendix H) for potential mitigation and optimisation purposes.

Potential impacts to watercourses from diversions

The potential impacts of diversions on watercourses are summarised by watercourse below with risk assessment outcomes included in Table 14-116.

There are two design diversions that impact three watercourses (drainage features):

- ▶ Ch 120.76 km–121.43 km, watercourses SC 5 (in cut) and SC 6, Culvert 120.77:
 - ▶ C120.77 has downstream scour protection for 10.8 m
 - ▶ upstream and downstream design flow velocity are within 10% of the Existing Case flow velocity
 - ▶ culvert not aligned to watercourse
 - ▶ diversion includes a sharp channel bend of close to 90-degrees
 - ▶ SC 6 potential impacts include erosion and downstream channel type and planform change
 - ▶ SC 5 potential impacts include deposition and erosion
 - ▶ SC 5 does not appear to be in the hydraulic model; therefore, the hydraulic model outcomes may not be representative of Developed Case conditions; however, SC 5 is unlikely to have significant flow as the Project alignment intersects this Strahler order 1 watercourse near the upper end of its headwater, and it has two upstream human-made ponds, which would reduce flow in the watercourse.
- ▶ Ch 192.00 km, watercourse OC 4, Culvert C192.09:
 - ▶ C192.09 has downstream scour protection for 10.8 m
 - ▶ upstream and downstream increase in flow velocity
 - ▶ upstream increase in flow velocity occurs in constructed diversion channel, and downstream increase occurs mainly in the area of scour protection in the revised reference design
 - ▶ culvert not aligned to watercourse at outlet
 - ▶ diversion includes close to 90-degree angles
 - ▶ potential impacts include erosion and downstream channel type and planform change.

Figure 14-29g shows the location of SC5 and SC6 along the alignment. Both these watercourses are headwaters, and the water remains in the local catchment. SC 6 channel downstream of the alignment will take an increased capacity until its pre-Project intersection with SC 5 downstream. Figure 14-29h shows the location of OC4, also a headwater, being diverted north to cross the alignment.

Potential impacts to watercourses from cuts

The potential impacts of cuts on watercourses are summarised by watercourse below with risk assessment outcomes included in Table 14-116.

Three watercourses are in areas of cut along the Project alignment. Due to the impossibility of building culverts at these locations, cut drainage and embankment drainage has been incorporated into the revised reference design. The following watercourses are in cut:

- ▶ C Ck 4
- ▶ C Ck 5
- ▶ SC 1

Drainage at a cut location will run along the cut until the next culvert. This results in potential for deposition upstream and erosion downstream; however, these impacts are considered unlikely for the following reasons:

- ▶ These watercourses are headwaters with channel types of washslope/non-channelised valley floor flow, they typically do not carry bedload and are unlike to result in increased deposition
- ▶ The culverts the watercourses will drain to (C113.28 for C Ck 4 and C Ck 5, C133.02 for SC 1) have downstream scour protection included in the revised reference design.

There is no hydraulic model for these sites and drainage design will be assessed in more detail during detailed design.

Potential impacts to watercourses with no cross-drainage design

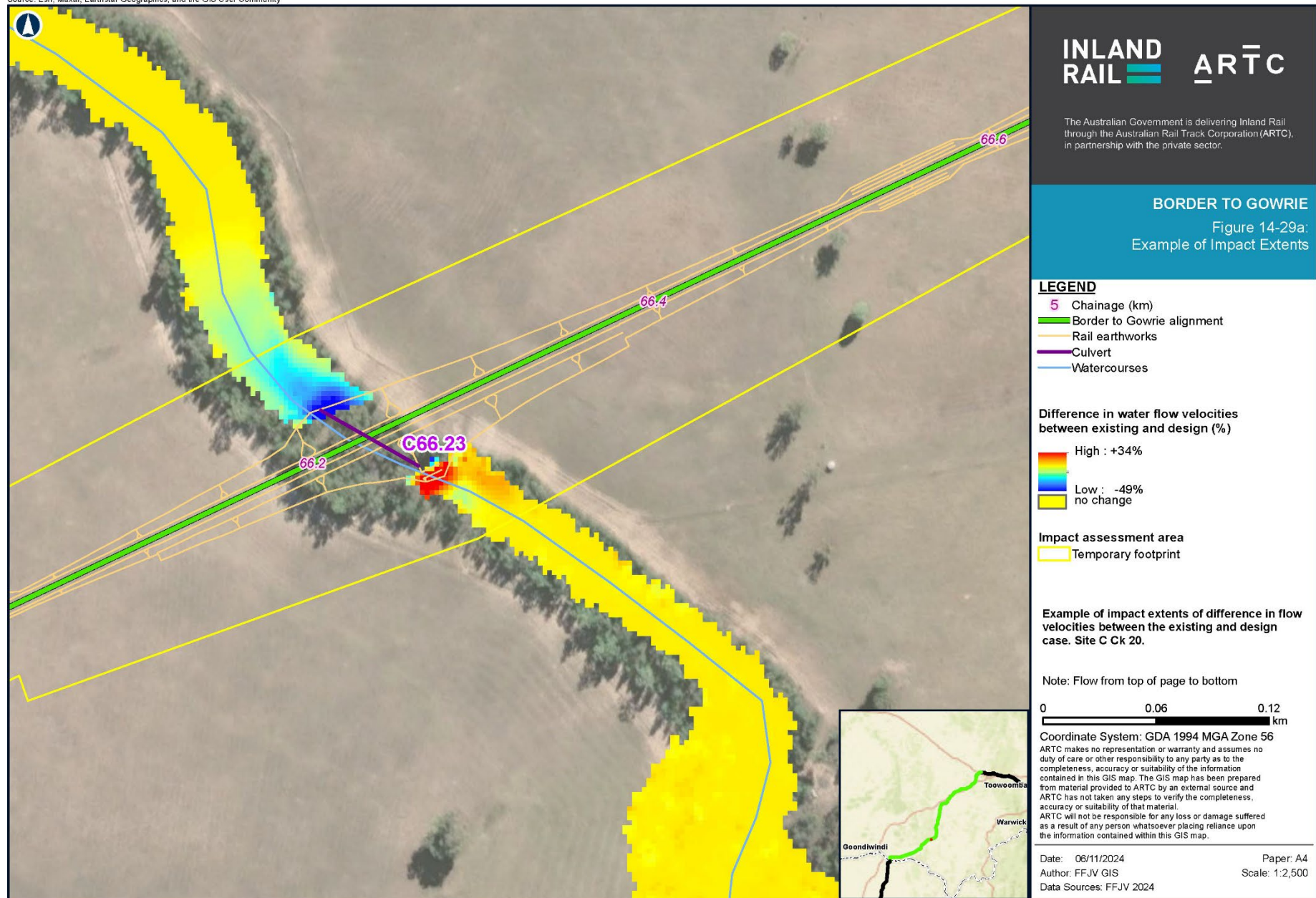
The potential impacts of no design cross-drainage on watercourses are summarised by watercourse below with risk assessment outcomes included in Table 14-116.

There are three watercourses with no drainage design that are not in cut.

- ▶ C Ck 1
 - ▶ C Ck 1 is a headwater with a 32 ha catchment.
 - ▶ Its flow path intersects the revised reference design northern abutment of the Millmerran–Inglewood rail-over-road bridge (310-BR37) and then joins C Ck 2 to the west of the Project alignment. Design flow is redirected a short distance around the end of the northern abutment and flows under the bridge to its existing flow path at C Ck 2.
 - ▶ The revised reference design and design hydraulic model for the site is illustrated in Figure 14-29i.
 - ▶ C Ck 1 and C Ck 2 are currently impacted by flows concentrated along the Millmerran–Inglewood Road.
- ▶ NC 16
 - ▶ NC 16 is a headwater with a 420.8 ha catchment.
 - ▶ Located at the existing Southwestern Line rail embankment, Existing Case flow is directed along the Southwestern Line rail embankment towards the southwest.
 - ▶ There is a human-made pond directly upstream of the Project alignment, which likely reduced downstream flow.
 - ▶ Existing Case conditions are highly modified.
- ▶ PC 1
 - ▶ PC 1 is a local–poorly developed channel with a 1,082 ha catchment.
 - ▶ It is located at the accessway to the Turallin facility.
 - ▶ Potential impacts at these three sites include erosion, deposition and planform change.

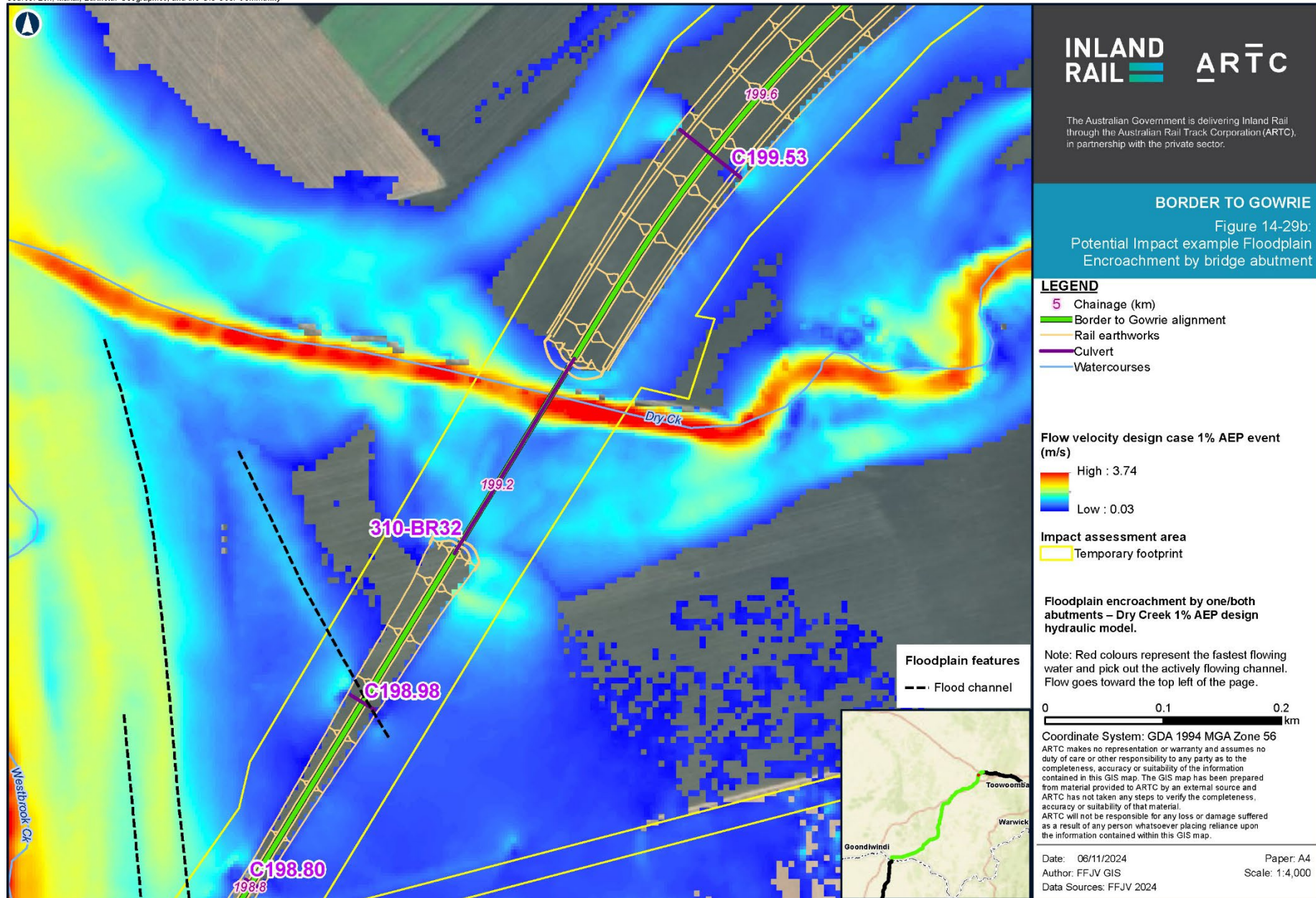
These sites do not have both Existing Case and Developed Case hydraulic models; drainage design will be assessed in more detail during detailed design.

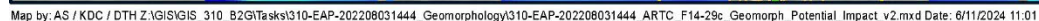
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 Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

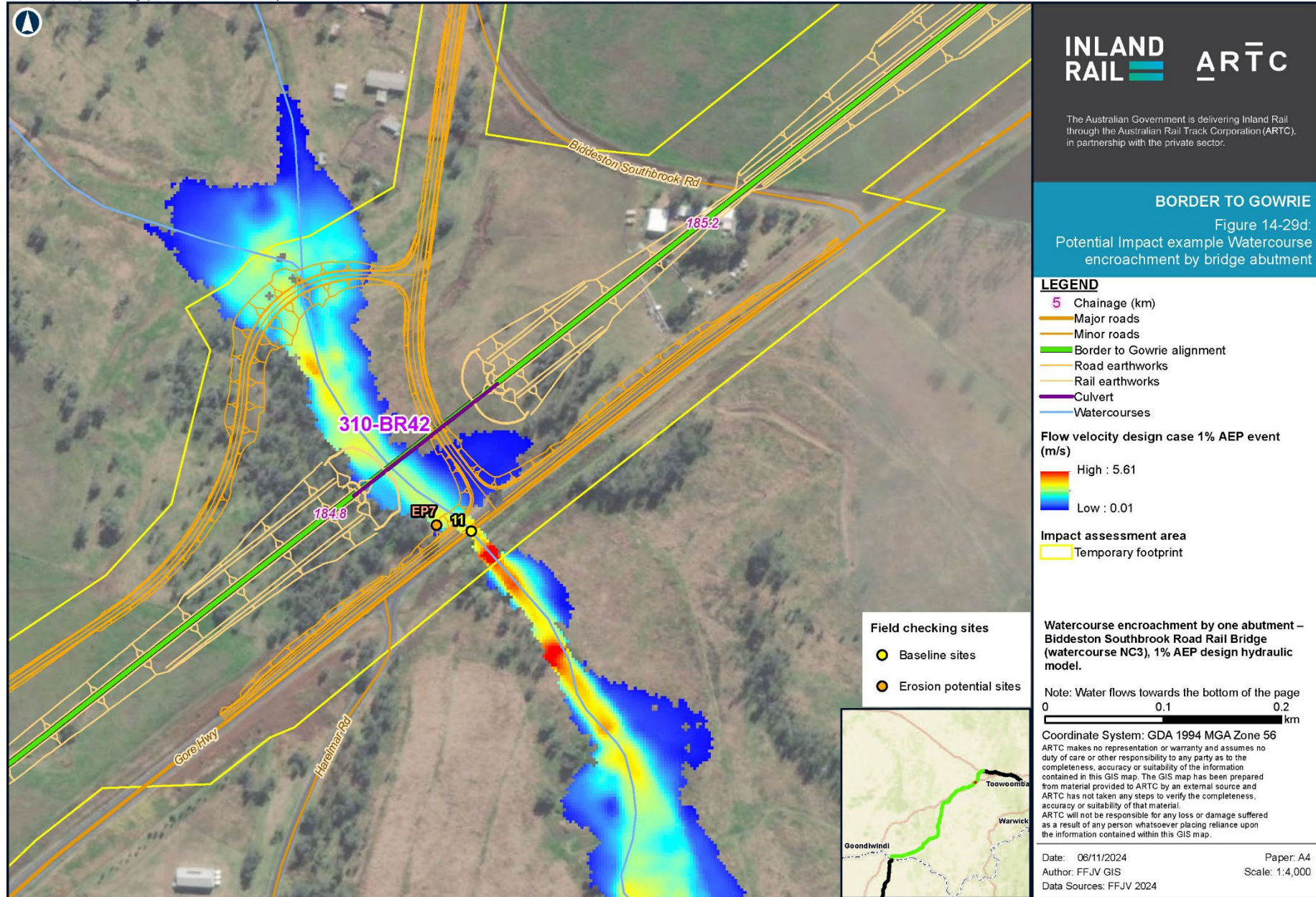


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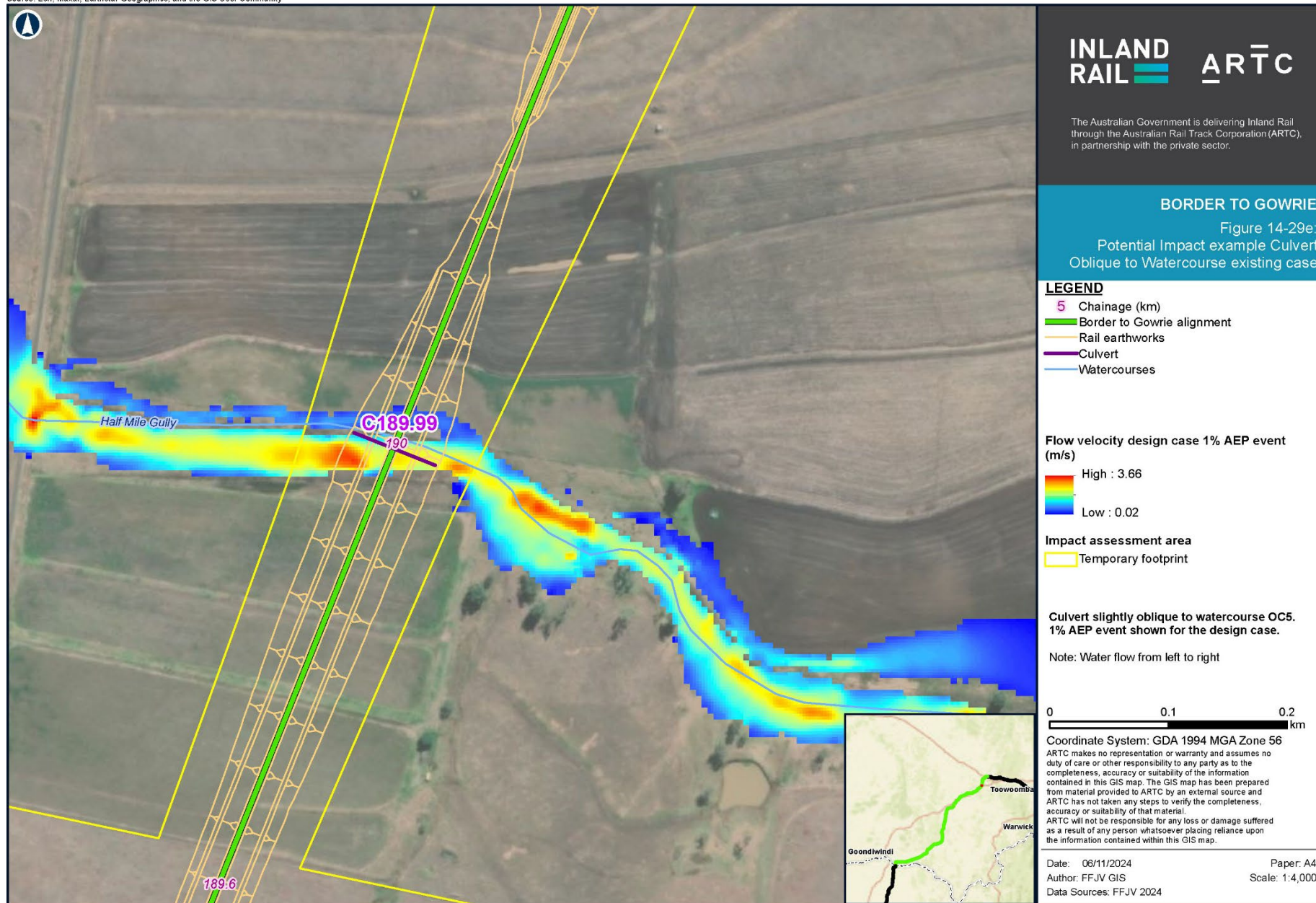
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community





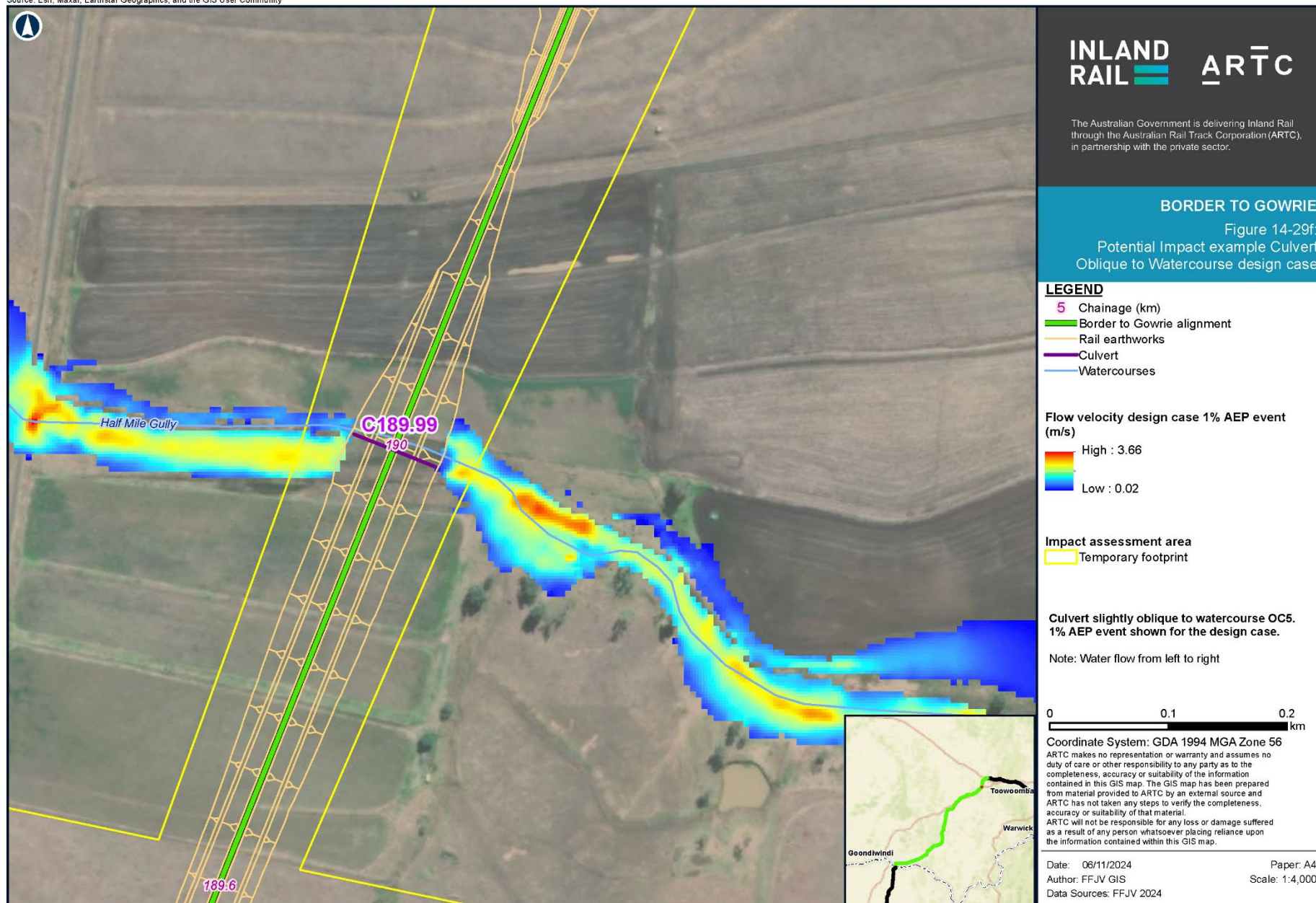


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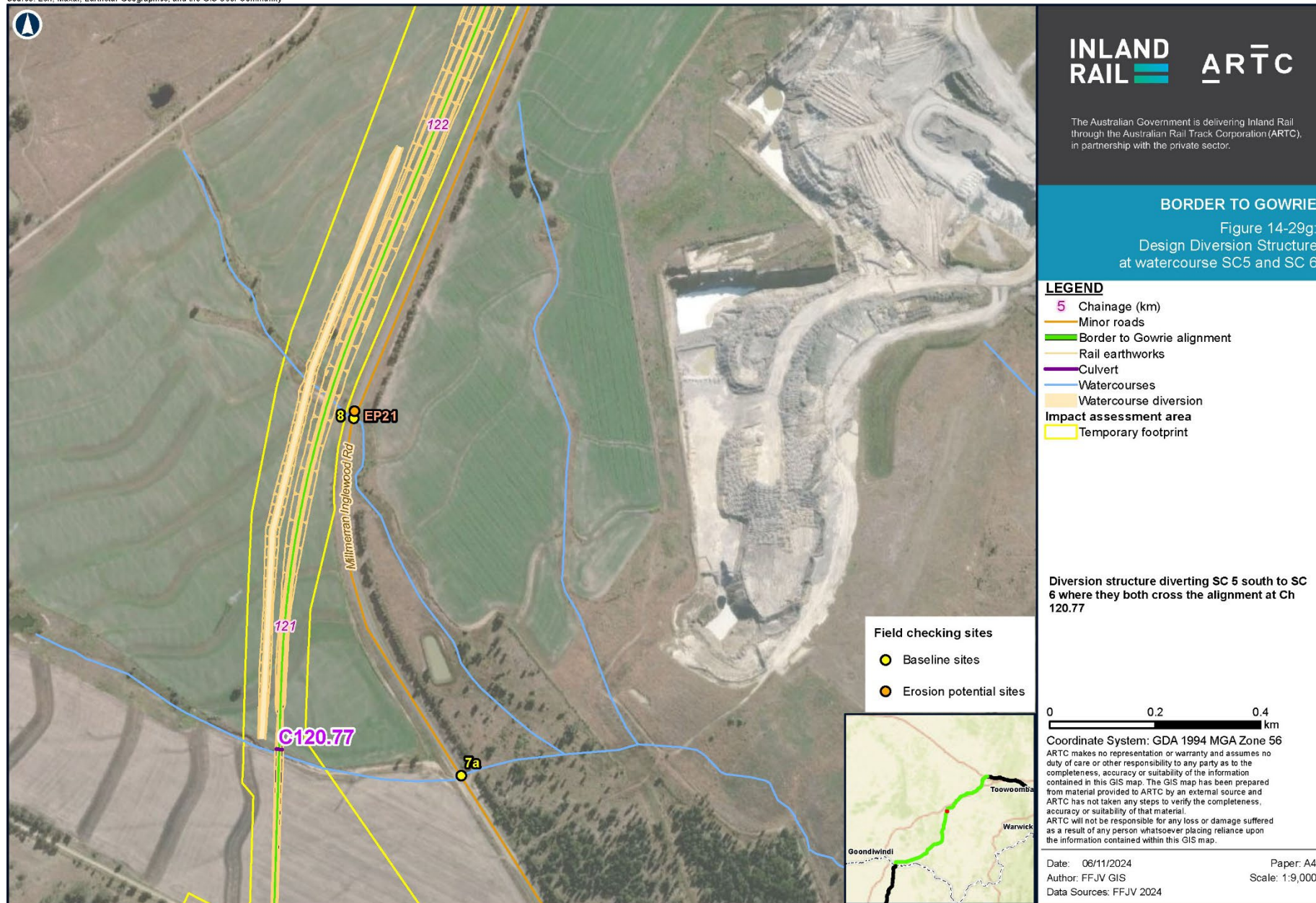
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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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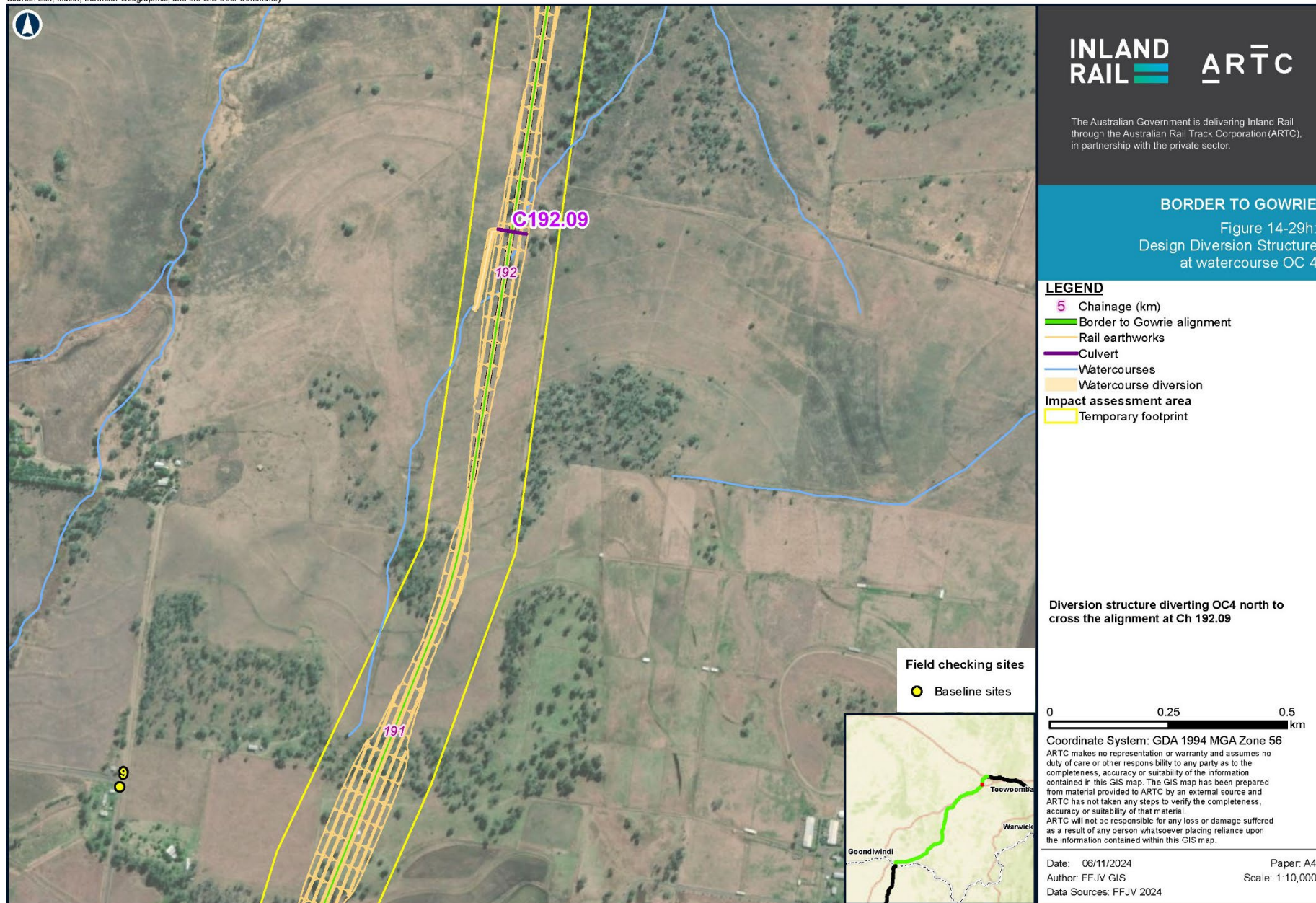


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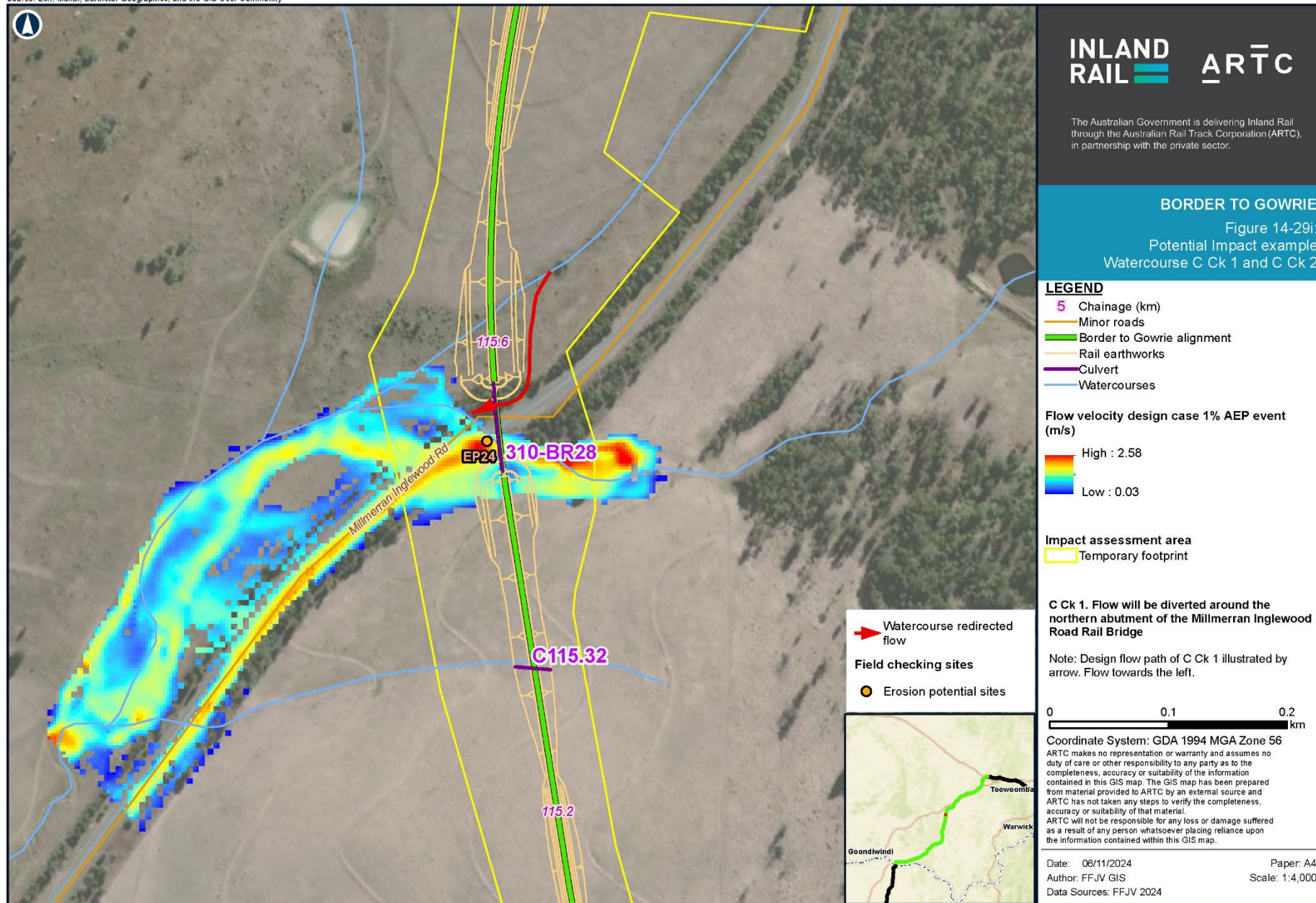
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
 Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Map by: AS / KDC / DTH Z:\GIS\GIS_310_B2\Tasks\310-EAP-202208031444_Geomorphology\310-EAP-202208031444_ARTC_F14-29g_Geomorph_Potential_Impact_v2.mxd Date: 6/11/2024 11:35



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



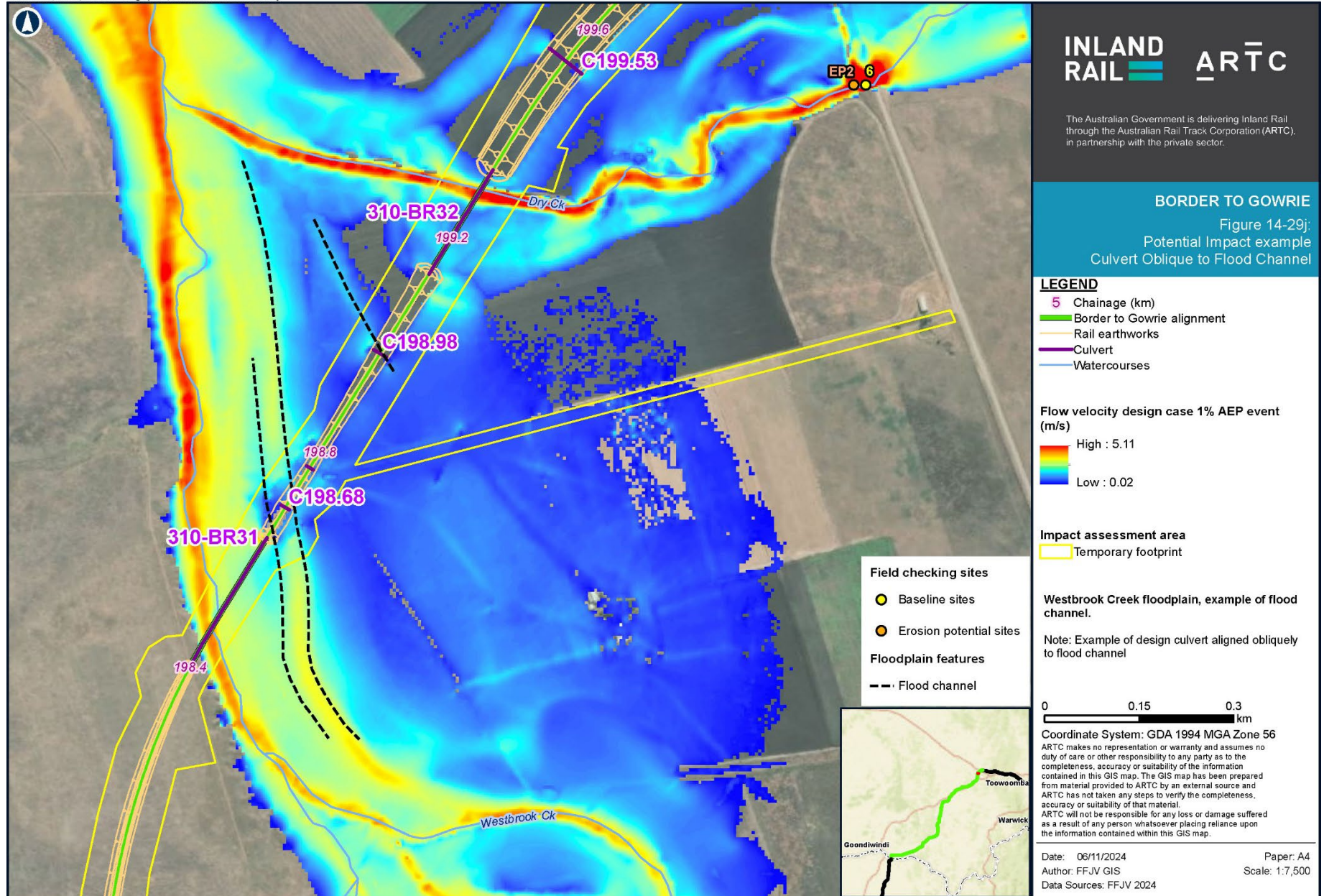


TABLE 14-111 POTENTIAL IMPACT OUTCOME KEY FOR WATERCOURSES BRIDGES, CULVERTS AND FLOODPLAINS

Potential Impact Outcome	Key
Criteria not triggered	
Criteria triggered, impacts unlikely	
Criteria triggered, potential impact	

TABLE 14-112 POTENTIAL IMPACTS—WATERCOURSE BRIDGES

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)				Comments
				Erosion	Deposition	Planform change	Channel type change	
1. No encroachment	Cattle Creek rail bridge (310-BR06)	Cattle Creek	2					Does not intersect watercourse or floodplain up to and including the 1% AEP event.
2. Floodplain encroachment by one/both abutments	Condamine River Main Branch Combined rail bridge (310-BR25/26)	Condamine River	5					Less than 10% change in max velocities for 20% and 1% AEP; impacts unlikely.
	Grasstree Creek rail bridge (310-BR21/22)	Grasstree Creek	2					
	Native Dog Creek rail bridge (310-BR07)	Native Dog Creek	2					
	Westbrook Creek rail bridge (310-BR31)	Westbrook Creek	3					
	Macintyre River Viaduct Span A (270-BR11A)	Macintyre River	3					
	Condamine North Branch rail bridge (310-BR27)	Condamine North Branch	US-4 DS-2					Less than 10% change in max velocities for 20% flow event; impacts unlikely. In the 1% AEP event, design flow velocity upstream has an increase of more than 10%, while downstream has a decrease of more than 10%; potential erosion and deposition may occur.

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Planform change	
3. Floodplain encroachment/ sidling by one/both abutments	Back Creek rail bridge (310-BR38)	Back Creek 1	2				In the 20% AEP event, downstream design flow velocity has a reduction of more than 10%, however flow velocity is >1 m/s and sufficient to transport bedload; impacts are considered unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10%; both upstream and downstream and erosion may occur.
	UT1 Macintyre Brook rail bridge (310-BR03)	MB 7	1				Less than 10% change in max velocities for 20% AEP; impacts unlikely. In the 1% AEP event, where change in design flow velocity has of more than 10% has occurred, it is within 10% of the Existing Case upstream or downstream flow velocity, and therefore impacts are considered unlikely. Design flows are sufficient to transport bedload.
	Dry Creek rail bridge (310-BR32)	Dry Creek	4				Less than 10% change in max velocities for 20% and 1% AEP; impacts unlikely.
	Bringalily Creek 3 rail bridge (310-BR10)	Bringalily	2				
	Pariagara Creek rail bridge (310-BR05)	C Ck 18	3				
		Pariagara Creek	3				

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Planform change	
4. Floodplain encroachment by abutment up to channel edge	Toowoomba Cecil Plains Road rail bridge (310-BR20)	Four Mile Gully	2				Generally, less than 10% change in max velocity; however, impacts such as potential to change watercourse planform and channel type may occur due to location of abutment up to channel edge.
	Millmerran Inglewood Road rail bridge (310-BR37)	SC 2	2				In a 20% AEP event, SC 2 has a design flow velocity of more than 10% less than the Existing Case; however, the design flow velocity is ~1.2 m/s and considered sufficient to transport any bedload present.
	Nicol Creek rail bridge (310-BR11)	Nicol Creek	2				In a 1% AEP event, downstream erosion may occur at Four Mile Gully and upstream erosion may occur at SC 2. Back Creek 2 has a design flow velocity of more than 10% less than the Existing Case; however, the design flow velocity is ~1.3 m/s and considered sufficient to transport any bedload present.
	Bringalily Creek 1 rail bridge (310-BR08)	Back Creek 2	2				
5. Watercourse encroachment by one/both abutments	Biddeston Southbrook Road rail bridge (310-BR42)	NC3	2				Less than 10% change in max velocities for 20% and 1% AEP; impacts unlikely; however major impacts such as potential to change watercourse planform and channel type due to location of abutment in the channel.
	Millmerran Inglewood Road rail bridge #2 (310-BR28)	C Ck 2	4				
	Oakey Pittsworth Road rail bridge (310-BR30)	NC 9	4				Impacts such as potential to change watercourse planform and channel type due to location of abutment in the channel. Reduction in design flow velocity of more than 10% for both the 20% and 1% AEP events; however, the watercourse has a non-channelised valley floor with no evidence for bedload, and therefore potential impacts of increased deposition are considered unlikely.

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)				Comments
				Erosion	Deposition	Planform change	Channel type change	
	UT2 Macintyre Brook rail bridge (310-BR04)	MB 6	2					Impacts such as potential to change watercourse planform and channel type due to location of abutment in the channel. In a 20% AEP event, an increase in flow velocity of more than 10% may result in erosion. For the 1% AEP flow event there is a reduction in design flow velocity of more than 10%; however, the watercourse has a non-channelised valley floor with no evidence for bedload, and therefore potential impacts of increased deposition are considered unlikely.

Table note:
Existing Case geomorphic sensitivity to change, 1 being low and 5 being high

TABLE 14-113 COMMISSIONING AND OPERATIONS STAGE RISKS–WATERCOURSES BRIDGES

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹			Residual risk ²		
					Consequence at	Risk		Consequence at	Risk	
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1. No encroachment	Impacts unlikely	Cattle Creek rail bridge (310-BR06)	Cattle Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
2. Floodplain encroachment by one/both abutments	Impacts unlikely	Condamine River Main Branch Combined rail bridge (310-BR25/26)	Condamine River	5	Not significant	Not significant	Low	Not significant	Not significant	Low
		Grasstree Creek rail bridge (310-BR21/22)	Grasstree Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		Native Dog Creek rail bridge (310-BR07)	Native Dog Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		Westbrook Creek rail bridge (310-BR31)	Westbrook Creek	3	Not significant	Not significant	Low	Minor to Moderate	Minor to Moderate	Low
		Macintyre River Viaduct Span A (270-BR11A)	Macintyre River	3	Not significant	Not significant	Low	Not significant	Not significant	Low
	20% AEP event impacts unlikely 1% AEP erosion	Condamine North Branch rail bridge (310-BR27)	Condamine North Branch	US - 4 DS - 2	Not significant	Minor	Low	Not significant	Minor	Low
	20% AEP event impacts unlikely 1% AEP erosion	Back Creek rail bridge (310-BR38)	Back Creek 1	2	Not significant	Major	Low	Not significant to Minor	Minor	Low
	Impacts unlikely	UT1 Macintyre Brook rail bridge (310-BR03)	MB 7	1	Not significant	Not significant	Low	Not significant	Not significant	Low

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹		Residual risk ²			
					Consequence at	Risk	Consequence at	Risk		
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
3. Floodplain encroachment/sidling by one/both abutments	Impacts unlikely	Dry Creek rail bridge (310-BR32)	Dry Creek	4	Not significant	Not significant	Low	Not significant	Not significant	Low
		Bringalily Creek 3 rail bridge (310-BR10)	Bringalily	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		Pariagara Creek rail bridge (310-BR05)	C Ck 18	3	Not significant	Not significant	Low	Not significant	Not significant	Low
			Pariagara Creek	3	Not significant	Not significant	Low	Not significant	Not significant	Low
4. Floodplain encroachment by abutment up to channel edge	20% planform and channel type change 1% planform and channel change (major) and erosion (minor/moderate)	Toowoomba Cecil Plains Road rail bridge (310-BR20)	Four Mile Gully	2	Major	Major	High	Minor	Minor	Low
	20% planform and channel type change 1% planform and channel change and erosion	Millmerran Inglewood Road rail bridge (310-BR37)	SC 2	2	Major	Major	High	Minor	Minor	Low
	Planform and channel type change	Nicol Creek rail bridge (310-BR11)	Nicol Creek	2	Moderate-Major	Moderate-Major	High	Minor	Minor	Low
		Bringalily Creek 1 rail bridge (310-BR08)	Back Creek 2	2	Moderate-Major	Moderate-Major	High	Minor	Minor	Low

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹		Residual risk ²			
					Consequence at	Risk	Consequence at	Risk		
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
5. Watercourse encroachment by one/both abutments	Planform and channel type change MB 6 also has minor increased erosion potential in the 20% AEP event	Biddeston Southbrook Road rail bridge (310-BR42)	NC3	2	Major	Major	High	Minor	Minor	Low
		Oakey Pittsworth Road rail bridge (310-BR30)	NC 9	4	Moderate	Major	Medium	Minor	Minor	Low
		Millmerran Inglewood Road rail bridge #2 (310-BR28)	C Ck 2	4	Moderate to Major	Moderate to Major	High	Minor	Minor	Low
		UT2 Macintyre Brook rail bridge (310-BR04)	MB 6	2	Moderate	Moderate to Major	Medium	Minor	Minor	Low

Table notes:

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= low; 5= high, in terms of potential for change

1 Includes implementation of initial mitigation measures specified 1

2 Assessment of residual risk once the Project's mitigation measures for future have been applied

TABLE 14-114 POTENTIAL IMPACTS—WATERCOURSE CULVERTS

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts criteria Refer Table 14-111 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
1. Within 10% of existing flow	C164.29	NC 14	2					Less than 10% change in max velocities for 20% AEP; impacts unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10%; however, the increased velocity occurs in the area of scour protection in the revised reference design and is unlikely to result in a potential impact.
	C125.48	SC 3	2					Less than 10% change in max velocities for 20% and 1% AEP; impacts unlikely
2. Upstream within 10% of existing flow, downstream decrease	C193.10	One Mile Creek	4					Downstream increased potential planform change at all sites and deposition at One Mile Creek and C Ck 13 (based on evidence of bedload and design flow velocities). In the 1% AEP event, downstream design flows at One Mile Creek show an increase of greater than 10%; however, the increased velocity occurs in the area of scour protection in the revised reference design and is unlikely to result in a potential impact.
	C87.37	C Ck 12	4					
	C84.38	C Ck 13	2					
	C30.60	MB 10	4					
3. Upstream within 10% of existing flow, downstream increase	C124.44	SC 4	1					Increased potential erosion, planform and channel type change downstream.
4. Upstream decrease, downstream within 10% of existing flow	C207.15	OC 1	4					Increased deposition upstream at C Ck 16 and MB 3; all other watercourses are washslopes/non-channelised valley floor channel types with no evidence of bedload, therefore impacts are unlike at these sites. Increased downstream planform change may occur where culvert is not aligned to flow. In the 1% AEP event, downstream design flows at NC 6, NC 8, SC 9, SC 10 and MB 3 show an increase of greater than 10%. However, in the area of increased flow velocity NC 6, NC 8, SC 9 and MB 3 have scour protection in the revised reference design and it is unlikely to result in a potential impact. SC 10 does not have scour protection, and up to major erosion may occur in the 1% AEP event.
	C186.16	NC1	4					
	C181.21	NC 6	2					
	C178.63	NC 7	2					
	C176.89	NC 8	2					
	C118.43	SC 9	2					
	C117.60	SC 10	2					
	C113.07	C Ck 7	4					
	C79.01	C Ck 15	4					
	C73.68	C Ck 16	5					
	C61.90	MB 3	1					
	C61.60	MB 4	1					

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts criteria Refer Table 14-111 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
5. Upstream increase, downstream within 10% of existing flow	C114.36	C Ck 3	4					Increased potential erosion upstream and channel type change. Increased planform change at C Ck 10.
	C92.08	C Ck 10	4					Design flows at C Ck 3 in the 1% AEP have a reduction in flow velocity of greater than 10%; however, watercourse is a non-channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport.
6. Upstream decrease in flow, downstream increase	C208.21	End catchment	4					Potential deposition at CCs 21a, all other sites are washslope/non-channelised valley floor with no bedload, therefore reduced design flow velocity is unlikely to result in increased deposition.
	C202.8	OC 2	2					
	C186.16	NC 2	1					All watercourses excluding C Ck 17 and CCs 21a have scour in the revised reference design, which mitigates increased erosion and channel type change potential caused by the increase in downstream design flow velocity.
	C181.78	NC 5	2					
	C164.16	NC 15*	2					
	C119.38	SC 8	4					For CCs 21a, in the 20% AEP event, downstream design flows show an increase of greater than 10%; however, the increased velocity of 0.86 m/s is less than the Existing Case upstream velocity of 0.87 m/s along a straight channel and increased in erosion potential from the Existing Case is unlikely.
	C113.28	C Ck 6	2					
	C90.96	C Ck 11	2					
	C82.35	C Ck 14	2					
	C73.44	CCs 21a	5					At C Ck 17, while an increase of more than 10% is modelled, design flows are still <0.2 m/s and erosion and channel type change are unlikely. Increased erosion and channel type change may occur in the 1% AEP event at this stie.
	C68.76	C Ck 17	2					
	C66.81	C Ck 19	2					Channel type change at sites other than C Ck 17 is unlikely as scour protection included in the revised reference design mitigates the increased erosion potential that drives change in channel type.
	C66.23	C Ck 20	2					
	C63.15	MB 1	1					
	C62.94	MB 2	1					Increased downstream planform change may occur where culvert is not aligned to flow.

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts criteria Refer Table 14-111 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
7. Upstream and downstream decrease	C189.99	OC 5	2					Increased potential for deposition at three gully channels, C Ck 16, CCs 21 and CCs 22, and SC 7. CCs 19 is a gully with bedload; however, while the design flow velocities are less than existing, they are still ~1 m/s and likely to be able to transport the bedload, therefore reduced design flow velocity is unlikely to result in increased deposition. Other sites are washslope/non-channelised valley floor with no bedload, therefore reduced design flow velocity is unlikely to result in increased deposition. Increased downstream planform change may occur where culvert is not aligned to flow.
	C182.99	NC 4	4					
	C171.90	NC 10	4					
	C169.89	NC 12	2					
	C165.06	NC 13	4					
	C120.31	SC 7	5					
	C109.43	C Ck 8	2					
	C107.22	C Ck 9	4					
	C74.97	CCs 19	5					
	C73.61	C Ck 16a	5					
	C73.53	CCs 21	5					
	C73.37	CCs 22	5					
	C60.44	MB 5	5					
	C48.41	MB 8	2					
	C43.16	MB 9	1					
8. Upstream and downstream increase	C194.69	OC 3	4					There is increased potential upstream erosion and channel type change at all sites. Downstream increases in design flow velocities extend beyond the scour mitigation in the revised reference design at NC 11 and OC 3. There is no scour mitigation in the revised reference design for MR1. Increased downstream planform change may occur where culverts are not aligned to flow. MR1 has no flow in the 20% AEP event.
	C170.55	NC 11	4					
	C117.4	SC 11	4					
	C34.7 (NS2B)	MR 1	2					

Table notes:

* Culvert aligned to pass flows travelling along/adjacent to roadway

Appendix H: Geomorphology Report (Appendix H) provides further details on scour protection included in the reference design at culverts

Existing Case sensitivity to change: 1= low; 5= high, in terms of potential for change

TABLE 14-115 COMMISSIONING AND OPERATIONS STAGE RISKS—WATERCOURSES CULVERTS

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1. Within 10% of existing flow	Impacts unlikely.	C164.29	NC 14	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		C125.48	SC 3	2	Not significant	Not significant	Low	Not significant	Not significant	Low
2. Upstream within 10% of existing flow, downstream decrease	20% AEP deposition	C193.10	One Mile Creek	3	Minor to Moderate	Major	Medium	Not significant to Minor	Minor	Low
	Planform change	C87.37	C Ck 12	4	Not significant	Not significant	Low	Not significant	Not significant	Low
	Planform change deposition	C84.38	C Ck 13	2	Minor	Moderate	Low	Not significant to Minor	Minor	Low
	Planform change	C30.60	MB 10	4	Minor	Moderate	Low	Not significant to Minor	Minor	Low
3. Upstream within 10% of existing flow, downstream increase	Erosion, planform and channel type change.	C124.44	SC 4	1	Moderate	Moderate to Major	Medium	Minor	Minor	Low
4. Upstream decrease, downstream within 10% of existing flow	Planform change	C207.15	OC 1	4	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C186.16	NC1	4	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Impacts unlikely	C181.21	NC 6	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Impacts unlikely	C178.63	NC 7	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Impacts unlikely	C176.89	NC 8	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Planform change	C118.43	SC 9	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Impacts unlikely at the 20% AEP 1% AEP erosion	C117.60	SC 10	2	Not significant to Minor	Moderate to Major	Low	Minor	Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Impacts unlikely	C113.07	C Ck 7	4	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Planform change	C79.01	C Ck 15	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Deposition	C73.68	C Ck 16	5	Moderate to Major	Moderate	High	Minor	Moderate	Low
	Deposition	C61.90	MB 3	1	Moderate	Moderate to Major	Medium	Minor	Moderate to Major	Low
	Planform change	C61.60	MB 4	1	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
5. Upstream increase, downstream within 10% of existing flow	Erosion Channel type change	C114.36	C Ck 3	1	Moderate	Minor	Medium	Minor	Minor	Low
	Erosion Channel type change and planform change	C92.08	C Ck 10	2	Moderate	Moderate	Medium	Minor	Minor	Low
6. Upstream decrease in flow, downstream increase	Planform change	C208.21	End Catchment	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C202.8	OC 2	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C186.16	NC2	1	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Impacts unlikely	C181.78	NC 5	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Planform change	C164.16	NC 15*	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C119.38	SC 8	1	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C113.28	C Ck 6	2	Minor to Moderate	Moderate to Major	Medium	Minor	Moderate	Low
	Impacts unlikely	C90.96	C Ck 11	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Impacts unlikely	C82.35	C Ck 14	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Deposition	C73.44	CCs 21a	5	Moderate to Major	Moderate to Major	High	Minor	Moderate	Low
	Erosion, planform change, channel change	C68.76	C Ck 17	2	Not significant	Moderate	Low	Not significant	Minor	Low
	Impacts unlikely	C66.81	C Ck 19	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Impacts unlikely	C66.23	C Ck 20	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	Low
	Planform change	C63.15	MB 1	1	Minor to Moderate	Moderate	Medium	Minor	Moderate	Low
	Planform change	C62.94	MB 2	1	Minor to Moderate	Moderate	Medium	Minor	Moderate	Low
	Planform change	C189.99	OC 5	2	Minor to Moderate	Minor to Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C182.99	NC 4	4	Minor	Moderate	Low	Not significant to Minor	Minor	
	Impacts unlikely	C171.90	NC 10	4	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	
7. Upstream and downstream decrease	Planform change	C169.89	NC 12	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C165.06	NC 13	4	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Deposition	C120.31	SC 7	5	Moderate to Major	Moderate	High	Minor	Moderate	Low
	Impacts unlikely	C109.43	C Ck 8	2	Not significant to Minor	Not significant to Minor	Low	Not significant to Minor	Not significant to Minor	
	Planform change	C107.22	C Ck 9	1	Minor	Minor	Low	Not significant to Minor	Minor	
	Impacts unlikely	C74.97	CCs 19	5	Minor	Minor	Low	Minor	Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Planform change (major) Deposition (moderate)	C73.61	C Ck 16a	5	Moderate to Major	Moderate to Major	High	Minor	Moderate	Low
	Deposition	C73.53	CCs 21	5	Moderate to Major	Moderate to Major	High	Minor	Moderate	Low
	Deposition	C73.37	CCs 22	5	Moderate to Major	Moderate to Major	High	Minor	Moderate	Low
	Planform change	C60.44	MB 5	5	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C48.41	MB 8	2	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C43.16	MB 9	1	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Planform change	C194.69	OC 3	4	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
8. Upstream and downstream increase	Erosion Planform change Channel type change	C194.69	OC 3	4	Minor to Moderate	Moderate	Medium	Not significant to Minor	Minor	Low
	Erosion Channel type change	C170.55	NC 11	4	Major	Major	High	Minor	Moderate	Low
	Erosion Planform change Channel type change	C117.4	SC 11	1	Minor to Moderate	Moderate to Major	Medium	Minor	Minor	Low
	Erosion Channel type change	C34.7 (NS2B)	MR 1	2	Not significant	Minor	Low	Not significant	Minor	Low

Table notes:

* Culvert aligned to pass flows travelling along/adjacent to roadway

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= low; 5= high, in terms of potential for change

1 Includes implementation of initial mitigation measures specified

2 Assessment of residual risk once the Project's mitigation measures for future stages identified, have been applied

TABLE 14-116 COMMISSIONING AND OPERATIONS STAGE RISKS—WATERCOURSES WITH DIVERSIONS, IN CUT OR WITH NO CROSS-DRAINAGE

Potential impact category	Potential impacts on watercourse channel	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
				Initial risk			Residual risk		
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
Diversions	Deposition, erosion	SC 5	2	Minor to Moderate	Moderate	Medium	Minor	Minor	Low
	Erosion, planform and channel type change	SC 6	2	Moderate	Major	Medium	Minor	Minor	Low
	Erosion, planform and channel type change	OC 4	2	Moderate	Major	Medium	Minor	Minor	Low
Cut	Impacts unlikely.	C Ck 4	1	Not significant	Not significant	Low	Not significant	Not significant	Low
		C Ck 5	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		SC 1	2	Not significant	Not significant	Low	Not significant	Not significant	Low
No cross-drainage	Erosion, deposition and planform change	C Ck 1	2	Minor to Moderate	Moderate	Medium	Minor	Minor	Low
		NC 16	2	Minor	Minor	Low	Not significant	Not significant	Low
		PC 1	2	Minor	Minor	Low	Minor	Minor	Low

Table notes:

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change.

Potential impacts to floodplains

Commissioning and operations stage potential impacts were assessed for 17 watercourses and are summarised in Table 14-117. Four potential impact categories were identified:

- ▶ No encroachment–no impacts
 - ▶ bridge embankments do not intersect the flow on the geomorphic floodplain
- ▶ Floodplain sidling
 - ▶ embankment located within a floodplain, roughly perpendicular to direction of flow
- ▶ Floodplain constriction
 - ▶ embankment is located within a floodplain, and flow is semi-parallel to the embankment
- ▶ Floodplain constriction and sidling
 - ▶ embankment is located within the floodplain and both constriction and sidling occur due to relative changes in orientation of the floodplain and Project alignment.

As floodplain cross-drainage typically comprises a range of design infrastructure types, including main channel bridges/culverts, floodplain bridges and floodplain culverts, potential impacts have been assessed for the entire floodplain. Figure 14-29j illustrates the potential impact of design culverts not aligned to flood channels.

The potential impacts that met impact assessment criteria and risk outcomes are summarised by floodplain in Table 14-118 and Table 14-119. The most common potential impact is erosion, which was identified as a possible impact at 10 of the floodplains. However, only MB 6 had erosion as a potential impact for the 20% AEP event; the other floodplains only had erosion identified for the 1% AEP event. The potential impact of deposition was identified at three floodplains. All floodplain sites that triggered the criteria to assess for reduced floodplain connectivity had design cross-drainage, mitigating this potential impact.

TABLE 14-117 SUMMARY OF COMMISSIONING AND OPERATIONS STAGE POTENTIAL IMPACTS FOR FLOODPLAINS, INCLUDING THE NUMBER OF FLOODPLAINS THAT MEET IMPACT ASSESSMENT CRITERIA (GEOMORPHOLOGY TECHNICAL REPORT)

Design infrastructure Potential impact category	Number of floodplains	Number of floodplains by potential impact (# of floodplains that met impact assessment criteria)		
		Erosion	Deposition	Reduced connectivity
1. No encroachment	1	0 (0)	0 (0)	0 (0)
2. Floodplain sidling	1	1 (1)	0 (1)	0 (1)
3. Floodplain constriction	12	6 (6)	2 (7)	0 (0)
4. Floodplain sidling and constriction	3	3 (3)	1 (3)	0 (3)
TOTAL	17	10 (10)	3 (11)	0 (4)

Condamine River floodplain

There is existing erosion occurring on the Condamine River floodplain, most notably in the flood basin between the Condamine Main Branch and Grasstree Creek between Ch 142.61 km and Ch 142.07 km. The central part of the flood basin where the existing erosion is occurring corresponds with the highest maximum Existing Case flow velocities along the proposed alignment in the Condamine floodplain, between 0.50 m/s and 0.67 m/s for the 20% AEP (culverts C142.61 to C142.07). Potential impacts due to the Project are unlikely in the flood basin area for the following reasons:

- ▶ Developed Case maximum velocities at culverts in this area are less than 0.35 m/s for the 20% AEP event
- ▶ Most design culverts have scour protection in the revised reference design
- ▶ Design flow velocity at the flood basin bridge is within 10 per cent of Existing Case flow velocities, at 0.55 m/s.

Outside of the flood basin between the Condamine Main Branch and Grasstree Creek, the Existing Case flow velocities are less than 0.5 m/s for the 20% AEP event and design flow velocities are less than 0.4 m/s and, as a result, impacts due to the Project are unlikely.

Design flow velocities for many floodplain culverts are below 0.5 m/s for the 1% AEP event, except for two areas. One of these areas comprised four culvert sites, C149.02 to C147.82, and has design flow velocities within 10 per cent of the Existing Case and, as a result, impacts are unlikely. The other area comprises three culvert sites, C141.46 to C141.38, and has downstream design flow velocities of up to 1.02 m/s for the 1% AEP, 0.38 m/s higher than the Existing Case and, as a result, erosion may occur. Two of these culvert sites have downstream scour protection in the revised reference design, which largely mitigate any potential impacts of erosion.

TABLE 14-118 POTENTIAL IMPACTS–FLOODPLAINS COMBINED INFRASTRUCTURE

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Reduced connectivity	
1. No encroachment	Cattle Creek	Main channel bridge that also spans the geomorphic floodplain	2				No rail infrastructure intersects the floodplain; impacts unlikely.
2. Floodplain sidling	Macintyre Brook	Project alignment does not cross main channel Floodplain culverts	5				In the 20% AEP event, flows range from within 10% change from Existing Case, with no flow to more than 10% decrease in design flow; as these flow velocities are considered sufficient to transport any sediment, potential impacts are unlikely. In the 1% AEP event, downstream flow velocities greater than 10% increase from Existing Case extend beyond scour protection in revised reference design and up to major erosion may occur; minor erosion may also occur upstream on some culverts. Three areas of floodplain sidling all have design cross-drainage to mitigate potential reduced connectivity at: ▶ 31.44-32.03 (three culvert sites) ▶ 35.03 to 35.60 (one culvert site) ▶ 42.87 to 45.64 (23 culvert sites).
3. Floodplain constriction	Dry Creek	Main channel bridge	4				Less than 10% change in max velocities for 20% and 1% AEP events; impacts unlikely.
	One Mile Creek	Main channel bridge	3				Less than 10% change in max velocities for 20% and 1% AEP events; impacts unlikely.
	Native Dog Creek	Main channel bridge	2				Less than 10% change in max velocities for 20% and 1% AEP events; impacts unlikely.
	Nicol Creek	Main channel bridge	2				Less than 10% change in max velocities for 20% and 1% AEP events; impacts unlikely.
	Back Creek 1	Main channel bridge	2				In the 20% AEP event, downstream design flow velocity has a reduction of more than 10%; however, flow velocity is >1 m/s and sufficient to transport bedload and impacts are considered unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10% both upstream and downstream and erosion may occur on the floodplain.

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Reduced connectivity	
	Four Mile Gully	Main channel bridge Floodplain culvert	2				For the floodplain culvert in 20% and 1% AEP events there is a downstream reduction in flow velocity of more than 10%; however, design flows are greater than Existing Case upstream flows, and impacts are unlikely. Bridge, 1% AEP event, erosion may occur on the floodplain.
	Westbrook Creek	Main channel bridge Floodplain culverts	3				For floodplain culverts in 20% AEP events: deposition is possible. C198.98 has increased design flow velocity more than 10%; however, impacts are unlikely as the design flow is only 0.37 m/s, and the culvert has scour protection in the revised reference design. For a 1% AEP event, there is reduction in flow velocity of more than 10%; however, design flows are assessed as sufficient to transport sediment. C198.98 has increased design flow velocity more than 10% and erosion may occur as the increased erosion extends beyond the scour protection in the revised reference design. For the bridge, there is less than 10% change in max velocities for 20% and 1% AEP events and impacts are unlikely.
	Condamine River	Bridges over three anabranches Flood basin bridge Floodplain culverts	5				For floodplain culverts in 20% AEP events, a number of culverts do not flow, the maximum design velocity is <0.4 m/s and impacts are unlikely. For a 1% AEP event, erosion may occur at some culvert sites. For floodplain bridge and main channel anabranch bridges, there is less than 10% change in max velocities except for the North Condamine bridge in the 1% AEP event, where erosion may occur on the floodplain.
	Back Creek 2	Main channel bridge	2				There is less than 10% change in max velocities for 20% AEP and impacts unlikely. In the 1% AEP event, Back Creek 2 has a design flow velocity of more than 10% less than the Existing Case; however, the design flow velocity is ~1.3 m/s and considered sufficient to transport any bedload present.

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Reduced connectivity	
	SC 2	Main channel bridge Floodplain culverts	2				Floodplain culverts in 20% AEP events are aligned to accommodate backflow from embankment. Design results in reduction in flow, particularly downstream (to <0.1 m/s); however, as the culvert in this area flows directly back into the main channel, deposition is unlikely to occur during a flood event as any material will be mobilised by flows in the main channel. For the bridge in a 20% AEP event SC 2 has a design flow velocity of more than 10% less than the Existing Case; however, the design flow velocity is ~1.2 m/s and considered sufficient to transport any bedload present. In a 1% AEP event, downstream erosion may occur on the floodplain.
	SC 7	Main channel culvert Floodplain culvert	5				For the floodplain culvert located on flood channel, there is a reduction in design flow velocity of more than 10%; however, as design flows are approximately 1 m/s this reduction in flow will not impact floodplain sediment transport and impacts are unlikely. The natural channel for SC 7 has been impacted by the human-made pond upstream and experiences reduced flows; most flow in the Existing Case now goes across the floodplain in the area of this floodplain culvert. For the main channel culvert, design flow velocities are reduced and in-channel deposition may occur; some deposition may also occur on the floodplain.
	Macintyre River	Main channel bridge Floodplain bridges Floodplain culverts	3				For the floodplain culverts in a 20% AEP event there is no flow. In a 1% AEP event, there is increased design flow velocity of more than 10% and erosion possible. For the main channel and floodplain bridges, there is less than 10% change in max velocities except for one of the floodplain bridges in the 1% AEP and erosion may occur.
4. Floodplain constriction and sidling	MB 6	Main channel bridge Floodplain culverts	2				For the floodplain culverts in 20% and 1% AEP events, erosion may occur. For the bridge in a 20% AEP event, an increase in flow velocity of more than 10% may result in erosion. For the 1% AEP flow event there is a reduction in design flow velocity of more than 10%; however, the watercourse has a non-channelised valley floor with no evidence for bedload, and therefore potential impacts of increased deposition are considered unlikely. The area of floodplain sidling has design cross-drainage to mitigate potential reduced connectivity at: 55.4-55.36 (two culvert sites).

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Potential impacts criteria (refer Table 14-111 for key)			Comments
				Erosion	Deposition	Reduced connectivity	
	Bringalily Creek	Main channel bridge Floodplain culverts	2				For the floodplain culverts in a 20% AEP event, most have no flow. Some culverts have design flow changes greater than 10 per cent of the Existing Case flow velocities and impacts are unlikely due to flow reduction as velocities are sufficient to transport flood sediments; where elevated, design velocities are only up to 0.4 m/s and there is also scour protection in the revised reference design. In a 1% AEP event, deposition and erosion may occur. For the bridge, there is less than 10% change in max velocities for both 20% and 1% AEP events and impacts unlikely. The area of floodplain sidling has design cross-drainage to mitigate potential reduced connectivity at: ▶ 97.29.03 to 100.69 (nine culvert sites).
	Pariagara Creek	Main channel bridge Floodplain culverts	3				For the floodplain culverts in a 20% AEP event, most have no flow. Some culverts have design flow changes greater than 10 per cent of the Existing Case flow velocities; impacts are unlikely as design velocities are 0.4 m/s or less and there is also scour protection in the revised reference design. For a 1% AEP event, erosion may occur. For the bridge, there is less than a 10% change in max velocities for both 20% and 1% AEP events and impacts unlikely. The area of floodplain sidling has design cross-drainage to mitigate potential reduced connectivity at: ▶ 67.17 to 69.93 (18 culvert sites).

Table note:
Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change

TABLE 14-119 COMMISSIONING AND OPERATIONS STAGE RISKS—FLOODPLAINS (COMBINED INFRASTRUCTURE)

Potential impact category*	Potential impacts	Floodplain	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
				Initial risk assessment			Residual risk assessment		
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1 No encroachment	Impacts unlikely	Cattle Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
2. Floodplain sidling	20% AEP, impacts unlikely. 1% AEP, erosion	Macintyre Brook	5	Not significant	Minor to Major	Low	Not significant	Minor to Moderate	Low
3. Floodplain constriction	Impacts unlikely	Dry Creek	4	Not significant	Not significant	Low	Not significant	Not significant	Low
		One Mile Creek	3	Not significant	Not significant	Low	Not significant	Not significant	Low
		Native Dog Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		Nicol Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
	20% AEP, impacts unlikely 1% AEP, erosion	Back Creek 1	2	Not significant	Major	Low	Minor	Minor	Low
	20% AEP, impacts unlikely 1% AEP, erosion	Four Mile Gully	2	Not significant	Major	Low	Not significant	Minor	Low
	20% AEP, deposition 1% AEP, erosion	Westbrook Creek	3	Not significant to Minor	Minor to Moderate	Low	No flow to Minor	Minor	Low
	20% AEP, impacts unlikely 1% AEP, erosion	Condamine River	5	Not significant to Minor	Minor to Moderate	Low	Not significant	Minor	Low
	Impacts unlikely	Back Creek 2	2	Not significant	Not significant	Low	Not significant	Not significant	Low
	20% AEP, impacts unlikely 1% AEP, erosion	SC 2	2	Not significant	Minor to Moderate	Low	Minor to Not significant	Minor	Low
	20% AEP, deposition	SC 7	5	Minor	Minor	Low	Minor	Minor	Low
	20% AEP, impacts unlikely 1% AEP, erosion	Macintyre River	3	Not significant	Minor to Moderate	Low	Not significant	Minor	Low

Potential impact category*	Potential impacts	Floodplain	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
				Initial risk assessment		Residual risk assessment			
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
4. Floodplain constriction and sidling	Erosion	MB 6	2	Minor	Minor	Low	Minor	Minor	Low
	20% AEP, impacts unlikely 1% AEP, erosion and deposition	Bringalily Creek	2	Not significant	Moderate erosion at C97.38 Not significant to minor elsewhere	Low	Not significant	Minor	Low
	20% AEP, impacts unlikely 1% AEP, erosion	Pariagara Creek	3	Not significant	Moderate to Major for culverts C69.80 to C68.89 Not significant to Minor elsewhere	Low	Not significant	Minor	Low

Table note:

* Assessment does not take into consideration local effects of bridge piers.
 Minor to Moderate: the highest consequence has been used to derive the risk
 Moderate to Major: the highest consequence has been used to derive the risk

14.8.2.3 Detailed assessment of high-risk sites

The outcomes of the detailed assessment at the remaining five sites are summarised below:

- ▶ The following sites were investigated in the field and found to be initial case low-risk after detailed site investigations:
 - ▶ SC7
 - identified as a high-risk site in the initial risk assessment due to the hydraulic Developed Case indicating potential large reduction in flow velocity upstream and downstream from the Existing Case
 - Detailed assessment determined that the design flow would be sufficient to transport the silty clay and silty fine sand sampled at the site
 - No additional site-specific mitigation measures other than monitoring.
 - ▶ C Ck 16
 - identified as a high-risk site in the initial risk assessment due to the hydraulic Developed Case indicating a large reduction in flow velocity upstream.
 - Detailed assessment determined that the reduction in velocity would likely result in medium to coarse grained gravel not being transported. However, as particles of this grain size only make up a small proportion of the sediment load, the impacts of the Project on the fluvial system are considered low and readily mitigated in routine maintenance.
 - Channel constriction may also lead to some accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert.
 - Monitoring is recommended, in particular for deposition of gravel and woody debris at the culvert entrance that may need to be removed.
 - ▶ SC 2
 - Identified as a high risk site in the initial desktop risk assessment due to the location of the design west bridge embankment at the apex of the meander bend approximately 100 m west of the crossing potentially impacting the watercourse planform behaviour.
 - Detailed assessment determined that encroachment of the west bridge embankment at the apex of the meander bend approximately 100 m west of the crossing will stop southwards migration of the bend and may result in impacts to the long-term watercourse planform behaviour. The watercourse could avulse, and if so, the water would flow for 50 m along the side of the embankment. Were this to occur the embankment would need some form of erosion protection. This would not be difficult to implement and would not result in adverse geomorphic effects. This section of the channel has already been modified previously with an earth embankment to contain the flow, and no active erosion on the outside of the bend was observed. Therefore, the avulsion risk is considered to be very low in the short to medium term.
 - Major channel erosion was observed from 75 m downstream of Millmerran-Inglewood Road. A build-up of woody debris within the channel has dammed the channel creating a 1 m base level change of the channel bed with extensive erosion and slumping of the channel banks observed directly downstream of this.
 - Monitoring, in particular at the meander bend approximately 100 m west of the crossing that abuts the proposed embankment for scour/avulsion and the existing erosion that starts 75 m downstream of road crossing.
 - Scour protection along the western side of the southwest bridge embankment to the east of the sharp bend to be considered at detailed design or if erosion observed during monitoring.
- ▶ The following site was investigated in the field and found to be initial case medium-risk after detailed site investigations:
 - ▶ CCs 21
 - Identified as a high-risk site in the initial risk assessment due to the hydraulic Developed Case indicating a large reduction in flow velocity upstream.
 - Detailed assessment determined that the reduction in velocity Developed Case could result in reduced transport of fine to coarse grained gravel; however, as particles of this grain size only make up a small proportion of the sediment load, the impacts of the Project on the fluvial system are considered low and readily mitigated in routine maintenance.
 - Channel constriction will likely lead to accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert.
 - Monitoring is recommended, in particular for deposition of gravel and woody debris at the culvert entrance that may need to be removed.

- ▶ The following site was investigated in the field and confirmed as initial case high-risk after detailed site investigations:
 - ▶ NC 11
 - Identified as a high-risk site in the initial risk assessment due to the hydraulic Developed Case indicating potential large increase in velocity downstream (i.e. erosion) from the Existing Case.
 - Detailed assessment determined that channel lining/protection will be required downstream from the culvert exit until the channel bed is rock to accommodate the increased flow velocities.
 - Monitoring for scour and mitigation if scour is observed.

14.8.2.4 Enhancement opportunities

The following opportunities for the enhancement of the geomorphic environment were identified:

- ▶ Where existing bridges or existing rail embankment with culverts are to be replaced with longer bridges resulting in less encroachment on water flow:
 - ▶ Condamine North Branch–310-BR27 Condamine River North Branch rail bridge
 - ▶ Condamine Main Branch–310-BR25/26 Condamine River Main Branch
 - ▶ Grasstree Creek–310-BR21/22 Grasstree Creek rail bridge
 - ▶ Condamine River South Branch rail bridge 310-BR24
- ▶ Mitigation of gully sites within the Project footprint:
 - ▶ CCs 22
 - ▶ CCs 21a
 - ▶ CCs 21
 - ▶ C Ck 16a
 - ▶ C Ck 16
 - ▶ CCs 19
- ▶ Culvert cross-drainage across the Condamine floodplain:
 - ▶ design cross-drainage culverts result in a reduction from Existing Case flow velocities at most sites
 - ▶ remediation could be undertaken at sites damaged by poorly performing Existing Case cross-drainage within the Project footprint.

14.9 Mitigation measures

This section details the ARTC approach to mitigating construction and operational flooding and geomorphic impacts of the Project including those measures already embedded within the revised reference design as well as those to be implemented in future project stages. Detail is also provided on the approach for the management of residual impacts after application of all feasible and reasonable mitigations.

The Project's proposed environmental management framework is detailed in Chapter 24: Draft Outline Environmental Management Plan.

14.9.1 Mitigation and management

14.9.1.1 Mitigation through revised reference design stage

Following additional work undertaken since notification of the draft EIS and consideration of the issues raised from the community, agencies and other stakeholders in their submissions to the draft EIS and follow-up consultation, the reference design was amended to its current design, the revised reference design, as presented in Appendix B1: Design Drawings, described in Chapter 5: Project Description, and with respect to flooding infrastructure, the Cross Drainage Register in Appendix T1: Flooding and Hydrology Technical Report–Volume 1 (Appendix B).

The revised reference design for the Project has been developed with the objectives of minimising potential impacts on the surrounding environment and land use. The Project has been designed to achieve the hydraulic design criteria (Table 14-3) including 1% AEP flood immunity to rail formation level. At the same time, the design seeks to minimise impacts that do not meet the FIOs (Table 14-4) for the flooding and drainage regime.

Key mitigation strategies and measures that have been incorporated in the revised reference design to minimise and reduce flood impacts include:

- ▶ Flood models were developed in consultation with stakeholders and, where possible, models were calibrated and validated using stakeholder-supplied information. Some examples of this information include surveyed flood marks of historical flooding observed by long term residents and general observations of residents of timing and behaviour of historical floods. Recent flood events (i.e. December 2021) have also been used to validate the flood models. The models were strengthened further following a comprehensive review by the Expert Flood Panel. A detailed summary of the issues raised by the Expert Flood Panel and ARTC's responses are presented in the Issues Management Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix A).
- ▶ The Project uses the existing South Western Railway Line and Millmerran Branch Railway Line rail corridors as far as possible to avoid introducing a new linear infrastructure corridor across floodplains. This means that approximately 69 km of the total 217.48 km Project length is located within existing rail corridor (i.e. brownfield development).
- ▶ In greenfield sections of the Project, the selection of the Project alignment considered flooding constraints to avoid and minimise impact to areas experiencing existing inundation. For example, the Project alignment predominantly avoids the 1% AEP regional floodplains of the Macintyre Brook and Gowrie Creek.
- ▶ The Project incorporates bridge and culvert structures to maintain existing flow paths and flood-flow distributions, such as across the Condamine River floodplain, where four significant bridges were incorporated into the Project's revised reference design with a combined opening width greater than 6 km. The Project's cross-drainage provisions (e.g. bridges and culverts) are presented in the Cross Drainage Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix B) and include the following:
 - ▶ 1,193 reinforced concrete box culverts at 133 locations
 - ▶ 2,134 reinforced concrete pipe culverts at 222 locations
 - ▶ a series of viaducts/bridge structures spanning a total of 11 km of watercourses and floodplains
 - ▶ 1.6 km of rock scour protection at culvert outlets.
- ▶ Bridge and culvert structures were located and sized to minimise increases in peak water levels, flow distribution, velocities, time of inundation and hazard in accordance with the FIOs.
- ▶ Additional assessments and the refinement of the revised reference design to address key stakeholder concerns regarding changed flooding conditions leading to erosion, sedimentation, increased risks of flooding and environmental concerns. Design refinements include updates to bridge and culvert designs (e.g location, number of cells and dimensions) and additional scour and erosion protection measures in areas identified to be at risk from increases in velocity.
- ▶ In response to concerns regarding the dispersive nature of soils particularly in floodplains, site specific soil and geomorphology assessments were undertaken to identify erosion and landform risks, inform the scour and erosion protection strategy and allow updates to the flooding mitigations.
- ▶ An extreme event assessment was undertaken to identify whether there is any potential risk to life as a result of the potential collapse of rail infrastructure by flood waters, and suitable mitigation and management measures were identified (Section 14.8.1.2.14).
- ▶ The revised reference design includes the modification of the existing Yelarbon flood levee for the township of Yelarbon with the addition of the Project. At a minimum, the flood levee augmentation will ensure no worsening of existing flood risk to the township of Yelarbon.
- ▶ A climate change assessment was undertaken for the 1% AEP design event. This assessment is in accordance with ARR 2019 and was used to determine the sensitivity of the Project's revised reference design and flood sensitive receptors to the potential increase in rainfall intensity.
- ▶ Potential blockage of hydraulic structures caused by floodplain debris, as highlighted by stakeholders in Section 14.5, has been factored into the revised reference design by allowing an additional 25 per cent flow capacity in culverts, and by placing appropriately sized bridges over major debris transportation paths.
- ▶ Consultation with potentially impacted flood sensitive receptors and landowners was undertaken during the reference design development to validate flood model outcomes and inform acceptable mitigation measures and design outcomes.

14.9.1.2 Proposed mitigation framework–future Project stages

It is recognised that further refinement and confirmation of site-specific mitigation measures will be undertaken during future design, construction and operational stages with respect to FIOs. It is noted the purpose of the FIOs is to identify areas where additional consideration is required and to determine whether the impact is acceptable, or mitigation is required. Mitigation measures adopted within the detailed design will be selected on a case-by-case basis and be subject to an analysis of their ability to reduce flood impact objective exceedances as well as their respective social, environmental, economic, engineering and landowner constraints, and will be informed by ongoing and collaborative consultation with landowners. This approach will allow for a robust process of mitigation selection to ensure that a focus on reducing flood impact objective exceedances is not considered in isolation from other Project aspects.

Additional detailed survey and local soils/vegetation information will be gathered to inform detailed design, along with ongoing consultation and discussion with landowners and stakeholders. These steps will aid in defining the preferred detailed design solution. Project and design constraints will also play a role in this definition process to ensure defensible and robust design solutions are achieved, as is the norm for linear infrastructure projects of this nature. It is recognised that it may not be possible to eliminate FIO exceedances due to environmental or engineering constraints or due to prohibitive costs. It also may not be necessary where further assessment determines that the exceedances are not material and do not warrant further action.

Updated modelling will be undertaken in detailed design which will consider the effect of additional inputs such as noise walls and fauna connectivity requirements at a local catchment scale, for all defined AEP events. Mitigation measures will be reviewed and updated as required based on updated modelling in the detailed design stage.

The Project's flood and geomorphic Impacts Mitigation Framework is presented in Figure 14-30 and discussed below.

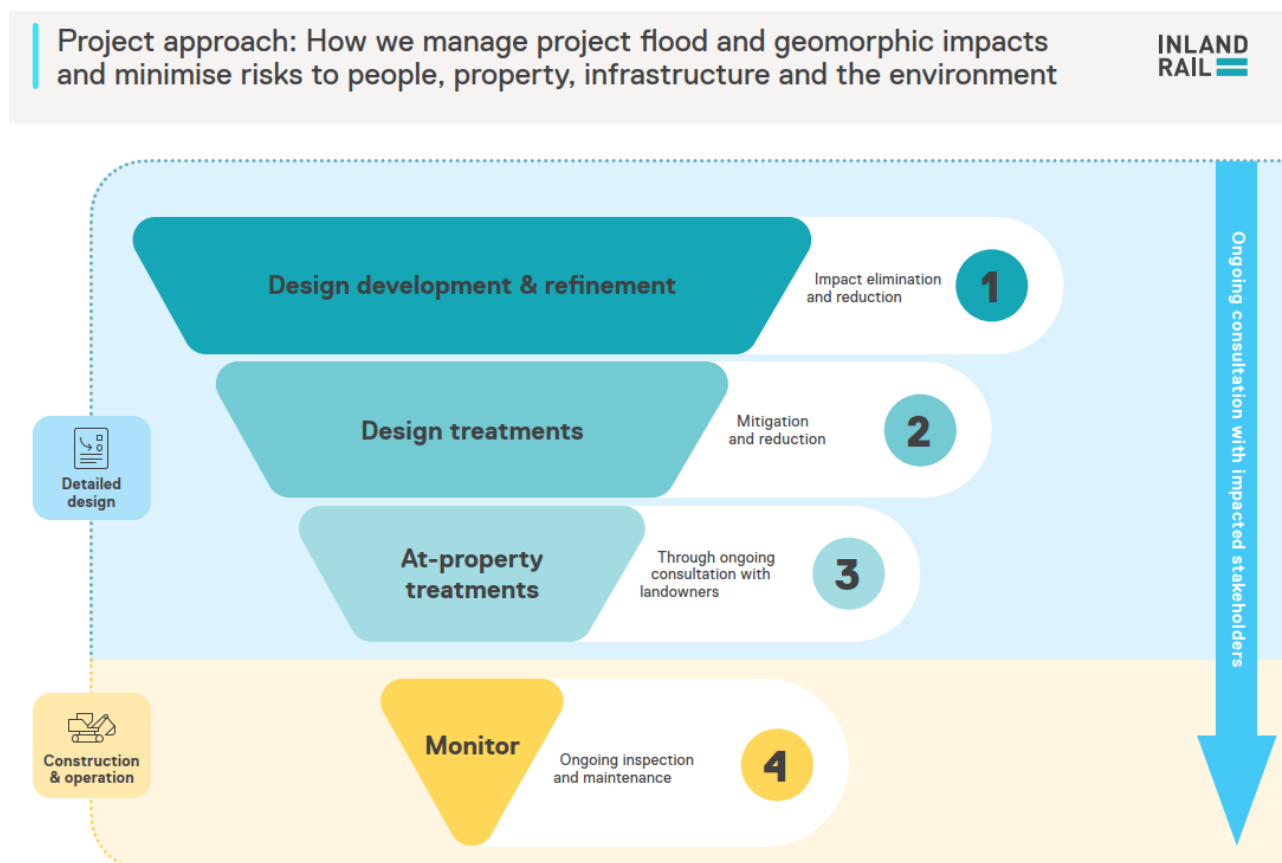


FIGURE 14-30 ARTC FLOOD AND GEOMORPHIC IMPACTS MITIGATION FRAMEWORK

Where residual FIOs exceedances or geomorphic impacts not yet eliminated (or not yet reduced to an acceptable level during the revised reference design) were identified, ARTC will investigate alternative design measures, directly related to the Project's revised reference design, to mitigate these impacts.

A hierarchy of potential mitigation measures for each flood impact objective category is shown in Table 14-120. It should be noted that in some cases, a combination of these measures may be required to mitigate flood impact objective exceedances and/or geomorphic impacts, and not all exceedances will be mitigatable. The following mitigation process will be applied in the detailed design stage (steps 1 to 3) and pre-construction, early works and construction works stage and commission and operations stage (step 4) and further expand on the four-step process identified in Figure 14-30:

- ▶ Step 1: Further design development and refinement (detailed design):
 - ▶ refine the flood models further in line with Expert Flood Panel recommendations. Refer to the Issues Management Register in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Appendix A) that relate to detailed design requirements
 - ▶ further detailed consideration of, or investigation into, flood impact objective exceedances and geomorphic impacts to understand their consequences on land, waterways and flood sensitive receptors
 - ▶ engage with impacted landowners on a case-by-case basis to understand how flood impact objective exceedances and geomorphic impacts are likely to affect their assets and/or operations
 - ▶ develop the Project's hydraulic design further (e.g. through additional cross-drainage structures, relocation or reconfiguration of cross drainage structures) to eliminate or reduce flood impact objective exceedances and geomorphic impacts further, in consultation with directly impacted landowners.
- ▶ Step 2: Revised design treatments (detailed design):
 - ▶ introduce alternative cross-drainage solutions (e.g. additional cells, alternative types of structures, changes to pipe/box angles, changes to invert levels/grades, spreading of culvert cells)
 - ▶ scour and erosion protection measures
 - ▶ modifications to bridge configurations to minimise encroachment into waterway channels and geomorphic impacts
 - ▶ flow energy dissipators
 - ▶ consideration of the proposed design treatment's ability to reduce flood impact objective exceedances and geomorphic impacts balanced with their social, environmental and economic impacts.
- ▶ Step 3: At-property/lot treatment (detailed design and pre-construction, early works stage):
 - ▶ land agreements such as deed of release, easements, positive covenant, freehold acquisition
 - ▶ compensation for mitigation such as raising or restumping a house
 - ▶ consideration of the at-property treatment's ability to manage residual flooding and geomorphic impacts balanced with their social, environmental and economic impact.
- ▶ Step 4: Monitor or adjust and refine (pre-construction, early works and construction works stage and commissioning and operations stage):
 - ▶ Inspection and monitoring
 - establish baseline ground conditions through a detailed survey
 - identify any non-conformances
 - ▶ Corrective action, if required
 - investigate non-conformances
 - identification and implementation of corrective/preventative actions
 - develop reporting, close-out and ongoing maintenance/monitoring requirements
 - ▶ Ongoing inspection, maintenance and reporting.

TABLE 14-120 HIERARCHY OF MEASURES TO REDUCE FLOOD IMPACTS

Hierarchy of control measures to reduce flood impacts

Mitigation Steps		Afflux	Velocity	Duration of inundation	Hazard	Distribution of Flow
General order of mitigation preference	Step 1 Design development and refinement	- Improved survey and LiDAR - Hydrologic/hydraulic model refinement - Bathymetric survey - Incorporation of EIS Conditions of approval - Confirmation of geotechnical conditions - Confirmation of vertical/horizontal alignment	- Improved survey and LiDAR - Hydrologic/hydraulic model refinement - Bathymetric survey - Incorporation of EIS Conditions of approval - Confirmation of geotechnical conditions - Confirmation of vertical/horizontal alignment	- Improved survey and LiDAR - Hydrologic/hydraulic model refinement - Bathymetric survey - Incorporation of EIS Conditions of approval - Confirmation of geotechnical conditions - Confirmation of vertical/horizontal alignment	- Improved survey and LiDAR - Hydrologic/hydraulic model refinement - Bathymetric survey - Incorporation of EIS Conditions of approval - Confirmation of geotechnical conditions - Confirmation of vertical/horizontal alignment	- Improved survey and LiDAR - Hydrologic/hydraulic model refinement - Bathymetric survey - Incorporation of EIS Conditions of approval - Confirmation of vertical/horizontal alignment
	Step 2 Design treatments	- Culvert location and spread - Culvert grade and invert levels - Culvert inlet/outlet realignment to existing flowpaths - A reduction or increase in culvert cell numbers - Realignment of abutments outside flow paths - Temporary water storage during a flood (flood mitigation dams and retarding and detention basins) with pumping systems - Revegetation of the catchment	- Scour protection (rip rap or gabions) - Culvert location and spread - Culvert grade and invert levels - Culvert inlet/outlet realignment to existing flowpaths - A reduction or increase in culvert cell numbers - Realignment of abutments outside flow paths - Lowering of culvert cell invert level to allow boulders and rocks to be deposited in cells - Flow baffles/energy dissipators	- Culvert location and spread - Culvert grade and invert levels - Culvert inlet/outlet realignment to existing flowpaths - A reduction or increase in culvert cell numbers - Realignment of abutments outside flow paths - Improved flood conveyance, including cutoff drains - Temporary water storage during a flood (flood mitigation dams and retarding and detention basins) with pumping systems	- Culvert location and spread - Culvert grade and invert levels - Culvert inlet/outlet realignment to existing flowpaths - A reduction or increase in culvert cell numbers - Realignment of abutments outside flow paths	- Culvert inlet/outlet realignment to existing flowpaths - Realignment of abutments outside flow paths - Formalising flowpaths for any diversions that may be required
	Step 3 At-property treatment	- Permanent levee and weir systems - Temporary barriers - Temporary water storage during a flood (flood mitigation dams and retarding and detention basins) with pumping systems - Revegetation of the catchment - Property specific solutions/compensation in consultation with impacted landowner	- Riparian vegetation/revegetation along the riverbanks and within the catchment - Property specific solutions/compensation in consultation with impacted landowner	- Permanent levee and weir systems - Temporary barriers - Temporary water storage during a flood (flood mitigation dams and retarding and detention basins) with pumping systems - Property specific solutions/compensation in consultation with impacted landowner	Property specific solutions/compensation in consultation with impacted landowner	Property specific solutions/compensation in consultation with impacted landowner
	Step 4 Monitor	- Compliance and monitoring in accordance with the finalised Construction Environmental Management Plan (CEMP), Operations Environmental Management Plan (Operations EMP) and other relevant project requirements. - Inspection and maintenance of stormwater infrastructure - Corrective action if required	- Compliance and monitoring in accordance with the finalised CEMP, Operations EMP and other relevant project requirements. - Inspection and maintenance of stormwater infrastructure - Corrective action if required	- Compliance and monitoring in accordance with the finalised CEMP, Operations EMP and other relevant project requirements. - Inspection and maintenance of stormwater infrastructure - Corrective action if required	- Compliance and monitoring in accordance with the finalised CEMP, Operations EMP and other relevant project requirements. - Improving availability of flood information i.e. searchability and sharing of information under appropriate arrangements and public availability of key project outputs - Development of Flood Emergency Management Plans - Evacuation route planning and improvement - Community flood awareness and preparedness - Development controls	- Compliance and monitoring in accordance with the finalised CEMP, Operations EMP and other relevant project requirements. - Improving availability of flood information i.e. searchability and sharing of information under appropriate arrangements and public availability of key project outputs - Development of Flood Emergency Management Plans - Evacuation route planning and improvement - Community flood awareness and preparedness - Development controls

It is important to note that a FIO exceedance would not necessarily cause an impact. As discussed in Section 14.6.3.3, the FIOs define the threshold as to the point at which a more detailed consideration of impacts is required when they are exceeded. Depending on land use, the underlying ground conditions and gradient, a site-specific assessment in consultation with the landowner will determine if the FIO exceedance is likely to lead to an impact.

Mitigation strategies were developed by ARTC to demonstrate how flood impact objective exceedances will be managed in the commissioning and operations stage. Modelling was undertaken to demonstrate viability and practicality of proposed mitigation strategies. This process is discussed in Appendix T1: Hydrology and Flooding Technical Report–Volume 1 (Section 22.4.1.3) with a summary provided in Section 14.9.1.4. Proposed monitoring programs to be implemented during the pre-construction, early works and construction works stage and the commissioning and operations stage are also discussed in this section.

The consultation undertaken with landowners regarding the anticipated flood impacts to their property/lot, including preliminary mitigation that has been identified through the consultation process, is discussed in Appendix E: Consultation Report. Ongoing consultation between ARTC and impacted landowners will occur throughout all four steps of the flood and geomorphic Impacts Mitigation Framework to ensure landowner sentiment is used to guide the mitigation process.

A management framework has been provided for the Project to enable the identified outcomes to be achieved for the life of the Project, through detailed design, pre-construction, early works and construction works stage and the commissioning and operations stages. This includes the process for the preparation and implementation of the CEMP and the Operation EMP, including plans.

The CEMP will provide a structured approach to the management of environmental issues during the delivery of the Project. The CEMP will be endorsed by the Environmental Monitor as being consistent with the draft Outline EMP, Conditions of Approval, and all relevant laws, prior to the commencement of any relevant Project works. Implementation of flooding and geomorphology elements of the CEMP and compliance against conditions of approval will be monitored, audited and reported.

As part of the CEMP, a Flood Risk Management Plan will be developed to outline management and control measures, as well as emergency procedures, to be implemented during the pre-construction, early works and construction works stage in order to mitigate flood impacts. As part of this sub-plan, details around the requirements associated with flood risk assessments will be included to manage the impacts of high-risk construction works. Pre-construction, early works and construction works will be managed by the following criteria:

- ▶ Minimise re-direction of flood water flow
- ▶ No adverse increases to flood levels at flood sensitive receptors
- ▶ Maintain existing velocities where practical
- ▶ Erosion and sediment control managed in accordance with the construction Erosion and Sediment Control Plan (ESCP).

The effectiveness of flood mitigation controls will be monitored in accordance with the CEMP and associated Flood Risk Management Plan.

During the commissioning and operations stage of the Project, flood impacts will be managed via the operation EMP which will be supplemented by a Flood Emergency Management Plan.

Residual exceedances

It is expected that through the implementation of mitigation measures, and refinement of the design in the detailed design stage, that some flood impact objective exceedances will be reduced or removed; however, not all flood impact objective exceedances will be able to be mitigated through engineering design. Due to the presence of the Project, some constriction, expansion and redirection of flow will result due to embankment and cross-drainage locations resulting in remnant flood impact objective exceedances.

All endeavours will be made during the detailed design stage to mitigate and reduce flood impact objective exceedances by modification of the Project design using measures detailed above. In the instance a flood impact objective exceedance remains owing to certain project/design constraints, post detailed design mitigation, engagement with impacted landowners will be undertaken to discuss the residual exceedances, the impact of the exceedance on their property and potential further site-specific mitigation measures. Site-specific mitigation measures will be individual to each landowner and informed via a consultation process.

Dispute resolution of unresolved matters

The Project will continue to incorporate environmental management and design features to ensure that indirect flooding impacts are managed and mitigated to the extent practicable, based on a case-by-case, risk-based approach. ARTC will consult with relevant stakeholders in good faith, guided by advice from qualified and experienced personnel. In situations where impacted landowners and ARTC cannot reach agreement on sufficient mitigation or a mutually accepted outcome regarding flood impacts above the target flood impact objective levels, ARTC will consider alternative dispute resolution processes, including mediation. The selection of the appropriate dispute resolution mechanism will depend on the specific circumstances and will be negotiated between landowners and ARTC.

14.9.1.3 Summary of mitigation measures

Table 14-121 summarises the proposed additional mitigation measures to be implemented during detailed design and for future Project stages.

TABLE 14-121 HYDROLOGY AND FLOODING AND GEOMORPHOLOGY MITIGATION FOR FUTURE STAGES OF PROJECT DELIVERY

Delivery stage	Aspect	Proposed mitigation measure
Detailed design	General	▶ The Project will be designed to achieve a 1% AEP flood immunity to rail formation level and manage FIOs detailed in accordance with the Project's Flooding and Geomorphic Impact Mitigation Framework. ▶ Any design modifications during the detailed design stage will be subject to re-runs of the updated existing flood models to demonstrate continued compliance with the design objectives of the Project, including for extent and time of inundation, afflux, hazard and flow velocities. The modelling updates that are required during detailed design, as stipulated by the Expert Flood Panel (and committed by ARTC) are summarised in each catchment chapter in Appendix T1: Hydrology and Flooding Technical Report–Volume 1. ▶ ARTC will employ a series of mitigation measures within the detailed design stage to mitigate flood impact objective exceedances and reduce geomorphic impacts including changing culvert location and spread, culvert grade and invert levels, realignment of culvert inlets and outlets and reduction or increase in culvert cell numbers. A hierarchy of potential controls for each stage of the Project has been provided in Table 14-120. ▶ ARTC will continue to consult with impacted landowners regarding the flood modelling results and residual flood impact objective exceedances through development of the detailed design. Mitigation measures to effectively manage residual flood impact objective exceedances will be discussed with affected landowners, in line with the Project's flood and geomorphic Impacts Mitigation Framework (Figure 14-30). ▶ In situations where impacted landowners and ARTC cannot reach agreement on sufficient mitigation or a mutually accepted outcome regarding flood impacts above the flood impact objective target, ARTC will consider alternative dispute resolution processes, including mediation. The selection of the appropriate dispute resolution mechanism will depend on the specific circumstances and will be negotiated between landowners and ARTC. ▶ The design requirements for modifying the existing Yelarbon levee will be confirmed through further consultation with GRC and incorporated into the detailed design in order to mitigate impacts from the Project on the Yelarbon township. Development approval for the modification of the Yelarbon levee will be obtained prior to the commencement of any modification works. ▶ Finalise the Draft Soil Management Plan (Appendix AB) with the results informing flooding infrastructure design to minimise impacts on watercourses and floodplains from erosion and sedimentation. Mitigations to consider the prevalence of specific soil types from sampling, and associated management measures appropriate for each soil types including those which are highly erodible and sensitive to change, such as cracking clays or texture contrast soils. ▶ Development of an Erosion and Sediment Control Plan as a component of the CEMP to confirm the number of, and locations for, specific temporary/permanent erosion and sediment control measures, including sediment basins, to reduce erosion/deposition impacts on channels and floodplains during construction. ▶ Development of construction plans and schedules to consider works and controls adjacent waterways and minimise impacts to existing flowpaths. ▶ Consideration of the controls detailed within the Department of Primary Industries (1988) <i>Floodplain management for erosion control and high productivity on the Darling Downs</i> document, will be undertaken during the detailed design stage to further refine the revised reference design. In particular permanently grass areas at culvert inlets and outlets to spread flow and reduce erosion and mitigation of active gullies.

Delivery stage	Aspect	Proposed mitigation measure
		▶ Additional fluvial geomorphology considerations for management plans include: ▶ reinstatement design to take into account the original landform setting, along with the new infrastructure to ensure sustainable functioning of runoff (i.e. slopewash, non-channelised flow and overland flow paths), channels, and floodplain environments in and around the ground disturbance areas ▶ where ground disturbance has occurred, return to a state that functions appropriately within the context of the pre-disturbance fluvial geomorphic (i.e. soil and landform) environment ▶ Sodosols and Vertosols are highly susceptible to rilling and gullying if disturbed; as a result, it is vital that ground cover is established quickly during construction. Consider methods to distribute flow and reduce direct downslope flow during construction such as surface contouring or temporary low brush fencing. Consider the use of grasses effective at stabilising Vertosol soils. ▶ develop the Rehabilitation and Landscaping Management Plan, to require revegetation to be undertaken with suitable, native species (e.g. water couch and native (Aussie) blue grass) appropriate to the landscape context and nursery/seed stock sources. ▶ Assessment of the following will be undertaken: ▶ positioning of bridge embankments with setback distances to be confirmed during detailed design, to manage geomorphology considerations ▶ consider options to move the embankment out of the meander bend in watercourse SC 2, approximately 100 m west of bridge BR310-37 to reduce geomorphic impacts ▶ reduce short radius bends in any permanent divisions and maintaining as close to natural channel orientation and geometry as possible ▶ consideration of hydraulic jumps will be undertaken during detailed design at locations where the proposed rail alignment is adjacent to existing cross-drainage structures to determine any potential changes to geomorphic conditions due to their formation ▶ consideration of assessing differences in flow duration at elevated velocities for sites at increased risk of erosion will be undertaken to inform further mitigations ▶ design of stabilisation measures for active gully erosion areas to minimise erosion and gully development within the Project permanent footprint, with consideration of the mitigation and management measures detailed in the <i>Soil conservation guidelines for Queensland</i> includes a chapter on gully erosion and its control (Chapter 13, Carey et al., 2015b) and the <i>Gully and Stream Bank Toolbox</i> (Wilkinson <i>et al.</i>, 2022) ▶ design for high sediment transport areas, such as those sites with active gully erosion, to allow for the sediment to pass through culverts to minimise changes on the geomorphic environment ▶ review of culvert dimensions for C Cs21 (culvert C73.53) to reduce potential blockage by woody debris ▶ watercourses with no hydraulic Existing Case and Developed Case models to be further assessed, including C Ck 4, C Ck 5, SC 1, C Ck 1, NC 16 and PC 1. ▶ Relevant mitigations including those relating to erosion treatment options within and external to the corridor will be reviewed and revised as necessary based on the ETV analysis undertaken via direct testing methods.

Delivery stage	Aspect	Proposed mitigation measure
		A Flood Risk Management Plan will be developed for the Project during detailed design, as a component of the CEMP. The plan will outline management and control measures, as well as emergency procedures to be implemented during the pre-construction activities and early works, and construction works stages to ensure risks to the public, workers and the environment are managed. The plan will detail: ▶ the requirements for flood risk assessments to manage the impacts of high-risk construction works ▶ the following management criteria: ▶ minimise re-direction of flood water flow ▶ no adverse increases to flood levels at flood sensitive receptors ▶ maintain existing velocities, where practical ▶ erosion and sediment control managed in accordance with the ESCPs as a component of the CEMP). ▶ Detail mitigations specific to each of the Project's temporary Project facilities as detailed below: ▶ for the Whetstone Material Distribution Centre (MDC): – further optimisation of the Project's cross-drainage culverts will be undertaken to mitigate afflux at the Whetstone MDC – the design is intended to allow the land to handle flooding events without adversely affecting adjacent stakeholders, ensuring a balance between the site's flood immunity and the broader community's flood immunity – siting of any office/workshop buildings will consider the outcomes of a flood risk assessment and be located in areas away from hazardous areas – buildings and other critical infrastructure, such as electrical and chemical equipment, will be constructed on elevated foundations or pilings to lift them above the expected flood levels. The piles will utilise reinforced concrete or steel to support elevated platforms and working spaces above the peak flood depth. ▶ for the Yelarbon non-resident workforce accommodation facility: – the location and nature of the access road will be re-considered to ensure that safe access and egress to and from the site is achievable, and that any road works do not exacerbate flood risk elsewhere ▶ for the Inglewood non-resident workforce accommodation facility: – the site will be designed to maintain the existing flow regimes within and around the site – any proposed floor levels will provide appropriate freeboards above the peak flood levels determined in the current flood risk assessment ▶ for the Turallin facility: – future connection to Turallin Road will ensure adequate provisions of conveyance and erosion protection on the Pine Creek main channel and avoid substantial development in the immediate overbank areas to minimise flood risk to site patrons and environmental impact to the watercourse – a future connection to Ellerslie Road, to the south of the site, will be considered as an alternative to the current proposed access to Turallin Road – any future development will consider impacts on nearby FSRs including the residential property present on the eastern bank of Pine Creek, adjacent the site access and Turallin Road connection – proposed floor levels in flood-prone areas will provide appropriate freeboards above the peak flood levels determined in the current flood risk assessment.

Delivery stage	Aspect	Proposed mitigation measure
	Emergency access route severance	Impacts to emergency access routes will be managed by the following workflow: ▶ mitigation modelling and flood impact objective exceedance assessment ▶ identification of impacted roads where flood impact objective exceedances cannot be mitigated ▶ assessment of the impacted road as a 'link' to determine if the impact is negligible due flooding elsewhere and the road already inaccessible. This will be assessed against the Existing Case flooding (i.e. without the Project) ▶ ranking of impacts based on road use (e.g. State-controlled/local/track) and 'link' assessment ▶ Consultation with both TRC and GRC LDMGs to discuss residual impacts and identify alternative local evacuation procedures, where necessary
	Safety risk to downstream population due to rail embankment failure during extreme flood event	To minimise the potential risk to downstream receptors due to a rail embankment failure, the following mitigation measures will be considered on a case-by-case basis: ▶ embankment failure mechanisms during overtopping events for selected AEP design flood events ▶ design for overtopping events, including: ▶ crest level against design water surface profiles for selected AEP design flood events ▶ overtopping flow rate for selected AEP design flood events ▶ landward slope steepness, topsoil material and revetment lots ▶ maintenance regime employed ▶ armouring of sections of embankment (e.g. rock, geotextile) to minimise overtopping scour potential. ▶ local solutions to reduce the effects of overtopping including a 'low point' or spillway, to help control extreme situations in which a levee is overtopped by ensuring that the water overtops in the least vulnerable area, combined with sufficient drainage systems to get rid of the overtopped water ▶ ensure the design provides sufficient cross-drainage capacity to limit any head differential and hydrostatic pressure across the embankment during extreme events ▶ consideration of blockage risk and in turn, at any critical locations, consideration of the risk this could pose to potentially high risk receptors. Mechanisms to manage this could include blockage mitigation measures (e.g. fencing, debris screens and deflector walls) or redundant capacity, alternate structure types or configurations ▶ development and application of a Project Flood Response Plan including coordination with the relevant local council and LDMG ▶ consideration of the ARTC Emergency Management (RLS-PR-044) (2024) including coordination with the relevant local council and LDMG ▶ ensuring an appropriate Inland Rail embankment inspection and maintenance program as per relevant ARTC Rail Track Engineering Practice Manuals for Civil Engineering ▶ flood warning and community preparedness in accordance with the TRC and GRC Local Disaster Management Plans.

Delivery stage	Aspect	Proposed mitigation measure
Pre-construction, early works and construction works	General	▶ For works that occur within the 1% AEP extent, flood risk assessments will be completed for pre-construction, early works and construction works within the Project temporary footprint that are deemed to be high risk based on their proximity to flood sensitive receptors. FRAs in these areas will assess impacts for more frequent events including two Exceedances per Year (EY), one EY, 50% AEP, 20% AEP and 10% AEP event given the temporary and dynamic nature of construction activities with consideration of methodology detailed in ARR 2019. Larger (i.e. rarer) flood events will be considered on a case-by-case basis where the risk profile of the proposed works would warrant it. Where there are interfaces between other Inland Rail projects, Flood Risk Assessments will be undertaken in consultation with other projects to ensure that consideration of whole of Inland Rail impacts is undertaken rather than in isolation. Pre-construction, early works and construction works will be managed by the following criteria: ▶ minimise re-direction of flood water flow ▶ no adverse increases to flood levels at flood sensitive receptors ▶ maintain existing velocities where practical ▶ erosion and sediment control is managed in accordance with the Construction ESCP. Using detailed and confirmed construction methodology, the FRAs will be used to inform appropriate site controls and documented by a Flood Risk Management Plan. FRAs will be used to ensure impacts to flood regimes and natural overland flow from construction activities are localised and temporary in nature. ▶ For works within defined watercourses, the following measures will be adopted: ▶ in-stream works will be undertaken in accordance with the requirements of the <i>Riverine Protection Permit Exemption Requirements</i> (Department of Regional Development, Manufacturing and Water, 2023a) ▶ disturbance areas will be minimised and work zones delineated to ensure areas of disturbance are limited ▶ excavation will be undertaken in a manner to prevent erosion or slip, working faces will be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion ▶ reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively and in accordance with the site Rehabilitation and Landscaping Management Plan ▶ stockpiling of material will be undertaken away from defined watercourses ▶ in the event of wet weather, the following additional controls would be implemented: – Project will be subscribed to BoM flood warning notifications – protection of exposed bank areas by geofabrics or similar. ▶ removal of any construction waste and equipment away from potential areas of inundation and watercourses. ▶ Locations of the laydown areas will be chosen to avoid areas that are within the 1% AEP floodplains where possible; however, due to the requirement of laydown areas for constructing bridges, some laydown areas must be within floodplains and near watercourses or drainage features. Laydown areas and other temporary project facilities that are located within the 1% AEP event inundation extents will be short-term in use. In such instances, the following precautions will be taken: ▶ the potential site will be surveyed prior to site establishment to understand the exact extent of potential flooding impact to facilities and storage areas ▶ the earthworks and temporary drainage will be designed to minimise flooding impacts. ▶ Mobile plant will not be stored in the 1% AEP extent when not scheduled or in use for construction purposes.

Delivery stage	Aspect	Proposed mitigation measure
	Temporary project facilities (including Whetstone MDC, Yelarbon and Inglewood non-resident workforce accommodation and Turallin facility)	▶ Implement the Flood Risk Management Plan for temporary Project facilities to ensure risks to the public, workers and the environment are managed through the construction and operation of the facilities, noting the specific mitigations particular to each site. ▶ A site-specific Storm Water Management Plan will be developed for each facility to effectively manage the overland flow within each site and discharge to the receiving environment under-developed conditions.
	Afflux	▶ As per those listed in the General category above.
	Velocity	▶ As per those listed in the General category above. ▶ Excavation will be undertaken in a manner to prevent erosion or landslip, working faces will be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion. ▶ The following mitigation and monitoring program will be implemented to manage and reduce impacts from increases in velocity: ▶ a baseline survey will be undertaken at cross-drainage structures and any other relevant stormwater-related infrastructure, to confirm the occurrence of, or pre-existence of, scour. The future occurrence or worsening of scour associated with the construction or operation of the Project will be evident in comparison with the baseline survey. Equally, the pre-existence of scour in advance of any construction or operational works will also be evident in reviewing the baseline survey. ▶ erosion and sediment control measures will be implemented (as per the CEMP) to adequately manage scour and sedimentation on surrounding lands ▶ where possible, work will be sited away from rivers and drainage lines, with adequate temporary drainage provided through sites ▶ monitoring for scour at cross-drainage structures (and any other relevant stormwater-related infrastructure) during the pre-construction, early works and construction works stage will be undertaken on the following periodic basis: – following rainfall events that have generated significant flow through either permanent or temporary cross-drainage structures (or at any other relevant stormwater-related infrastructure) – frequency is to be determined by ARTC during the detailed design stage. ▶ Where clear evidence of scour is observed in the monitoring data, this will be contrasted against the baseline survey data to confirm whether it is (a) pre-existing scour with no observed change, (b) pre-existing scour that has been clearly exacerbated, or (c) newly generated scour ▶ if the findings point to (b) or (c) above, an engineer will document this in a report of their findings and recommend mitigation or remediation measures which will be implemented on site as soon as practicable. This may include, but is not limited to: – terrain remediation and/or stabilisation, including vegetation and/or revegetation strategies, or the introduction of other natural forms of energy dissipation – dumped rock/riprap (i.e. flexible erosion protection measures) – gabion baskets and reno-mattresses (i.e. semi-flexible erosion protection measures). ▶ Consultation with affected landowners, asset owners, or stakeholders may be warranted as part of the mitigation and remediation works, depending on the nature and extent of the works and any scour being experienced. This will ensure that community concerns are understood, and impacts rectified in consultation with the landowner.

Delivery stage	Aspect	Proposed mitigation measure
	Time of inundation	▶ As per those listed in the General category above.
	Hazard	▶ As per those listed in the General category above. ▶ Construction tasks will be scheduled to avoid, where possible, bulk earthwork activities within the 1% AEP during periods of elevated flood risk. Where works cannot be scheduled outside of this time period, activity specific flood readiness and response planning will be required. This planning will be developed in consultation with the relevant local government and Queensland Fire and Emergency Services.
	Flow distribution	▶ As per those listed in the General category above. ▶ Application of a Project Flood Response Plan (via the Flood Risk Management Plan) including coordination with the relevant local council and LDMG to minimise risk to the community. ▶ Flood warning and community preparedness in accordance with the TRC and GRC Local Disaster Management Plans.
Commissioning and operations	General	▶ Monitoring to ensure the operation of the Project is not resulting in negative impacts to the surrounding environment (e.g. increased scour). ▶ Inspection and maintenance of stormwater infrastructure to minimise ongoing impacts to property and infrastructure. ▶ Corrective action of any non-conformances against the operations EMP if required. ▶ Development of a Flood Emergency Management Plan, to ensure protection of the community downstream of the Project. ▶ Evacuation route planning and improvement to ensure safe access and egress for the community and operations personnel during flood events. ▶ Additional signage of any residual risks due to the operation of the Project. ▶ Community flood awareness and preparedness of the new flood hazards due to the presence of the Project. ▶ Improving availability of flood information to allow the community to understand any residual risks due to the Project, including searchability and sharing of information under appropriate arrangements and public availability of key project outputs. ▶ Stakeholder engagement with impacted landowners including dispute resolution where necessary.
	Afflux	▶ As per those listed in the General category above for commissioning and operations.
	Velocity	▶ As per those listed in the General category above for commissioning and operations. ▶ The following mitigation and monitoring program will be implemented to manage and reduce impacts from increases in velocity: ▶ inspections will be carried out on waterway and drainage systems and erosion at prescribed intervals, with frequency to be determined by ARTC during the detailed design stage, ahead of the pre-commencement of operations ▶ physical inspections may be implemented in any defined high risk or sensitive areas, or where it might be deemed preferable and more suitable ▶ where clear evidence of scour is observed as per the monitoring data, this will be contrasted against the baseline survey data to confirm whether it is (a) pre-existing scour with no observed change, (b) pre-existing scour that has been clearly exacerbated, or (c) newly generated scour ▶ if the findings point to (b) or (c) above, an engineer will document this in a report of their findings and recommend mitigation and/or remediation measures to ensure the integrity of the drainage system is reinstated and any impact outside the permanent footprint will be rectified as soon as practicable and in consultation with the relevant landowner/asset manager ▶ where defects are identified and corrective actions are required, rectification works will be undertaken to reinstate defects back to baseline conditions ▶ asset inspections will be completed as soon as safe access can be achieved following a flood event.

Delivery stage	Aspect	Proposed mitigation measure
	Time of inundation	▶ As per those listed in the General category above for commissioning and operations.
	Hazard	▶ As per those listed in the General category above for commissioning and operations ▶ Consultation with both TRC and GRC LDMG to discuss residual impacts and identify alternative local evacuation procedures, where necessary.
	Flow distribution	▶ As per those listed in the General category above for commissioning and operations. ▶ Application of a Project Flood Response Plan including coordination with the relevant local council and LDMG to minimise the risk to the community. ▶ Application of the ARTC Emergency Management (RLS-PR-044) (2024) including coordination with the relevant local council and LDMG. ▶ Flood warning and community preparedness in accordance with the TRC and GRC Local Disaster Management Plans.

14.9.1.4 Expected effectiveness of mitigation measures

Flood modelling has been undertaken for the Project in accordance with industry standard guidelines, including ARR 2019 and flood management planning documents relevant to the study area. Further assessment and refinement during detailed design in accordance with these will be undertaken with the aim of avoiding or minimising, as far as practicable, impacts on flood sensitive receptors and infrastructure.

The geomorphology risk assessment has been undertaken for the Project with consideration of upstream catchment characteristics, soils data, hydraulic modelling, characterisation of channel and floodplain types, current and past behaviour, existing sensitivity to change and field investigations. Further assessment and refinement during detailed design will be undertaken with the aim of avoiding or minimising, as far as practicable, impacts on the fluvial geomorphic environment.

The mitigation measures outlined in Section 14.9.1 that have been incorporated in the Project are industry standard measures, underpinned by research, technical standards and engineering best practice. To demonstrate the effectiveness of mitigation measures, a representative sample of culvert sites that currently experience a range of flood impact objective exceedances in the revised reference design, were selected and hydraulic modelling simulations conducted at these locations with a varying degree of mitigation applied. The outcomes of this assessment are reported below.

Monitoring and auditing would be undertaken during construction and operations to ensure that the relevant plans included in the Project's CEMP and operations EMP, and monitoring program are being implemented. Watercourse condition monitoring would also be undertaken to observe any changes in the geomorphological stability of the watercourses that may be attributable to the Project and to inform appropriate management responses.

The proposed mitigation measures are expected to be effective in managing the potential impacts on people and property as a result of the Project.

Mitigation effectiveness

During the detailed design stage of the Project, design modifications will occur which will be subject to re-runs of the existing models to demonstrate continued compliance with design objectives of the Project, including for flood extent, time of inundation, afflux, velocity and hazard. Modelling will consider the effect of additional inputs such as noise walls at a local catchment scale, for all defined AEP events. As a part of this assessment, mitigation measures can be embedded within the Project design to further reduce flood impact objective exceedances across the Project alignment.

Mitigation measures adopted within the detailed design will be selected on a case-by-case basis and be subject to an analysis of their ability to reduce flood impact objective exceedances as well as their respective social, environmental and economic impacts. This approach will allow for a robust process for mitigation selection to ensure that a focus on reducing flood impact objective exceedances is not considered in isolation from other Project aspects.

Dependent on the outcomes of the detailed design modifications, the following mitigation measures will be further explored in order to mitigate and reduce flood impact objective exceedances:

- ▶ Culvert location and spread
- ▶ Culvert grade and invert levels
- ▶ Culvert inlet/outlet realignment to existing flowpaths
- ▶ A reduction or increase in culvert cell numbers.

To demonstrate the effectiveness of mitigation measures, a representative sample of culvert sites which currently experience a range of flood impact objective exceedances, including afflux, time of inundation, velocity and hazard, were selected and hydraulic simulations conducted at these locations with a varying degree of mitigation applied. Details of mitigation measures applied at each culvert location can be found in Table 14-122 and outcomes of this assessment are presented in Table 14-123.

TABLE 14-122 EXAMPLE MITIGATION MEASURES TESTED

Culvert locations	Mitigation measures applied
C62.94 and C63.15	▶ Increase in box culvert span ▶ Increase in culvert cell numbers and spread along the Project alignment ▶ Culvert inlet/outlet realignment to existing flowpaths.
C77.20, C77.47 and C77.77	▶ Increase in culvert barrel numbers and spread along the Project alignment ▶ Culvert inlet/outlet realignment to existing flowpaths ▶ Modification of culvert invert levels ▶ Inlet/outlet works to direct runoff through culvert structures.
C84.38 and C85.35	▶ Increase in culvert barrel numbers and spread along the Project alignment ▶ Culvert inlet/outlet realignment to existing flowpaths ▶ Modification of culvert invert levels ▶ Inlet/outlet works to direct runoff to/from the dedicated culvert structure.
C119.75, C119.88, C120.08, C120.25 and C120.31	▶ Increase in culvert barrel numbers and spread along the Project alignment ▶ Culvert inlet/outlet realignment to existing flowpaths ▶ Modification of culvert invert levels ▶ Inlet/outlet works to direct runoff to/from the dedicated culvert structure.

TABLE 14-123 EXAMPLE MITIGATION MEASURE EFFECTIVENESS

Culvert location	Lot Plan/Asset Impacted	Reduction in flood impact objective exceedance ¹			
		Afflux (mm)	Time of inundation (%)	Velocity (%)	Hazard (%)
C62.94 and C63.15	78MA3480	N/A	18	22	35
	141MH193	305	11	22	17
C77.20, C77.47 and C77.77	102MH643	N/A	-24	15	0
	Millmerran-Inglewood Road easement	118	N/A	7	134
C84.38 and C85.35	54SP129536	N/A	39	-3	90
	2SP214649	N/A	1	24	N/A
	Millmerran-Inglewood Road easement	296	15	97	681
C119.74, C119.88, C120.08, C120.25 and C120.31	94DY180	N/A	37	-29	230
	3SP166689	N/A	150	69	251

Table note:

1. A positive number indicates a decrease in exceedance, a negative number indicates an increase in exceedance

It was found that through the introduction of the above measures, significant reduction in flood impact objective exceedances both in extent and magnitude resulted, demonstrating the effectiveness of the mitigation measures. During future stages of design, flood impact objective exceedances that are determined to occur will be explored further and measures such as those demonstrated above, will be implemented to further mitigate these exceedances.

14.10 Impact assessment summary

The assessment of potential impacts on flooding and geomorphic processes by the Project is summarised in Table 14-124. An initial risk assessment of the potential alterations to the existing flooding regime and geomorphic processes from the Project was undertaken first. The initial risk assessment has been undertaken on the assumption that the design considerations factored into the revised reference design have been implemented.

Additional mitigation measures, as outlined in Sections 14.9.1.2 and 14.9.1.3, were then applied to future stages of the Project for medium and high-risk sites to reduce the level of potential impact and derive a residual risk.

TABLE 14-124 SUMMARY RISK ASSESSMENT—FLOODING AND GEOMORPHOLOGY

Aspect	Potential Impact	Project Stage	Potential impacts of the Project on the existing flooding regime and geomorphic processes					
			Initial risk ¹			Residual risk ²		
			Likelihood	Consequence	Risk ⁸	Likelihood	Consequence	Risk
Afflux	▶ Changes in peak water levels and associated areas of inundation	Pre-construction activities and early works and construction works	Likely	Moderate	High	Possible	Minor	Low
		Operations	Likely	Moderate	High	Possible	Minor	Low
	▶ Increased depth of water affecting trafficability of roads and tracks	Pre-construction activities and early works and construction works	Possible	Major	High	Possible	Moderate	Medium ³
		Operations	Likely	Moderate	High	Possible	Moderate	Medium ⁴
Velocity	▶ Increased velocities leading to localised scour and erosion on the floodplain	Pre-construction activities and early works and construction works	Likely	Moderate	High	Possible	Moderate	Medium
		Operations	Likely	Moderate	High	Unlikely	Moderate	Low
	Channel erosion: ▶ Bank retreat ▶ Scour holes ▶ Bed degradation ▶ Erosion of in-channel features (e.g. ponds, pools, woody debris, bars)	Pre-construction activities and early works and construction works	Possible	Moderate	Medium	Possible	Moderate	Medium
		Operations	Possible	Not significant to Major	74 Low	Possible	Minor	Low
					10 Medium			
					1 High			
	Channel deposition: ▶ Bed aggradation ▶ Bar aggradation ▶ Pond, pool infilling	Pre-construction activities and early works and construction works	Possible	Minor	Low	Possible	Minor	Low
		Operations	Possible	Not significant to Major	77 Low	Possible	Minor	Low
					3 Medium			
					5 High			
	Floodplain erosion: ▶ Scour holes ▶ Floodplain stripping ▶ Erosion of floodplain landforms such as wetlands, ponds	Pre-construction activities and early works and construction works	Rare	Moderate	Low	Rare	Moderate	Low
		Operations	Rare	Not significant to Major	Low	Rare	Not significant to Moderate	Low

Aspect	Potential Impact	Project Stage	Potential impacts of the Project on the existing flooding regime and geomorphic processes					
			Initial risk ¹			Residual risk ²		
			Likelihood	Consequence	Risk ⁸	Likelihood	Consequence	Risk
	Floodplain deposition:	Pre-construction activities and early works and construction works	Rare	Minor	Low	Rare	Minor	Low
	▶ Deposition in drainage infrastructure	Operations	Rare	Not significant to moderate	Low	Rare	Not significant to Moderate	Low
	▶ Infill of floodplain landforms such as flood channels, wetlands, ponds and pools							
	▶ Fines in railway ballast							
Duration of inundation and flow	▶ Changes in time of inundation, and subsequent impacts to the design life of existing assets and the viability and tolerance of crops	Pre-construction activities and early works and construction works	Likely	Moderate	High	Possible	Moderate	Medium ³
		Operations	Possible	Moderate	Medium	Possible	Moderate	Medium ⁴
Hazard	▶ Increased depth x velocity combination leading to higher flood hazard	Pre-construction activities and early works and construction works	Possible	Major	High	Unlikely	Moderate	Low
		Operations	Possible	Moderate	Medium	Unlikely	Moderate	Low
	▶ Impacts to effectiveness of emergency services response during and after flood events	Pre-construction activities and early works and construction works	Likely	Moderate	High	Possible	Moderate	Medium
		Operations	Possible	Moderate	Low	Unlikely	Moderate	Low
Flow distribution	▶ Concentration of flows, redirection of flows and/or changes to flood flow patterns	Pre-construction activities and early works and construction works	Likely	Moderate	High	Unlikely	Moderate	Low
		Operations	Possible	Moderate	Medium	Unlikely	Moderate	Low
	▶ Safety risk to downstream population due to rail embankment failure during extreme flood event	Pre-construction activities and early works and construction works	Possible	Major	High	Rare	Major	Low
		Operations	Possible	Major	High	Rare	Major	Low
	▶ Risk to downstream infrastructure and operations due to rail embankment failure during extreme flood event	Pre-construction activities and early works and construction works	Possible	Major	High	Rare	Major	Low
		Operations	Possible	Major	High	Rare	Major	Low

Aspect	Potential Impact	Project Stage	Potential impacts of the Project on the existing flooding regime and geomorphic processes					
			Initial risk ¹			Residual risk ²		
			Likelihood	Consequence	Risk ⁸	Likelihood	Consequence	Risk
	Channel planform change	Pre-construction activities and early works and construction works	Possible	Not significant	Low	Possible	Not significant	Low
	▶ Meander bend migration							
	▶ Avulsion	Operations	Possible	Not significant to Major	50 Low	Possible	Moderate	Low
					28 Medium			
					7 High			
	Channel type change	Pre-construction activities and early works and construction works	Possible	Moderate	Medium	Possible	Moderate	Medium
	▶ Change from one channel type to another (e.g. change from non-channelised valley floor to low sinuosity channel)	Operations	Possible	Not significant to Major	70 Low	Possible	Minor	Low
					8 Medium			
					7 High			

Table notes:

1. Based on the revised reference design and mitigations already integrated in the design.
2. Assessment of residual risk once proposed additional mitigation measures (Section 14.9) have been applied.
3. The 'medium' residual risk rating does not imply that an impact to crops/roads will necessarily occur due to changes in duration of inundation/depth during construction. A flood impact objective exceedance is not guaranteed to translate into an impact. The medium-risk rating is a prompt for more detailed assessment to be undertaken prior to construction to quantify and potential residual impacts, and to develop mitigation measures informed by the contractor's construction methodologies.
4. The 'medium' residual risk rating does not imply that an impact to crops/roads will necessarily occur due to changes in duration of inundation/depth as a result of the Project. A flood impact objective exceedance is not guaranteed to translate into an impact. The medium-risk rating is a prompt for more detailed assessment to be undertaken during detailed design to quantify and potential residual impacts, and to develop mitigation measures in consultation with impacted landowners and stakeholders.
5. The impact has been assessed using the 20% AEP event hydraulic data, which is the closest hydraulic modelling data to bankfull conditions.
6. The impact has been assessed using the 1% AEP event hydraulic data, which is the event with full floodplain flow.
7. Refers to overland flow on hill slopes, not watercourses.
8. Operational stage risk to watercourses from the Project has been assessed individually. This column includes the number of 'geomorphic' watercourses as defined in the fluvial geomorphic assessment and is not a reference to 'watercourse' as defined in the Water Act 2000 (Qld).
9. Potential impacts on changes to Existing Case geomorphic process in the channel by the Project have been assessed for the 'bankfull' conditions, when the most channel change occurs. This event is closest to the 20% AEP event, which corresponds to likelihood 'possible'. Potential impacts on floodplains have been assessed during a full floodplain flow event, corresponding to a 1% AEP event.

14.11 Conclusions

This chapter assesses the potential flood and geomorphology impacts of the Project on the surrounding land and infrastructure based on the current design of the Project. The chapter has been written to address the 'Flood Management' section of the ToR inclusive of ToR items 11.64 to 11.69 of which Appendix A2: Terms of Reference Cross-reference Table provides section links to the relevant ToR. In addition, this chapter also addresses the additional information requests issued by the Coordinator-General following the public notification of the EIS. In doing so, the assessment has evaluated a comprehensive range of issues encompassing potential impacts of the Project on the surrounding land and infrastructure.

In order to determine impacts from the Project, Existing Case conditions were first assessed for both flooding and geomorphology including:

- ▶ Development of hydrological and hydraulic models for 13 key waterways as well as minor drainage paths in local catchments
- ▶ Calibration of the models, where possible, to multiple historical events using stream gauges records, community feedback and available anecdotal data
- ▶ Geomorphic assessment including channel/floodplain characterisation and descriptions of existing processes for all watercourses and floodplains. A total of 55 field checking sites were investigated at representative crossings to confirm baseline conditions and gather observations on the impacts of existing infrastructure on watercourse and floodplain processes.

The proposed works associated with the Project were incorporated into the hydraulic models (i.e. the Developed Case) and assessment of the potential impacts on the existing flooding and fluvial geomorphic regime were undertaken. Changes in peak water levels, velocities, flow patterns and flood inundation extents and durations have been identified, mapped or tabulated. Developed Case hydraulic modelling results have also been utilised to inform the potential impacts on the geomorphic environment.

For detailed design and commissioning and operations stages, the outcomes of the Developed Case modelling were compared against FIOs developed in consultation with the Expert Flood Panel as detailed in Section 14.6.3.3.

Due to construction works being temporary in nature and in various forms as the Project progresses, flood impacts will be highly influenced by any planned construction staging, planned embankment raises and cuts and temporary drainage works. At this stage of planning for the Project, detailed construction phasing is not available and will be developed as construction contractors are onboarded to the Project. Subsequently, full construction stage impacts cannot be determined until this information is available. As such, it is proposed as part of the pre-construction, early works and construction works stage, and for works that occur within the 1% AEP extent, flood risk assessments be completed for works within the temporary footprint that are deemed to be high-risk based on their proximity to flood sensitive receptors. The flood risk assessment approach is discussed in Section 14.9.

Key findings of the flooding and geomorphic impact assessments are as follows:

- ▶ Assessments of temporary project facilities indicated that:
 - ▶ The Whetstone MDC is located within a high risk flood zone and becomes partially inundated in the 10% AEP event.
 - ▶ The proposed Yelarbon non-resident workforce accommodation facility is not affected by 1% AEP flood risk, but access to and from the site off the Cunningham Highway is predicted to become inundated.
 - ▶ Some areas of the Inglewood non-resident workforce accommodation facility are predicted to be inundated within the 1% AEP event by overland flow conditions, although this is predicted to be low-risk.
 - ▶ The Turallin facility is subject to Pine Creek flooding in the 1% AEP event with the central portion of the site being flood-free in the 1% AEP event and therefore imposes no constraints on future site activities. The eastern site area traversed by the Pine Creek main channel corridor is considered highly hazardous, which should be avoided for all non-essential development activities. The eastern corner of the site is subject to relatively deep inundation and may pose an increased flood risk. Further assessment is required at detailed design to assess and mitigate potential impacts on the fluvial geomorphic environment of any cross-drainage of the accessway across Pine Creek and mitigations may include consideration of relocating the accessway.
 - ▶ The assessment of laydown areas indicated that 44 of the 77 laydown areas are impacted by flooding up to the 1% AEP event.
- ▶ Construction stage potential impacts on the fluvial geomorphic environment were assessed as follows for both initial case and residual risk: medium-risk erosion and channel type change, low-risk deposition and planform change were assessed as low.
- ▶ A total of 8.3 km of State-controlled roads are potentially impacted by a flood impact objective exceedance during the commissioning and operations stage.

- ▶ A total of 27.9 km of local roads are potentially impacted by a flood impact objective exceedance during the commissioning and operations stage.
- ▶ A total of 6.4 km of existing rail infrastructure is potentially impacted by a flood impact objective exceedance during the commissioning and operations stage.
- ▶ Changes in peak water level that exceed the flood impact objective targets may potentially occur during the commissioning and operations stage on:
 - ▶ a total of 37 flood sensitive receptors including:
 - twenty one dwellings (six between Pampas and Yandilla, 14 at Yelarbon and Kurumbul, and one at Pittsworth)
 - two sheds at Pampas, one shed at Yarranlea and 10 sheds at Yelarbon and Kurumbul
 - four commercial buildings (grain silos) at Yandilla and one Stockyard near Kurumbul
 - ▶ a total of 7.5 km of State-controlled roads
 - ▶ a total of 23.8 km of local roads
 - ▶ a total of 5.6 km of existing rail infrastructure
 - ▶ a total of 278 ha of private land outside the Project's permanent footprint.
- ▶ Changes in time of inundation that exceed the flood impact objective targets may potentially occur during the commissioning and operations stage on:
 - ▶ a total of 2.5 km of State-controlled roads
 - ▶ a total of 9.0 km of local roads
 - ▶ a total of 2.5 km of existing rail infrastructure
 - ▶ a total of 1,526 ha of private land outside the Project's permanent footprint.
- ▶ Changes in velocity that exceed the flood impact objective targets may potentially occur during the commissioning and operations stage on:
 - ▶ a total of 0.1 km of State-controlled roads
 - ▶ a total of 2.5 km of local roads
 - ▶ a total of 0.5 km of existing rail infrastructure
 - ▶ a total of 168 ha of private land outside the Project's permanent footprint.
- ▶ Changes in flood hazard that exceed the flood impact objective targets may potentially occur during the commissioning and operations stage on:
 - ▶ a total of two flood sensitive receptors
 - ▶ a total of 1.1 km of State-controlled roads
 - ▶ a total of 4.9 km of local roads
 - ▶ a total of 2.3 km of existing rail infrastructure
 - ▶ a total of 142 ha of private land outside the Project's permanent footprint.
- ▶ Time of inundation is the predominant exceedance across the Project alignment on property, roads and rail. The presence of the Project results in some minor changes of flow behaviour from the Existing Case scenario resulting in an increase in time of inundation in places. In instances where the Project is removing the existing rail line, the upgrade of cross-drainage infrastructure results in increased conveyance across the alignment and increase in time of inundation in these areas.
- ▶ Flow distribution—the Project has minimal impacts on flood flows and floodplain conveyance and storage with significant floodplain structures included to maintain the existing flood regime. Some change occurs directly adjacent to cross-drainage structures and abutments due to the constriction of flow through these areas.
 - ▶ Geomorphic floodplain connectivity is maintained through design; cross-drainage infrastructure and reduced connectivity is unlikely.
 - ▶ Planform change potential impacts were the most common impact on the fluvial geomorphic environment, identified at 41 watercourses, seven of which were assessed as initial case high-risk, 28 medium-risk and the rest low-risk. Channel type change potential impacts were identified at 18 watercourses; seven were assessed as initial case high-risk, eight medium-risk and the remainder low-risk. This is largely driven by design bridge abutments that are very close to or within a channel, and design culverts not aligned to flow. Two sites had potentially more complex processes occurring, and detailed site investigations and assessment was undertaken to confirm conditions and identify additional site-specific mitigations. Residual risk at all sites was assessed as low after applying additional mitigations.

- ▶ In general, changes in velocities occur directly adjacent to the Project alignment, around cross-drainage structures. Where flow velocities increase occurred between Existing Case and Developed Case conditions, the extent was found to typically reduce to Existing Case velocities over a short distance.
- ▶ Some flood impact objective exceedances appear to be large but are generally attributed to an increase in flood extent and newly flood-affected hydraulic model cells with adjacent cells having similar high velocities.
- ▶ Under the fluvial geomorphology assessment, erosion potential impacts were identified at 18 watercourses where scour protection in the revised reference design was not assessed as sufficient to mitigate for increased erosion potential or was not present. Of these, one site was initial case high-risk, 10 were medium and the rest low-risk. Detailed site investigations were undertaken at the high risk site to confirm conditions and identify additional site-specific mitigations. Residual risk at all sites was assessed as low after applying additional mitigations.
- ▶ Deposition potential impacts were identified at 13 watercourses where there was a reduction in design flow velocity; of these, five were assessed as initial high-risk (four were gully sites), two medium-risk and the rest low-risk. Detailed site investigations and assessment were undertaken at three high-risk sites, including two gully sites. Residual risk at all sites was assessed as low after applying additional mitigations.
- ▶ The criteria to assess for erosion and deposition potential was triggered at 10 watercourses and three floodplains, respectively and all were assessed as low risk.
- ▶ A review of commissioning and operations stage impacts under extreme events (i.e. the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events) has been undertaken with the existing flood depths and increase in peak water levels at flood sensitive receptors identified on each floodplain. Considering the flood depths that occur, particularly under the PMF event, indicates that the changes in peak water levels would be unlikely to exacerbate flood conditions during extreme events. An embankment overtopping failure risk assessment has been completed, with the risk to life considered low during extreme events.
- ▶ Climate change has been assessed in accordance with ARR 2019 requirements with the Representative Concentration Pathway 8.5 (2090 horizon) scenario adopted. The impacts resulting from changes in peak water levels under the 1% AEP event with climate change are generally similar to those seen under the 1% AEP event, with some additional impacts on flood sensitive receptors. An analysis of changes to flow velocity within the Project permanent footprint has been undertaken to determine the sensitivity of geomorphic process to potential long-term changes in climate (1% AEP event). Westbrook Creek was identified as the most sensitive to climate change-driven changes in flow velocity; Cattle Creek, MB 6 and Native Dog Creek regional models were the least sensitive.
- ▶ Blockage of drainage structures has been assessed in accordance with ARR 2019 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. Two blockage sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts assessed. The resulting changes in peak water levels associated with the Project alignment are localised but impact some flood sensitive receptors. The geomorphology assessment identified large woody debris in some channels, in particular in gully-type channels. Review of culvert dimensions was included for one site, channel C Cs21 (culvert C73.53), in detailed design to reduce potential blockage.

The revised reference design for the Project has been developed with the objectives of minimising the potential for adverse impacts on existing water flows including overland flow, minimising impacts to the existing flooding and geomorphological regime, having regard to the FIOs developed in consultation with the Expert Flood Panel and to minimise risks to people, property, infrastructure and the environment.

Project works will be designed, planned and implemented to minimise the potential for adverse impacts on existing water flows including overland flow and flooding profiles. A management framework has been provided with respect to the identified outcomes being achieved for the relevant stages of the Project. This includes the process for the preparation and implementation of the CEMP and the Operation EMP, including component plans.

The CEMP will provide a structured approach to the management of environmental issues during the delivery of the Project. The CEMP will be endorsed by the Environmental Monitor as being consistent with the draft Outline EMP, Conditions of Approval, and all relevant laws, prior to the commencement of any relevant Project works. Implementation of flooding and geomorphology elements of the CEMP and compliance against conditions of approval will be monitored, audited and reported. A Flood Risk Management Plan will be developed as a plan to the CEMP.

Where residual flood impact objective exceedances or geomorphic impacts not yet eliminated (or not yet reduced to an acceptable level during the revised reference design) have been identified, ARTC will investigate alternative design measures, directly related to the Project's revised reference design, to mitigate these impacts. Proposed mitigation measures for the detailed design, pre-construction, early works, construction, commissioning and operations stages have been detailed in Section 14.9.

A four-step flood and geomorphic Impacts Mitigation Framework has been developed that will be implemented throughout the detailed design, pre-construction, early works, construction, commissioning and operations stages to mitigate impacts including:

- ▶ Step 1: Design development and refinement
- ▶ Step 2: Design treatments
- ▶ Step 3: At-property treatments
- ▶ Step 4: Monitor.

In future stages, ARTC will continue to work with:

- ▶ Landowners concerned with hydrology and flooding throughout the detailed design, pre-construction, early works, construction, commissioning and operations stages of the Project
- ▶ Directly impacted landowners affected by the alignment throughout the detailed design, pre-construction, early works, construction, commissioning and operations stages of the Project
- ▶ Local councils, State government agencies and local flood specialists throughout the detailed design, pre-construction, early works, construction, commissioning and operations stages of the Project.

Prior to the commencement of Project operations, an Operation EMP will be prepared to ensure all applicable environmental requirements are achieved.