CHAPTER 12

Surface Water and Hydrology

INLAND RAIL—BORDER TO GOWRIE ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

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12.1 Introduction

The purpose of this chapter is to provide a description of the surface water quality and the hydrology and flooding impact assessments for the Inland Rail—Border to Gowrie Project (the Project).

For surface water, this includes an assessment of the quality of water and the existing uses of surface waters (known as environmental values (EVs)), as well as the water quality objectives (WQOs) that have been established to protect these values.

For hydrology and flooding this includes a detailed hydraulic assessment establishing the existing flooding regime, followed by consideration of the proposed works and refinement of the major drainage structures to minimise impacts to acceptable 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 surface waterways have been assessed based on a review of the Project's construction and operation phases. The results of the impact assessment and recommended mitigation measures have been outlined along with potential cumulative impacts.

Full details of the surface water quality assessment are provided in Appendix P: Surface Water Quality Technical Report. Full details of the hydrology and flooding assessment are provided in Appendix Q1: Hydrology and Flooding Technical Report and Appendix Q2: Hydrology and Flooding Technical Report Figures.

12.2 Independent International Panel of Experts for Flood Studies in Queensland

The Australian and Queensland governments established an Independent International Panel of Experts (The Panel) for flood studies, to provide advice to the Commonwealth and the Queensland Governments on the flood models and structural designs developed by the Australian Rail Track Corporation (ARTC) for Inland Rail in Queensland. As an advisory body to government, The Panel is independent of the ARTC in respect of the development, public consultation and approvals for the Inland Rail EIS process. Relevant submissions received from public notification of the draft EIS will be provided to The Panel for consideration as part of its review.

Information on The Panel may be viewed here**: tmr.qld.gov.au/projects/inland-rail/independent-panel-of-experts-for-flood-studies-in-queensland**.

12.3 Terms of Reference requirements

This chapter has been prepared to address sections of the Terms of Reference (ToR) that relate to surface water and hydrology. A compliance check of this chapter against each of the relevant components of the ToR is presented in Table 12.1. Relevant sections of the ToR have also been addressed in Appendix P: Surface Water Technical Report and Appendix Q1: Hydrology and Flooding Technical Report.

Compliance of the draft EIS against the full ToR is documented in Appendix B: Terms of Reference Compliance Table.

TABLE 12.1 COMPLIANCE AGAINST RELEVANT SECTIONS OF THE TERMS OF REFERENCE

Surface water and hydrology Terms of Reference requirements		Draft EIS section
Water		
Existing environment		
10.4	Describe and illustrate the topography of the proposed rail alignment and surrounding area, and highlight any significant features shown on the maps. Include and name all waterways and floodplains, including watercourses, rivers and creeks. Maps should include a scale and have contours at suitable increments relevant to the scale, location, potential impacts and type of Project, shown with respect to Australian Height Datum (AHD) and drafted to GDA94.	Section 12.7
11.24	The EIS must also provide details on the current state of groundwater and surface water in the region as well as any use of these resources.	Sections 12.7 and Chapter 13: Groundwater

Surface water and hydrology Terms of Reference requirements		Draft EIS section
11.36	Identify the water related environmental values and describe the existing surface water and groundwater regime within the study area and the adjoining waterways in terms of water levels, discharges and freshwater flows.	Sections 12.5 and 12.7
11.37	With reference to *the EPP (Water and Wetland Biodiversity) Policy 2009*, Section 9 of the EP Act, and SPP State Interest Guideline - Water Quality, identify the environmental values of surface water and groundwater within the Project area and immediately downstream that may be affected by the Project, including any human uses of the water and any cultural values.	Sections 12.5 and 12.7 and Chapter 13: Groundwater
11.38	At an appropriate scale, detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the Project. Include a description of the natural water quality variability within the study area associated with climatic and seasonal factors, and flows.	Sections 12.7.1 and 12.8.1 and Chapter 13: Groundwater
11.39	Describe any existing and/or constructed waterbodies adjacent to the proposed alignment.	Section 12.7.1.2
Water quality		
Impact assessment		
11.41	The assessment of impacts on water will be in accordance with the DES Information guideline for an environmental impact statement – TOR Guideline – Water, where relevant, located on the DES website (refer to Appendix 1).	The assessment contained within this chapter and Appendix P: Surface Water Quality Technical Report is consistent with the Department of Environment and Science (DES) information guideline for an environmental impact statement—TOR Guideline—Water
11.42	Identify the quantity, quality and location of all potential discharges of water and wastewater by the Project, whether as point sources (such as controlled discharges) or diffuse sources (such as irrigation to land of treated sewage effluent).	Sections 12.8.1.1 and 12.10.1
11.43	Assess the potential impacts of any discharges on the quality and quantity of receiving waters taking into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts.	Sections 12.8 and 12.10
11.44	Where significant cuttings are proposed, identify the presence of any sulphide minerals in rocks with potential to create acidic, metalliferous and saline drainage. Should they be present, describe the practicality of avoiding their disturbance. If avoidance is not practicable, characterise the potential of the minerals to generate contaminated drainage and describe abatement measures that will be applied to avoid adverse impacts to surface and groundwater quality.	Sections 12.7.1.5, 12.8 and 12.9.1
11.45	Describe the potential impacts of in-stream works on hydrology and water quality.	Section 12.7.1.1 and 12.7.1.2
11.46	Undertake a salinity risk assessment in accordance with Part B of the Salinity Management Handbook, Investigating Salinity (refer to Appendix 1). In particular, consider how the Project will change the hydrology of the Project area and provide results of the risk assessment.	Sections 12.7.1.5, 12.8, 12.9 and 12.10
Mitigation measures		
11.47	Describe how the water quality objectives identified above would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Section 12.9.1

Surface water and hydrology Terms of Reference requirements		Draft EIS section
11.48	Describe appropriate management and mitigation strategies and provide contingency plans for:	-
	(a) potential accidental discharges of contaminants and sediments during construction and operation	Sections 12.8, 12.9 and 12.10
	(b) stormwater runoff from the Project facilities and associated infrastructure during construction and operation, including the use of appropriate best practice erosion and sediment control practices (refer to Appendix 1), and the separation of clean stormwater runoff from disturbed and operational areas of the site	Sections 12.9.1.1 and 12.9.1.2
	(c) flooding of relevant river systems, the effects of tropical cyclones and other extreme events	Sections 12.7.1.1 and 12.9.2
	(d) management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Sections 12.8, 12.9 and 12.10
11.49	Describe treatment processes for all waste water produced as a result of the Project.	Section 12.9.1.2
11.50	Propose suitable measures to avoid or mitigate the impacts of in stream works on water quality and the stabilisation and rehabilitation of any such works.	Sections 12.8, 12.9 and 12.10
11.51	Where a salinity risk is identified, detail strategies to manage salinity ensuring the development must be managed so that it does not contribute to the degradation of soil, water and ecological resources or damage infrastructure via expression of salinity. See Part C of the salinity management handbook second edition, Department of Environment and Resource Management 2011 (refer to Appendix 1).	Sections 12.7.1.5, 12.8 and 12.9
Water resources		
Impact assessment		
11.52	Provide details of any proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the Water Act, Water Supply (Safety and Reliability) Act 2008 or Planning Act.	Chapter 3: Legislation and Project Approvals Process Chapter 5: Project Description Section 12.8.1.3
11.53	Detail any significant diversion or interception of overland flow. Include maps of suitable scale showing the location of diversions and other water-related infrastructure.	Section 12.8.1.1
11.54	Develop hydrological models as necessary to describe the inputs, movements, exchanges and outputs of all significant quantities and resources of surface water and groundwater that may be affected by the Project. The models should address the range of climatic conditions that may be experienced at the site, and adequately assess the potential impacts of the Project on water resources. This should enable a description of the Project's impacts at the local scale and in a regional context including proposed:	-
	(a) changes in flow regimes from structures and water take	Section 12.10.2
	(b) alterations to riparian vegetation and bank and channel morphology	Section 12.10.2
	(c) direct and indirect impacts arising from the Project	Section 12.8.1 and 12.10.2
	(d) impacts to aquatic ecosystems, including groundwater dependent ecosystems and environmental flows.	Sections 12.10.1
11.55	Provide information on the proposed water usage by the Project including details about:	-
	(a) the estimated supply required to meet the demand for construction and full operation of the Project, including timing of demands	Section 12.8.1.2

Surface water and hydrology Terms of Reference requirements		Draft EIS section
11.55 (cont'd)	(b) the quality and quantity of all water supplied to the site during the construction and operational phases based on minimum yield scenarios for water reuse, rainwater reuse and any bore water volumes	Section 12.8.1.2
	(c) a plan outlining actions to be taken in the event of failure of the main water supply	Section 12.8.1.2
	(d) sufficient hydrogeological information to support the assessment of any temporary water permit applications.	Chapter 13: Groundwater
11.56	Describe proposed sources of water supply given the implication of any approvals required under the Water Act. Estimated rates of supply from each source (average and maximum rates) must be given and proposed water conservation and management measures must be described.	Section 12.8.1.2
11.57	Determination of potable water demand must be made for the Project, including the temporary demands during the construction period. Include details of any existing town water supply to meet such requirements. Detail should also be provided to describe any proposed onsite water storage and treatment for use by the site workforce.	Section 12.8.1.2
11.58	Identify relevant Water Plans and Resources Operations Plans under the Water Act. Describe how the Project will impact or alter these plans. The assessment should consider, in consultation with Department of Natural Resources, Mines and Energy (DNRME), any need for:	-
	(a) a resource operations licence	A resource operations licence is not considered to be required by the Project
	(b) an operations manual	An operations manual is not considered to be required by the Project
	(c) a distribution operations licence	A distribution operations licence is not considered to be required by the Project
	(d) a water licence	Section 12.8.1.2
	(e) a water management protocol.	A water management protocol is not considered to be required by the Project
11.59	Identify other water users that may be affected by the proposal and assess the Project's potential impacts on other water users.	Sections 12.7.1.3 and 12.8.1.2
11.60	Identify and quantify likely activities involving the excavation or placement of fill or the removal of vegetation that will be undertaken in any watercourse, lake or spring. Where works are not consistent with the Riverine Protection Permit Exemption Requirements (Appendix 1) provide sufficient information to meet riverine protection permit requirements.	Section 12.8.1
Mitigation measures		
11.61	Provide designs for all infrastructure used in the treatment of onsite water, including how any onsite water supplies are to be treated, contaminated water is to be disposed of and any decommissioning requirements and timing of temporary water supply/treatment infrastructure is to occur.	Section 12.9
11.62	Describe measures to minimise impacts on surface water and ground water resources.	Section 12.9
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	Section 12.9

Surface water and hydrology Terms of Reference requirements		Draft EIS section
Flood management		
Existing environment		
11.64	A detailed desktop assessment of the proposed alignment and surrounding catchments, including but not limited to the Border Rivers Basin, the Macintyre River catchment, Macintyre Brook catchment and the Condamine River Basin must be undertaken and the potential for flooding qualitatively described. The assessment must include existing surface drainage patterns, flows and history of flooding including extent, levels and frequency.	Sections 12.7.5 and 12.7.6
11.65	The desktop assessment must also identify any high-risk watercourse crossing or floodplain locations that warrant further detailed quantitative assessment.	Sections 12.7.5 and 12.7.6
Impact assessment		
11.66	A detailed flood study including Gowrie Creek, Dry Creek and Westbrook Creek, in addition to the catchments assessed in Section 11.64 of this TOR must include:	-
	(a) a description and justification of the method of modelling	Section 12.6.3
	(b) quantification of flood impacts on upstream and downstream properties, land uses, existing infrastructure and future transport corridors surrounding the proposed alignment from redirection or concentration of flows	Section 12.10.2
	(c) Identification and quantification of likely changes in flood levels, increased flow velocities, increased sediment flows or increased time of flood inundation as a result of the Project	Section 12.10.2
	(d) details of all hydraulic and hydrological calculations to assess the impacts of peak discharge, any potential for loss of floodplain storage and increases in impervious area between the pre and post-development scenarios. Include the assumptions and baseline data underpinning these analyses	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Sections 6 to 18
	(e) current accepted best practice and statutory requirements in relation to floodplain management	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Section 4
	(f) Describe and assess the flood risk for a range of annual exceedance probabilities (including probable maximum flood) within floodplains. Assess how the Project may change flooding characteristics (e.g. afflux, frequency and duration of flooding, peak discharges and flow velocities) and identify affects such as erosion, sedimentation and scouring and other impacts of changed flooding regimes	Section 12.10.2
	(g) The study should consider all infrastructure associated with the Project including levees, roads and linear infrastructure.	Section 12.10.2
11.67	The flood study should incorporate the relevant aspects of:	
	(a) applicable New South Wales and Queensland local planning schemes and regional plans	Appendix Q1: Hydrology and Flooding Technical Report—Volume I
	(b) the Inglewood Flood Study 2015	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Section 15
	(c) the proponent's Condamine River Floodplain Study	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Section 8
	(d) the draft Floodplain Management Plan for the Border Rivers Valley Floodplain 2018	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Section 18

Surface water and hydrology Terms of Reference requirements		Draft EIS section
11.67 (cont'd)	(e) flood assessments and studies produced by relevant councils	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Sections 6 to 18
	(f) other relevant and publicly available information.	Appendix Q1: Hydrology and Flooding Technical Report—Volume I: Sections 6 to 18
11.68	The EIS should describe the consultation that has taken place with landowners and directly affected stakeholders along the proposed alignment regarding modelled potential impacts of the Project on flooding. It should also include a discussion of how the results of consultation have been considered by the proponent in the EIS process.	Section 12.6.3.4 Appendix C: Stakeholder Engagement Report
Mitigation measures		
11.69	Describe all proposed measures and their effectiveness to avoid or minimise risks to life, property, infrastructure, community (including damage to other properties) and the environment as a result of Project impacts during flood events particularly flood risks on individual properties and businesses.	Section 12.9.2

12.4 Policies, standards and guidelines

The policies, standards and guidelines relevant to the Project with respect to surface water, hydrology and flooding are presented in Table 12.2.

Legislation of relevance with respect to this assessment is as follows:

- *Water Act 2007* (Cth)
- *Water Act 2000* (Qld)
- *Environmental Protection Act 1994* (Qld) (EP Act).

The relevance of these items of legislation and the Project's compliance with each is discussed in Chapter 3: Legislation and Project Approvals Process.

TABLE 12.2 POLICIES, STANDARDS AND GUIDELINES RELEVANT TO THIS ASSESSMENT

Policy, standard or guideline	Relevance to the Project
Environmental Protection (Water) Policy 2019 [EPP (Water and Wetland Biodiversity)]	The quality of Queensland waters is protected under the EPP (Water and Wetland Biodiversity) and seeks to achieve the objective of the EP Act in relation to Queensland waters. Schedule 1 of the EPP (Water and Wetland Biodiversity) lists the EVs and WQOs that need to be considered by planners and managers when making decisions about waters and/or water quality. The quality of water within the impact assessment area is required to be assessed against the EPP (Water and Wetland Biodiversity) environmental values (EVs) and WQOs.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ), 2018)	The ANZG provides an agreed framework for assessing water quality in terms of whether the water is suitable for a range of EVs (including human uses). The framework guides users through the necessary steps for planning and managing water quality or sediment quality. The guidelines provide detailed approaches, identifying indicators and values for selected indicators to protect management goals. The ANZG values can be regarded as guideline values that can be modified into regional, local or site-specific guidelines, with consideration to the variability of the subject environment, soil type, rainfall and contaminant exposure. Exceedances of the guideline values would indicate a potential environmental issue and trigger an environmental management response.
Queensland Water Quality Guidelines (QWQG) (Department of Environment and Heritage Protection (DEHP), 2009)	The QWQG provide a framework for assessing water quality in Queensland by setting of WQOs. The QWQG are intended to address the need identified in the ANZG Guideline (2018) by: - Providing guideline values (numbers) that are tailored to Queensland regions and water types - Providing a process/framework for deriving and applying more locally specific guidelines for waters in Queensland.

Policy, standard or guideline	Relevance to the Project
Monitoring and Sampling Manual: Environmental Protection (Water) Policy (Department of Environment and Science (DES), 2018a)	The *Monitoring and Sampling Manual* provides an overview of the common techniques, methods and standards for the collection, handling, quality assurance and control, custodianship and data management in relation to water-quality samples. The manual helps to ensure that monitoring data is collected in a consistent and scientifically accurate manner.
Healthy Waters Management Plans	Healthy Waters Management Plans are a key planning mechanism to improve the quality of Queensland waters under the EPP (Water and Wetland Biodiversity). Healthy Waters Management Plans provide an ecosystem-based approach to integrated water management. The Healthy Waters Management Plans provide: ▸ Identification and mapping of EVs, desired levels of aquatic ecosystem protection and management goals for Queensland waters ▸ WQOs under the *National Water Quality Management Strategy* (Australian Government, 2018) to protect the EVs. The relevant Healthy Waters Management Plans for the Project include: ▸ Ch 30.6 km (NS2B) to Ch 117.0 km: within the boundaries of the Border Rivers basin. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins* (DES, 2019a). ▸ Ch 117.0 km to Ch 206.9 km: within the boundaries of the Condamine–Balonne River basin. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Condamine River Basin* (DES, 2019b). As the Queensland Border Rivers and the Condamine River basins are located within the Murray–Darling basin, these Healthy Water Management Plans also contribute to the requirements of a Water Quality Management Plan (WQM Plan) under the *Commonwealth Water Act 2007—Basin Plan 2012*.
Basin Plan 2012 (Basin Plan)	The Basin Plan is an Australian Government instrument, made under subparagraph 44(3)(b)(i) of the *Water Act 2007* (Cth), that provides a framework to manage the water resources of the Murray–Darling basin and sets out limits for sustainable use of surface water and groundwater in each water resource plan area. The impact assessment area is located within the Condamine and Balonne and the Border Rivers and Moonie water resource plan area, which are covered by the Basin Plan.
Water Plans	Water sharing plans were developed under the Water Act to sustainably manage and allocate water resources in Queensland. The plans apply to water in watercourses and lakes, water in springs, overland flow water, and groundwater and allow for identification of availability of water options for Project uses. Three water-sharing plans are relevant to the Project: ▸ Water Plan (Border Rivers and Moonie) 2019 ▸ Water Plan (Condamine and Balonne) 2019 ▸ Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017.
Shaping South East Queensland (SEQ) Regional Plan 2017 (ShapingSEQ) (Department of Infrastructure, Local Government and Planning (DILGP), 2017a)	ShapingSEQ is the Queensland government's plan to guide the future of the South East Queensland (SEQ) region. ShapingSEQ is based on the understanding that the region relies on its environmental assets to support our communities and lifestyles. ShapingSEQ provides strategies to protect and sustainably manage the region's catchments to ensure that the quality and quantity of water in waterways, aquifers, wetlands, estuaries, Moreton Bay and oceans meets the needs of the environment, industry and community. The Project has been identified as a key priority in the region and is considered to be consistent with ShapingSEQ.

Policy, standard or guideline	Relevance to the Project
Darling Downs Regional Plan 2013 (Department of State Development, Manufacturing, Infrastructure and Planning (DSDIP), 2013b)	The *Darling Downs Regional Plan 2013* identifies priority outcomes for the region's transport network, which include prioritisation of transport programs to improve freight movement and reduce conflicts in urban areas with other network users. The plan also identifies opportunities for protecting the quality of the surface and groundwater quality of the region. The Project is considered to be consistent with the *Darling Downs Regional Plan 2013* via the adoption of WQO under Schedule 1 of EPP (Water and Wetland Biodiversity) as a basis of existing environment conditions.
State Planning Policy 2017 (SPP) (including *State Planning Policy – State Interest Guideline (Water Quality) 2016)* (DILGP, 2017c)	The SPP is a key component of the Queensland land-use planning system, which expresses the State's interest (as defined under the *Planning Act 2016* (the Planning Act) (Qld)) in land-use planning and development. The SPP defined the Queensland Government's State interests in land-use planning and development, which notably includes State transport infrastructure. The SPP includes an SPP code (Water Quality Appendix 2) that provides performance outcomes to ensure development is planned, designed, constructed and operated to manage stormwater and wastewater in ways that support the protection of EVs identified in the EPP (Water and Wetland Biodiversity). While no components of the Project are assessable under the provisions of a local government planning scheme, State approval requirements will trigger the Chief Executive of the Department of State Development, Tourism and Innovation (DSDTI) as a referral agency for a number of applications. As such, relevant provisions of the SPP will be required to be addressed as part of the supporting application materials to be submitted (around water quality performance outcomes with discharge from tunnel infrastructure) and will be considered in the assessment process.
Australian Rainfall and Runoff: A Guide to Flood Estimation (Ball et al., 2019)	Australian Rainfall and Runoff (ARR) is a national guideline document, data and software suite that can be 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 ARR 2016. ARR 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 ensures that development does not occur in high-risk areas and that infrastructure is appropriately designed. ARR 2016, being the current version of this guideline during the formative stages of Inland Rail 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.
AS7637:2014*: Railway Infrastructure—Hydrology and Hydraulics* (Standards Australia, 2014)	This standard describes the hydrological and hydraulic requirements (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.
Guide to Road Design Part 5: Drainage—General and Hydrology Considerations (Austroads, 2013a)	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.
Evaluating Scour at Bridges: Fifth edition (US Department of Transport—Federal Highway Administration (FHWA), 2012)	This manual is part of a set of Hydraulic Engineering Circulars issued by the Federal Highway Administration (USA) 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.

Policy, standard or guideline	Relevance to the Project
Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular Number 14 (HEC–14), Third Edition (FHWA, 2006)	This manual is part of a set of Hydraulic Engineering Circulars issued by the FHWA to provide design procedures for energy dissipator designs for highway applications.
Bridge Scour Manual: Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour (Department of Transport and Main Roads (DTMR), 2019g)	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.

12.5 Water quality objectives and environmental values

The Project alignment traverses through the Border Rivers basin (Ch 30.6 km (NS2B) to Ch 117.0 km) and the Condamine River basin (Ch 117.0 km to Ch 206.9 km), as recognised under the EPP (Water and Wetland Biodiversity) (refer Figure 12.2).

Water quality objectives have been developed under the provisions of the EPP (Water and Wetland Biodiversity), under the EP Act, to support and protect different EVs identified for waters within both the Condamine River and Border River basin areas. Under the EVs, it is expected that each WQO is achieved in order to maintain existing water-quality standards, or aspirational water-quality standards, where present. Typically, WQOs are assessed against a median assessment of the existing environment; however, for this assessment, grab samples were assessed against the WQO with reference to prevailing conditions and trending data in regard to seasonal conditions.

12.5.1 Environmental values

The Project alignment crosses through eight sub-catchments of the Condamine River basin and the Border Rivers basin, each of which are recognised for their own unique EVs, as outlined in Table 12.3.

TABLE 12.3 ENVIRONMENTAL VALUES FOR SUB-CATCHMENTS THAT THE PROJECT ALIGNMENT INTERSECTS

Environmental values	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural, spiritual and ceremonial values
Sub-catchments of the Condamine River basin												
Upper Oakey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hodgson Creek	✓	✓	✓	✓		✓			✓			✓
Ashall Creek	✓	✓	✓	✓					✓		✓	✓
Condamine River North Branch	✓	✓	✓						✓	✓	✓	✓
Condamine River South Branch	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
Sub-catchments of the Border Rivers basin												
Canning Creek	✓	✓		✓					✓			✓
Lower Macintyre Brook	✓	✓	✓	✓		✓	✓		✓	✓		✓
Macintyre Barwon Floodplain	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓

Source: DES (2019a & 2019b)

12.5.2 Water quality objectives

The Project alignment extends through the following water type zones within the Border Rivers and Condamine basins, as published in the relevant Healthy Waters Management Plan:

- Condamine River basin:
  - Oakey Creek
  - Central Condamine
  - Southern Condamine.
- Border Rivers basin:
  - Canning Creek
  - Lower Macintyre Brook
  - Macintyre Barwon floodplain.

Water quality objectives for each of these water type zones are presented in Table 12.4 and Table 12.5.

The WQOs in Table 12.4 are for physico-chemical parameters and are consistent with the accreditable water-quality target values published in the relevant Healthy Waters Management Plan. WQOs in Table 12.4 are presented for low-flow and high-flow conditions.

The WQOs in Table 12.5 are for heavy metals and other toxic contaminants and are consistent with the toxicant default guideline values published in the ANZG (ANZECC & ARMCANZ, 2018).

TABLE 12.4 WATER QUALITY OBJECTIVES FOR MODERATELY DISTURBED WATERS INTERSECTED BY THE PROJECT

Water type zone	Water flow	Turbidity (NTU)	Total P (µg/L)	Chlorophyll *a* (µg/L)	Total nitrogen (µg/L)	Oxidised nitrogen (µg/L)	Ammonium N (µg/L)	Dissolved oxygen		pH	EC µS/cm	Salinity mg/L	TSS mg/L
								mg/L	%sat				
Condamine River basin[1]													
Oakey Creek (Sites 34–43)	Low flow	13	110	5	1,000	5	10	ID	60–110	7.7–8.3	510	NA	14
	High flow	55	340	ID	1,280	ID	ID			7.4–8.1	380		65
Central Condamine (Sites 27–33)	Low flow	25	170	9	860	4	4			7.4–8.3	890		25
	High flow	220	950	4	2,200	480	ID			7.0–7.6	290		130
Southern Condamine (Sites 21–26)	Low flow	9	45	5	595	3	6			7.2–7.9	170		8
	High flow	25	60	ID	830	ID	ID			7.0–7.6	160		17
Border Rivers basin[2]													
Canning Creek (Sites 9–20)	Low flow	35	30	ID	520	6	10	>5	60–110	7.2–7.8	200	NA	25
	High flow	50	40	ID	600	ID	ID			6.9–7.9	165		60
Lower Macintyre Brook (Sites 3–8)	Low flow	11	55	ID	710	18	8			7.4–8.0	370		10
	High flow	25	70	ID	910	ID	ID			7.2–8.0	250		25
Macintyre Barwon Floodplain (Sites 1–2)	Low flow	30	70	3	575	10	20			7.4–8.0	240		25
	High flow	110	150	ID	900	195	ID			7.0–7.5	180		70

Table notes:

P, EC and TSS = phosphorus, electrical conductivity and total suspended solids respectively.
µg/L = micrograms per litre
NTU = Nephelometric Turbidity Units
mg/L = milligrams per litre
ID = Insufficient data for determination of water quality objective
µS/cm = microsiemens per centimetre

Source: 1. Healthy Waters Management Plan: Condamine River Basin (DES, 2019b); 2. Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins (DES, 2019a)

TABLE 12.5 WATER QUALITY OBJECTIVES FOR PROTECTION OF SLIGHTLY TO MODERATELY DISTURBED WATERS: HEAVY METALS AND OTHER TOXIC CONTAMINANTS

Water type zone	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickle (mg/L)	Zinc (mg/L)	Naphthalene (mg/L)
Condamine River basin									
Oakey Creek	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Central Condamine	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Southern Condamine	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Border Rivers basin									
Canning Creek	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Lower Macintyre Brook	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Macintyre Barwon floodplains	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016

Source: *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2018)

12.6 Methodology

12.6.1 Impact assessment area

The impact assessment area for the assessment of surface water and hydrology is 1 km either side of the Project alignment. The impact assessment area includes the whole of the Project footprint and has been established to enable assessment of foreseeable direct and indirect impacts to water quality or the existing flooding regime.

The impact assessment area is shown on Figure 12.1 in relation to the Project alignment and surrounding hydrological features.

12.6.2 Surface water quality

12.6.2.1 Assessment methodology

The methodology adopted for the assessment of surface water has been established to provide sufficient information to determine:

- Existing receiving surface water condition
- Impacts to surface water quality and resources that may arise as a result of the Project
- Mitigation measures that can feasibly be implemented through future Project phases to avoid or reduce the significance of impacts to surface water
- Cumulative impacts to surface waters, as a result of Project activities occurring in parallel to activities of other projects in the region.

The existing condition of surface waters within the impact assessment area was established through assessment of publicly available datasets, in combination with water-quality data collected across five sampling events (with seasonal variation) (refer Section 12.6.2.2).

In combination, these datasets were used to determine the quality of receiving waters within the impact assessment area and were subsequently used to assess the potential for impacts to surface waters to arise as a result of Project activities.

The assessment of potential impacts to surface water quality and resources was undertaken using a significance-based impact assessment framework, as described in Chapter 4: Assessment Methodology.

In the context of surface water, the significance-based impact assessment method requires consideration of the likely sensitivity of a receptor (e.g. the quality or resource value of surface waters) and the magnitude (e.g. intensity, duration and spatial extent) of potential impact on that receptor. In combination, the sensitivity of a receptor and the magnitude of potential impact enable the significance of a risk to be established.

Further information on the adopted impact assessment methodology is provided in Chapter 4: Assessment Methodology and Appendix P: Surface Water Quality Technical Report.

12.6.2.2 Water quality sampling and analysis

Four surface water sampling events were initially planned, approximately three months apart, with two surveys undertaken at the same time as aquatic ecology surveys (June and December 2018) (refer Chapter 10: Flora and Fauna) and the remaining two surveys scheduled as dedicated surface water sampling events in September 2018 and February 2019.

The September 2018 water quality sampling event was not undertaken due to dry conditions across the impact assessment area. Instead, the September 2018 sampling event was rescheduled for April/May 2019, when water was more likely to be present in local waterways. In summary, five water quality sampling events were completed, as follows:

- 11–20 June 2018 (aquatic ecology and surface water)
- 26 November to 3 December 2018 (aquatic ecology and surface water)
- 11–19 February 2019 (surface water only)
- 29 April to 2 May 2019 (surface water only)
- 15–19 May 2019 (aquatic ecology and surface water).

Field personnel undertaking the surveys were experienced in the collection and analysis of water quality samples.

Selection of sampling sites

Forty-three sites along the Project alignment were initially selected as potentially suitable sampling sites. This number was significantly more than what was intended to be surveyed but allowed for sites to be removed from the selection if land access proved to be problematic or if sites were found to be unsuitable when accessed in the field. The inclusion of a large number of potential sampling sites also provided greater certainty that sufficient water would be present at a representative selection of sites in the event that dry conditions were experienced.

Sites were positioned as close as possible to locations where the reference design rail alignment traversed watercourses, waterways or other drainage features. Sites were nominally assigned into one of the following categories:

- Aquatic ecology and surface water quality sites—where an assessment of aquatic ecology habitat values and surface water quality was to be undertaken
- Surface water quality sites—where assessment of surface water quality only was to be undertaken.

The distribution of sampling sites along the rail alignment was determined from a range of factors, including:

- Mapping and aerial photography products that provide information on aquatic habitat features, including Department of Agriculture and Fisheries (DAF) waterway barriers and DES aquatic habitat mapping
- Inclusion of waterways with a variety of stream orders within the Project footprint, ensuring water features of varying size and complexity were sampled
- Representation of a variety of aquatic habitat types and surrounding land uses (e.g. areas where remnant riparian vegetation was intact, and areas that had been subject to disturbance from existing infrastructure or agricultural land uses)
- A relatively even spread of survey sites along the Project alignment, to determine spatial variability in aquatic and water quality values
- Practicality of access to the site and the safety of field teams.

Where practical, surface water quality sites were located upstream and downstream of the reference design, if access was possible. This positioning of sampling sites ensured that the collected data retained value for assessment purposes, in the event that localised alignment shifts occurred during the design development process.

Consistent and reliable access was obtained for 34 sites that were suitable for surface water assessments. These 34 sites consisted of 12 sites where aquatic ecology assessment and surface water quality sampling was conducted and 22 sites where surface water quality sampling was conducted. A summary of all sites identified for potential sampling is provided in Table 12.6 with their location along the rail alignment shown in Figure 12.1.

Sites were assigned a number in approximate numerical order from southwest to northeast. On some occasions, when a site could not be accessed, an alternative site was identified on public land nearby and labelled with the site number and the letter 'R' (e.g. Site 20R). This allowed the assessment of water quality information from areas adjacent to the original site.

TABLE 12.6 SAMPLING SITES TARGETED DURING THE FIELD SURVEYS AND ASSOCIATED BASIN AND WATER TYPE ZONE

Site	Assessment type	Watercourse/waterway	Tenure
Border Rivers basin			
Macintyre Barwon Floodplain water type zone			
1#	Aquatic ecology and surface water	Macintyre River	Private land
2	Aquatic ecology and surface water	Macintyre River	Private land
Lower Macintyre Brook water type zone			
3	Surface water	Macintyre Brook	Public land
4	Aquatic ecology and surface water	Unnamed	Public land
5	Aquatic ecology and surface water	Unnamed	Private land
6	Surface water	Macintyre Brook	Private land
7	Surface water	Macintyre Brook	Public land
8	Aquatic ecology and surface water	Unnamed	Private land

Site	Assessment type	Watercourse/waterway	Tenure
Canning Creek water type zone			
9	Aquatic ecology and surface water	Pariagara Creek	Private land
10	Surface water	Pariagara Creek	Private land
11	Surface water	Canning Creek	Private land
12	Aquatic ecology and surface water	Unnamed	Public land
13	Aquatic ecology and surface water	Cattle Creek	Public land
14	Surface water	Unnamed	Private land
15	Aquatic ecology and surface water	Unnamed	Private land
16	Aquatic ecology and surface water	Unnamed	Private land
17	Aquatic ecology and surface water	Unnamed	Private land
18	Surface water	Unnamed	Public land
19	Aquatic ecology and surface water	Nicol Creek	Public land
20	Surface water	Nicol Creek	Private land
Condamine River basin			
Southern Condamine water type zone			
21#	Aquatic ecology and surface water	Unnamed	Private land
22#	Surface water	Unnamed	Public land
23	Surface water	Unnamed	Public land
24	Surface water	Grasstree Creek	Public land
25#	Aquatic ecology and surface water	Grasstree Creek	Private land
26#	Surface water	Grasstree Creek	Private land
Central Condamine water type zone			
27	Surface water	Condamine River	Public land
28	Aquatic ecology and surface water	Condamine River	Private land
29	Surface water	Unnamed	Public land
30	Surface water	Condamine River	Public land
31	Surface water	Condamine River (North Branch)	Public land
32	Aquatic ecology and surface water	Condamine River (North Branch)	Public land
33	Surface water	Condamine River (North Branch)	Public land
Oakey Creek water type zone			
34#	Aquatic ecology and surface water	Unnamed	Private land
35	Surface water	Unnamed	Public land
36	Surface water	Unnamed	Public land
37#	Surface water	Westbrook Creek	Private land
38#	Aquatic ecology and surface water	Westbrook Creek	Private land
39	Surface water	Westbrook Creek	Public land
40	Surface water	Dry Creek	Public land
41#	Aquatic ecology and surface water	Dry Creek	Private land
42	Surface water	Dry Creek	Public land
43	Aquatic ecology and surface water	Unnamed	Public land

Table notes:
# indicates that access to the site was not reliable for all field surveys or the site was found not to be suitable for assessment

Surface water quality data was collected at accessible sites in accordance with the DES *Monitoring and Sampling Manual* (DES, 2018a). Information about site characteristics was recorded using the *Water Quality Sampling Field Sheet* (Department of Natural Resources and Mines (DNRM), 2002).

The following values were recorded at each surface water sampling site:

- Site ID and name
- Date and time
- Sampling location (latitude, longitude and reach orientation looking downstream)
- Weather (rain in the past week, cloud cover, wind)
- Observations at water sampling site (within 2 m of sampling point or on closest bank), including:
  - Shading (per cent)
  - Water odour
  - Water surface condition
  - Algae (per cent) (on substrate, in water column)
  - Macrophytes (per cent) (emergent, submerged, floating, fringing)
  - Impact (per cent) (human, pastoral animals, non-pastoral animals).

A multi-probed, battery operated water quality meter (YSI Professional Plus) was used to measure physio-chemical parameters. The device was calibrated in the field prior to the collection of data and used to take measurements of the following parameters:

- Dissolved oxygen (DO) (mg/L) and saturation (per cent)
- pH
- Electrical conductivity (EC) (µs/cm)
- Temperature (°C)
- Turbidity (NTU)
- Total dissolved solids (TDS) (ppm)
- Oxidation reduction potential (ORP) (mV).

Water quality samples were collected using sampling containers prepared and provided by the National Association of Testing Authorities accredited laboratory Australian Laboratory Services (ALS). Nitrile gloves were worn during sampling and field teams maintained best-practice protocols to assist in prevention of onsite contamination.

Water samples collected for the purpose of analysis for dissolved metals were filtered in the field through a 0.45 µm filter using a sterile syringe. Once collected, samples were immediately placed in a refrigerator or on ice, in an esky, and delivered with Chain of Custody forms to ALS for analysis of the following analytes:

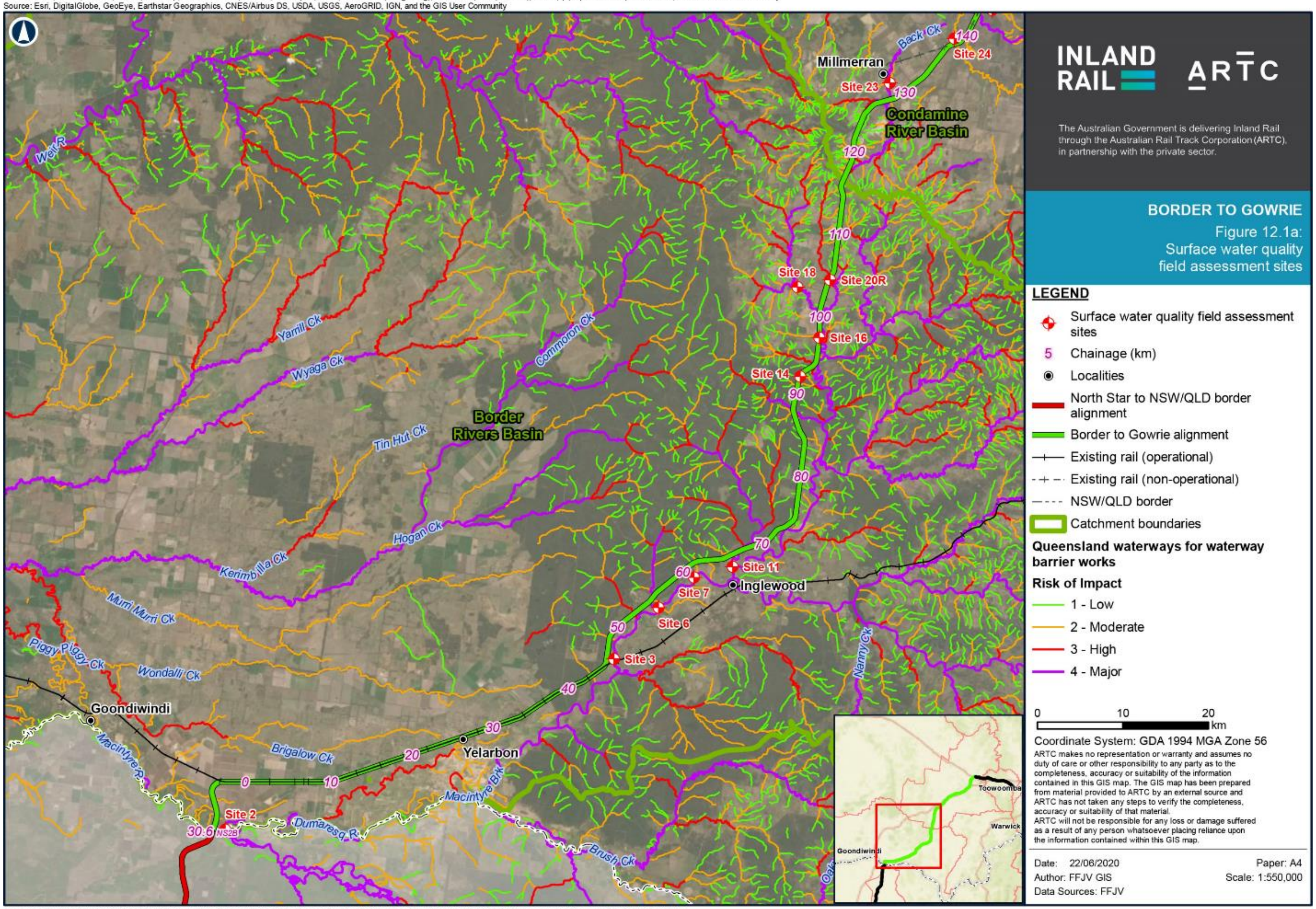
- Conductivity and salinity
- Total suspended solids
- Total hardness as CaCO3 (Alkalinity)
- Nutrient suite (ammonia, nitrite, nitrate, total nitrogen, total Kjeldahl nitrogen (TKN), nitrogen oxides (NOx), reactive phosphorus (P) and total phosphorous (TP)
- Organic nitrogen
- Dissolved metals (eight metals suite: arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury)
- Polycyclic aromatic hydrocarbons (PAHs)
- Chlorophyll *a*.

Quality assurance and quality control measures adopted during the water quality sampling events are described in Appendix P: Surface Water Quality Technical Report.

The parameters listed above were analysed to establish a baseline of the existing water quality within the impact assessment area, against general WQOs to protect aquatic ecosystems, as indicated by EPP (Water and Wetland Biodiversity).

Field and laboratory results were compared against the WQOs presented in Table 12.4 and Table 12.5.

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

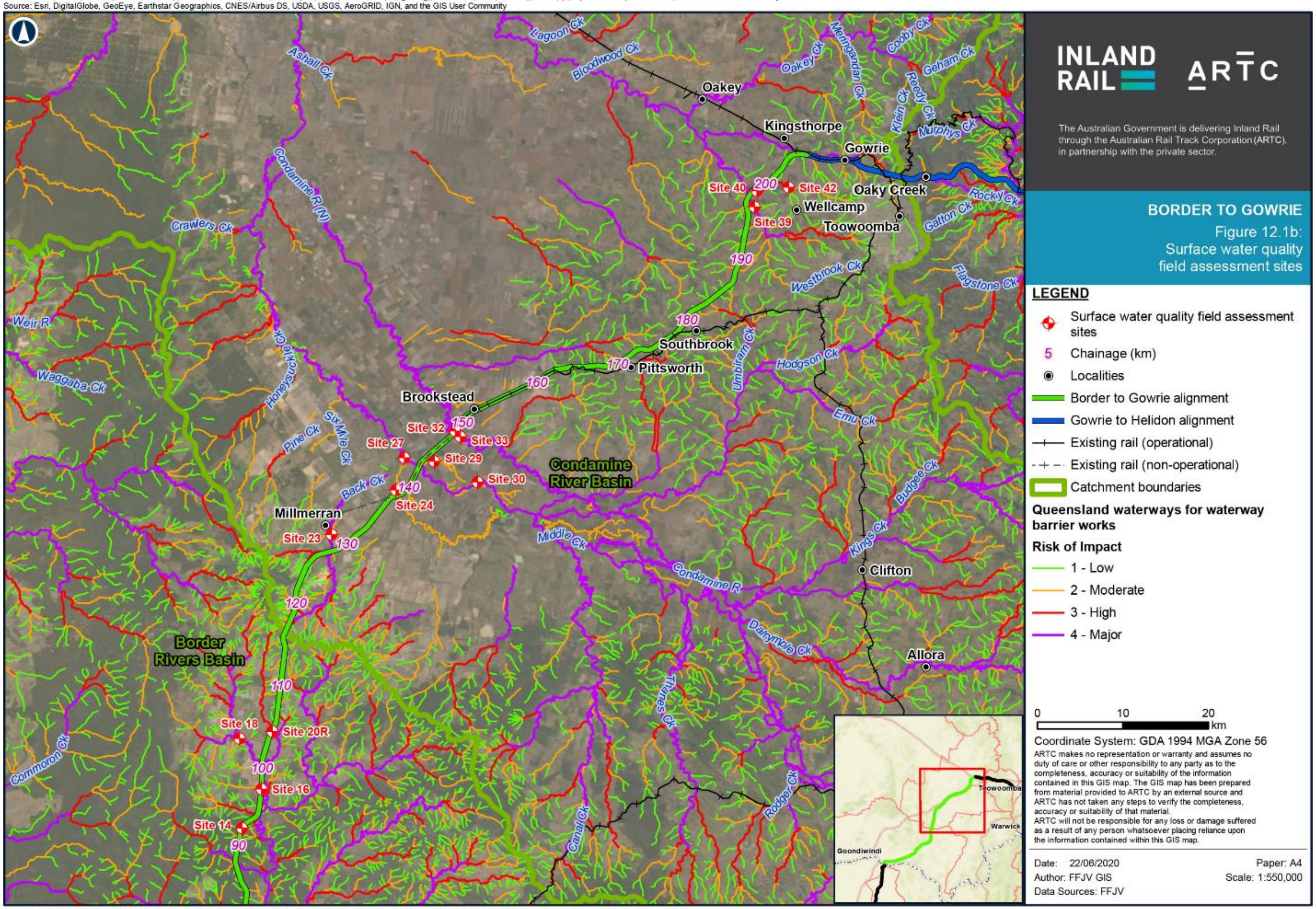


BORDER TO GOWRIE

Figure 12.1a: Surface water quality field assessment sites

Map by: DTH/NCW/KG Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.1_Assessment_Sites.mxd Date: 22/06/2020 14:14

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: DTH/NCW/KG Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.1_Assessment_Sites.mxd Date: 22/06/2020 14:14

12.6.3 Hydrology and flooding

The Project design has been guided and refined in reference to the adopted hydraulic design criteria and flood impact objectives as detailed below.

12.6.3.1 Hydraulic design criteria

The reference design for the Project has been developed in reference to the hydraulic design criteria presented in Table 12.7. Detailed hydrologic and hydraulic modelling has been undertaken to meet these design criteria, with a series of iterations undertaken to incorporate design refinement and stakeholder and community feedback. The resulting design outcomes relative to these design criteria have been incorporated into the reference design and are fully detailed in Appendix Q1: Hydrology and Flooding Technical Report.

TABLE 12.7 PROJECT HYDRAULIC DESIGN CRITERIA

Performance criteria	Requirement
Flood immunity	Rail line—1% annual exceedance probability (AEP) flood immunity with 300 mm freeboard to formation level.
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design to be undertaken based on ARR 2016 and State/local government guidelines. ARR 2016 interim climate change guidelines are to be applied with an increase in rainfall intensity to be considered. No sea level change consideration required due to location outside tidal zone. ARR 2016 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 ensure efficient conveyance and spread of floodwaters.
Sensitivity testing	Consider climate change and blockage in accordance with ARR 2016. Understand risks posed and Project design sensitivity to climate change and blockage of structures.

12.6.3.2 Flood impact objectives

The impact of the Project on the existing flood regime was quantified and compared against flood impact objectives, as detailed in Table 12.8. These objectives address the requirements of the ToR and have been used to guide the development and refinement of the reference design. Acceptable impacts will ultimately be determined on a case-by-case basis with interaction with stakeholders/landowners through the community engagement process, using these objectives as guidance. This will consider flood-sensitive receptors and land use within floodplains that are traversed by the Project.

Outcomes of the flood impact assessment are outlined in Section 12.10.2 with additional detail provided in Appendix Q1: Hydrology and Flooding Technical Report.

TABLE 12.8 FLOOD IMPACT OBJECTIVES

Parameter	Objectives					
Change in peak water levels[1]	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways Rail lines	Agricultural (cropping) land	Agricultural (grazing) land/forest areas and other non-agricultural land
	⩽ 10 mm	⩽ 50 mm	⩽ 100 mm	⩽ 100 mm	⩽ 100 mm with localised areas up to 400 mm	⩽ 200 mm with localised areas up to 400 mm
	Changes in peak water levels are to be assessed against the above proposed limits. Changes in peak water levels can have varying impacts on different infrastructure/land, and flood impact objectives were developed to consider the flood-sensitive receptors in the vicinity of the Project. In some instances, the presence of existing buildings or infrastructure may limit the change in peak water levels.					
Change in duration of inundation[1]	▶ Identify changes to duration of inundation through determination of Time of Submergence (ToS)[2] ▶ For roads, determine the Average Annual Time of Submergence (AAToS) (if applicable) and consider impacts on accessibility during flood events ▶ Justify acceptability of changes through assessment of risk with a focus on land use and flood-sensitive receptors.					
Flood flow distribution[1]	▶ Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas ▶ Identify any changes and justify acceptability of changes through assessment of risk with a focus on land use and flood-sensitive receptors.					
Velocities[1]	▶ Maintain existing velocities where practical ▶ Identify changes to velocities and impacts on external properties ▶ Determine appropriate scour mitigation measures considering existing soil conditions ▶ Justify acceptability of changes through assessment of risk with a focus on land use and flood-sensitive receptors.					
Extreme event risk management	▶ Consider risks posed to neighbouring properties for events larger than the 1% AEP event to ensure no unexpected or unacceptable impacts.					
Sensitivity testing	▶ Consider risks posed by climate change and blockage in accordance with ARR 2016 ▶ Undertake assessment of impacts associated with Project alignment for both scenarios.					

Table notes:

1. These flood impact objectives apply for events up to and including the 1% AEP event
2. Changes to duration of inundation of >+/- 1hour change, and > 0.2 ha affected have been reported in this chapter

12.6.3.3 Assessment methodology

The hydrology and flooding assessment of the Project has adopted a quantitative approach to impact assessment 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 draft EIS.
- Determination of critical flooding mechanisms for waterways and drainage paths in the impact assessment area (i.e. regional flooding versus local catchment flooding)
- Determination of high-risk watercourses that the alignment crosses, qualitatively, considering:
  - The catchment size, resulting flood flows and velocities
  - The land use in the vicinity of the rail alignment
  - The extent and depth of flood inundation
  - The duration of flood events and catchment response time
  - The proximity to and nature of flood sensitive receptors (e.g. houses, sheds, roads, etc).
- Development of tailored hydrologic and hydraulic models for key waterways as base modelling (Existing Case) for the assessment
- Validation of the hydrologic and hydraulic models against available recorded data for historical flood events
- Community and stakeholder engagement to validate model performance in an effort to gain acceptance of modelling and calibration outcomes
- Update of hydrologic and hydraulic models to include ARR 2016 design event methodology
- Simulation of ARR 2016 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. The range of flood event magnitudes assessed included the 20%, 10%, 5%, 2%, 1% events, extreme events including the 1 in 2,000 and 1 in 10,000 AEP events and the probable maximum flood (PMF).
- Inclusion of Project elements (proposed rail alignment, road reconfigurations and associated drainage structures) (Developed Case) into the hydraulic models and simulation of ARR 2016 design events. The Developed Case also includes the North Star to NSW/Queensland Border and the Gowrie to Helidon Inland Rail projects, which are being concurrently developed. The North Star to NSW/Queensland Border and the Gowrie to Helidon Inland Rail projects have been included in the Developed Case for this Project to enable cumulative impacts to be considered and addressed.
- Assessment of impacts of the Project using the suite of design floods, including consideration of change in flood levels, flow distributions, velocities and duration of inundation
- Determination of appropriate mitigation measures to manage potential impacts, including refinement of location and dimensions of drainage structures under the Project alignment and for road reconfigurations. Iterations undertaken in the hydraulic models to achieve a design that meets the flood impact objectives.

Comprehensive details of the hydrologic and hydraulic modelling undertaken are provided in Appendix Q1/Q2: Hydrology and Flooding Technical Report.

12.6.3.4 Stakeholder engagement

Community consultation has been undertaken at key milestones, in alignment with ARTC's *Flood Study Engagement Framework* (ARTC, 2020c). This has included:

- Data collection
- Feedback on hydrologic and hydraulic modelling calibration results
- Periodic updates to the community via newsletters and community sessions
- Updates on flood modelling progress at Community Consultative Committee (CCC) meetings
- Phone calls and emails to key individual landowners
- Feedback on design flood modelling results—community feedback on preliminary design solutions have been used to make several design modifications
- One-on-one consultation with landowners affected by changes in flooding behaviour—this information has been incorporated into development of the reference design and the draft EIS, where relevant and possible.

Information collected during the consultation sessions was used to inform the development of the hydrologic and hydraulic models and provide validation of the performance of each model.

In addition to the community information and engagement sessions, input was sought from key landowners during the flood model calibration process on a one-to-one basis in relation to historical flood events. Several meetings were conducted with landowners within the floodplains upstream and downstream of the proposed rail crossing to gather further anecdotal flood data, which was used to improve the model validation process.

One-on-one meetings have been held with several landowners to discuss the impacts on the flooding regime associated with the proposed rail line. The one-on-one landowner meetings were used to discuss:

- Existing 1% AEP flood depths
- Predicted 1% AEP changes in peak water levels
- Potential impacts to houses and other infrastructure
- 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 Department of Natural Resources, Mines and Energy (DNRME).

Details of the stakeholder and community sessions undertaken are documented in Appendix C: Stakeholder Engagement Report.

Terminology

The hydrologic and flooding investigation has adopted the latest approach to design flood terminology as detailed in ARR 2016. Accordingly, all design events are quoted in terms of AEP, with the adopted terminology for the simulated design events shown in bold in Table 12.9.

TABLE 12.9 EVENT NOMENCLATURE

Exceedances per year (EY)	Annual Exceedance Probability (AEP %)	AEP (1 in x)	Average Recurrence Interval (ARI)
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

As an example, in general terms, a 1% AEP event means that there is a 1 per cent chance of an event of that magnitude occurring in any given year.

12.7 Existing environment

12.7.1 Catchment overview

The Project is located across two surface water catchment areas, the Condamine River basin and the Border Rivers basin (refer Figure 12.2). The Project alignment extends through the Borders Rivers basin from the NSW/QLD border to approximately 15 km southwest of Millmerran (Ch 117.0 km). From this point, the Project alignment is located in the Condamine River basin until its northern end point at Ch 206.9 km. Agriculture is the dominant land use in both basins—specifically irrigated cropping, dryland cropping and open grazing.

The impact assessment 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 (Bureau of Meteorology (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 peaks at 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 178.5 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 206.9 km, of 458 m.

The Border Rivers basin covers approximately 23,800 km^2 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, south-west 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 km^2 and comprises approximately 9 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 gigalitres) and Coolmunda Dam (capacity 69 gigalitres), which are approximately 68 km and 10 km from the Project footprint respectively (direct linear distance). The major water storage in the Condamine River basin is Leslie Dam, with a capacity of 106 gigalitres, which is located approximately 72 km east of the Project footprint (direct linear distance). Additionally, smaller water storages are present for the management of supplemented and non-supplemented (regulated or natural) flow for irrigation, stock and domestic uses throughout the catchment (DES, 2019a & 2019b).

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

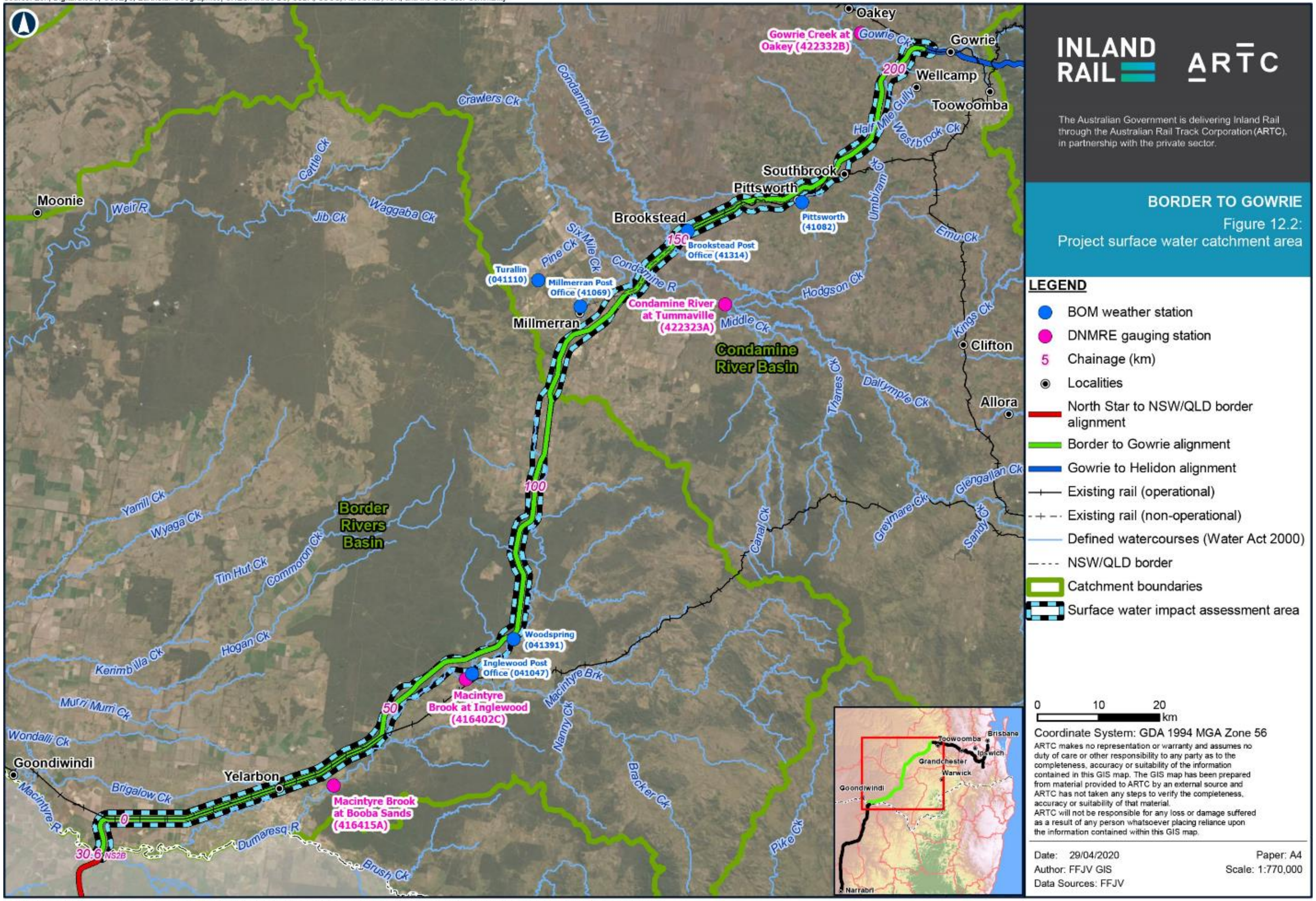


Figure 12.2: Project surface water catchment area

Map by: DTH/NCW Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.2_catchment_area.mxd Date: 7/05/2020 16:25

12.7.1.1 Climate

The Köppen climate classification system indicates that the impact assessment area falls within the Cfa—Humid Subtropical Climate region, which is characterised by hot and humid summers, and mild winters. A review of BoM climate data of relevance to surface water conditions within the impact assessment 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 impact assessment area, as identified in Table 12.10.

Table 12.10 summarises the recorded rainfall data for six BoM weather stations within the impact assessment 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 12.10 WEATHER STATIONS WITHIN THE IMPACT ASSESSMENT 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 km)	1954–2020	627.8	Dec (90.3)	Aug (28.8)
041047	Inglewood Post Office	Inglewood (2 km)	1883–2020	647.3	Jan (84.2)	Aug (32.3)
41069	Millmerran Post Office	Millmerran (2 km)	1900–2014	663.2	Jan (88.8)	Aug (30.9)
041110	Turallin	Turallin (10 km)	1909–2015	655.0	Jan (91.1)	Sep (31.5)
41314	Brookstead Post Office	Brookstead (<1 km)	1958–2020	639.8	Dec (103.1)	Jun (27.8)
41082	Pittsworth	Pittsworth (1 km)	1886–2020	694.6	Dec (98.2)	Aug (30.3)
041529	Toowoomba Airport	Toowoomba (8 km)	1996–2020	690.0	Dec (100.6)	Jul (26.6)

Source: BoM (2018a)

Other key climatic characteristics of the impact assessment 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 600–800 mm in the upper reaches in the east and low annual rainfall of around 300–500 mm in the lower reaches on the floodplains of the Darling Downs in the west (BoM, 2019a)
- Tropical cyclones can impact on the impact assessment area, especially the headwaters of the Condamine River basin. The most recent tropical cyclone to have impacted the impact assessment area was tropical cyclone Debbie, which yielded a total of 242 mm of rain at Killarney during March 2017.
- Long-term average rainfall varies from around 950 mm/annum in the north-eastern part of the impact assessment area, in Toowoomba, to around 660 mm/annum 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).

12.7.1.2 Defined watercourses, waterways and waterbodies

Watercourses and waterways

Waterways are defined under the *Fisheries Act 1994* (Qld) (Fisheries Act) 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.

Watercourses are defined under the Water Act 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.

The reference design includes full-width crossings of 15 major waterways (stream order ⩾ 3) and 66 minor waterways (stream order < 3).

Defined watercourses within the impact assessment area are listed below and shown on Figure 12.3. Where the watercourse is intersected by the Project alignment, the approximate chainage is given:

- Macintyre River
- Macintyre Brook
- Canning Creek
- Grasstree Creek—at Ch 13.5 km
- Pariagara Creek—at Ch 67.2 km
- Cattle Creek—at Ch 88.2 km
- Back Creek—at Ch 97.4 km
- Bringalily Creek—at Ch 100.1 km
- Nicol Creek—at Ch 104.3 km
- Back Creek drainage feature—at Ch 126.7 km and Ch 127.9 km
- Condamine River (Main Branch)—at Ch 142.9 km
- Condamine River (North Branch)—at Ch 148.7 km
- Umbiram Creek drainage feature—at Ch 185.9 km
- One Mile Creek drainage feature—at Ch 191.8 km
- Westbrook Creek—at Ch 188.7 km and Ch 197.2 km
- Dry Creek—at Ch 197.8 km
- Gowrie Creek.

Defined watercourses within the impact assessment area have been identified in reference to DNRME's *Water identification map—watercourses—Queensland,* last published 01 April 2020 (DNRME, 2020a). DNRME were requested by ARTC to provide confirmatory determination of the classification of waterways within the impact assessment area. Through this verification process, DNRME determined the occurrence of additional defined watercourses within the impact assessment area, not shown as such on the water identification mapping. The addition of these newly defined watercourses (refer Table 12.11) have been included as part of the impact assessment; however, have not been included in the figures denoting defined watercourses (validated against 01 April 2020).

TABLE 12.11 ADDITIONAL DEFINED WATERCOURSES AFTER DNRME CONSULTATION

Name	Chainage range	Verification advice from DNRME
Pariagara Creek	Ch 67.2–Ch 67.5 km	Considered a defined watercourse for impact assessment
Cattle Creek	Ch 88.2–Ch 88.4 km	Yet to be determined with certainty, considered a defined watercourse for impact assessment
Back Creek	Ch 97.4–Ch 97.7 km	Considered a defined watercourse for impact assessment
Bringalily Creek	Ch 100.1–Ch 100.7 km	Considered a defined watercourse for impact assessment
Nicol Creek	Ch 104.3–Ch 104.1 km	Tributary of Bringalily Creek and considered a defined watercourse for impact assessment
Back Creek drainage feature	Ch 126.7–Ch 127.1 km	Yet to be determined with certainty, considered a defined watercourse for impact assessment
Back Creek drainage feature	Ch 127.9–Ch 128.2 km	Considered a defined watercourse for impact assessment
Un-named drainage feature	Ch 183.5–Ch 183.7 km	Yet to be determined with certainty, considered a defined watercourse for impact assessment
Umbiram Creek drainage feature	Ch 185.9 km	Yet to be determined with certainty, considered a defined watercourse for impact assessment
One Mile Creek drainage feature	Ch 191.8 km	Yet to be determined with certainty, considered a defined watercourse for impact assessment

Water bodies

Dams and weirs are constructed barriers that hold back water to provide a reservoir for water supply. Various dams and weirs are located in the vicinity of the Project and are listed in Table 12.12. These dams have, subject to climatic conditions, the ability to supply the required volume for construction water for the Project; however, the transportation cost of sourcing all construction water from these locations is prohibitive. Therefore, other sources will need to be accessed to meet the full construction water demand for the Project.

TABLE 12.12 WATER STORAGES IN PROXIMITY TO THE PROJECT

Storage	Operator	Water supply scheme	Location	Full supply volume	Current capacity/ flow rate
Boggabilla Weir	Dumaresq–Barwon Border Rivers Commission	Border Rivers	9 km upstream of Goondiwindi on the Macintyre River and 12 km via road from the Project alignment	5,850 ML when reservoir water level at 216 m AHD [1]	Reservoir water level: 216.0 m AHD [2]
Ben Dor Weir	Sunwater	Macintyre Brook	11 km upstream of Yelarbon on the Macintyre Brook and 5 km via road from the Project alignment	700 ML	Volume: 572 ML (81.8%) [3]
Whetstone Weir	Sunwater	Macintyre Brook	17 km downstream of Inglewood and 2 km via road from the Project alignment	506 ML	Volume: 512 ML (>100%) [3]
Lemon Tree Weir	Sunwater	Upper Condamine	12 km downstream of Yandilla on the Condamine River and 14 km via road from the Project alignment	305 ML	Volume: 42 ML (13.7%) [3]
Yarramalong Weir	Sunwater	Upper Condamine	5 km downstream of Tummaville on the Condamine River and 7 km via road from the Project alignment	390 ML	Data not available

Storage	Operator	Water supply scheme	Location	Full supply volume	Current capacity/ flow rate
Talgai Weir	Sunwater	Upper Condamine	13 km upstream of Ellangowan and 60 km via road from the Project alignment	638 ML	Volume: 168 ML (26.3 %) [3]
Coolmunda Dam	Sunwater	Macintyre Brook	14 km east of Inglewood, 18 km via road to the Project alignment	69,060 ML	Volume: 19,889 ML (28.8%) [3]
Cooby Dam	TRC	Nil	14 km northeast of Kingsthorpe and 27 km via road from the Project alignment	19,703 ML	Volume: 3,763 ML (19.1 %) [4]
Perseverance Dam	TRC	Cressbrook Creek	35 km northeast of Kingsthorpe and 48 km via road from the Project alignment	26,893 ML	6,714 ML (25.0 %) [4]

Table notes:
AHD = Australian Height Datum
1. Resource Operations Licence (*Water Act 2000*), DNRME [**mdba.gov.au/sites/default/files/pubs/qld-border-rivers-water-supply-scheme-resource-operations-licence-2019.PDF**] [Accessed 30 October 2020]
2. NSW Dam and River Levels, WaterNSW [**realtimedata.waternsw.com.au/**] [Accessed 30 October 2020]
3. Water Storage Levels, Sunwater [**storagelevels.sunwater.com.au/win/reports/win_storages.htm**] [Accessed 30 October 2020]
4. Dam levels, rainfall and water use statistics, TRC [**tr.qld.gov.au/environment-water-waste/water-supply-dams/dams-bores/8066-water-supply-and-dam-level-statistics**] [Accessed 30 October 2020]

In addition to the managed water storages listed in Table 12.12, there are several smaller artificial/constructed waterbodies located within the impact assessment area that are intersected by the Project alignment. These artificial/constructed waterbodies are predominantly private farm dams used for agricultural purposes, and typically occur along unnamed drainage watercourses. Table 12.13 identifies artificial waterbodies that are intersected by the Project alignment.

TABLE 12.13 ARTIFICIAL WATERBODIES INTERSECTED BY THE PROJECT ALIGNMENT

Artificial waterbody (approximate chainage, in km)	Associated waterway
Ch 9.70 km	Named drainage feature of Dumaresq River
Ch 16.85 km	Named drainage feature of Dumaresq River
Ch 17.30 km	Named drainage feature of Dumaresq River
Ch 21.05 km	Named drainage feature of Dumaresq River
Ch 25.85 km	Named drainage feature of Dumaresq River
Ch 54.4 km	Un-named drainage feature of Macintyre Brook
Ch 54.80 km	Un-named drainage feature of Macintyre Brook
Ch 55.50 km	Un-named drainage feature of Macintyre Brook
Ch 60.60 km	Un-named drainage feature of Macintyre Brook
Ch 66.85 km	Pariagara Creek
Ch 72.90 km	Un-named drainage feature of Canning Creek
Ch 74.05 km	Un-named drainage feature of Canning Creek
Ch 75.45 km	Un-named drainage feature of Canning Creek
Ch 75.60 km	Un-named drainage feature of Canning Creek
Ch 76.45 km	Un-named drainage feature of Canning Creek
Ch 77.20 km	Un-named drainage feature of Canning Creek
Ch 77.80 km	Un-named drainage feature of Canning Creek
Ch 79.50 km	Un-named drainage feature of Canning Creek
Ch 81.20 km	Un-named drainage feature of Canning Creek
Ch 81.65 km	Un-named drainage feature of Canning Creek
Ch 82.20 km	Un-named drainage feature of Canning Creek
Ch 82.40 km	Un-named drainage feature of Canning Creek

Artificial waterbody (approximate chainage, in km)	Associated waterway
Ch 83.20 km	Un-named drainage feature of Canning Creek
Ch 83.60 km	Un-named drainage feature of Canning Creek
Ch 84.00 km	Un-named drainage feature of Canning Creek
Ch 85.00 km	Un-named drainage feature of Canning Creek
Ch 86.40 km	Un-named drainage feature of Canning Creek
Ch 88.20 km	Cattle Creek
Ch 92.10 km	Native Dog Creek
Ch 98.20 km	Back Creek
Ch 99.80 km	Named drainage feature of Canning Creek
Ch 100.00 km	Named drainage feature of Canning Creek
Ch 101.20 km	Bringalily Creek
Ch 104.40 km	Nicol Creek
Ch 106.80 km	Named drainage feature of Canning Creek
Ch 117.40 km	Back Creek
Ch 121.40 km	Back Creek
Ch 123.30 km	Back Creek
Ch 124.00 km	Un-named drainage feature of Back Creek
Ch 126.80 km	Back Creek drainage feature
Ch 133.50 km	Un-named drainage feature of Grasstree Creek
Ch 135.40 km	Un-named drainage feature of Grasstree Creek
Ch 135.60 km	Un-named drainage feature of Grasstree Creek
Ch 139.70 km	Un-named drainage feature of Grasstree Creek
Ch 158.80 km	Un-named drainage feature of Condamine River (North Branch)
Ch 161.60 km	Un-named drainage feature of Condamine River (North Branch)
Ch 167.30 km	Named drainage feature of Condamine River (North Branch)
Ch 168.30 km	Named drainage feature of Condamine River (North Branch)
Ch 169.30 km	Named drainage feature of Condamine River (North Branch)
Ch 172.50 km	Named drainage feature of Condamine River (North Branch)
Ch 174.30 km	Un-named drainage feature of Spring Creek
Ch 174.60 km	Un-named drainage feature of Spring Creek
Ch 175.60 km	Un-named drainage feature of Spring Creek
Ch 177.80 km	Un-named drainage feature of Spring Creek
Ch 179.00 km	Un-named drainage feature of Umbiram Creek
Ch 181.70 km	Un-named drainage feature of Umbiram Creek
Ch 187.00 km	Un-named drainage feature of Westbrook Creek
Ch 187.20 km	Un-named drainage feature of Westbrook Creek
Ch 192.10 km	Un-named drainage feature of Westbrook Creek
Ch 193.40 km	Un-named drainage feature of Westbrook Creek

Waterways for waterway barrier works

Waterways for waterway barrier works are regulated under the Fisheries Act and the Planning Act 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.

A review of the DAF Queensland Waterways for Waterway Barrier Works mapping was undertaken, identifying a total of 86 waterways for waterway barrier works that are intersected by the Project alignment. Of the 86 waterways, several of the waterways are crossed by the Project alignment in multiple locations. These waterways are classified as follows:

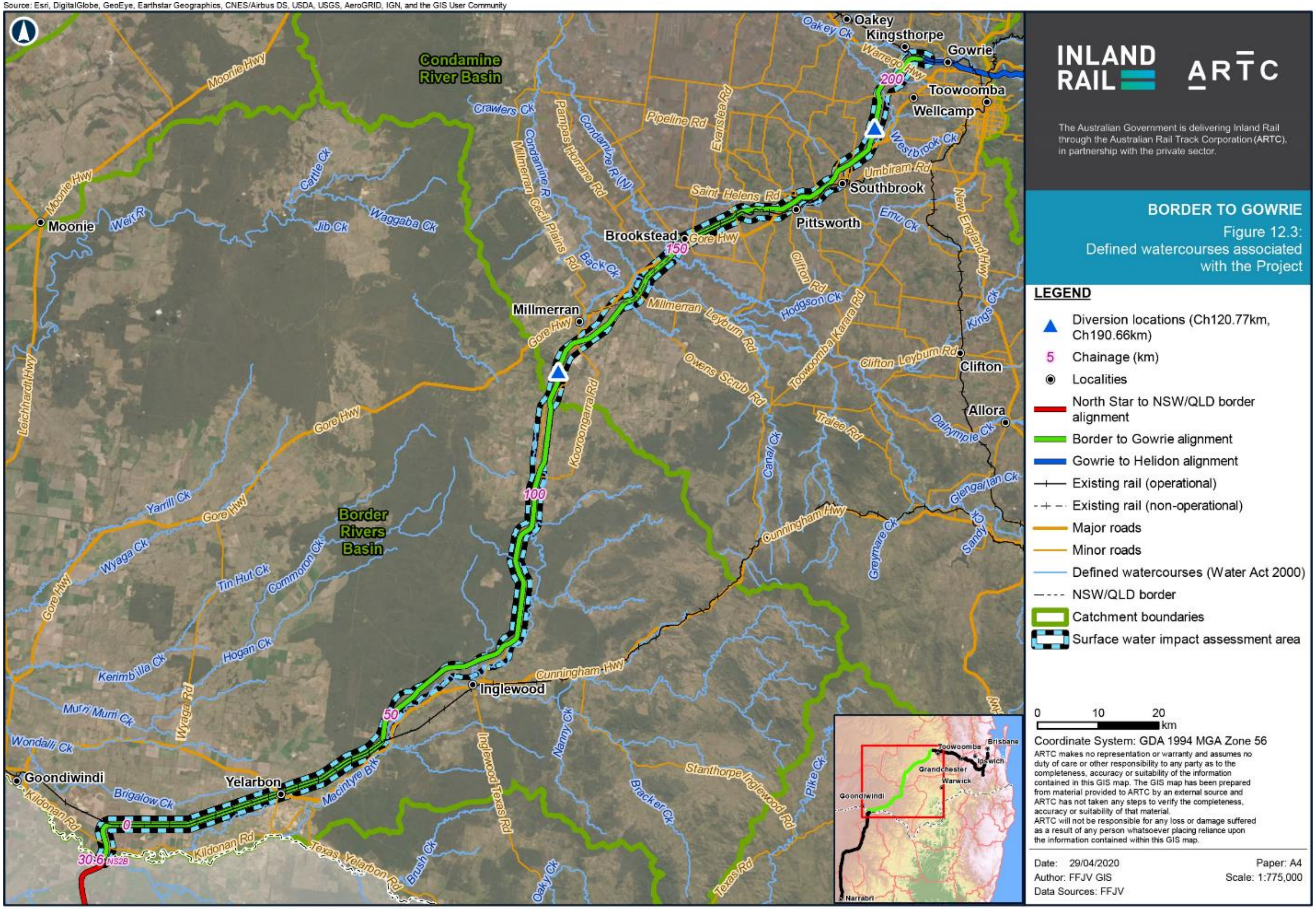
- Low risk of impact (category 1)—The Project alignment intersects 43 waterways mapped as 'low'
- Moderate risk of impact (category 2)—The Project alignment intersects 28 waterways mapped as 'moderate'
- High risk of impact (category 3)—The Project alignment intersects 7 waterways mapped as 'high'
- Major risk of impact (category 4)—The Project alignment intersects 9 waterways mapped as 'major'.

Table 12.14 identifies the locations where the Project alignment crosses waterways for waterway barrier works, including the relevant waterway impact risk (refer Figure 12.1).

TABLE 12.14 WATERWAYS FOR WATERWAY BARRIER WORKS THAT ARE INTERSECTED BY THE PROJECT ALIGNMENT

Waterway impact risk (DAF)	Waterway and approximate chainage of intersection (km)
Major (Category 4)	▸ Un-named tributary of Macintyre Brook (Ch 55.6) ▸ Pariagara Creek (Ch 67.3) ▸ Cattle Creek (Ch 88.3) ▸ Bringalily Creek (Ch 100.5) ▸ Back Creek drainage feature (Ch 127.0, Ch 128.0) ▸ Condamine River (Ch 142.9) ▸ Condamine River (Northern Branch) (Ch 148.7) ▸ Westbrook Creek drainage feature (Ch 197.2)
High (Category 3)	▸ Un-named tributary of Macintyre Brook (Ch 52.6) ▸ Un-named tributary of Canning Creek (Ch 87.4) ▸ Native Dog Creek (Ch 93.9) ▸ Nicol Creek (Ch 104.4) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 117.3) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 119.4) ▸ Dry Creek drainage feature (Ch 197.9 km)
Moderate (Category 2)	▸ Un-named tributary of Macintyre Brook (Ch 32.6, Ch 34.7, Ch 48.4, Ch 43.2) ▸ Un-named tributary of Macintyre Brook (Ch 61.9) ▸ Un-named tributary of Canning Creek (Ch 66.2) ▸ Un-named tributary of Canning Creek (Ch 92.0, Ch 90.9) ▸ Back Creek (Ch 97.6, Ch 96.9, Ch 96.4, Ch 96.2, Ch 95.4) ▸ Un-named tributary of Canning Creek (Ch 107.2) ▸ Un-named tributary of Canning Creek (Ch 109.5) ▸ Un-named tributary of Canning Creek (Ch 114.4) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 118.5, Ch 117.7, Ch 117.6) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 124.5, Ch 120.3) ▸ Grasstree Creek (Ch 138.6, Ch 139.7) ▸ Half Mile Creek—drainage feature (Ch 188.7, Ch 183.6) ▸ Un-named tributary of Westbrook Creek (Ch 193.4, Ch 191.8) ▸ Un-named tributary of Westbrook Creek (Ch 196.0)
Low (Category 1)	▸ Un-named tributary of Macintyre Brook (Ch 61.5, Ch 60.4) ▸ Un-named tributary of Macintyre Brook (Ch 63.1, Ch 62.8) ▸ Un-named tributary of Canning Creek (Ch 86.6, Ch 85.2, Ch 84.4, Ch 83.4, Ch 82.3, Ch 80.6, Ch 80.6, Ch 78.9, Ch 77.7, Ch 73.7) ▸ Un-named tributary of Canning Creek (Ch 88.5) ▸ Un-named tributary of Canning Creek (Ch 93.4) ▸ Un-named tributary of Canning Creek (Ch 108.5) ▸ Un-named tributary of Canning Creek (Ch 113.1, Ch 110.9) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 116.2, Ch 115.6, Ch 115.5, Ch 114.9) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 119.0) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 121.5, Ch 121.4, Ch 120.8) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 124, Ch 123.4) ▸ Un-named tributary of Leonard (Back Creek) Gully (Ch 125.5) ▸ Un-named tributary of Condamine River (North Branch) (Ch 168.6, Ch 169.7, Ch 169.3, Ch 170.9, Ch 170.6) ▸ Un-named tributary of Upper Tributary Umbiram Creek (Ch 181.7) ▸ Un-named tributary of Upper Tributary Umbiram Creek (Ch 185.9, Ch 184.8) ▸ Un-named tributary of Westbrook Creek (Ch 190.7) ▸ Un-named tributary of Westbrook Creek (Ch 195.7) ▸ Un-named tributary of Dry Creek (Ch 201.4 km) ▸ Un-named tributary of Gowrie Creek (Ch 205.8 km, Ch 205 km)

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: DTH/NCW Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.3_Watercourses.mxd Date: 7/05/2020 16:33

12.7.1.3 Licenced water users

The Water Act provides a framework under which catchment-based Water Plans and Water Management Protocols (previously Resource Operations Plans) are developed in Queensland. Water Plans are part of the *Basin Plan 2012* (Cth) and set new rules on how much water can be taken from the system (as licenced water harvesting), ensuring the sustainable diversion limit is not exceeded over time.

Surface water resources within the impact assessment area are primarily managed by the *Water Plan (Condamine and Balonne) 2019* and *Water Plan (Border Rivers and Moonie) 2019*. Both water plans include performance indicators and objectives to ensure sustainable water diversion limits such as:

- Environmental flow objectives
- Water allocation security objectives.

Water management protocols for the Condamine River basin are implemented under the *Water Plan (Condamine and Balonne) 2019* while the water management protocols for the Border Rivers basin are implemented under the *Water Plan (Border Rivers and Moonie) 2019.*

Within the impact assessment area, licenced water usage is comprised of recreational, commercial and domestic uses (refer to Table 12.15). The catchments provide hydrological flow into the Murray–Darling Basin, contributing to the availability of water for water harvesting practices (DES, 2019a & 2019b).

TABLE 12.15 SUMMARY OF 2018–2019 WATER LICENCE DATA FOR MAJOR WATERCOURSES AND NOMINAL ALLOCATIONS RELEVANT TO THE IMPACT ASSESSMENT AREA

Water source	No. of water licences issued and current	Water made available (ML/yr)
Canning Creek (surface water source)	20	N/A
Condamine River (surface water source)	264	124,665
Condamine River (alluvial water source)	21	N/A
Condamine River-North Branch (surface water source)	28	24,763
Dry Creek (surface water source)	2	N/A
Macintyre Brook (surface water source)	90	109,877
Macintyre Brook (alluvial water source)	15	2,535
Macintyre River (surface water source)	6	N/A
Macintyre River (alluvial water source)	3	1,490
Westbrook Creek (surface water source)	14	762
Oakey Creek (surface water source)	50	12,247
Other surface water sources	77	9,660

12.7.1.4 Sensitive environmental areas

This section provides a summary of sensitive environmental areas that occur within the impact assessment area. These sensitive environmental areas are wetland areas, identified fish habitat and groundwater-dependent ecosystems within receiving waters. Additionally, the endangered aquatic ecological community, Lowland Darling River Aquatic Ecological Community, is known to occur within the New South Wales Border Rivers Basin. This basin includes the Macintyre River, which is recognised as a high sensitivity receptor due to the presence of the Lowland Darling River Aquatic Ecological Community.

Wetlands

There are no wetlands of international importance (Ramsar wetlands) within, or within 10 km of the impact assessment area.

The *Map of Queensland wetland environmental values* (DES, n.d.) identifies multiple palustrine (non-riverine) wetlands along the Project alignment, which are also recognised as high ecological significance (HES) under the EPP (Water and Wetland Biodiversity). The HES wetlands within the impact assessment area are associated with Brigalow Creek, Canning Creek and the Condamine River. While the wetlands are within the impact assessment area, there is limited intersection between the Project alignment and any HES wetland. The HES wetlands are considered a matter of State environmental significance (MSES) under the Planning Act. For further assessment of wetland values identified as MSES refer to Chapter 10: Flora and Fauna and Appendix K: Aquatic Ecology Technical Report.

The aquatic conservation assessment using Aquatic Biodiversity Assessment Mapping Method (AquaBAMM) assesses the conservation and ecological value of wetland systems based on a series of national and international criteria, including naturalness (aquatic and catchment), diversity and richness, threatened species/ecosystems, priority species/ecosystems, special features, connectivity and representativeness (Clayton et al., 2006).

The results of an Aquascore riverine assessment against each water-quality monitoring site are presented in Table 12.16. The majority of water-quality monitoring sites scored at a moderate or above, indicating a moderate environmental condition.

TABLE 12.16 AQUABAMM SCORE FOR ALL WATER QUALITY MONITORING SITES

Aquascore	Monitoring site
Very low	-
Low	16, 27
Medium	18, 20R, 23, 24, 32, 33, 39, 40, 42
High	14
Very high	2, 2R, 3, 6, 7, 11, 29, 30

Source: State of Queensland (2018)

Fish habitat

There are no declared fish habitat areas mapped within the impact assessment area.

Groundwater-dependant ecosystems

Both aquatic and terrestrial groundwater-dependant ecosystems (GDEs) have been mapped by DES along the Project footprint, between the NSW/QLD border and Millmerran. Terrestrial GDEs are most dominant and concentrated in the Inglewood to Millmerran section of the Project alignment, while aquatic GDEs are scattered towards the NSW/QLD border end of the Project alignment. The terrestrial GDEs are associated with the watercourses Canning Creek and Macintyre Brook, both of which intercept the Project.

Several ephemeral springs (sourced from bedrock aquifer systems) have been mapped by DES at the Gowrie end of the Project alignment (refer Table 12.17).

Low potential aquatic GDEs are located within the impact assessment area towards the NSW/QLD border end of the Project alignment (Ch 0.0 to 50.0), some of which are associated with the Macintyre Brook. From Ch 65.0 to Ch 69.0, the aquatic GDEs are associated with Canning Creek (refer Table 12.17).

TABLE 12.17 SUMMARY OF AQUATIC GROUNDWATER-DEPENDENT ECOSYSTEM SPRINGS

Spring name/site #	Distance from alignment (km)	Direction from alignment	Spring type	Source aquifer
Stone Spring/1145	2	NW of Ch 173.0 km	Active and non-permanent	MRV
Jimna Springs/1147	5.3	SE of Ch 178.0 km		MRV
Springside/1146	5.7	N of Ch 168.0 km		MRV
Wellcamp Spring/1150	7.4	E of Ch 195.0 km		MRV
Leigh Spring/1144	8.8	NW of Ch 173.0 km		MRV
Meringandan Creek/1155	9.4	NE of Ch 206.0 km		MRV
Eustondale Spring/1154	11.6	E of Ch 195.0 km		MRV
Lilligren Spring/1156	12.1	NE of Ch 206.0 km		MRV
Westbrook Creek/1153	14.4	E of Ch 195.0 km		MRV
Kearneys Spring/1139	17.5	E of Ch 195.0 km	Active—Permanent	MRV

Source: Department of Science, Information Technology and Innovation (DSITI) (2017)

12.7.1.5 Salinity hazard

Existing salinity expressions within the impact assessment area and the potential for new expressions of salinity have been assessed in Chapter 8: Land Resources, in reference to published literature and the results of soil sample analysis as part of geotechnical investigations for the Project.

Two salinity risk assessments have previously been undertaken within the impact assessment area. The *Salinity Risk Assessment for the Queensland Murray–Darling Region* (Biggs et al., 2010b) provides coverage of the impact assessment area between the Macintyre River and east of Millmerran State Forest, and the *Strategic Salinity Risk Assessment in the Condamine Catchment* (Searle et al., 2007) provides coverage of the impact assessment area from east of Millmerran State Forest to Gowrie.

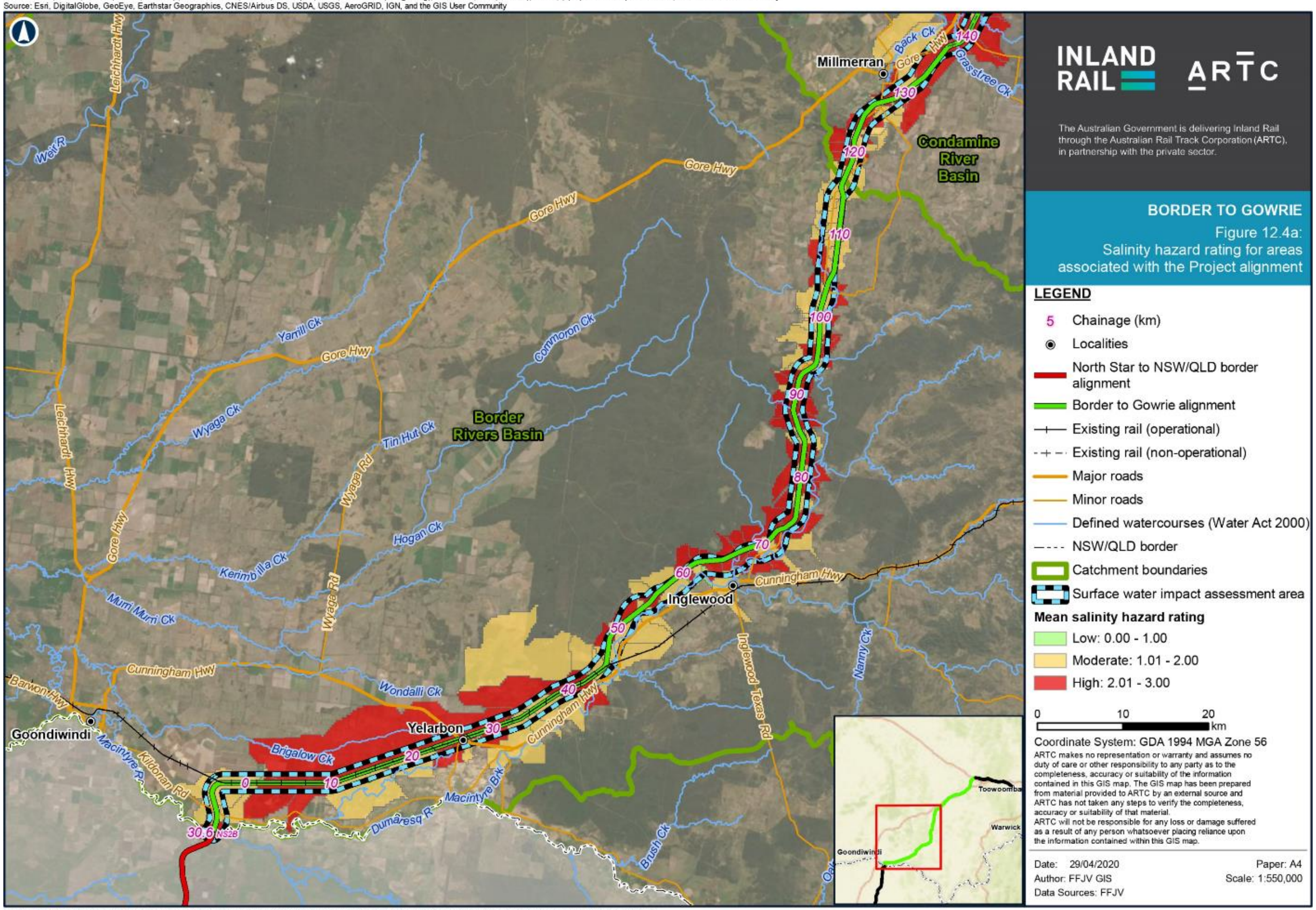
The *Salinity Risk Assessment for the Queensland Murray–Darling Region* identified 58 known salinity expression areas affected by secondary salinity, including the Yelarbon Desert in the Border Rivers basin. The Yelarbon area is known for its extremely alkaline, sodic sodosol soils, strongly attributed to upwelling of sodium-bicarbonate rich groundwater (Biggs et al., 2010a).

The salinity risk assessment identified the use of saline groundwater, leaking dams and dissolution of salts as the most common salinity types within the Border Rivers basin. The risk assessment concluded that salinity in the region will have a low risk to rail infrastructure, although it acknowledged that more research is required regarding secondary salinity formation and the impact of salinity on infrastructure assets (Biggs et al., 2010b).

The *Strategic Salinity Risk Assessment in the Condamine Catchment* (Searle et al., 2007) identified more than 170 salinity expression sites, with most influenced by climatic conditions. The strategic salinity risk assessment identified that a return to typical long-term weather patterns will likely increase the size and number of dryland salinity expressions in the region and increase salt load exported from the catchment. The impact assessment area intersects areas that are considered by the strategic salinity risk assessment to contain a very low, to high, overall salinity risk. The Millmerran area is considered to have a very low, to low, risk of secondary salinity, while the Pittsworth and Gowrie area are considered to have a moderate risk. An area of high salinity risk occurs within the impact assessment area near Southbrook and presents a 'current' threat to infrastructure assets in the area (Searle et al., 2007).

The salinity hazard rating of land within the impact assessment area has been assessed in Chapter 8: Land Resources and is shown in Figure 12.4.

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

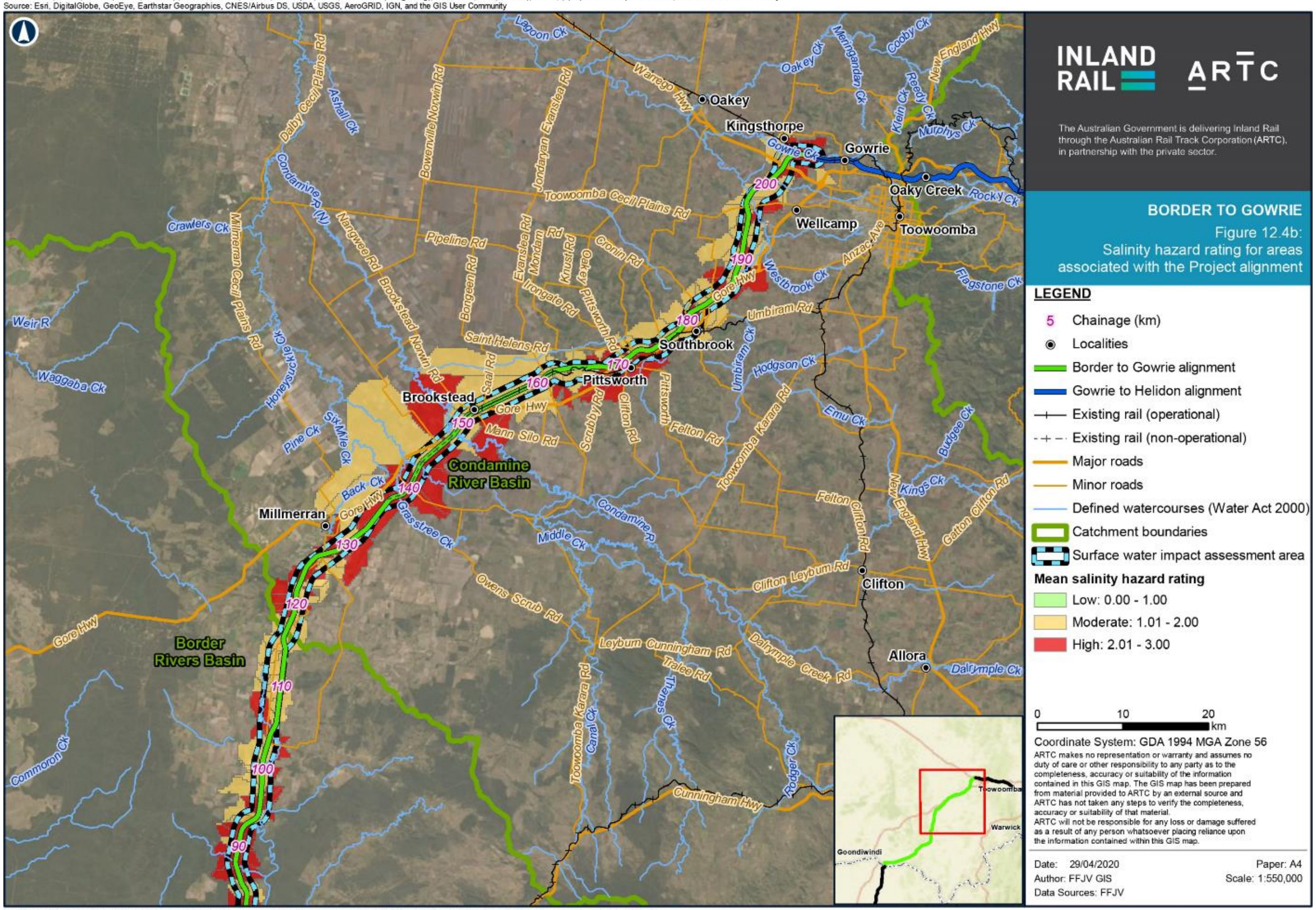


BORDER TO GOWRIE

Figure 12.4a: Salinity hazard rating for areas associated with the Project alignment

Map by: DTH/NCW Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.4_Salinity_Hazard.mxd Date: 1/05/2020 15:18

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: DTH/NCW Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910101214_SurfaceWaterQuality\310-EAP-201910101214_ARTC_Fig12.4_Salinity_Hazard.mxd Date: 1/05/2020 15:18

12.7.2 Surface water quality sampling and analysis

This section provides a summary of the results of field sampling and laboratory analysis of water quality. The locations of water quality monitoring sites are summarised in Table 12.6 and shown in Figure 12.1.

Water quality results are presented in the following sections and are grouped to facilitate assessment of sites consistent with the six water-type zones of the Border Rivers basin and the Condamine River basin. Generally, the results of water quality analysis can be summarised as follows:

- The pH values of water samples from waterways within the Border Rivers and Condamine River basins were typically neutral. Where WQO guidelines were exceeded, the magnitude of exceedance was typically minimal, with 18 exceedances across the Border Rivers basin and 13 exceedances across the Condamine River basin. The majority of pH exceedances were noted in spring/summer across both basins.
- Nineteen exceedances of the WQO guidelines for turbidity were recorded across the Border Rivers basin and 20 exceedances were recorded across the Condamine River basin. The majority of turbidity exceedances were noted in summer/autumn across both basins.
- Twenty-three exceedances of electrical conductivity WQO guidelines were recorded across the Border Rivers basin and 16 exceedances were recorded across the Condamine River basin. The majority of electrical conductivity exceedances were noted in autumn within the Border Rivers basin and distributed evenly across seasons within the Condamine River basin.
- Eighteen exceedances of dissolved oxygen saturation WQO guidelines were recorded across the Border Rivers basin and 12 exceedances were recorded across the Condamine River basin. The majority of dissolved oxygen saturation exceedances were noted in summer/autumn within the Border Rivers basin and summer within the Condamine River basin.
- Only five exceedances of the chlorophyll *a* WQO guideline were noted across the Border Rivers basin, principally due to insufficient data being available for calculation of a WQO under the Border Rivers Healthy Waterways targets. High chlorophyll *a* concentrations (> 50 µg/L) were recorded in autumn samples from sites 3, 11 and 16 (refer Table 12.6). Sixteen exceedances were noted across the Condamine River basin. The majority of dissolved oxygen saturation exceedances were noted in summer/autumn within the Border Rivers basin and the Condamine River basin.
- Patterns of water quality degradation were noted within several of the waterways across the sampling period, indicating the likelihood of influence from adjoining land-use practices. Specifically:
  - Within both Border Rivers and Condamine River basins, nutrient (primarily TP and TN) concentrations were recorded as exceeding WQOs, indicating limited improvement of water quality with an increase from low flow conditions to higher flow
  - Twenty-five exceedances in TP were recorded across the Border Rivers basin and 16 exceedances were recorded across the Condamine River basin. The majority of TP exceedances were noted in summer/autumn across both basins.
  - Twenty-two TN exceedances were recorded across the Border Rivers basin and 18 exceedances were recorded across the Condamine River basin. The highest number of TN exceedances were noted in summer/autumn across both basins.
  - Twenty-seven ammonia exceedances were recorded across the Border Rivers basin and 28 exceedances were recorded across the Condamine River basin. The highest number of ammonia exceedances were noted in summer/autumn across both basins.
- In general, WQO guidelines for metals were typically met across all assessable water quality monitoring sites for the survey period. Exceedances within five specific dissolved metals (arsenic, copper, lead, nickel and zinc) across the sampling were recorded. Four arsenic, four copper and one zinc exceedances were recorded in the Border River basin and 13 copper, one lead and four nickel exceedances were recorded in the Condamine River basin.
- Laboratory analysis of PAH concentrations at all sites were below detection limits, indicating no continued point source contamination of sampled sites; however, it is recognised that these compounds are volatile and do not maintain persistence in surface waters.

Typically, exceedances in WQO guidelines were most notable during summer/autumn (as that is the end of the wet season). Noting the lack of precipitation and surface water flow during the sampling period, the highest exceedances and nature of exceedances indicate continuing degradation of standing pools in low flow, or no flow conditions.

Description of each sampling site and laboratory certificates of analysis are provided in Appendix P: Surface Water Quality Technical Report.

12.7.2.1 Border Rivers basin

Macintyre Barwon floodplain (Sites 1 and 2)

Water quality at Macintyre Barwon floodplain water type sites was considered to be relatively good, with pH ranging from 6.77 to 7.76 and low electrical conductivity (refer Table 12.18). Turbidity and total suspended solids (TSS) were typically within WQO, with intermittent exceedances. Similarly, nutrient concentrations had intermittent exceedances of WQOs, with Site 2 consistently exceeding TN and P, chlorophyll *a* and reactive P concentrations (refer Table 12.19).

Dissolved metal concentrations were consistently low, with cadmium, chromium, copper, lead, zinc and mercury below laboratory detection limits. A single exceedance for copper at Site 2 in November 2018 against the ANZG 95 per cent aquatic system protection guideline was recorded (refer Table 12.20).

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

TABLE 12.18 WATER QUALITY RESULTS FOR SITES 1R, 2 AND 2R IN THE MACINTYRE BARWON FLOODPLAIN—PHYSICO-CHEMICAL

Physico-chemical		pH	Temp (°C)	DO (% Sat)	EC (µS/cm)	Salinity (mg/L)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25	N/A	N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.4 to 8.0		60 to 110	240		30	25			
High flow		7.0 to 7.5		60 to 110	180		110	70			
Site	**Field Trip**										
1R	Jun 2018	7.45	13.5	52.5	283	0.14	25.9	28	13	11	78
2	Jun 2018	Not sampled									
	Nov 2018	7.74	25.5	83.8	224	0.10	53.2	27	12	10	71
	Feb 2019	6.77	28.7	101.6	211	0.11	22.9	23	13	11	78
	Apr 2019	7.23	21.6	76.2	216	0.10	11.2	10	16	13	93
	May 2019	7.76	16.8	84.6	299	0.14	13.0	12	15	8	70
2R	Jun 2018	7.61	14.0	57.5	239	0.12	13.4	<5	10	8	58
	Nov 2018	7.27	25.0	90.2	223	0.1	96.0	43	12	9	67
	Feb 2019	7.31	28.9	89.5	211	0.11	25.7	24	13	11	78
	Apr 2019	7.68	22.3	71.6	215	0.10	12.2	7	16	13	93

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange.
N/A = No values available

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.19 WATER QUALITY RESULTS FOR SITES 1R, 2 AND 2R IN THE MACINTYRE BARWON FLOODPLAIN—NUTRIENTS

Nutrients (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.02			0.010			0.575	0.07	0.02	3
High flow		ID			0.195			0.9	0.15	ID	ID
Site	**Trip**										
1R	Jun 2018	0.02	<0.01	<0.01	<0.01	0.6	0.6	0.6	0.1	<0.01	<2
	Nov 2018	Not sampled									
	Feb 2019	Not sampled									
	Apr 2019	Not sampled									
2	Jun 2018	Not sampled									
	Nov 2018	<0.01	<0.01	<0.01	<0.01	0.5	0.5	0.5	0.12	0.04	9
	Feb 2019	0.07	<0.01	0.17	0.17	0.5	0.6	0.8	0.16	0.13	2
	Apr 2019	0.03	<0.01	<0.01	<0.01	0.5	0.5	0.5	0.08	0.04	5
	May 2019	0.02	<0.01	<0.01	0.02	0.7	0.7	0.7	0.03	<0.01	7
2R	Jun 2018	0.02	<0.01	<0.01	<0.01	0.5	0.5	0.5	0.05	0.01	<1
	Nov 2018	<0.01	<0.01	0.02	0.02	0.5	0.5	0.5	0.015	0.04	5
	Feb 2019	0.03	<0.01	0.16	0.16	0.6	0.6	0.8	0.16	0.13	2
	Apr 2019	0.02	<0.01	<0.01	<0.01	0.4	0.4	0.4	0.06	0.03	4

Table notes:
Values outside of the WQOs specified in Table 12.4.are shaded orange. All units mg/L unless stated otherwise
N/A = No values available

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.20 WATER QUALITY RESULTS FOR SITES 1R, 2 AND 2R IN THE MACINTYRE BARWON FLOODPLAIN—DISSOLVED METALS

Dissolved metals (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
1R	Jun 2018	0.002	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Nov 2018	Not sampled							
	Feb 2019	Not sampled							
	Apr 2019	Not sampled							
2	Jun 2018	Not sampled							
	Nov 2018	0.003	<0.0001	<0.001	0.002	<0.001	0.002	<0.005	<0.0001
	Feb 2019	0.004	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.003	<0.0001	<0.001	0.001	<0.001	0.003	<0.005	<0.0001
	May 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
2R	Jun 2018	0.002	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Nov 2018	0.003	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Feb 2019	0.004	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.003	<0.0001	<0.001	0.001	<0.001	0.002	<0.005	<0.0001

Table notes:
Values outside of the WQOs specified in Table 12.5 are shaded orange. All units mg/L unless stated otherwise.
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

Lower Macintyre Brook (Sites 3 to 8)

Water quality at sites in the Lower Macintyre Brook water type zone was characterised by low dissolved oxygen saturation, high electrical conductivity and elevated turbidity and TSS (refer Table 12.21). In contrast to the Macintyre Barwon floodplain sites, the Lower Macintyre Brook sites demonstrated higher impact from the reduced-flow environmental conditions throughout the impact assessment area. Nutrient data was also indicative of low-flow conditions, with exceedances in ammonia and TN in the majority of samples (refer Table 12.22). TP and oxidised nitrogen exceedances were also noted in May 2019 at Site 7.

Dissolved metal concentrations were consistently low, with arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury below laboratory detection limits (refer Table 12.23).

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

Canning Creek (Sites 9 to 20)

Water quality at sites in the Canning Creek water type zone was characterised by elevated electrical conductivity and instances of alkaline pH observations (ranging from 7.22 to 8.39), exceeding WQO guidelines (refer Table 12.24). Turbidity and TSS were elevated, with sites 14 and 16 demonstrating a continuing increase in turbidity and suspended solids (exceeding WQO guidelines) from initial water quality samples in June 2018 to the final samples in April 2019. Compliance with nutrient WQO guidelines was typically poor, with exceedances in ammonia, TN and TP occurring for all sites (refer Table 12.25).

Dissolved metal concentrations were consistently low, with cadmium, chromium, lead, zinc and mercury below laboratory detection limits. Exceedances of the ANZG 95 per cent aquatic system protection WQO guidelines for copper were recorded at Site 16 in November 2018, February 2019 and April 2019 (refer Table 12.26).

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

TABLE 12.21 WATER QUALITY RESULTS FOR SITES 3, 6 AND 7 IN THE LOWER MACINTYRE BROOK—PHYSICO-CHEMICAL

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25	N/A	N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.4 to 8.0		60 to 110	370		11	10			
High flow		7.2 to 8.0		60 to 110	250		25	25			
Site	**Trip**										
3	Jun 2018	5.58	10.7	46.1	383	0.2	9.7	<5	11	10	69
	Nov 2018	7.33	23.8	89.1	406	0.19	6.5	<5	14	10	76
	Feb 2019	6.65	25.1	50.1	357	0.19	6.9	8	15	10	79
	Apr 2019	7.77	19.6	63.4	423	0.20	14.7	12	20	12	99
6	Jun 2018	7.97	10.2	52.7	334	0.17	17.2	20@	9	8	55
	Nov 2018	7.08	21.0	51.4	427	0.2	20.8	14	15	10	79
	Feb 2019	7.20	25.1	49.7	389	0.20	15.1	12	16	10	81
	Apr 2019	7.45	18.4	53.1	433	0.21	13.7	10	20	12	99
7	Jun 2018	7.80	10.3	48.7	337	0.17	18.0	18	9	9	60
	Nov 2018	7.46	25.2	76.3	434	0.2	15.0	9	15	10	79
	Feb 2019	7.29	26.6	55.3	409	0.21	12.2	12	17	11	88
	Apr 2019	7.64	19.2	51.2	430	0.21	8.2	6	21	12	102
	May 2019	7.55	16.8	79.3	449	0.21	7.3	6	19	11	93

Table notes:
Values outside of the WQOs specified in Table 12.4.are shaded orange.
N/A = No values available
@ Result was outside the relative percent difference criterion of 35%.

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.22 WATER QUALITY RESULTS FOR SITES 3, 6 AND 7 IN THE LOWER MACINTYRE BROOK—NUTRIENTS

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.008			0.018			0.71	0.055	0.011	ID
High flow		ID			ID			0.91	0.07	ID	ID
Site	**Trip**										
3	Jun 2018	0.04	<0.01	<0.01	<0.01	0.8	0.8	0.8	0.04	<0.01	<2
	Nov 2018	<0.01	<0.01	<0.01	<0.01	0.6	0.6	0.6	0.04	<0.01	7
	Feb 2019	0.04	<0.01	<0.01	<0.01	1	1	1	0.06	<0.01	12
	Apr 2019	0.02	<0.01	<0.01	<0.01	1.6	1.6	1.6	0.08	<0.01	65
6	Jun 2018	0.03	<0.01	0.05	0.05	0.8	0.8	0.8	0.04	<0.01	<2.0
	Nov 2018	<0.01	<0.01	<0.01	<0.01	0.7	0.7	0.7	0.05	<0.01	4
	Feb 2019	0.05	<0.01	<0.01	<0.01	1.2	1.2	1.2	0.06	<0.01	5
	Apr 2019	0.03	<0.01	<0.01	<0.01	1.1	1.1	1.1	0.04	<0.01	10
7	Jun 2018	0.04	<0.01	0.15	0.15	0.9	0.9	1	0.04	<0.01	<2
	Nov 2018	<0.01	<0.01	0.02	0.02	0.7	0.7	0.7	0.06	<0.01	5
	Feb 2019	0.05	<0.01	0.03	0.03	1	1	1	0.04	<0.01	6
	Apr 2019	0.03	<0.01	0.09	0.09	1.1	1.1	1.2	0.04	<0.01	14
	May 2019	0.05	<0.01	0.24	0.24	1	1	1.2	0.02	<0.01	7

Table notes:
Values outside of the WQOs specified in Table 12.4.are shaded orange. All units mg/L unless stated otherwise.
N/A = No values available

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.23 WATER QUALITY RESULTS FOR SITES 3, 6 AND 7 IN THE LOWER MACINTYRE BROOK—DISSOLVED METALS

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
3	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Nov 2018	0.002	<0.0001	<0.001	0.001	<0.001	<0.001	<0.005	<0.0001
	Feb 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
6	Jun 2018	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Nov 2018	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Feb 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
7	Jun 2018	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Nov 2018	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Feb 2019	0.002	<0.0001	<0.001	0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	May 2019	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001

Table notes:
Values outside of the WQOs specified in Table 12.5 are shaded orange. All units mg/L unless stated otherwise.
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

TABLE 12.24 WATER QUALITY RESULTS FOR SITES 11, 14, 16 AND 18 IN CANNING CREEK AND SITE 20R IN NICOL CREEK—PHYSICO-CHEMICAL

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25	N/A	N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.2 to 7.8		60 to 110	200		35	25			
High flow		6.9 to 7.9		60 to 110	165		50	60			
Site	**Trip**										
11	Jun 2018	8.18	10.4	67.6	213	0.15	17	15	11	7	56
	Nov 2018	8.21	23.7	103.1	286	0.13	21	14	13	6	57
	Feb 2019	7.00	25.7	65.0	236	0.12	25	23	12	6	55
	Apr 2019	7.27	16.6	66.0	297	0.14	64	104	16	8	73
14	Jun 2018	7.70	14.7	64.30	160	0.10	44	20	4	7	39
	Nov 2018	8.09	22.5	86.60	248	0.11	37	<5	5	9	50
	Feb 2019	8.19	28.0	101.40	307	0.16	74	39	6	12	64
	Apr 2019	7.46	19.2	61.70	353	0.17	104	44	7	16	83
16	Jun 2018	7.66	12.6	56.30	184	0.11	147	32	14	4	51
	Nov 2018	7.82	18.8	82.30	382	0.17	161	56	27	8	100
	Feb 2019	8.39	29.4	120.00	636	0.33	259	170	25	12	112
	Apr 2019	7.62	19.5	32.00	1255	0.62	>1000	2170	42	18	179
18	Jun 2018	Not Sampled									
	Nov 2018	Not Sampled									
	Feb 2019	7.22	28.4	57.9	311	0.16	60.6	18	28	7	99
	Apr 2019	7.52	19.4	53.7	320	0.15	23.8	8	34	8	118
	May 2019	7.84	16.0	39.7	332	0.15	36.3	14	29	7	101

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
20R	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	Not sampled									
	Apr 2019	7.31	19.9	32.8	154	0.08	8.63	10	19	6	72

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange.
N/A = No values available

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.25 WATER QUALITY RESULTS FOR SITES 11, 14, 16 AND 18 IN CANNING CREEK AND SITE 20R IN NICOL CREEK—NUTRIENTS

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.001			0.006			0.52	0.03	0.008	ID
High flow		ID			ID			0.60	0.04	ID	ID
Site	**Trip**										
11	Jun 2018	0.02	<0.01	0.02	0.02	0.9	0.9	0.9	0.06	<0.01	<2
	Nov 2018	<0.01	<0.01	<0.01	<0.01	1.2	1.2	1.2	0.11	<0.01	40
	Feb 2019	0.04	<0.01	<0.01	<0.01	2.2	2.2	2.2	0.15	<0.01	23
	Apr 2019	0.02	<0.01	<0.01	<0.01	5.7	5.7	5.7	0.33	<0.01	460
14	Jun 2018	0.25	<0.01	<0.01	<0.01	1.0	1.2	1.2	0.03	<0.01	<1
	Nov 2018	<0.01	<0.01	<0.01	<0.01	0.7	0.7	0.7	0.03	<0.01	3
	Feb 2019	0.05	<0.01	<0.01	<0.01	1.6	1.6	1.6	0.07	<0.01	6
	Apr 2019	0.03	<0.01	<0.01	<0.01	2.3	2.3	2.3	0.10	<0.01	16

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
16	Jun 2018	0.02	<0.01	<0.01	<0.01	1.0	1.0	1.0	0.11	<0.01	<4
	Nov 2018	0.06	<0.01	0.01	0.01	1.3	1.4	1.4	0.17	<0.01	8
	Feb 2019	0.06	<0.01	0.02	0.02	4.1	4.2	4.2	0.31	<0.01	54
	Apr 2019	1.50	0.05	0.02	0.07	29.6	31.1	31.2	3.93	<0.01	545
18	Jun 2018	Not Sampled									
	Nov 2018	Not Sampled									
	Feb 2019	0.03	<0.01	<0.01	<0.01	1.2	1.2	1.2	0.10	<0.01	7
	Apr 2019	0.02	<0.01	<0.01	<0.01	0.8	0.8	0.8	0.04	<0.01	4
	May 2019	0.02	<0.01	<0.01	<0.01	0.8	0.8	0.8	0.04	<0.01	5
20R	Jun 2018	Not Sampled									
	Nov 2018	Not Sampled									
	Feb 2019	Not Sampled									
	Apr 2019	0.02	<0.01	<0.01	<0.010	1.6	1.6	1.6	0.32	0.10	21

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available.

Source: DES (2019a), Appendix K: Aquatic Ecological Technical Report

TABLE 12.26 WATER QUALITY RESULTS FOR SITES 11, 14, 16 AND 18 IN CANNING CREEK AND SITE 20R IN NICOL CREEK—DISSOLVED METALS

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
11	Jun 2018	0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.005	<0.0001
	Nov 2018	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Feb 2019	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
14	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.005	<0.0001
	Nov 2018	0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.005	<0.0001
	Feb 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
16	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.005	<0.0001
	Nov 2018	0.001	<0.0001	<0.001	0.002	<0.001	0.002	<0.005	<0.0001
	Feb 2019	0.003	<0.0001	<0.001	0.002	<0.001	0.002	<0.005	<0.0001
	Apr 2019	0.004	<0.0001	<0.001	0.002	<0.001	0.009	<0.005	<0.0001
18	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	0.002	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	0.001	<0.001	0.002	<0.005	<0.0001
	May 2019	<0.001	<0.0001	<0.001	0.001	<0.001	0.002	<0.005	<0.0001
20R	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	Not sampled							
	Apr 2019	0.003	<0.0001	<0.001	<0.001	<0.001	0.004	0.008	<0.0001

Table notes:
Values outside of the WQOs specified in Table 12.5. are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

12.7.2.2 Condamine River basin

Southern Condamine (Sites 21 to 26)

Water quality at sites in the Southern Condamine water-type zone was characterised by elevated electrical conductivity and instances of low dissolved oxygen saturation (refer Table 12.27). Turbidity and TSS were elevated in exceedance of WQO guidelines in the majority of samples where assessable water was present. Compliance with nutrient WQO guidelines was typically poor, with exceedances in ammonia, TN and TP occurring for both of the southern Condamine water type sites (refer Table 12.28), with additional exceedances in chlorophyll *a* WQO guidelines observed.

Dissolved metal concentrations were consistently low, with cadmium, chromium, zinc and mercury below laboratory detection limits. Single exceedances against ANZG 95 per cent aquatic system protection WQO guidelines were recorded for copper and lead from Site 24 during November 2018 and February 2019 (refer Table 12.29).

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

TABLE 12.27 WATER QUALITY RESULTS FOR SITES 23 AND 24 IN THE SOUTHERN CONDAMINE—PHYSICO-CHEMICAL

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25	N/A	N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.2 to 7.9		60 to 110	170		9	8			
High flow		7.0 to 7.6		60 to 110	160		25	17			
Site	**Trip**										
23	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	7.18	32.0	84.70	267	0.14	8.0	8	23	8	90
	Apr 2019	7.38	19.3	68.60	290	0.14	31.1	18	30	10	116
24	Jun 2018	7.77	7.9	45.90	345	0.16	239	98	14	11	80
	Nov 2018	8.18	30.9	89.50	580	0.27	251	194	27	18	142
	Feb 2019	7.42	27.2	47.80	281	0.14	135	60	13	8	65
	Apr 2019	Not sampled									

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.28 WATER QUALITY RESULTS FOR SITE 23 AND 24 IN THE SOUTHERN CONDAMINE—NUTRIENTS

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.006			0.003			0.595	0.045	0.015	5
High flow		ID			ID			0.830	0.060	0.020	ID
Site	**Trip**										
23	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	0.03	<0.01	<0.01	<0.01	1.4	1.4	1.4	0.10	0.02	2
	Apr 2019	0.02	<0.01	<0.01	<0.01	0.9	0.9	0.9	0.06	<0.01	7
24	Jun 2018	0.04	<0.01	<0.01	<0.01	0.5	0.5	0.5	0.07	<0.01	<4
	Nov 2018	0.08	<0.01	0.01	0.01	4.1	4.2	4.2	0.51	0.03	28
	Feb 2019	0.04	<0.01	<0.01	<0.01	1.8	1.8	1.8	0.35	0.07	9
	Apr 2019	Not sampled									

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange. All units are mg/L unless stated otherwise
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.29 WATER QUALITY RESULTS FOR SITE 23 AND 24 IN THE SOUTHERN CONDAMINE—DISSOLVED METALS

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
23	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	0.003	<0.0001	<0.001	<0.001	<0.001	0.001	<0.005	<0.0001
	Apr 2019	0.002	<0.0001	<0.001	<0.001	<0.001	0.003	<0.005	<0.0001
24	Jun 2018	<0.001	<0.0001	<0.001	0.001	<0.001	0.005	<0.005	<0.0001
	Nov 2018	0.002	<0.0001	<0.001	0.004	<0.001	0.006	<0.005	<0.0001
	Feb 2019	0.003	<0.0001	<0.001	0.001	0.006	<0.001	<0.005	<0.0001
	Apr 2019	Not sampled							

Table notes:
Values outside of the WQOs specified in Table 12.5. are shaded orange. All units are mg/L unless stated otherwise
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

Central Condamine (Sites 27 to 33)

Water quality at sites in the central Condamine water type sites was characterised by elevated variable dissolved oxygen saturation, instances of alkaline pH (ranging from 7.70 to 9.13) and significant turbidity and TSS WQO guideline exceedances (refer Table 12.30). Significant oversaturation of dissolved oxygen and an increase in chlorophyll *a* concentration (refer Table 12.31) was recorded from Sites 27 and 28 during February 2019, indicating potential diurnal fluxes in surface water dissolved oxygen concentrations due to algal growth. Exceedances in chlorophyll *a* across most of the sampled sites aligns with the exceedances recorded for ammonia, TN and TP (refer Table 12.31).

Dissolved metal concentrations were consistently low for arsenic, cadmium, chromium, lead, zinc and mercury, with numerous exceedances recorded for copper and nickel (refer Table 12.32).

Exceedances in copper concentrations were recorded for:

- Site 27 during June 2018 and April 2019
- Site 28 during February 2019 and April 2019
- Site 29 during April 2019
- Site 30 during November 2018
- Site 33 during November 2018.

Exceedances in nickel concentrations were noted from:

- Site 28 in February 2018 and April 2019
- Site 29 during April 2019
- Site 32 during February 2019.

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

TABLE 12.30 WATER QUALITY RESULTS FOR SITES 27, 28, 30, 32 AND 33 IN THE CENTRAL CONDAMINE—PHYSICO-CHEMICAL

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25	N/A	N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.4 to 8.3		60 to 110	890		25	25			
High flow		7.0 to 7.6		60 to 110	290		220	130			
Site	**Trip**										
27	Jun 2018	8.50	10.0	85.0	352	0.28	51.8	28	40	24	199
	Nov 2018	Not sampled									
	Feb 2019	8.34	30.3	134.1	503	0.26	87.5	74	37	25	195
	Apr 2019	7.72	17.2	50.6	233	0.11	671	214	21	12	102
28	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	9.13	35.2	233.6	519	0.27	75.6	73	26	22	156
	Apr 2019	7.93	23.1	21.1	315	0.15	477	175	30	18	149
29	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	Not sampled									
	Apr 2019	8.04	22.0	35.0	307	0.14	77.8	48	33	23	177
30	Jun 2018	-	14.3	65.5	356	0.22	30.0	11	29	18	146
	Nov 2018	8.83	28.8	104.6	507	0.24	98.1	63	22	19	133
	Feb 2019	8.45	25.1	59.6	365	0.19	43.0	35	25	16	128
	Apr 2019	7.71	18.7	70.4	449	0.21	95.6	70	34	26	192

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
32	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	7.8	23.4	82.2	588	0.30	11.5	95	37	27	204
	Apr 2019	Not sampled									
33	Jun 2018	Not sampled									
	Nov 2018	7.7	25.2	106.8	212	0.10	42.9	15	12	7	59
	Feb 2019	Not sampled									
	Apr 2019	Not sampled									

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.31 WATER QUALITY RESULTS FOR SITES 27, 28, 30, 32 AND 33 IN THE CENTRAL CONDAMINE—NUTRIENTS

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.004			0.004			0.86	0.17	0.02	9
High flow		ID			0.480			2.2	0.95	0.50	4
Site	**Trip**										
27	Jun 2018	0.03	<0.01	<0.01	<0.01	0.90	0.9	0.9	0.11	<0.01	5
	Nov 2018	Not sampled									
	Feb 2019	0.05	<0.01	0.01	0.01	2.20	2.2	2.2	0.23	<0.01	53
	Apr 2019	0.08	<0.01	<0.01	<0.01	1.40	1.5	1.5	0.51	0.04	24

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
28	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	0.07	<0.01	<0.01	<0.01	5.10	5.2	5.2	0.43	0.02	56
	Apr 2019	0.04	<0.01	<0.01	<0.01	1.50	1.5	1.5	0.31	0.01	26
29	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	Not sampled									
	Apr 2019	0.03	<0.01	<0.01	<0.01	1.80	1.8	1.8	0.66	0.37	18
30	Jun 2018	0.02	<0.01	<0.01	<0.01	0.50	0.5	0.5	0.07	<0.01	<2
	Nov 2018	0.10	0.01	0.03	0.04	4.50	4.6	4.6	0.39	0.05	57
	Feb 2019	0.06	<0.01	<0.01	<0.01	5.10	5.2	5.2	0.43	0.02	50
	Apr 2019	0.03	<0.01	<0.01	<0.01	3.30	3.3	3.3	0.38	<0.01	72
32	Jun 2018	Not sampled									
	Nov 2018	Not sampled									
	Feb 2019	0.09	<0.01	<0.01	<0.01	3.70	3.8	3.8	0.43	0.03	90
	Apr 2019	Not sampled									
33	Jun 2018	Not sampled									
	Nov 2018	0.03	<0.01	<0.01	<0.01	1.00	1.0	1.0	0.23	0.05	3
	Feb 2019	Not sampled									
	Apr 2019	Not sampled									

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.32 WATER QUALITY RESULTS FOR SITES 27, 28, 30, 32 AND 33 IN THE CENTRAL CONDAMINE—DISSOLVED METALS

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
27	Jun 2018	<0.001	<0.0001	<0.001	0.002	<0.001	0.006	<0.005	<0.0001
	Nov 2018	Not sampled							
	Feb 2019	0.002	<0.0001	<0.001	<0.001	<0.001	0.007	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	0.002	<0.001	0.008	<0.005	<0.0001
28	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	0.005	<0.0001	<0.001	0.002	<0.001	0.012	<0.005	<0.0001
	Apr 2019	0.001	<0.0001	<0.001	0.005	<0.001	0.011	<0.005	<0.0001
29	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	Not sampled							
	Apr 2019	0.003	<0.0001	<0.001	0.005	<0.001	0.015	<0.005	<0.0001
30	Jun 2018	<0.001	<0.0001	<0.001	0.001	<0.001	0.003	<0.005	<0.0001
	Nov 2018	0.002	<0.0001	<0.001	0.003	<0.001	0.004	<0.005	<0.0001
	Feb 2019	0.001	<0.0001	<0.001	<0.001	<0.001	0.003	<0.005	<0.0001
	Apr 2019	<0.001	<0.0001	<0.001	0.001	<0.001	0.006	<0.005	<0.0001
32	Jun 2018	Not sampled							
	Nov 2018	Not sampled							
	Feb 2019	0.003	<0.0001	<0.001	<0.001	<0.001	0.011	<0.005	<0.0001
	Apr 2019	Not sampled							

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
33	Jun 2018	Not sampled							
	Nov 2018	<0.001	<0.0001	<0.001	0.004	<0.001	0.008	<0.005	<0.0001
	Feb 2019	Not sampled							
	Apr 2019	Not sampled							

Table notes:
Values outside of the WQOs specified in Table 12.5. are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

Oakey Creek (Sites 34 to 43)

Water quality at sites in the Oakey Creek water type zone was characterised by alkaline pH (ranging from 8.13 to 8.54) and elevated electrical conductivity (refer Table 12.33). Turbidity and TSS were typically within the WQOs, with intermittent exceedances. Compliance with nutrient WQO guidelines was typically poor, with exceedances in ammonia, TN and TP occurring for the three sites (refer Table 12.34). Exceedances in chlorophyll *a* WQO guidelines were recorded for Site 39 during November 2018, February 2019 and April 2019, and Site 40 during November 2018.

Dissolved metal concentrations were consistently low for arsenic, cadmium, chromium, lead, nickel, zinc and mercury, with several exceedances noted for copper (refer Table 12.35). Exceedances in copper concentrations were noted for Site 39 during November 2018 and April 2019, Site 40 during November 2018 and Site 42 during November 2018.

The concentration of PAHs was below the laboratory level of detection at all sites for all surveys.

TABLE 12.33 WATER QUALITY RESULTS FOR SITES 39, 40 AND 42 IN THE OAKEY CREEK—PHYSICO-CHEMICAL

Guideline		pH units	Temp (°C)	DO (%Sat)	EC (µS/cm)	Salinity (g/kg)	Turbidity (NTU)	TSS (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness as $CaCO_3$ (mg/L)
ANZG WQO		6.5 to 7.5	N/A	90 to 110	30 to 350	N/A	2 to 25		N/A	N/A	N/A
Basin Plan			N/A			N/A			N/A	N/A	N/A
Low flow		7.7 to 8.3		60 to110	510		13	14			
High flow		7.4 to 8.1		60 to110	375		55	65			
Site	**Trip**										
39	Jun 2018	8.12	14.0	75.5	2,318	1.25	11.3	8	73	137	746
	Nov 2018	8.36	28.2	121.6	1,731	0.86	20.5	14	65	94	549
	Feb 2019	8.54	29.4	148.2	2,632	1.48	35.2	30	42	169	801
	Apr 2019	8.24	20.3	106.2	1,843	0.92	21.9	20	87	122	720
40	Jun 2018	8.42	10.4	74.6	1,320	0.69	8.1	10	51	82	465
	Nov 2018	8.25	24.8	92.0	692	0.33	12.5	9	32	38	236
	Feb 2019	Not sampled									
	Apr 2019	8.13	20.4	88.6	680	0.33	40.6	26	37	48	290
42	Jun 2018	8.52	9.80	72.8	1,287	0.69	4.6	6	55	81	471
	Nov 2018	8.30	32.5	116.7	1,157	0.56	6.1	10	49	67	398
	Feb 2019	8.44	30.8	146.6	1,339	0.73	10.3	8	43	91	482
	Apr 2019	8.15	22.9	85.0	850	0.41	14.6	12	48	60	367
	May 2019	8.25	16.2	105.4	1,339	0.64	5.5	<5	62	86	509

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.34 WATER QUALITY RESULTS FOR SITES 39, 40 AND 42 IN THE OAKEY CREEK—NUTRIENTS

Guideline (mg/L)		Ammonia	Nitrite	Nitrate	NOx	Organic N	TKN	TN	TP	Reactive P	Chlorophyll *a* (µg/L)
ANZG WQO		0.013	N/A	N/A	0.015	N/A	N/A	N/A	0.03	0.015	N/A
Basin Plan			N/A	N/A		N/A	N/A				
Low flow		0.010			0.005			1.000	0.110	0.045	5
High flow		ID			ID			1.280	0.340	0.09	ID
Site	**Trip**										
39	Jun 2018	0.04	0.01	0.51	0.52	0.3	0.3	0.8	0.02	<0.01	<1
	Nov 2018	0.05	<0.01	<0.01	<0.01	0.4	0.5	0.5	0.11	<0.01	13
	Feb 2019	0.06	<0.01	<0.01	<0.01	0.9	1.0	1.0	0.08	<0.01	12
	Apr 2019	0.04	<0.01	0.07	0.07	0.6	0.6	0.7	0.06	<0.01	31
40	Jun 2018	0.02	<0.01	<0.01	<0.01	0.3	0.3	0.3	0.02	<0.01	<1
	Nov 2018	0.06	0.02	0.72	0.74	0.3	0.4	1.1	0.20	0.02	7
	Feb 2019	Not sampled									
	Apr 2019	0.02	0.02	0.90	0.92	0.3	0.3	1.2	0.06	0.02	4
42	Jun 2018	0.02	<0.01	1.25	1.25	0.2	0.2	1.4	0.01	<0.01	<1
	Nov 2018	0.05	<0.01	0.82	0.82	0.2	0.2	1.0	0.17	0.01	<1
	Feb 2019	0.06	0.02	0.69	0.71	0.3	0.4	1.1	0.02	<0.01	3
	Apr 2019	0.05	0.02	1.25	1.27	0.2	0.2	1.5	0.04	0.02	2
	May 2019	0.03	0.02	1.38	1.40	0.2	0.2	1.6	<0.01	<0.01	1

Table notes:
Values outside of the WQOs specified in Table 12.4. are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available

Source: DES (2019b), Appendix K: Aquatic Ecological Technical Report

TABLE 12.35 WATER QUALITY RESULTS FOR SITES 39, 40 AND 42 IN THE OAKEY CREEK—DISSOLVED METALS

Guideline (mg/L)		Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
ANZG WQO		0.024	0.0002	0.0033#	0.0014	0.0034	0.011	0.008	0.00006
Basin Plan		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site	**Trip**								
39	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	0.004	<0.005	<0.0001
	Nov 2018	<0.001	<0.0001	<0.001	0.002	<0.001	0.007	<0.005	<0.0001
	Feb 2019	<0.001	<0.0001	<0.001	0.001	<0.001	0.006	<0.005	<0.0001
	Apr 2019	<0.001	<0.0001	<0.001	0.002	<0.001	0.010	<0.005	<0.0001
40	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Nov 2018	<0.001	<0.0001	<0.001	0.003	<0.001	0.004	<0.005	<0.0001
	Feb 2019	Not Sampled							
	Apr 2019	<0.001	<0.0001	<0.001	0.002	<0.001	0.003	<0.005	<0.0001
42	Jun 2018	<0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Nov 2018	<0.001	<0.0001	<0.001	0.002	<0.001	0.002	<0.005	<0.0001
	Feb 2019	<0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001
	Apr 2019	<0.001	<0.0001	<0.001	0.001	<0.001	0.003	<0.005	<0.0001
	May 2019	<0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.005	<0.0001

Table notes:
Values outside of the WQOs specified in Table 12.5.are shaded orange. All units are mg/L unless stated otherwise.
N/A = No values available

Source: ANZG (ANZECC & ARMCANZ, 2018), Appendix K: Aquatic Ecological Technical Report

12.7.3 Surface water quality receptors

A receptor is a feature, area or structure that may be affected by direct or indirect changes to the environment. Water quality receptors within the impact assessment area have been identified in reference to EPP (Water and Wetland Biodiversity) and relevant EVs for the relevant basins (refer Section 12.5.1). Subsequently, water quality receptors of relevance to the impact assessment area have been identified to be the following:

- Queensland's natural environment (including use by native flora and fauna)
- Finite natural resources, with specific regard to wetlands
- Watercourses conducive to the maintenance of existing landforms, ecological health and biodiversity.

Due to the interconnected nature of the watercourses that occur within the impact assessment area, the water quality receptors for the existing environment (as a whole of package) are considered to be of moderate sensitivity due to several factors, including:

- Protected by State legislation (Water Act, Fisheries Act and *Nature Conservation Act* (NC Act) (Qld)), with acknowledgement of potential habitat for matters of national environmental significance (MNES) species
- Important for biodiversity
- Existing sensitivity, with high exposure to impacts.

To be conservative, all waterways within the impact assessment area have been regarded as being moderate sensitivity water quality receptors, as a minimum, for the purpose of assessment.

High sensitivity water quality receptors were identified where a waterway was known to support another matter identified and protected under legislation, for example MNES species (fringing rush (*Fimbristylis vagans*), Murray cod (*Maccullochella peelii*), and Agassiz's glassfish (*Ambassis agassizii*) and MSES wetlands (refer Chapter 10: Flora and Fauna). The Macintyre River, Macintyre Brook, Canning Creek and the Condamine River were all identified as being high sensitivity water quality receptors for the purpose of this assessment.

12.7.4 Summary of existing water quality condition

Water quality data from collected samples has been compared to historical water quality data from DNRME's Macintyre Brook, Condamine River and Gowrie Creek gauging stations, as a general proxy for the impact assessment area. This comparison has identified that water quality values recorded during sampling for the Project are typically consistent with similar data obtained from the corresponding gauging stations.

Historic water quality was typically outside of WQOs with TSS exceeding WQOs both historically and within the current assessment. Total nitrogen and phosphorus as a typical anthropogenic contaminant was also consistent with historical data, with WQO exceedances recorded across all sampling events. Water quality across the impact assessment area was typically considered average to poor, with typical patterns of alkaline pH, high electrical conductivity, elevated concentrations of suspended sediment, nutrients and instances of diminished dissolved oxygen concentrations.

Data from the gauging stations showed that the majority of water-quality parameters (i.e. TSS, ammonia, TN and TP) did not meet WQOs. The gauging station data indicates that discharge within Macintyre Brook and Gowrie Creek was variable. Similarly, the Condamine River exhibited no flow conditions for much of the sampling period.

Due to the continued dry conditions, an assessment of sampling data obtained from a high flow period was not possible; therefore, the summary of the existing conditions is limited to low-to-no flow conditions. Although water quality is expected to degrade under 'first flush' conditions, with a return to high flow, it is expected that water quality during high flow (post first flush) would have highest receiving assimilative capacity to reduced water quality from inflow.

Low, medium and high Aquascore riverine wetlands are modelled along the Project alignment. Alongside the poor condition noted under the sustainable rivers audit, the scores suggest that connectivity remains the degrading factor for the health of both basins. The water quality monitoring sites with low Aquascores were those associated with sections of the Canning Creek and the Central Condamine water type zones. Those with medium Aquascores were on sections of the Canning Creek, Southern Condamine, Central Condamine and Oakey Creek water type zones. Those with high and very high Aquascores were on sections of the Canning Creek, Macintyre Barwon Floodplain, Lower Macintyre Brook, Canning Creek, Central Condamine and Oakey Creek.

In summary, water quality conditions observed within the impact assessment area are considered to be consistent with, and typical of, those expected during a period of extended dry conditions. Water quality impacts due to the diminished flow conditions were observed throughout the assessment. The existing water quality within the impact assessment area is considered average, with expectation of a period of poorer water quality coinciding with an initial return to base flow due to catchment run-off after an extended drier period.

12.7.5 Existing floodplain infrastructure

Key existing infrastructure on floodplain areas that are located within, or in proximity to the Project footprint, are as follows:

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

12.7.6 Existing flooding regime

Flooding in the vicinity of the Project alignment occurs through two mechanisms, or a combination of both mechanisms, being:

- Rainfall over the waterway catchment areas upstream of the Project alignment
- 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 impact assessment area to be assessed and for potential impacts of the addition 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 12.36. The extents of each of the hydraulic models are presented in Figure 12.5a–e.

TABLE 12.36 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[4]	URBS	TUFLOW
Macintyre Brook at Cremascos Road[4]	URBS	TUFLOW
Macintyre River	URBS	TUFLOW

Table note:
1. Commercial hydrologic modelling software package
2. Commercial hydraulic modelling software package
3. Commercial hydrologic modelling software package ('Unified River Basin Simulator')
4. The Bybera Road and Cremascos Road models are small and localised. Results at these locations are reported under the Macintyre Brook sections of this chapter.

12.7.6.1 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:

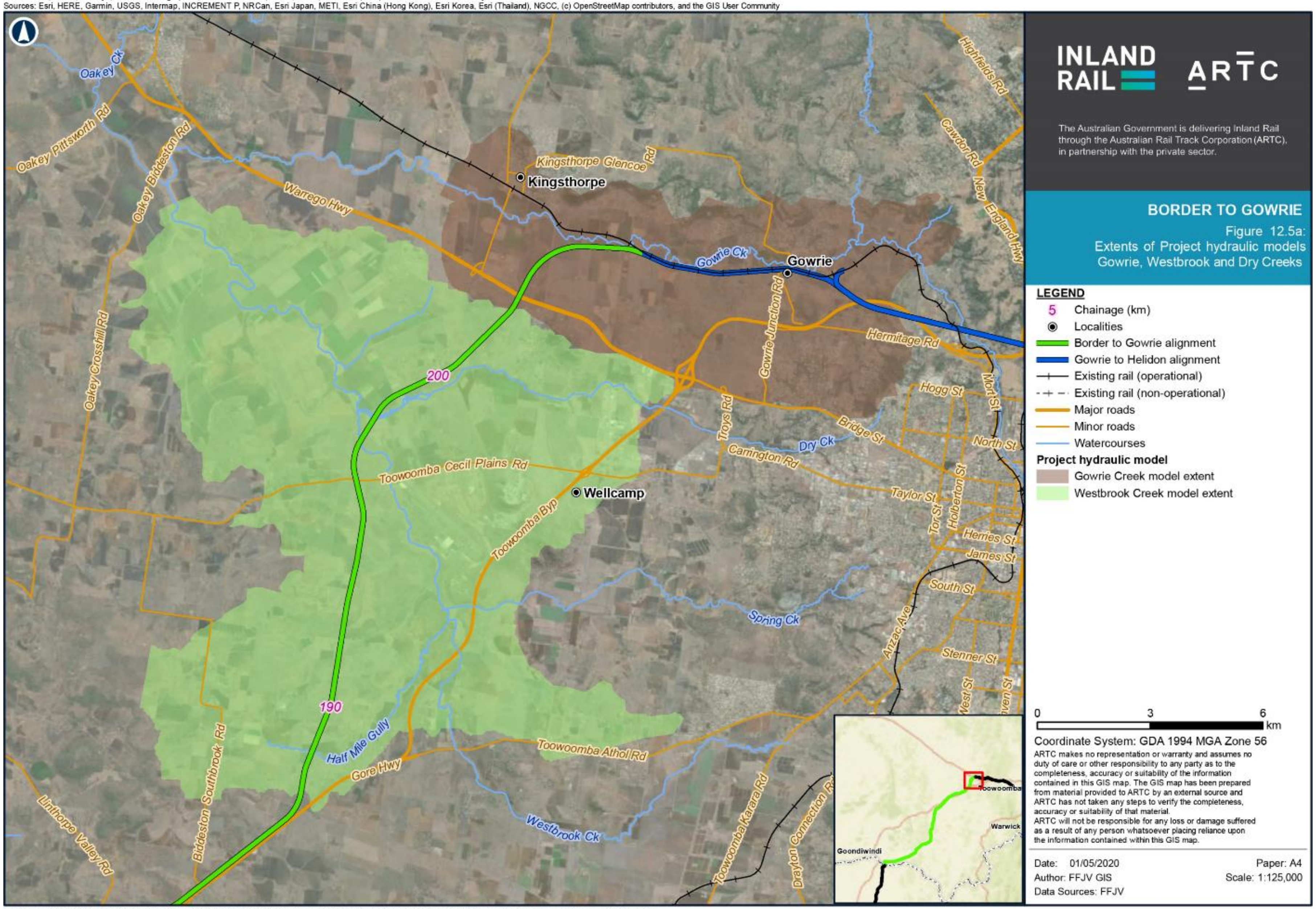
- BoM
- TRC
- GRC
- Sunwater Limited (Sunwater)
- Landowners and other affected stakeholders.

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 and 2011 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.

Further details regarding the calibration of the models is available in Appendix Q1: Hydrology and Flooding Technical Report.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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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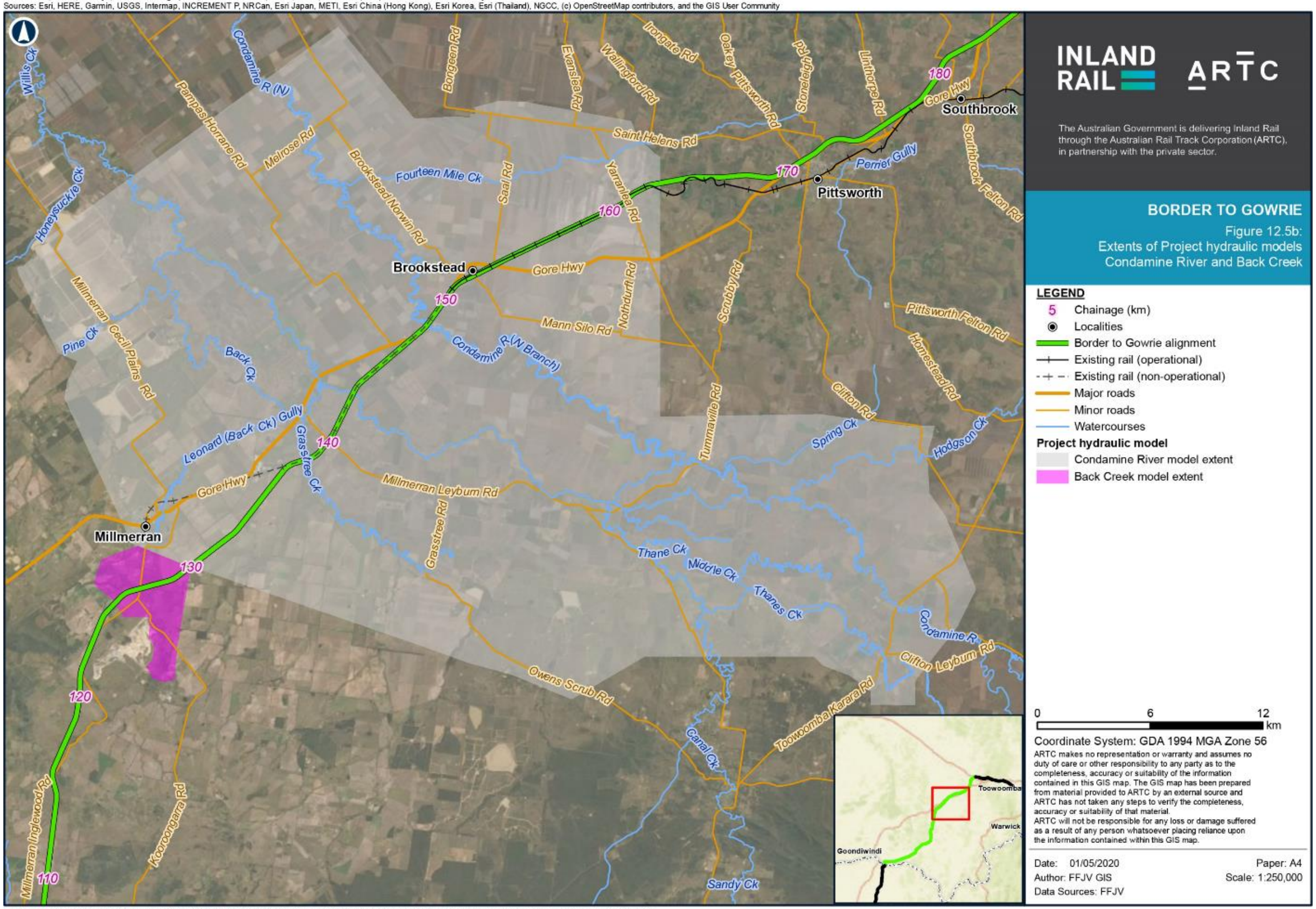

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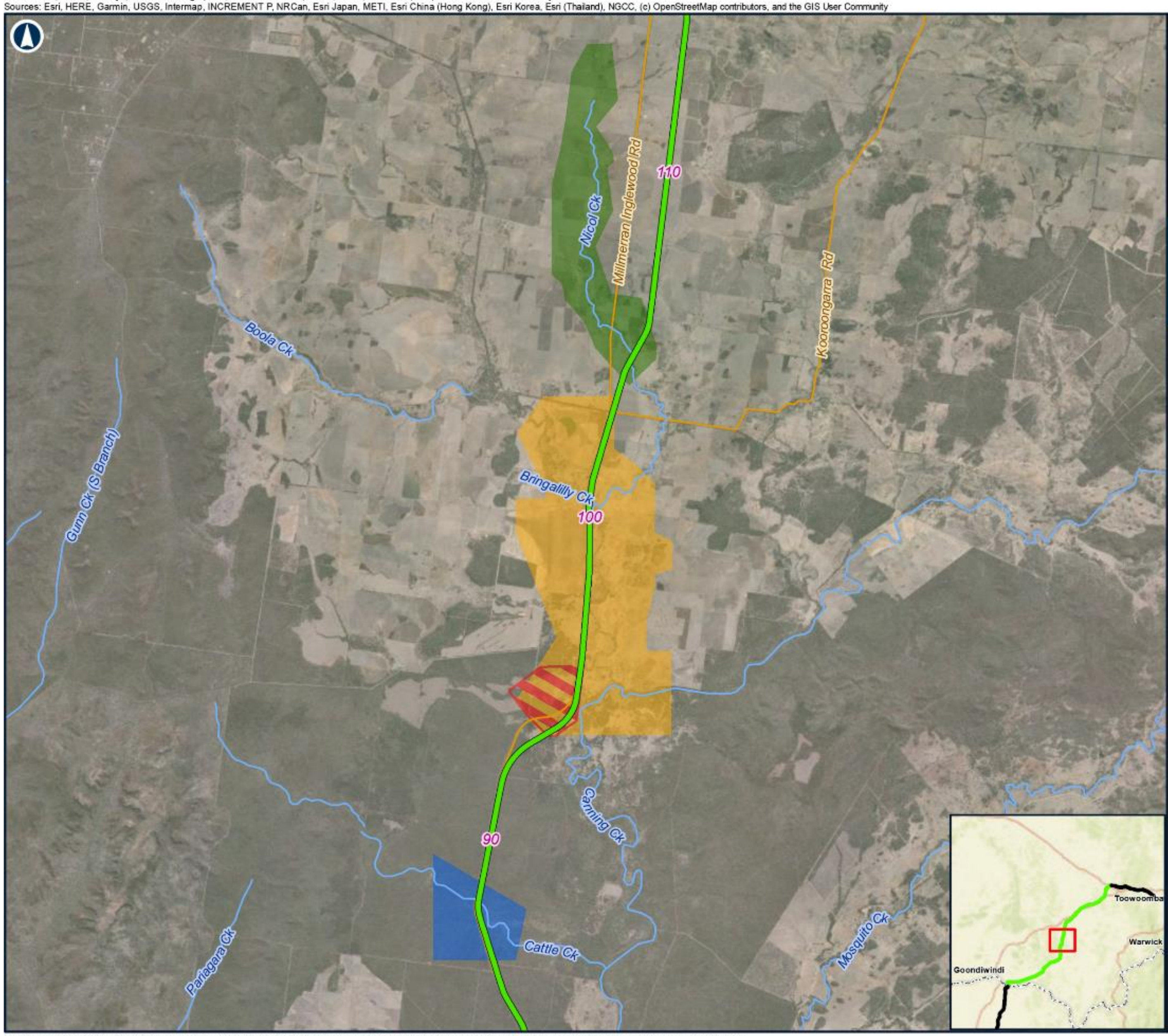

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BORDER TO GOWRIE

Figure 12.5c:
Extents of Project hydraulic models
Nicol, Bringalily, Native Dog & Cattle Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Minor roads
- Watercourses

Project hydraulic model

- Nicol Creek model extent
- Bringalily Creek model extent
- Native Dog Creek model extent
- Cattle Creek model extent

0 3.5 7 km

Coordinate System: GDA 1994 MGA Zone 56

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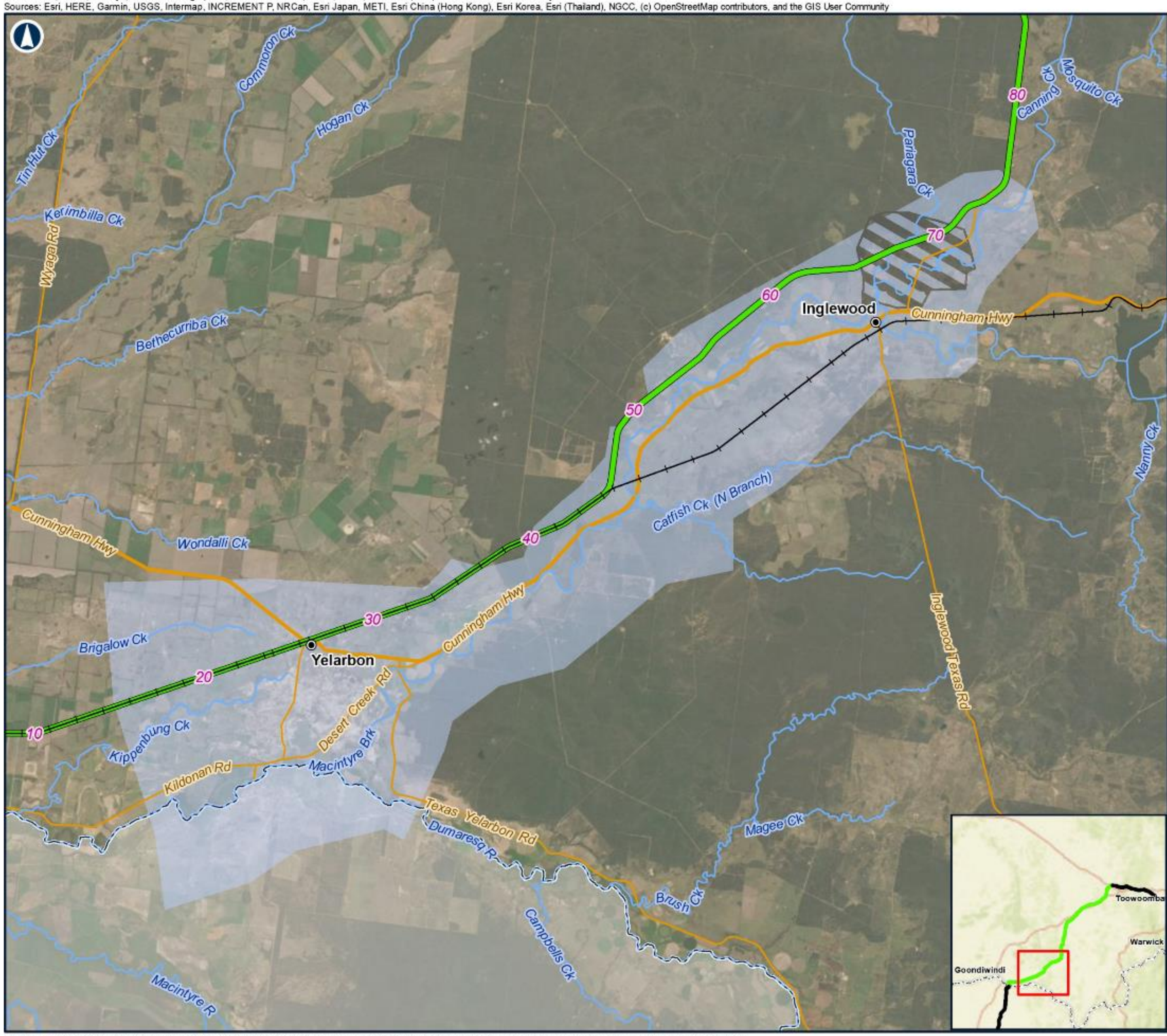

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BORDER TO GOWRIE

Figure 12.5d:
Extents of Project hydraulic models
Macintyre Brook including Pariagara Creek

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border

Project hydraulic model

- Pariagara Creek model extent
- Macintyre Brook model extent

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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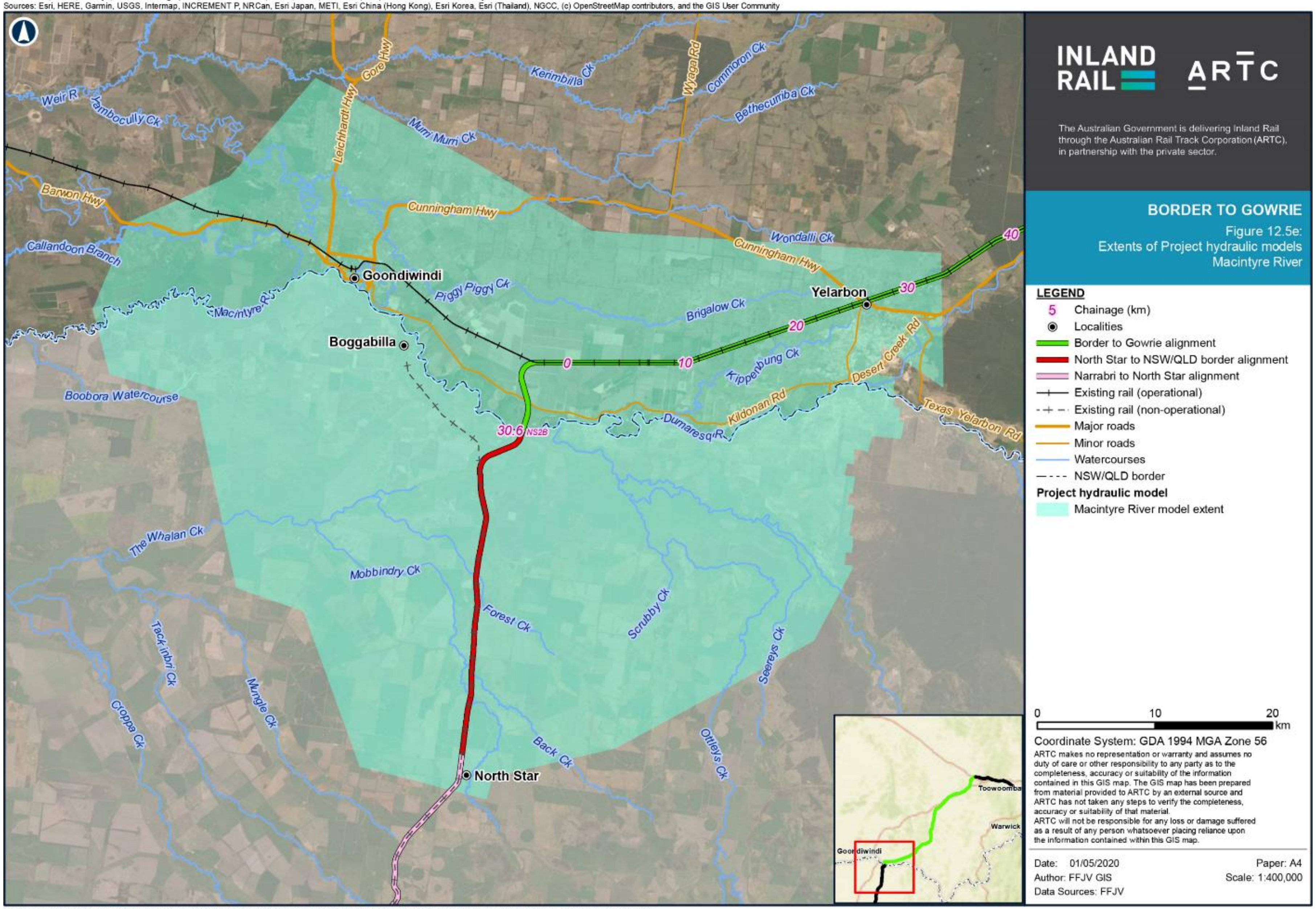

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The magnitude of each of the historical events has been estimated at each of the major stream gauges in the relevant waterway catchments. The estimated AEP of each event is outlined in Table 12.37, Table 12.38 and Table 12.39.

TABLE 12.37 ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS—GOWRIE CREEK

	Estimated historical event AEP (%)	
Stream gauge	**2010**	**2011**
Cranley	~10%	<1%
Oakey	~50%	~1%

Table note:
~ Approximate equivalent AEP
Shaded years indicate those used for model calibration purposes

TABLE 12.38 ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS—CONDAMINE RIVER

	Estimated historical event AEP (%)				
Stream gauge	**1956**	**1976**	**1991**	**2010**	**2013**
Warwick	No data	~0.6%	~33%	~2.6	~3.7
Talgai	No data	No data	~26%	~8.9	~2.1
Tummaville	No data	~1%	~25%	~13	~20
Cecil Weir	~3.7%	~2.2%	~23%	~0.8	~12

Table note:
~ Approximate equivalent AEP
Shaded years indicate those used for model calibration purposes

TABLE 12.39 ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS—MACINTYRE BROOK AND MACINTYRE RIVER

	Estimated historical event AEP (%)		
Stream gauge	**1976**	**1996**	**2011**
Booba Sands	~1%	~5%	~5%
Farnbro	~2%	~20%	~2%
Roseneath	5-2%	~20%	~2%
Holdfast	~1%	10-5%	~10%
Coolatai	No data	~10%	No data

Table note:
~ Approximate equivalent AEP
Shaded years indicate those 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 (QRT), ARR 2016's Regional Flood Frequency Estimation (RFFE) and scaling of donor catchment Flood Frequency Analysis (FFA) flows.

12.7.6.2 Existing case results

Modelling of the Existing Case (i.e. current state of development, without the Project) has been undertaken to provide a base case against which the introduction of the Project infrastructure and associated drainage structures can be assessed. The Existing Case inundation extent and peak water levels for the 1% AEP event for the modelled waterways are presented in Figure 12.6a–b, with 1% AEP event peak velocities presented in Figure 12.6b. Details of the existing flood regime on each floodplain in the vicinity of the Project are discussed in the sections below.

Gowrie Creek

The Project alignment does not cross Gowrie Creek, but instead skirts around 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 5 m in the Gowrie Creek channel, and up to around 1 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, un-named 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 12.40 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 12.6a.

TABLE 12.40 GOWRIE CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)					
Infrastructure	Location	1 in 2,000 AEP	1% AEP	2 % AEP	5 % AEP	10 % AEP	20 % AEP
Chamberlain Road	End of road near Gowrie Creek	1.18	0.70	0.63	0.50	0.33	0.27
Kingsthorpe–Tilgonda Road	Near Gowrie Creek (~650 m west of Lessons Road)	2.08	1.09	0.90	0.75	0.45	0.17
Leeson Road	Gowrie Creek Crossing	1.45	0.94	0.87	0.75	0.65	0.53
Existing QR West Moreton Line	~950 m west of Gowrie Creek/QR West Moreton Line	0.45	0.25	0.23	0.17	Dry	Dry

Peak 1% AEP velocities within the Gowrie Creek channel are high, in the order of 2 to 5 m/s. On the floodplain, velocities are generally in the order of 1 to 2 m/s as shown in Figure 12.6b.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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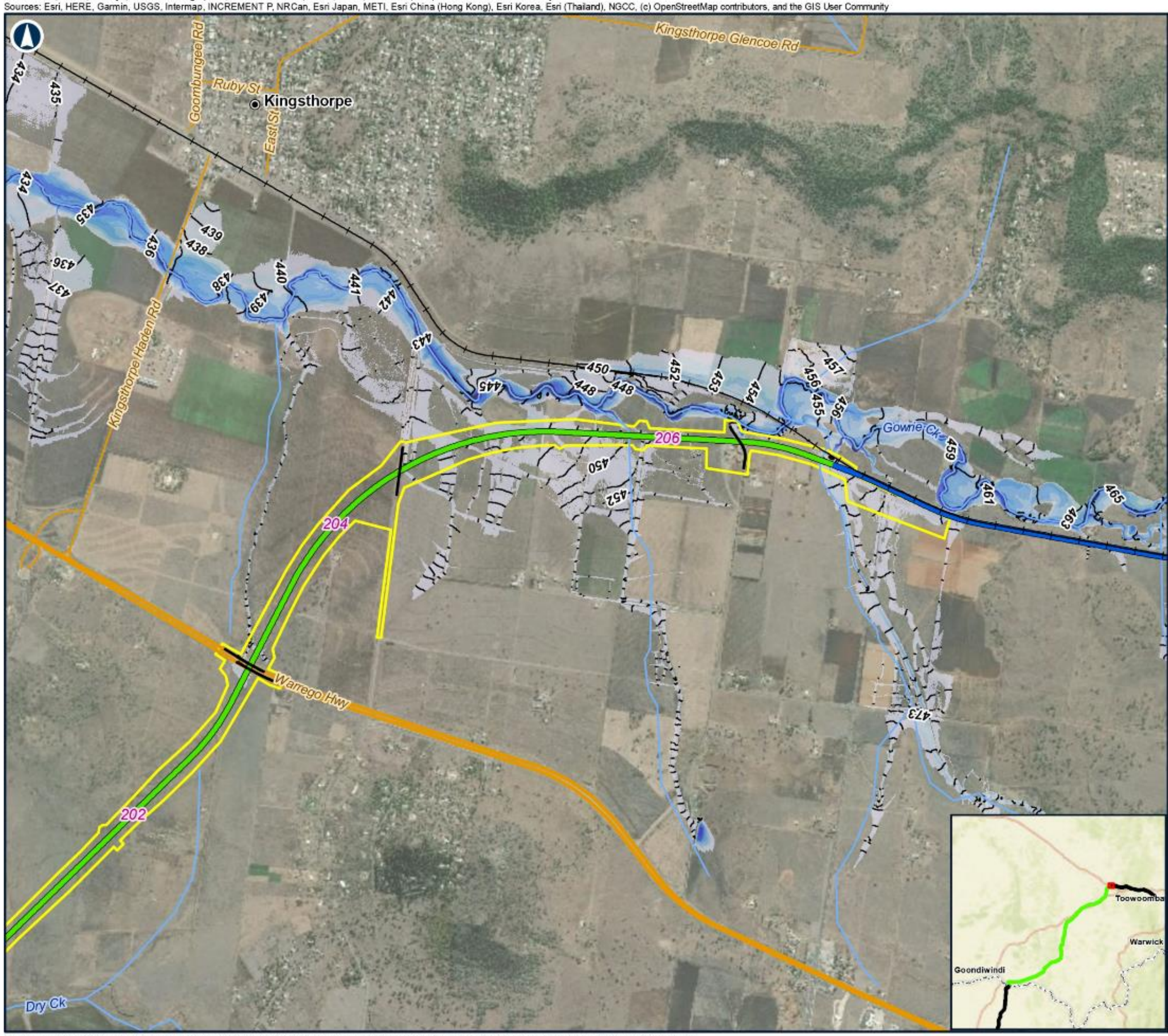

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BORDER TO GOWRIE

Figure 12.6a:
Existing Case – 1% AEP 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
- Road design
- Watercourses
- Project footprint
- 1m contour mAHD

Depth (m)

- 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

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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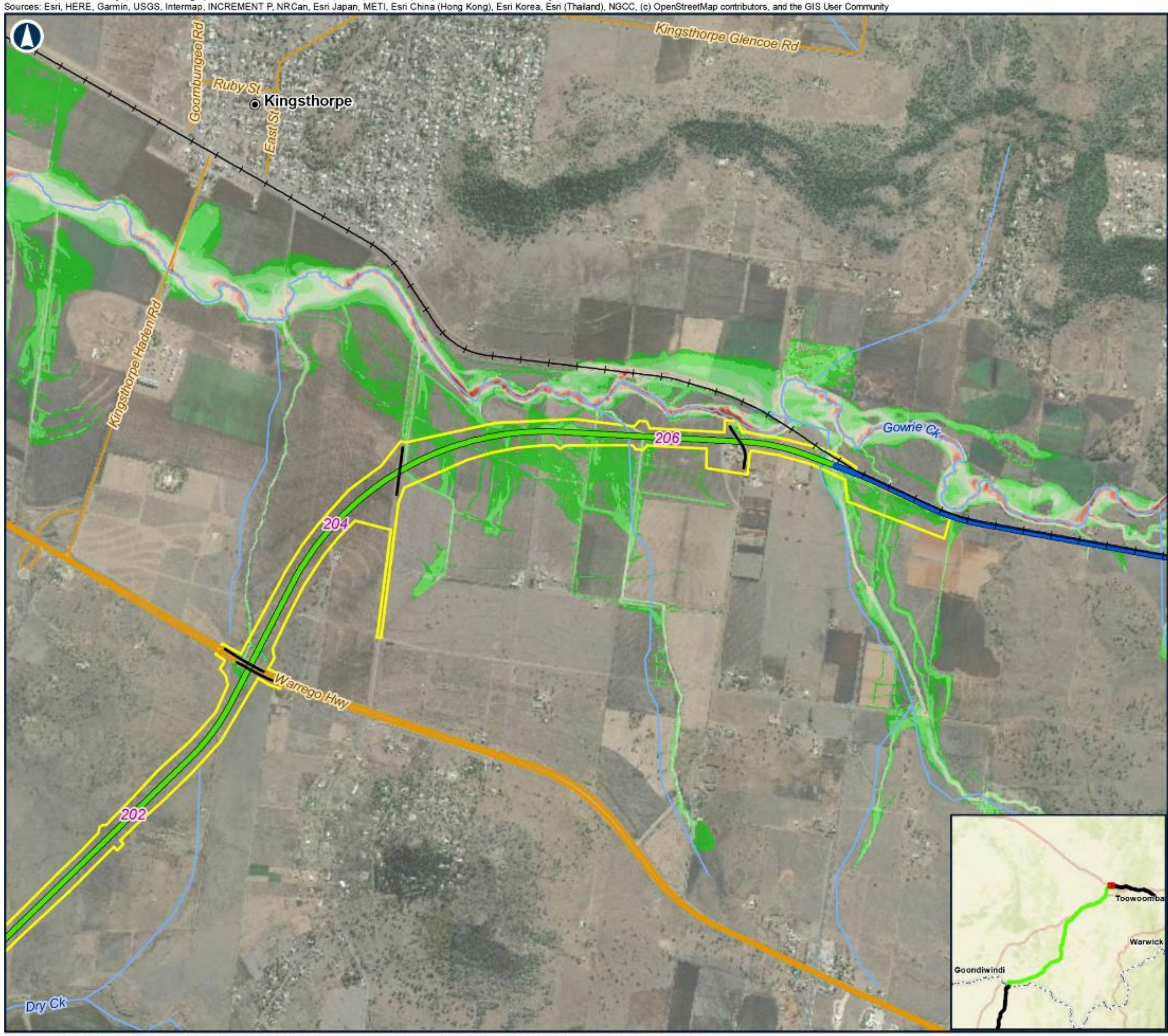

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BORDER TO GOWRIE

Figure 12.6b:
Existing Case – 1% AEP Peak velocities
Gowrie Creek

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Velocity (m/s)
- 0.0 to 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:30,000
Data Sources: FFJV

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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 the 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.

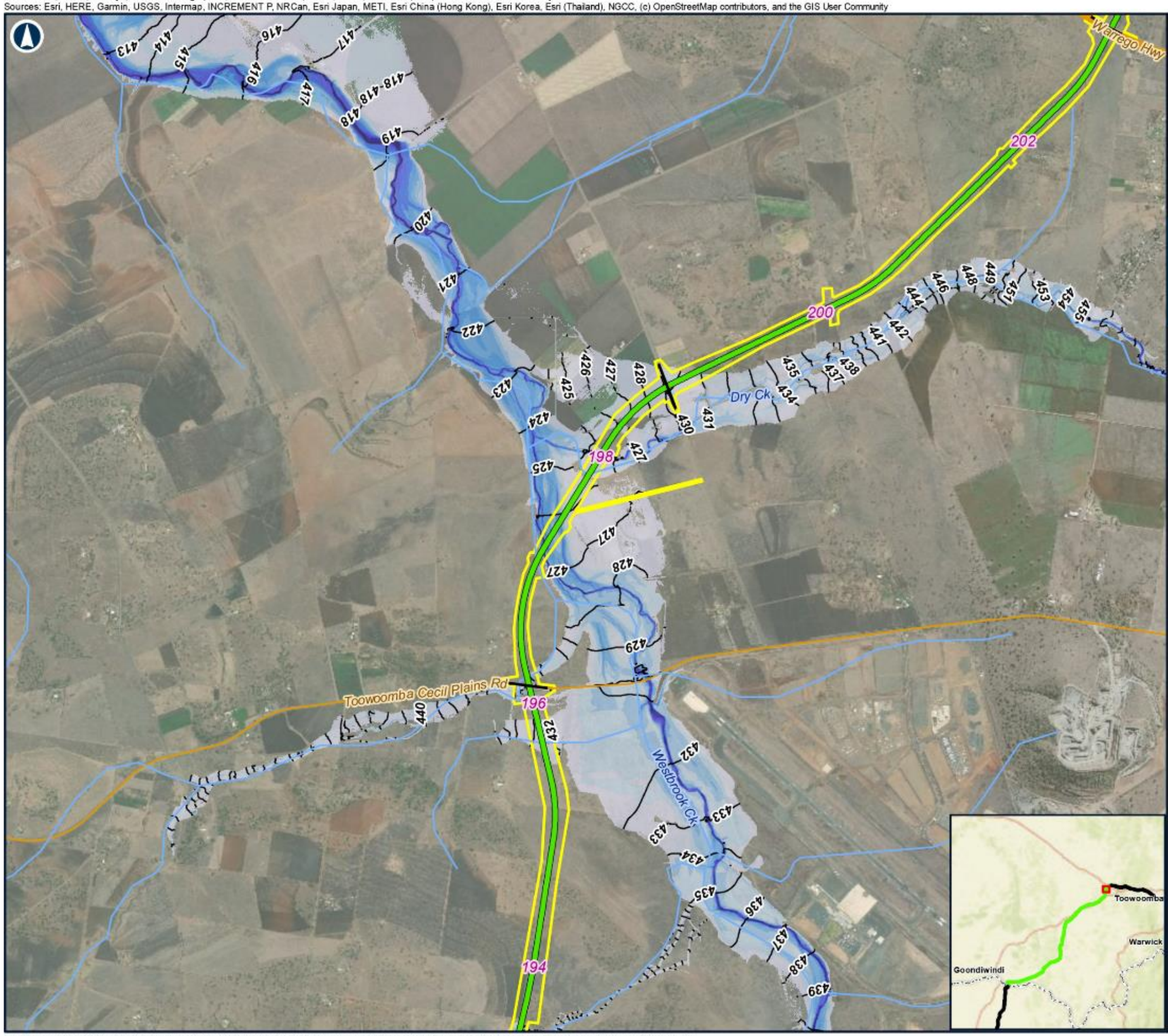
Table 12.41 presents a summary of overtopping depths for key roads near the Project under a range of design events. The 1% AEP event peak water levels are shown in Figure 12.7a.

TABLE 12.41 WESTBROOK CREEK AND DRY CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)					
Infrastructure	Location	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Anderson Road	Downstream of Westbrook Bridge	4.38	3.64	3.36	2.94	2.53	2.05
Brimblecombe Road	Dry Creek crossing	1.30	1.05	0.98	0.85	0.68	0.52
Toowoomba–Cecil Plains Road	Westbrook Creek crossing	0.90	0.57	0.50	0.41	0.31	0.18

Peak 1% AEP velocities within the channels of Westbrook and Dry Creeks at the Project alignment are relatively high, in the order of 2 m/s to 3 m/s, and on the floodplain velocities are generally in the order of 1 m/s to 1.5 m/s as shown in Figure 12.7b.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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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BORDER TO GOWRIE

Figure 12.7a:
Existing Case – 1% AEP Peak water levels
Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- 1m contour mAHD

Depth (m)

- 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

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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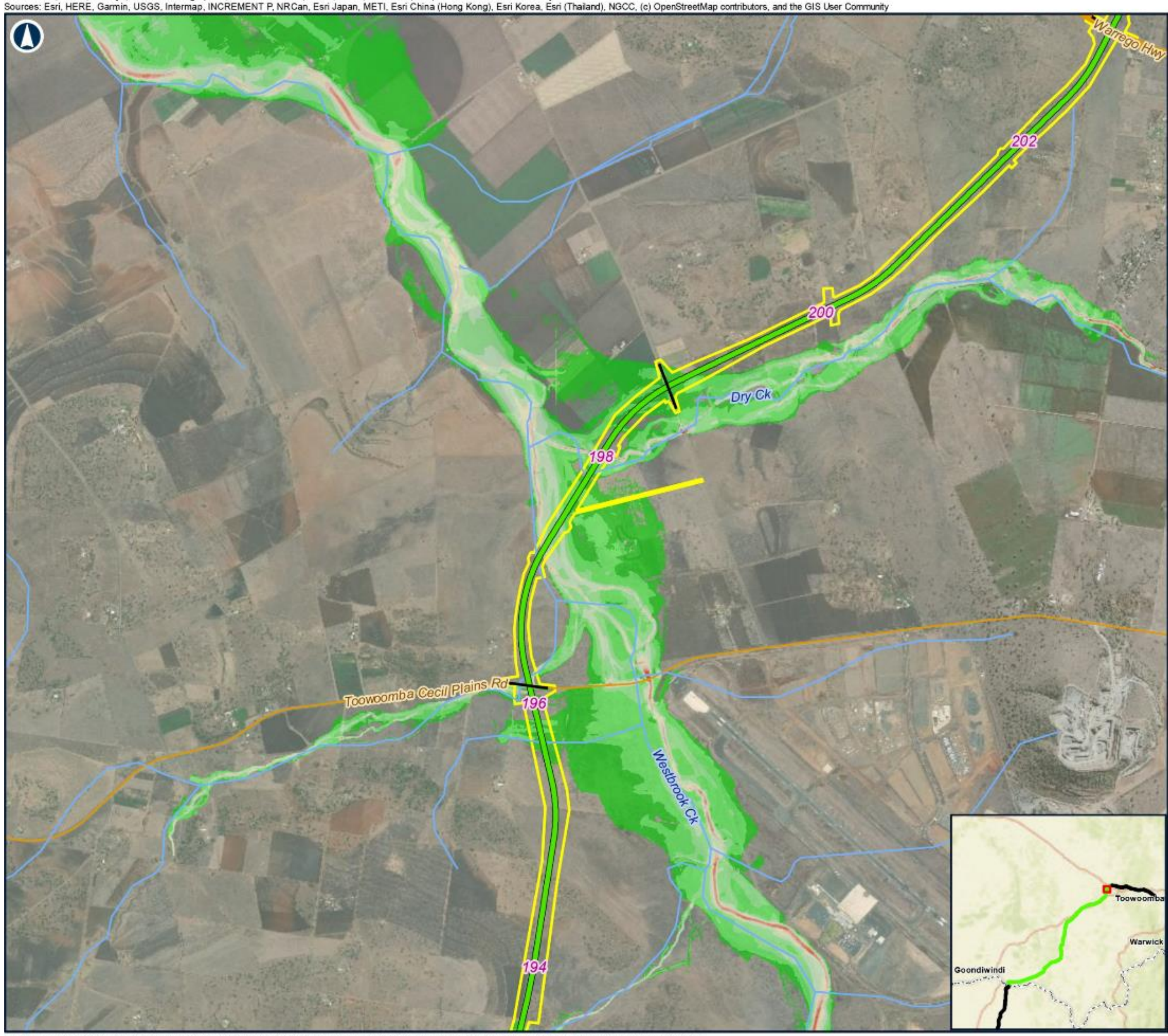
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the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



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BORDER TO GOWRIE

Figure 12.7b: Existing Case – 1% AEP Peak velocities Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Velocity (m/s)

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

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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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 channels begin to break their banks in a 50% AEP event, and then flow occurs 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 1% AEP inundated floodplain width at the Project alignment is approximately 12.5 km.

Under existing conditions, there are multiple pieces of infrastructure impacted by flooding, including the existing QR Millmerran Branch Line, multiple State-controlled roads, and various structures, including houses and sheds. State-controlled roads within the floodplain, which includes the Gore Highway, Millmerran–Leyburn Road and Pampas–Horrane Road, have low flood immunity. The Gore Highway is estimated to have an existing flood immunity of approximately 10% AEP, and Pampas–Horrane Road and Millmerran–Leyburn Road have an approximate 50% AEP flood immunity.

Under the 1% AEP event, the peak depth of water is approximately 4 m in the Condamine River channel, 1.5 m in the Condamine North Branch channel, and approximately 1 m deep in the Grasstree Creek channel.

Table 12.42 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 12.8a.

TABLE 12.42 CONDAMINE RIVER—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

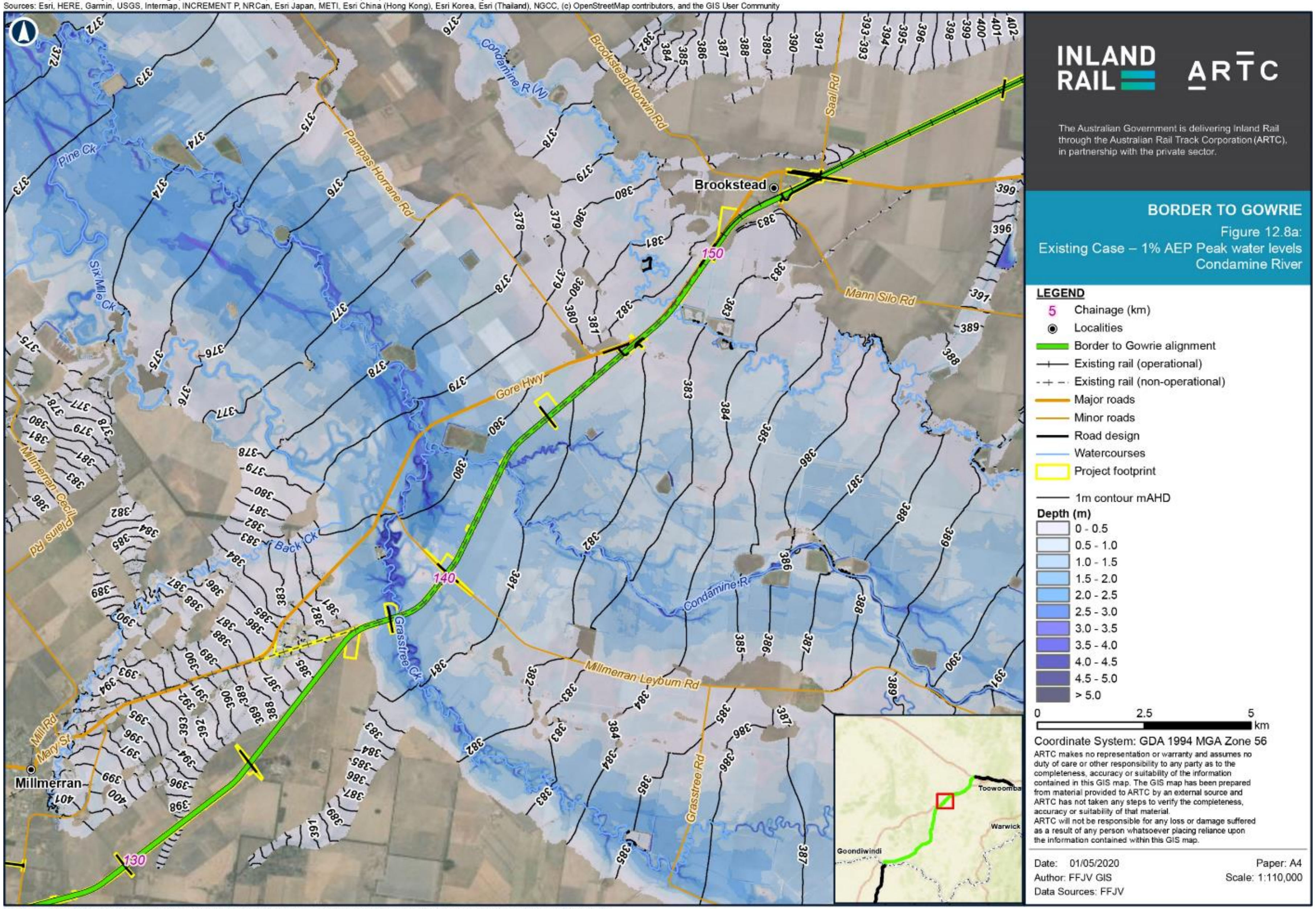
		Approximate overtopping depth (m)					
Infrastructure	Location	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Gore Highway	Downstream of Main Branch crossing	1.96	1.23	1.03	0.77	0.52	0.19
Millmerran–Leyburn Road	Upstream of the Project	1.64	0.80	0.57	0.34	0.23	0.18
Pampas–Horrane Road	Downstream of the Project	0.64	0.23	0.19	0.12	0.06	-
Existing QR Millmerran Branch Line[1]	Adjacent to Main Condamine crossing	2.77	2.09	1.93	1.72	1.51	1.24
Existing QR Millmerran Branch Line[1]	Adjacent to North Branch crossing	0.95	0.76	0.69	0.55	0.48	0.45
Yandilla grain silos	Yandilla, upstream of the Project	1.06	0.25	0.05	-	-	-

Table note:

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

Peak 1% AEP velocities in the Condamine River channel are typically in the order of 1 m/s to 2 m/s and, on the floodplain velocities, are generally in the order of <0.5 m/s as shown in Figure 12.8b.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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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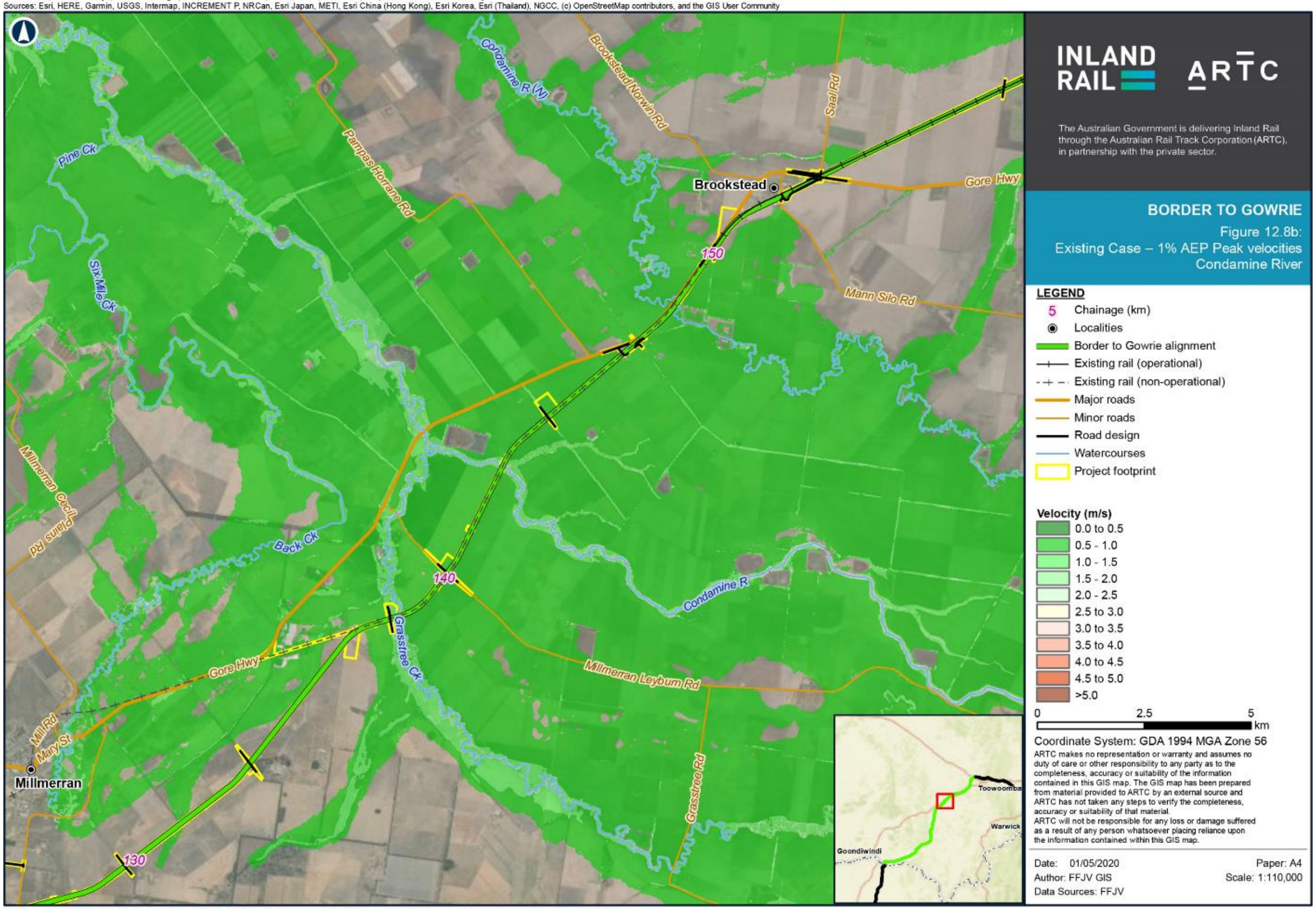

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Back Creek

The Project alignment crosses Back Creek as well as one of its small tributaries. Back Creek is a narrow and meandering system, which, 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 4.7 m at the Project crossing of the Back Creek channel. The 1% AEP inundated floodplain varies between 400 m and 1 km wide.

Table 12.43 presents a summary of overtopping depths for Millmerran–Inglewood Road, near the Project, under a range of design events. The 1% AEP event peak water levels are shown in Figure 12.9a.

TABLE 12.43 BACK CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	2.03	1.87	1.88	1.86	1.71	1.68

Peak 1% AEP velocities are expected to reach approximately 4.9 m/s in localised areas in the main creek channel, whereas the average velocity across the floodplain is approximately 0.6 m/s, as shown in Figure 12.9b.

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 3 m within the main channel, and between 0.3 m and 1 m in breakout areas. At the Project alignment, the 1% AEP flood depths are approximately 1.2 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.

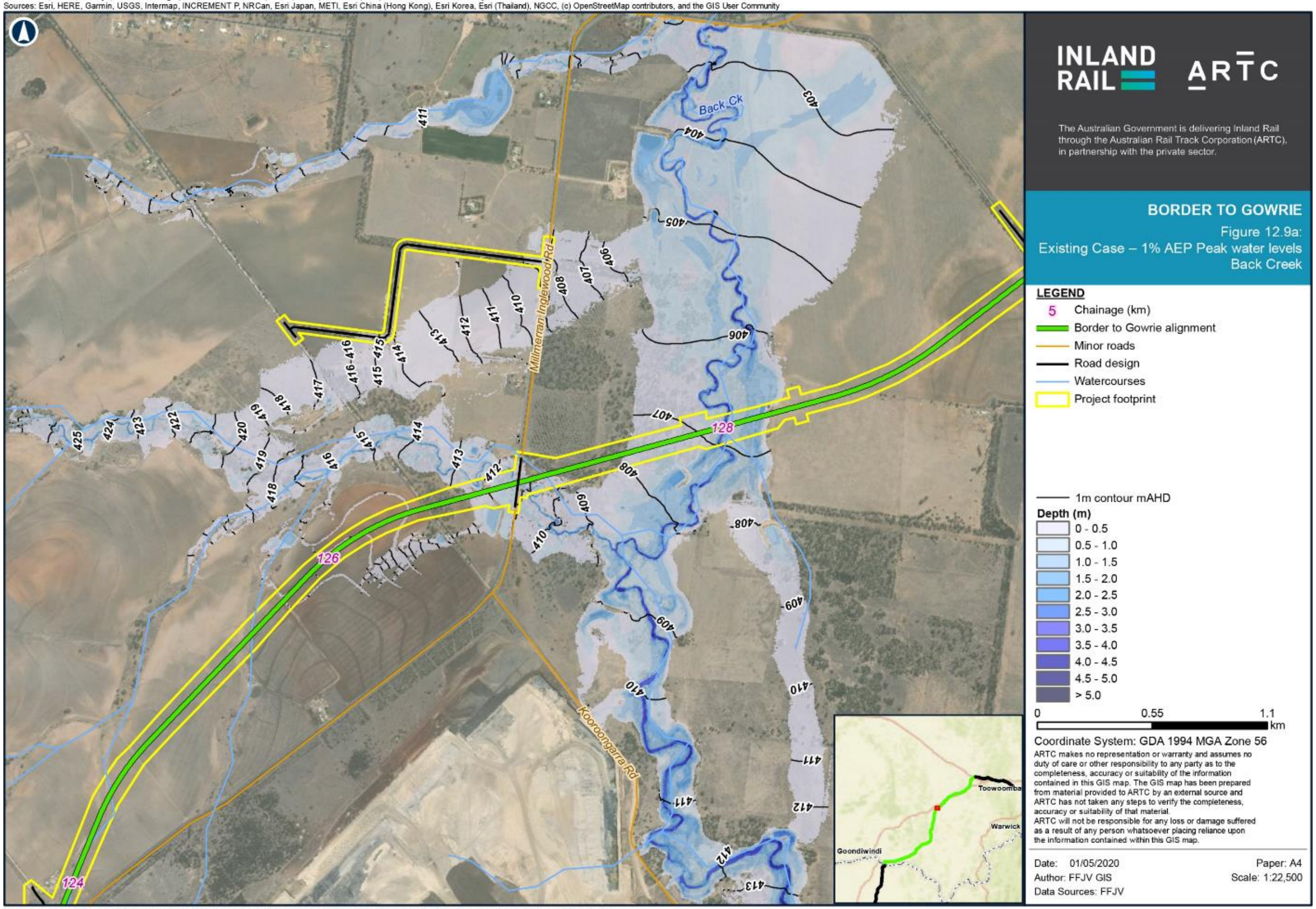
Table 12.44 presents a summary of overtopping depths Millmerran–Inglewood Road, near the Project, under a range of design events. The 1% AEP event peak water levels are shown in Figure 12.10a.

TABLE 12.44 NICOL CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	3.03	2.74	2.56	2.39	2.31	1.89

Peak 1% AEP velocities are expected to reach up to 4.6 m/s in localised areas, with an average velocity across the floodplain of approximately 0.7 m/s as shown in Figure 12.10b.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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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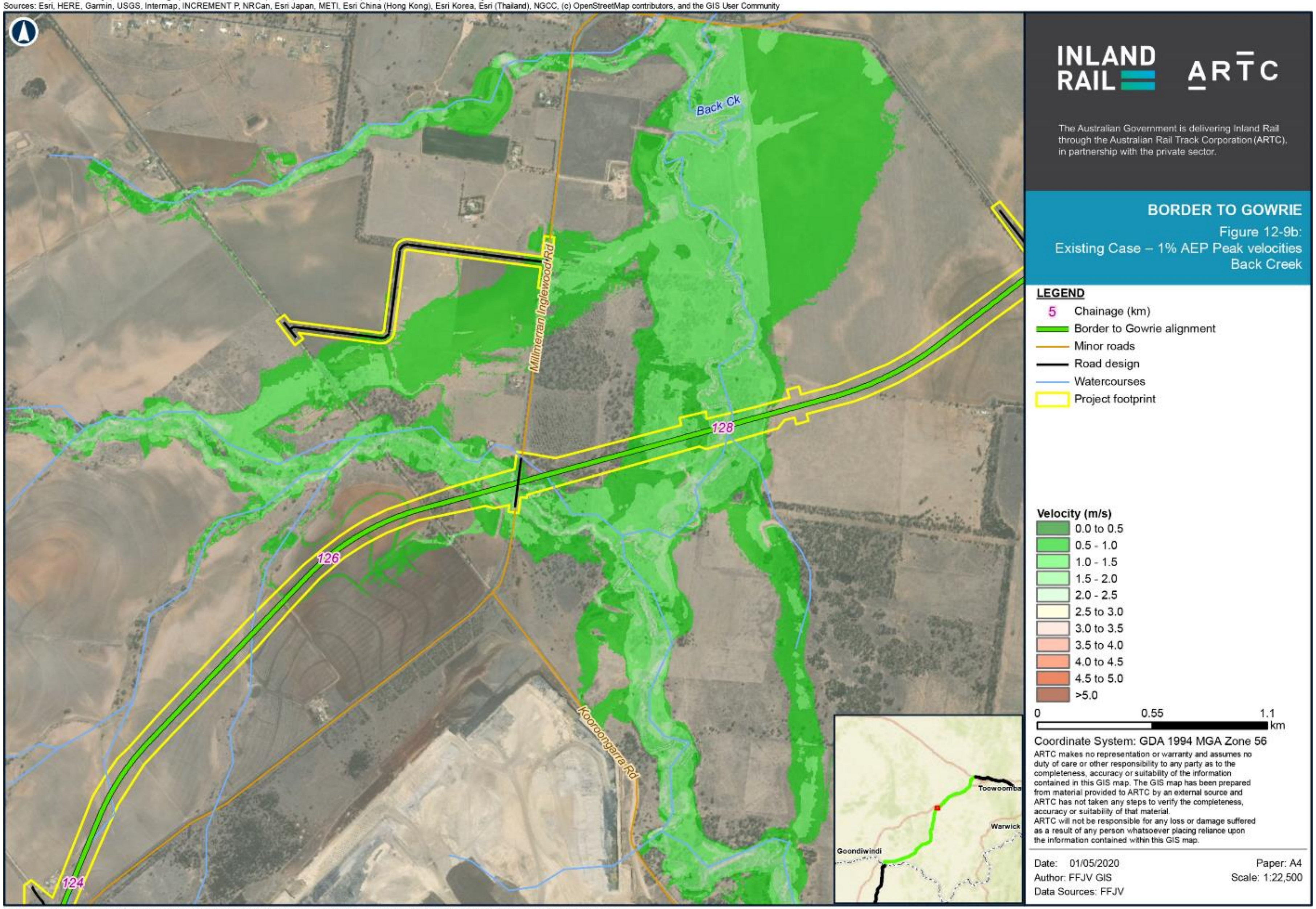

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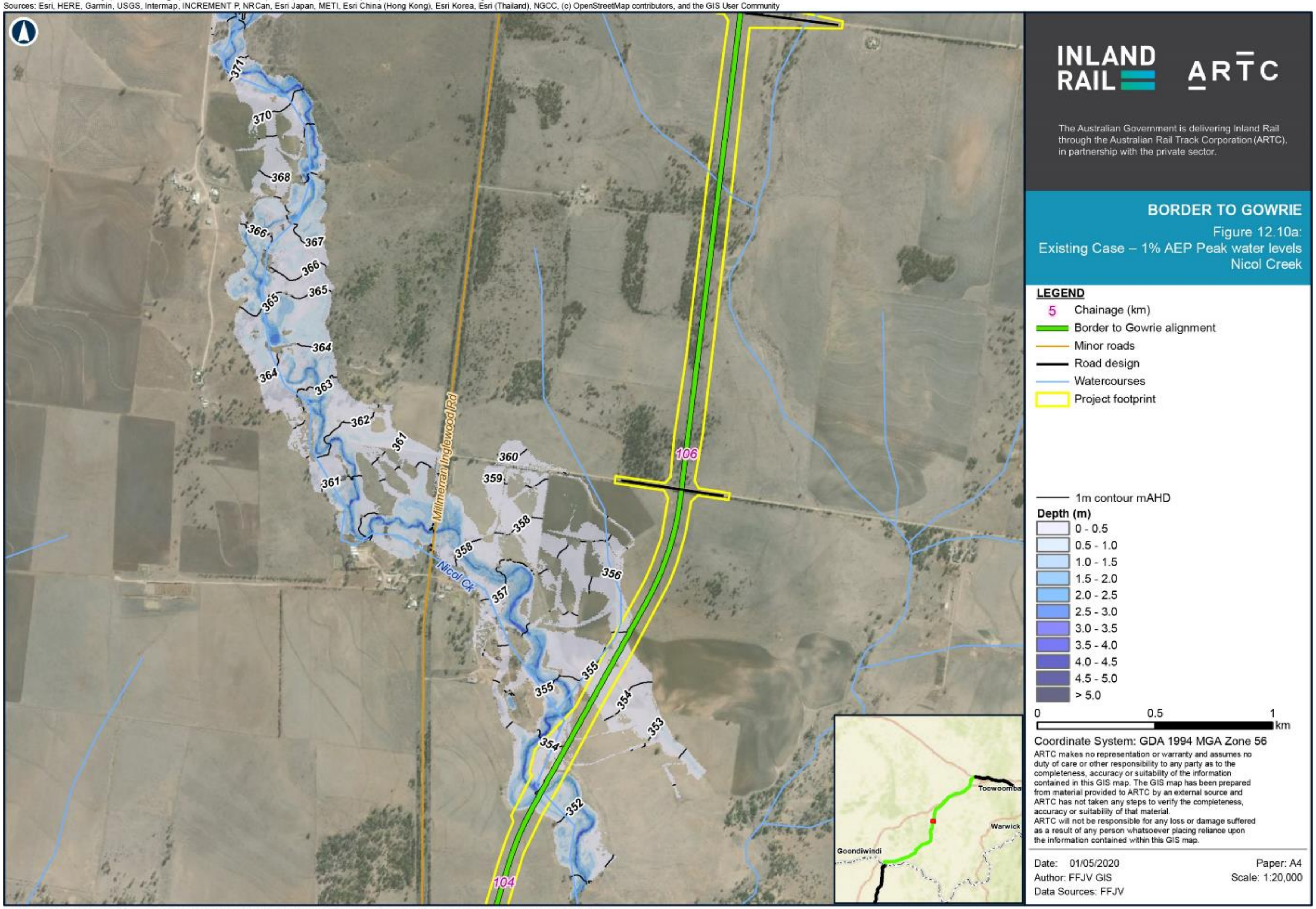

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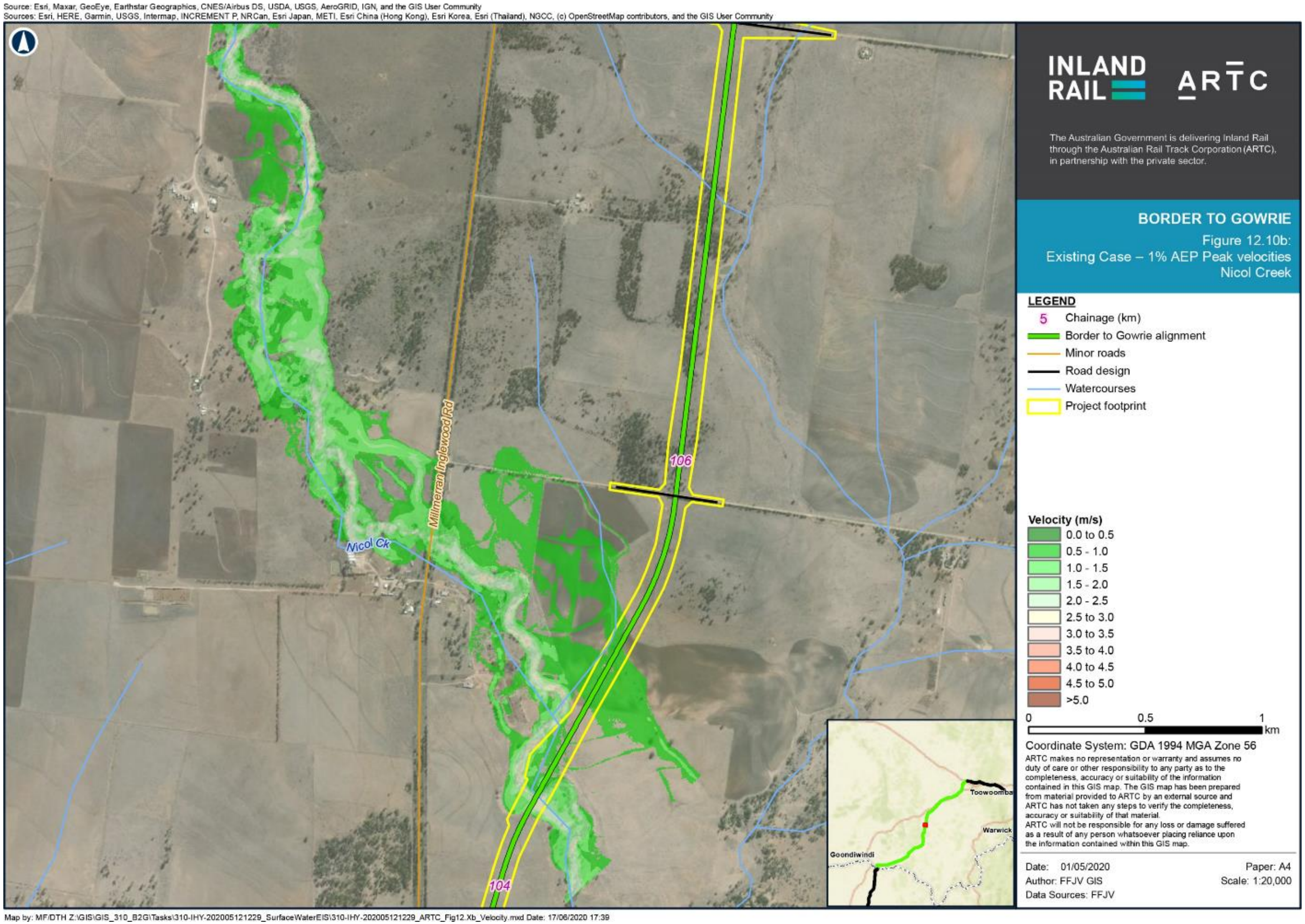

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BORDER TO GOWRIE
Figure 12.10b:
Existing Case – 1% AEP Peak velocities
Nicol Creek
LEGEND
5 Chainage (km)
Border to Gowrie alignment
Minor roads
Road design
Watercourses
Project footprint
Velocity (m/s)
0.0 to 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 to 3.0
3.0 to 3.5
3.5 to 4.0
4.0 to 4.5
4.5 to 5.0
>5.0
0
0.5
1
km
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Millmerran Inglewood Rd
Nicol Ck
106
104
Toowoomba
Warwick
Goondiwindi
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Bringalily Creek

Bringalily Creek is a well-defined watercourse with high sinuosity and is an upstream tributary of Canning Creek. Under the 1% AEP event, the flood depth in Bringalily Creek channel is up to approximately 7 m. On the floodplain, in the vicinity of the Project, flood depths range from 3 m/s to 4.5 m. The Bringalily Creek flood inundation extent is between 500 m and 1 km wide.

Table 12.45 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 12.12a.

TABLE 12.45 BRINGALILY CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road (middle)	3.01	2.46	2.36	1.81	1.51	1.28
Millmerran–Inglewood Road (south)	2.34	1.99	1.89	1.51	1.24	0.99
Millmerran–Inglewood Road (north)	1.42	0.86	0.78	0.24	-	-
Heckles Road	1.20	0.76	0.71	0.54	0.46	0.38
Forestry Road	0.36	0.32	0.39	0.28	0.26	0.26

Peak 1% AEP velocities are expected to reach up to 5 m/s in localised areas within the creek channel, with average velocities across the floodplain of approximately 0.6 m/s as shown in Figure 12.11b.

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.

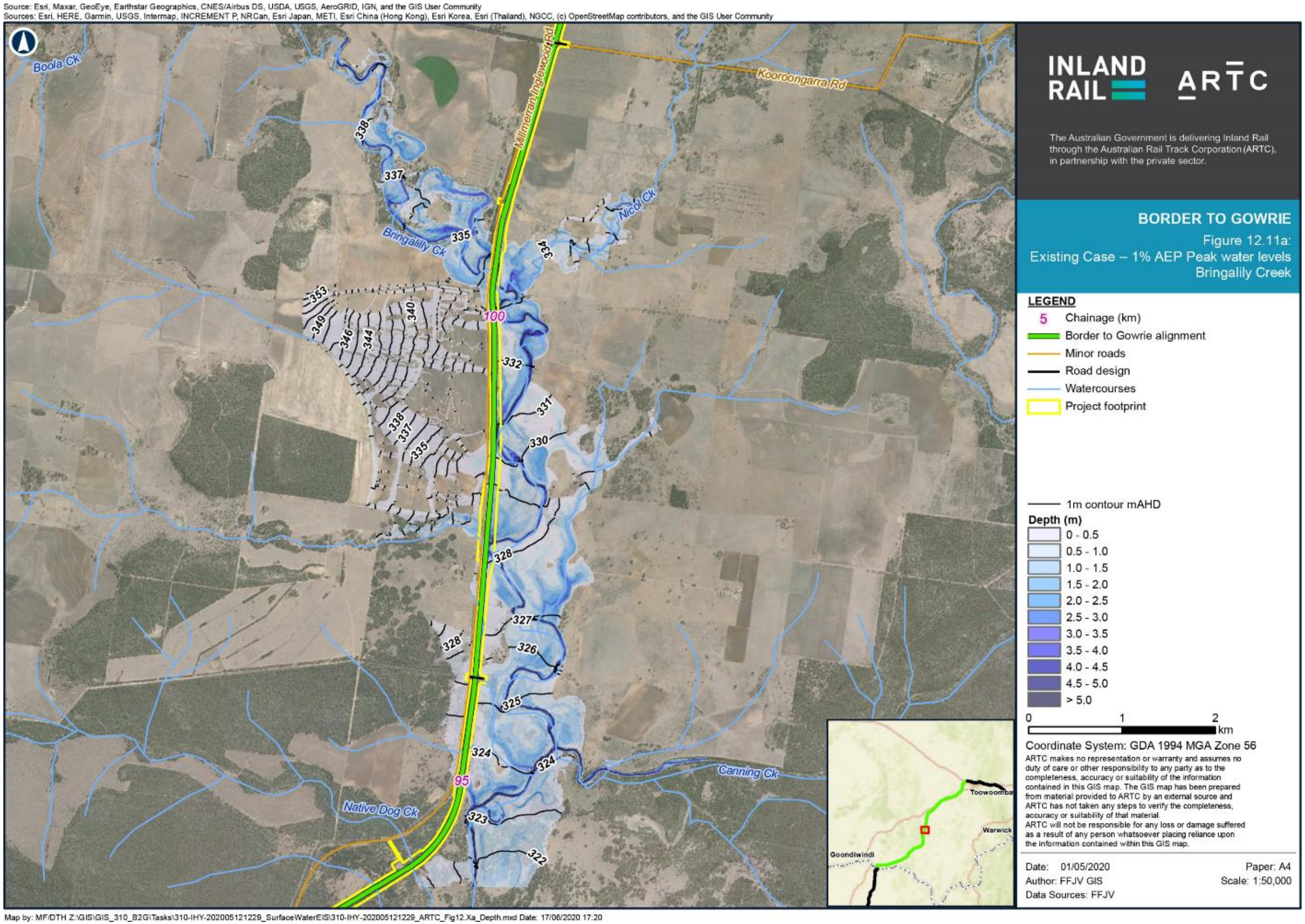
Under the 1% AEP event, the flood depth in Native Dog Creek channel is up to approximately 3 m and around 1 m on the floodplain area. The floodplain inundated extent is approximately 120 m wide.

Table 12.46 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 12.12a.

TABLE 12.46 NATIVE DOG CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	2.25	1.75	1.51	1.22	1.07	0.97

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 12.12b.



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Boola Ck
Millmerran Inglewood Rd
Kooroongarra Rd
Bringalily Ck
Nicol Ck
Canning Ck
Native Dog Ck
100
95
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BORDER TO GOWRIE
Figure 12.11a:
Existing Case – 1% AEP Peak water levels
Bringalily Creek
LEGEND
5 Chainage (km)
Border to Gowrie alignment
Minor roads
Road design
Watercourses
Project footprint
1m contour mAHD
Depth (m)
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
0 1 2 km
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Toowoomba
Warwick
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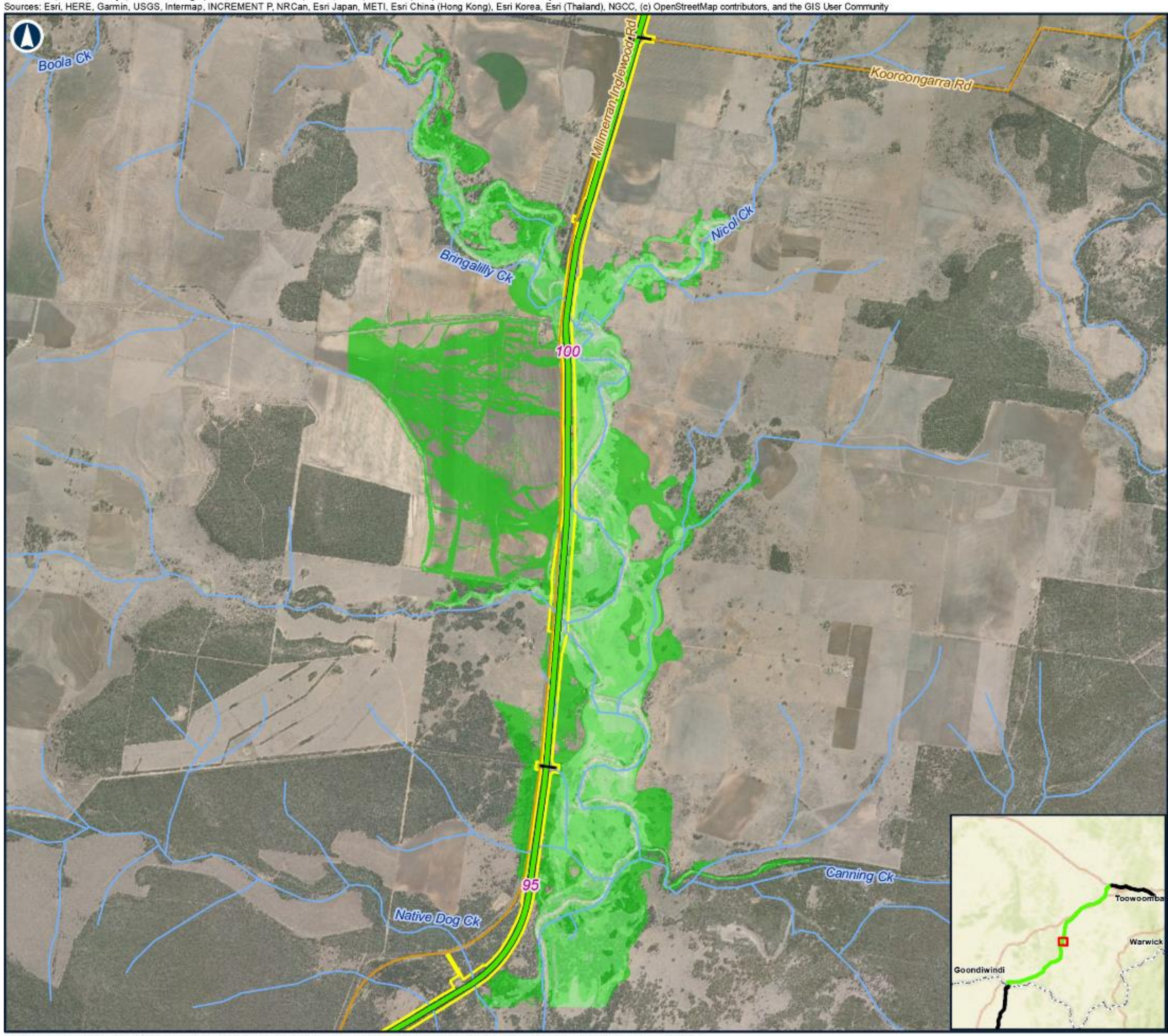

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BORDER TO GOWRIE

Figure 12.11b:
Existing Case – 1% AEP Peak velocities
Bringalily Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint

Velocity (m/s)

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

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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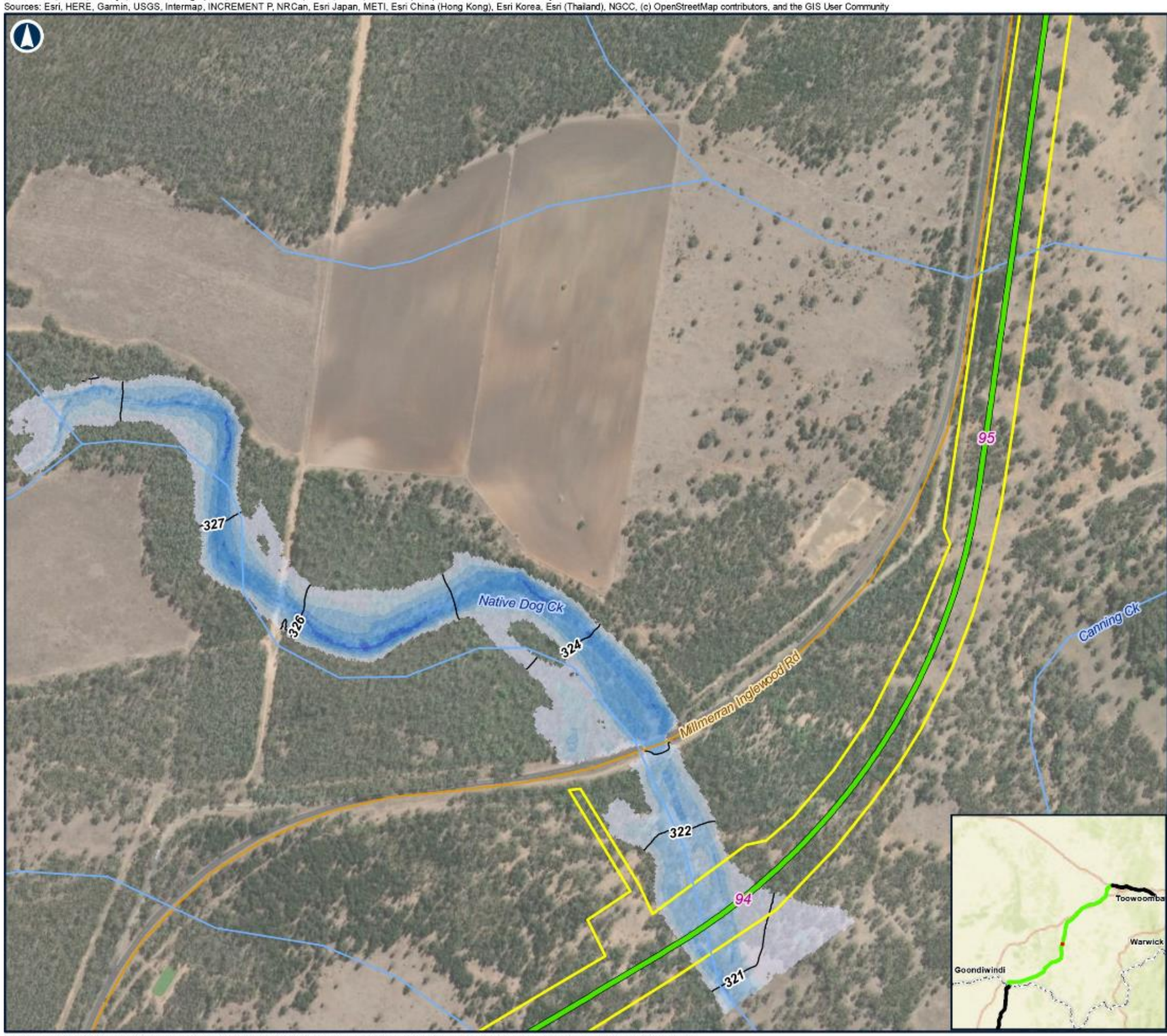

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BORDER TO GOWRIE

Figure 12.12a: Existing Case – 1% AEP Peak water levels Native Dog Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- 1m contour mAHD

Depth (m)

- 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

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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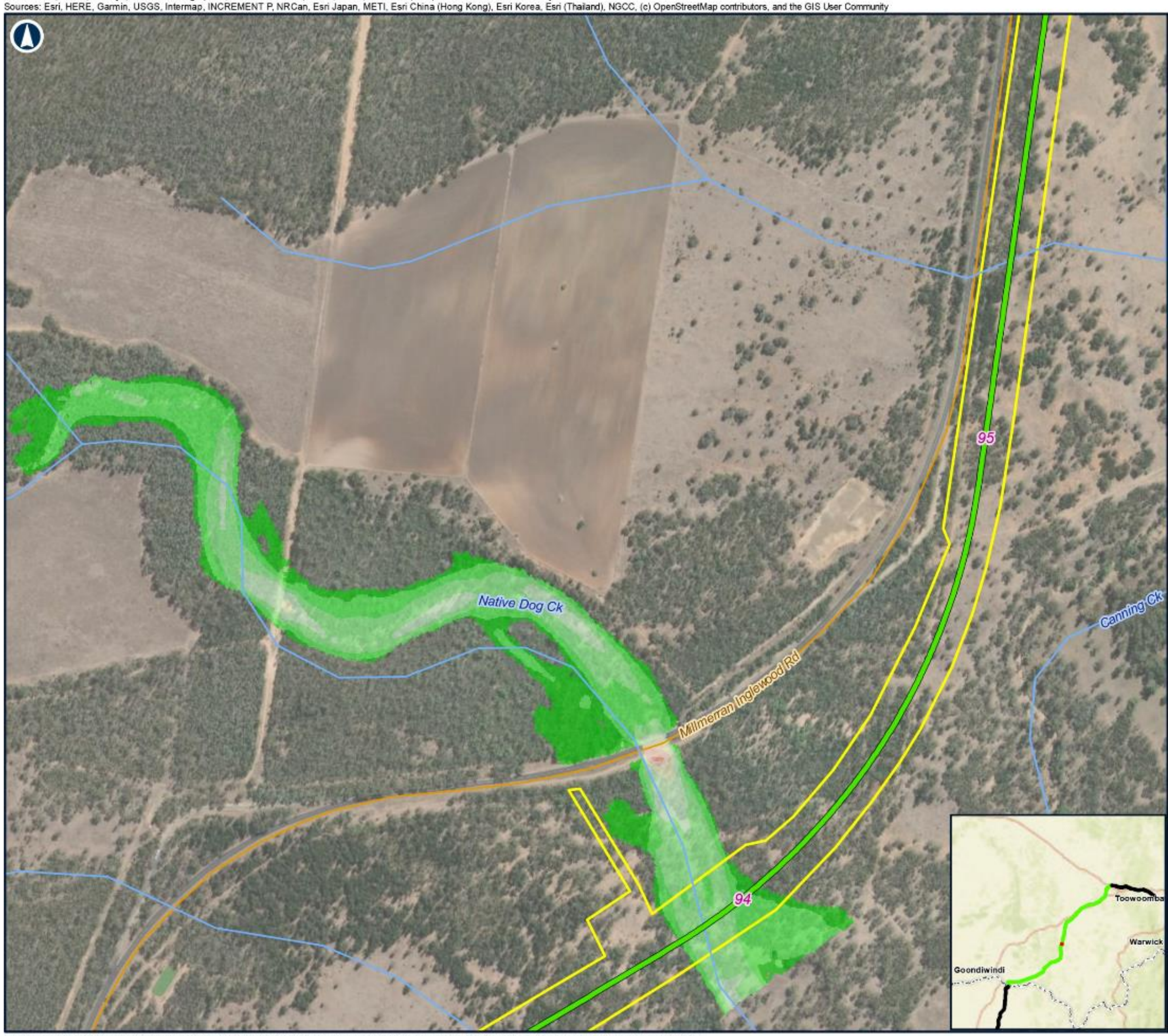

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BORDER TO GOWRIE

Figure 12.12b:
Existing Case – 1% AEP Peak velocities
Native Dog Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint

Velocity (m/s)

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

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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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 12.47 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 12.13a.

TABLE 12.47 CATTLE CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	3.17	2.55	2.22	1.87	1.65	1.46

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 12.13b.

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 5 m and approximately 1 m on the floodplain area. The floodplain inundated extent is approximately 2.7 km wide where the Project alignment crosses.

Table 12.48 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 12.14a.

TABLE 12.48 PARIAGARA CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Millmerran–Inglewood Road	0.32	0.01	-	-	-	-
Thornton Road	4.38	4.09	3.98	3.78	3.59	3.39

Peak 1% AEP velocities are expected to reach up to 5.9 m/s in localised areas, while the average velocity across the floodplain is approximately 0.5 m/s as shown in Figure 12.14b.

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BORDER TO GOWRIE

Figure 12.13a: Existing Case – 1% AEP Peak water levels Cattle Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- 1m contour mAHD

Depth (m)

- 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

0 0.35 0.7 km

Coordinate System: GDA 1994 MGA Zone 56

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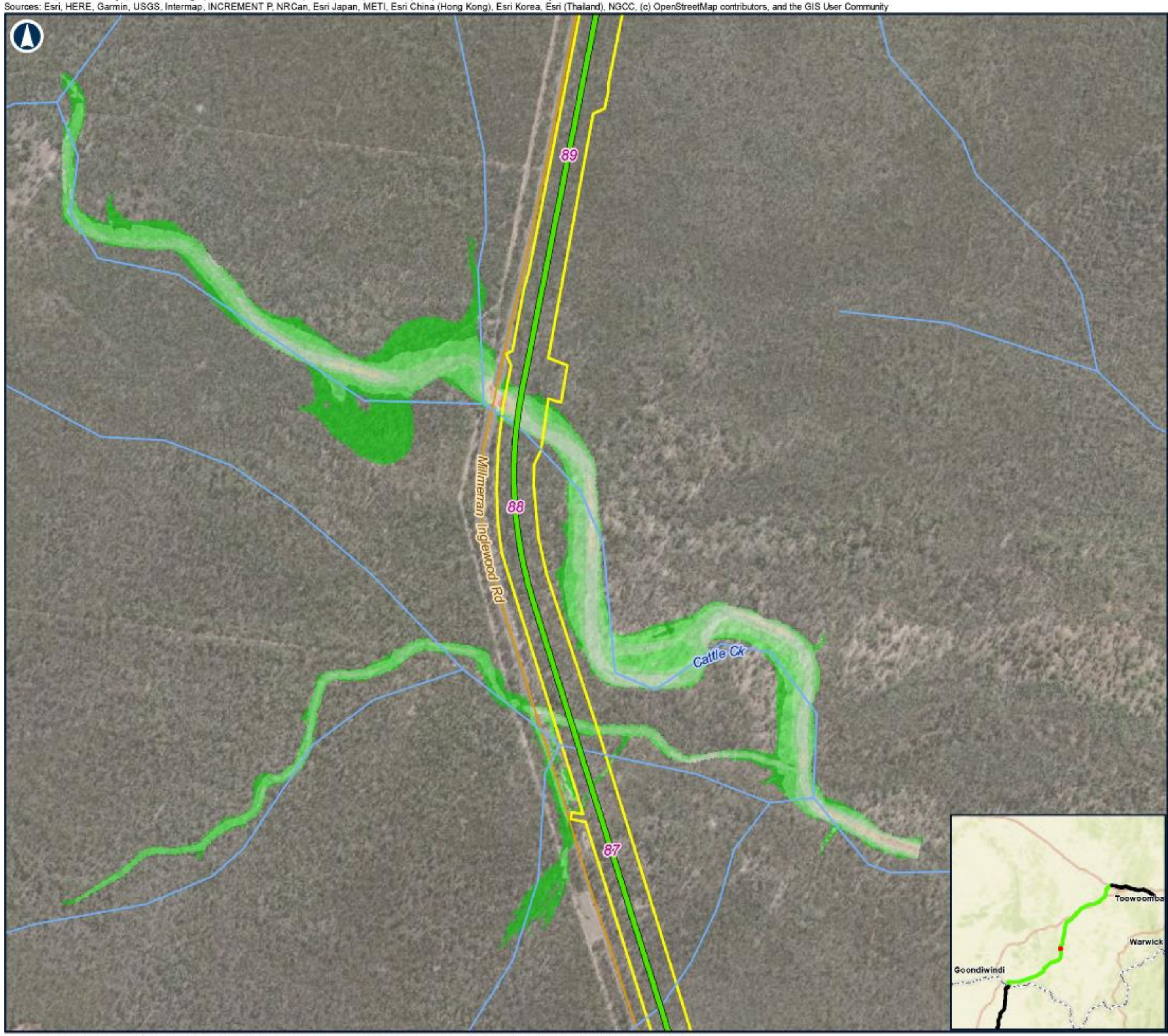

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BORDER TO GOWRIE

Figure 12.13b: Existing Case – 1% AEP Peak velocities Cattle Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint

Velocity (m/s)

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

0 0.35 0.7 km

Coordinate System: GDA 1994 MGA Zone 56

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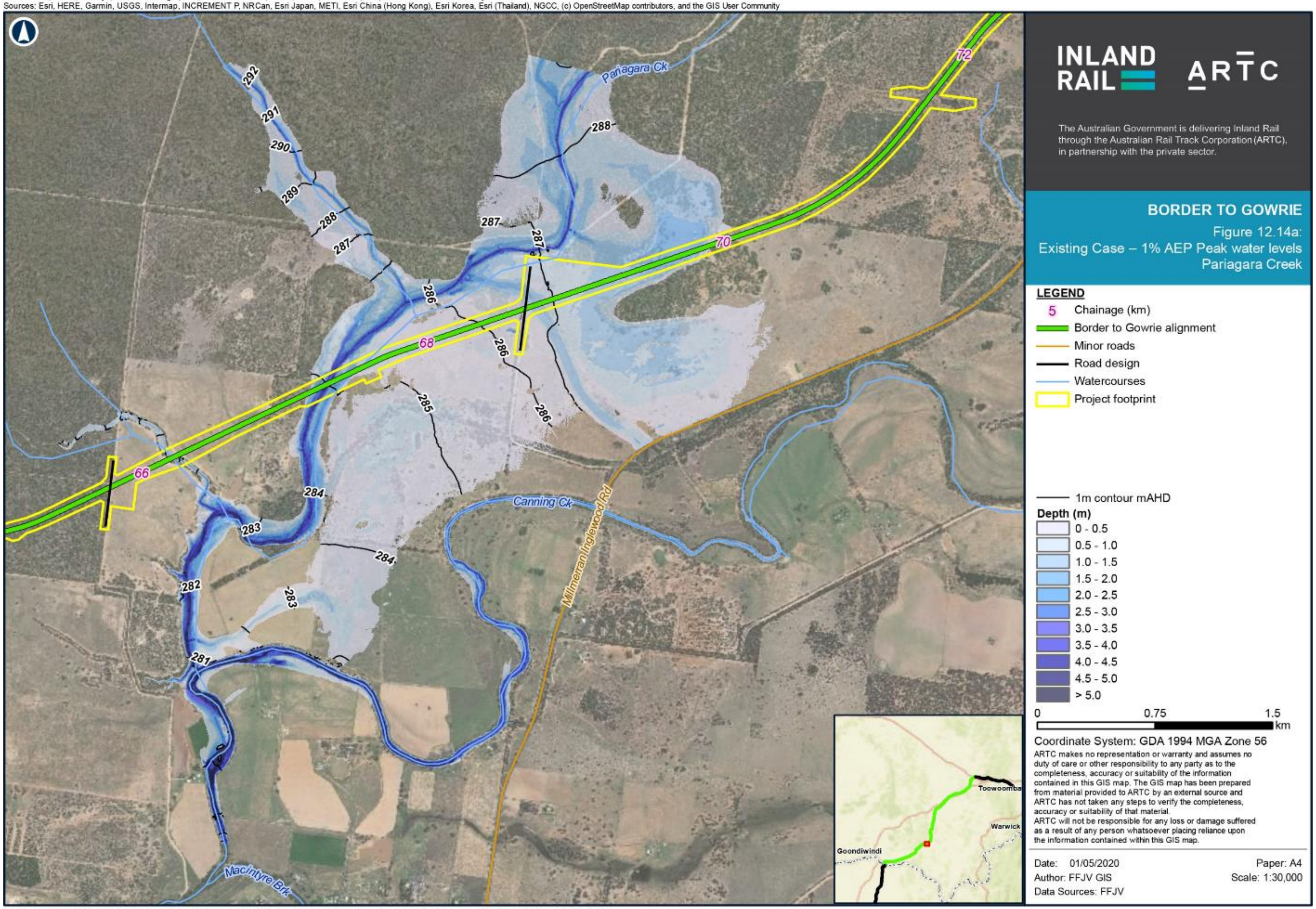

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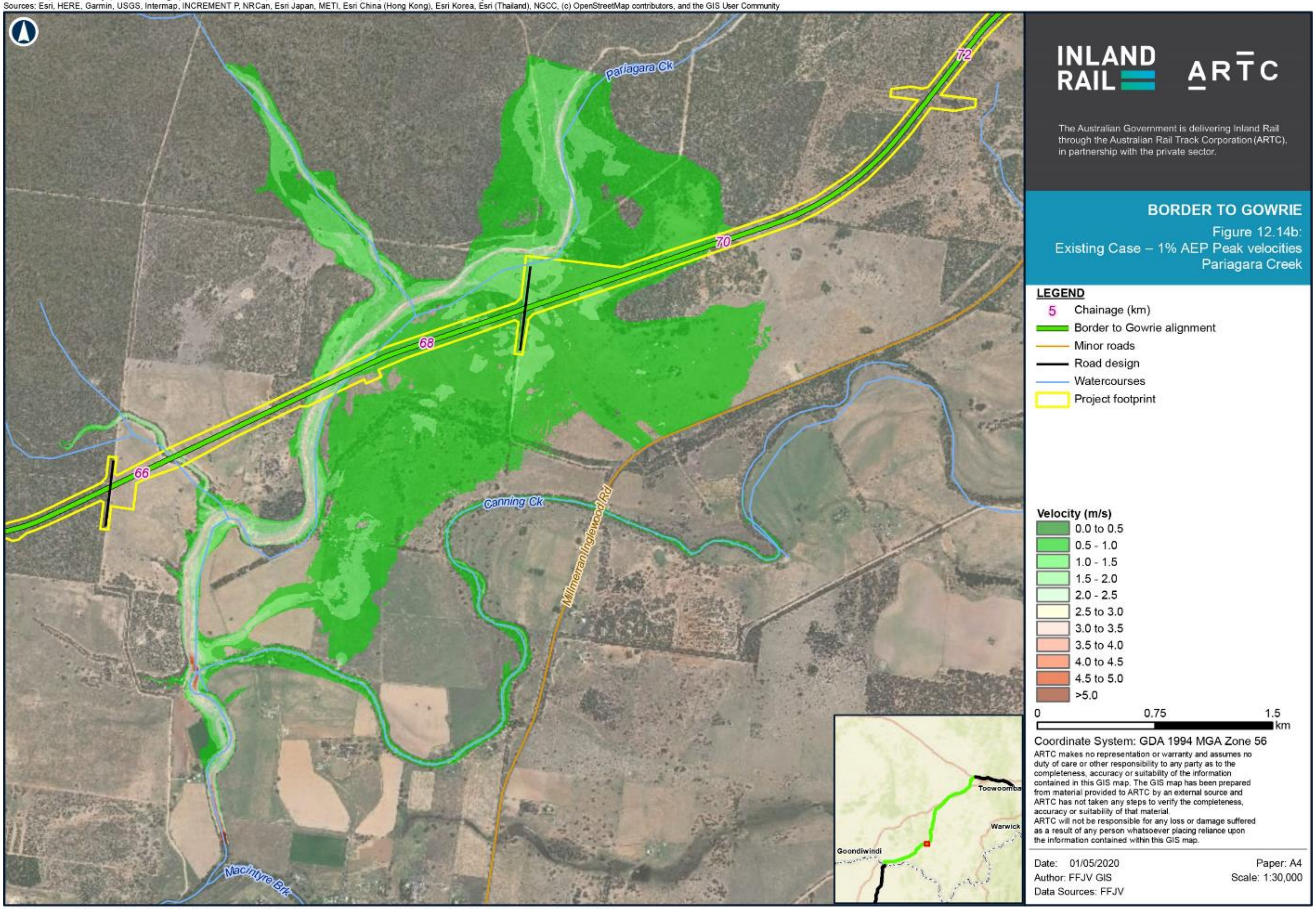

BORDER TO GOWRIE
Figure 12.14b: Existing Case – 1% AEP Peak velocities Pariagara Creek

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Macintyre Brook

Macintyre Brook runs in an east–west direction through Inglewood and south of Yelarbon. The Macintyre Brook is fed by several creek systems, as it flows from the east of Inglewood, westwards towards Yelarbon. These include Mosquito Creek and Canning Creek to the north of Inglewood. Coolmunda Dam is situated on Macintyre Brook and is located 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.

Table 12.49 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 12.15a.

TABLE 12.49 MACINTYRE BROOK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Cunningham Highway (Yelarbon)	1.10	0.70	0.40	0.10	-	-
Existing levee (Yelarbon)	0.70	0.30	0.20	0.10	-	-
Existing road bridge—Cunningham Highway, Inglewood	3.88	2.39	2.03	1.37	0.70	0.22
Existing road bridge—Millmerran–Inglewood Road	5.68	4.59	4.35	3.99	3.68	3.05

At Inglewood, peak 1% AEP velocities of approximately 1.9 m/s are predicted across the floodplain area, with higher velocities in the Macintyre Brook of up to 2.8 m/s. At Yelarbon velocities are predicted to be up to 1.3 m/s at the peak of the flood during a 1% AEP event. Generally, the average velocity across the floodplain is approximately 0.7 m/s as shown in Figure 12.15b.

Macintyre River

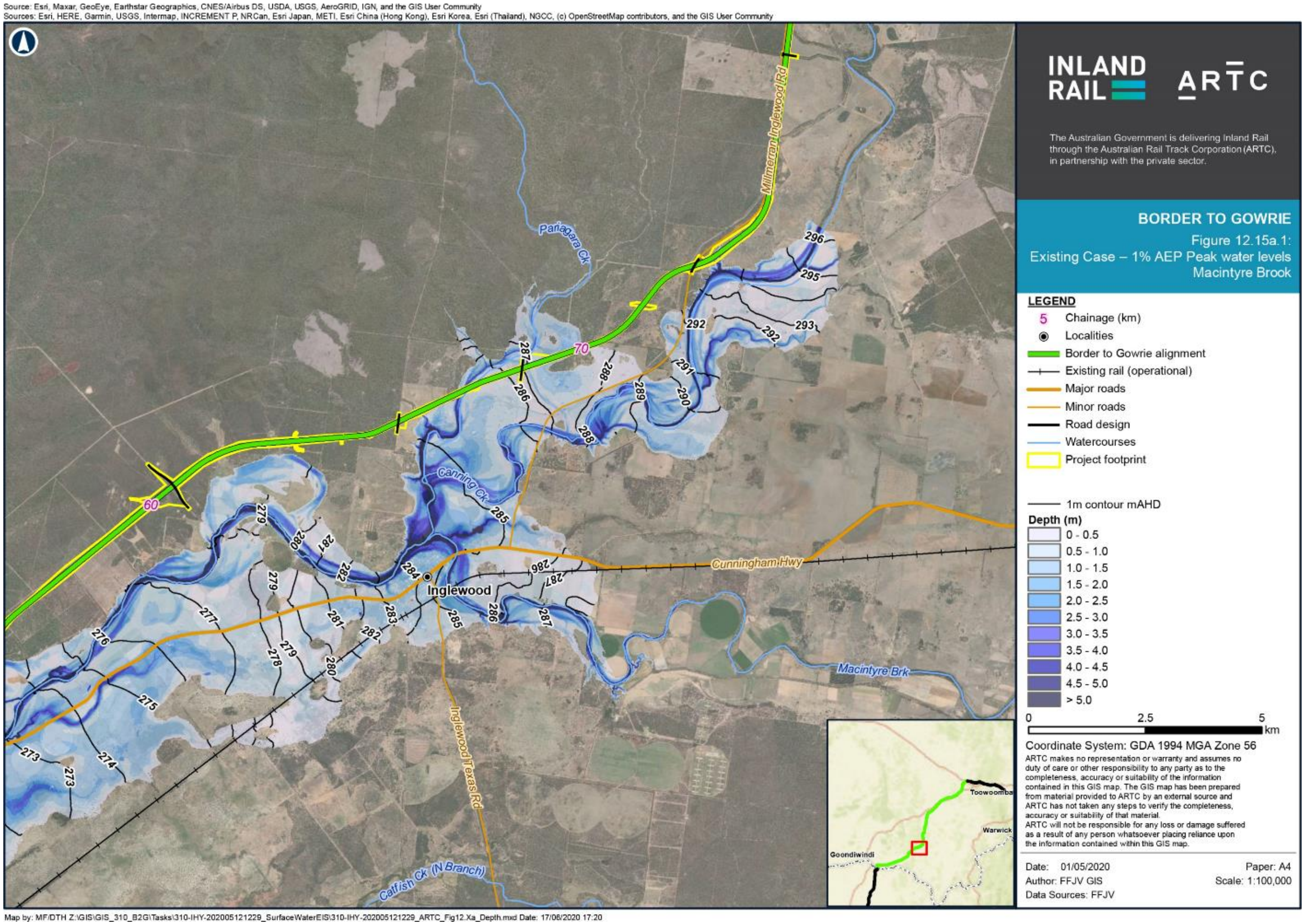
Widespread floodplain inundation is predicted under the 1% AEP event on the Macintyre River floodplain, with depths of approximately 10 m to 12 m in the Macintyre River channel, 6 m in the Whalan Creek channel and up to 2 m on the floodplain area. The Macintyre River floodplain spans across the border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

Table 12.50 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 12.16b.

TABLE 12.50 MACINTYRE RIVER—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE NORTH OF NSW/QLD BORDER

	Approximate overtopping depth (m)					
Infrastructure	1 in 2,000 AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Kildonan Road (downstream of the Project alignment)	2.4	1.6	1.4	0.7	0.06	Dry
Kildonan Road (upstream of the Project alignment)	3	1.7	1.1	Dry	Dry	Dry

Peak 1% AEP velocities of approximately 0.5 m/s are predicted across the floodplain area under the 1% AEP event, with higher velocities in the creek and river channels as shown in Figure 12.16b. Velocities increase in creek and river channels with peak 1% AEP velocities in the Macintyre River channel reaching up to 3.5 m/s.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BORDER TO GOWRIE
Figure 12.15a.1:
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
Road design
Watercourses
Project footprint
1m contour mAHD
Depth (m)
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
0 2.5 5 km
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Scale: 1:100,000
Inglewood
Millmerran Inglewood Rd
Cunningham Hwy
Inglewood Texas Rd
Canning Ck
Pariagara Ck
Macintyre Brk
Catfish Ck (N Branch)
60
70
Toowoomba
Warwick
Goondiwindi
Map by: MF/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202005121229_SurfaceWaterEIS\310-IHY-202005121229_ARTC_Fig12.Xa_Depth.mxd Date: 17/06/2020 17:20

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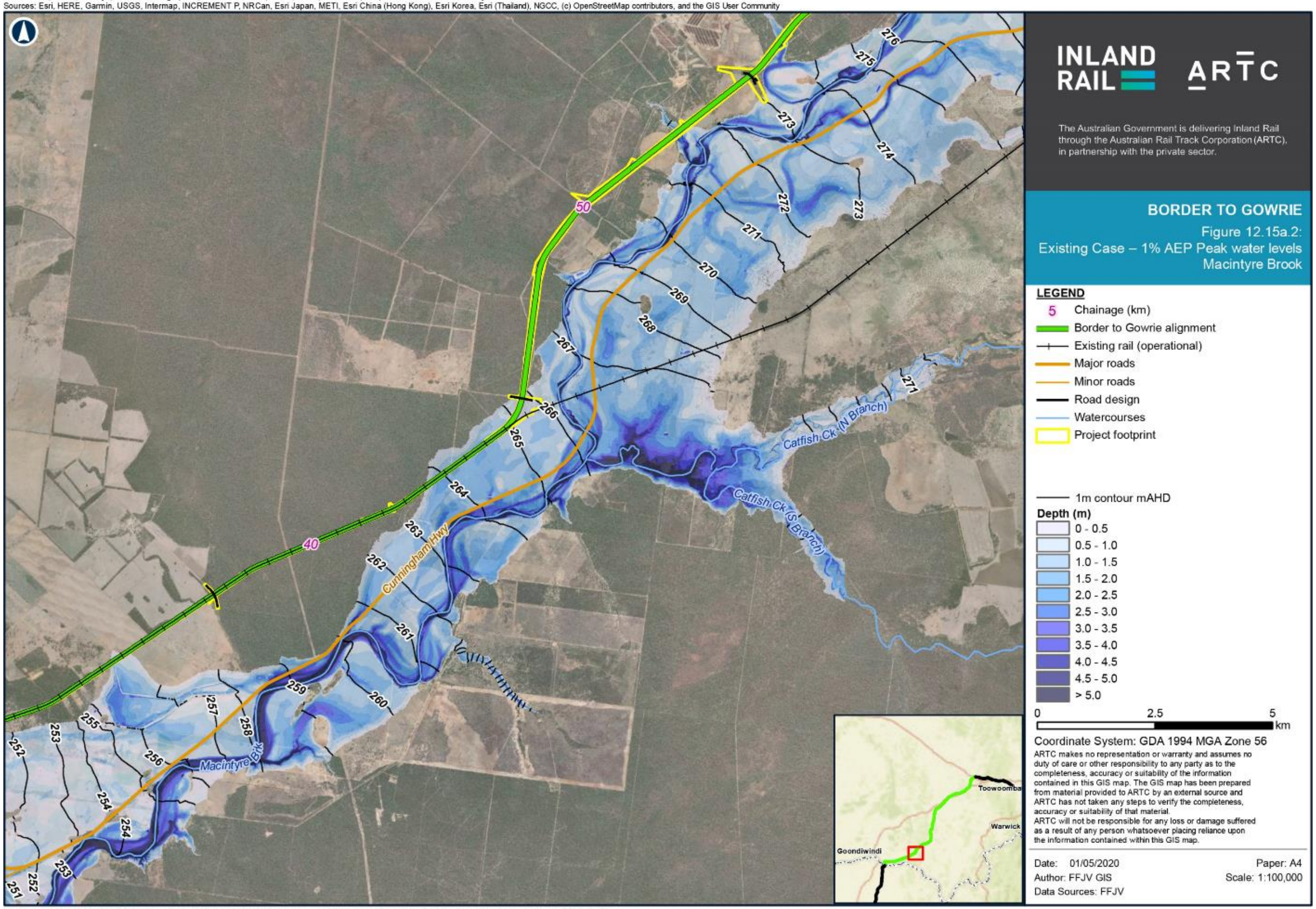

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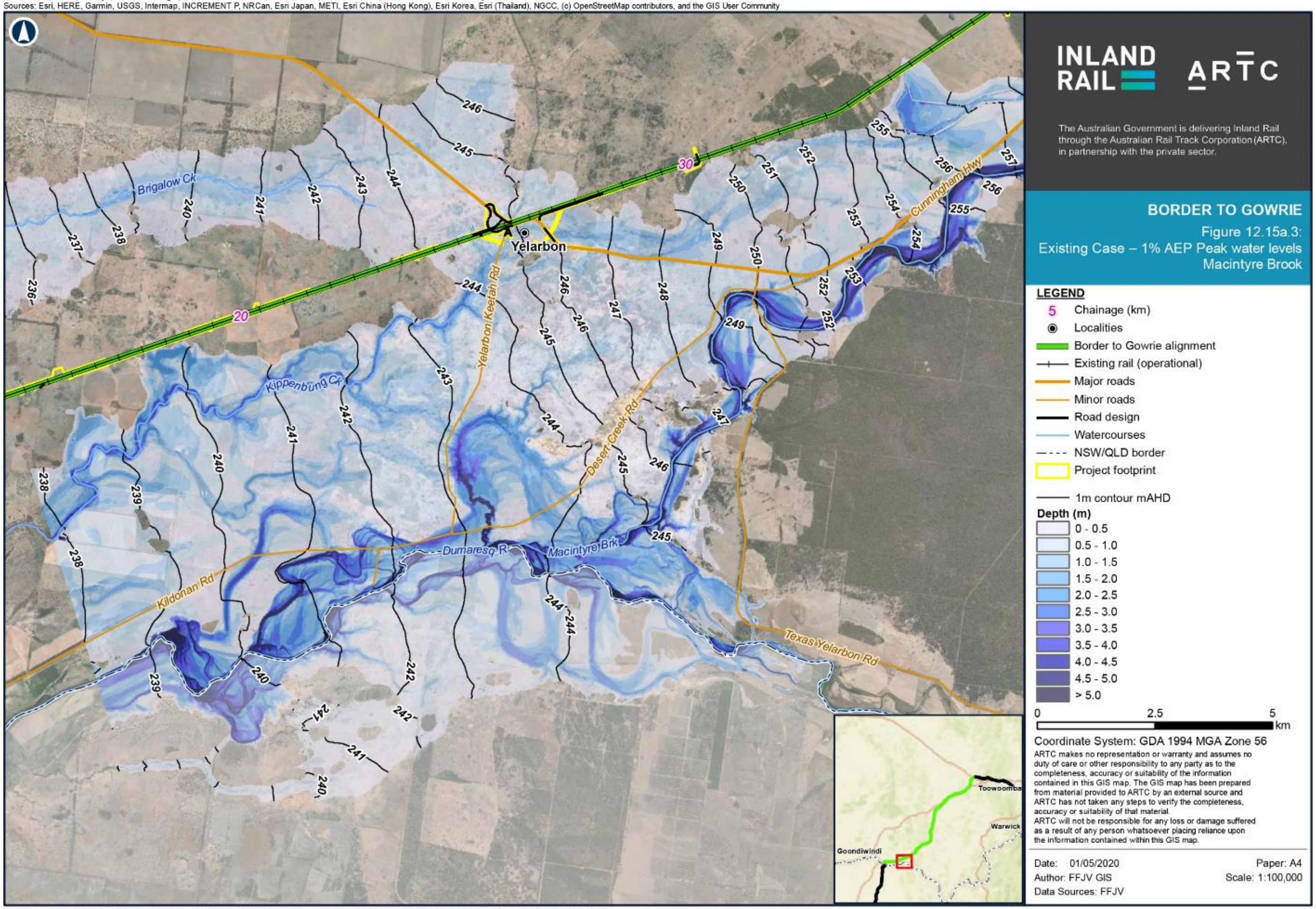

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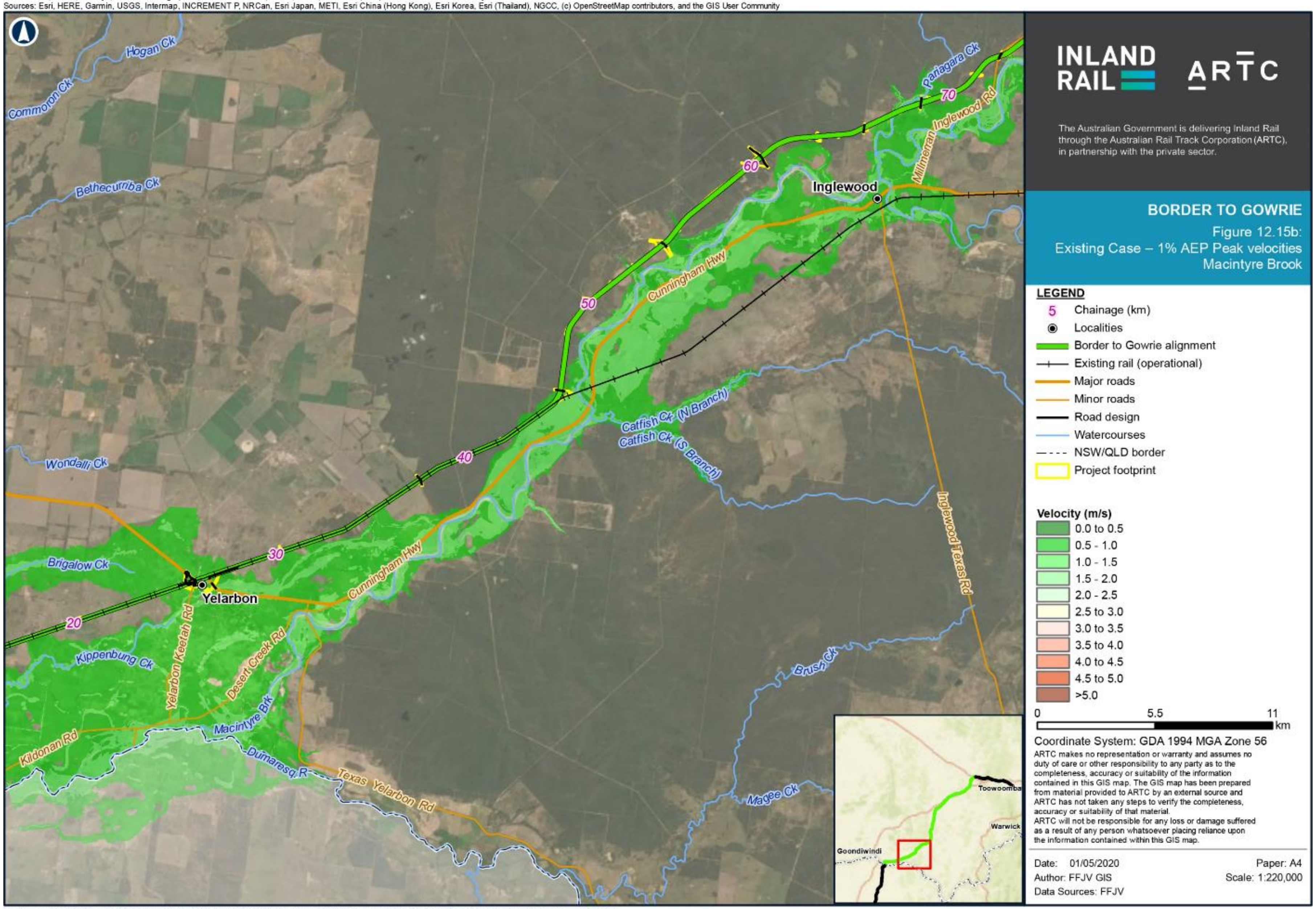

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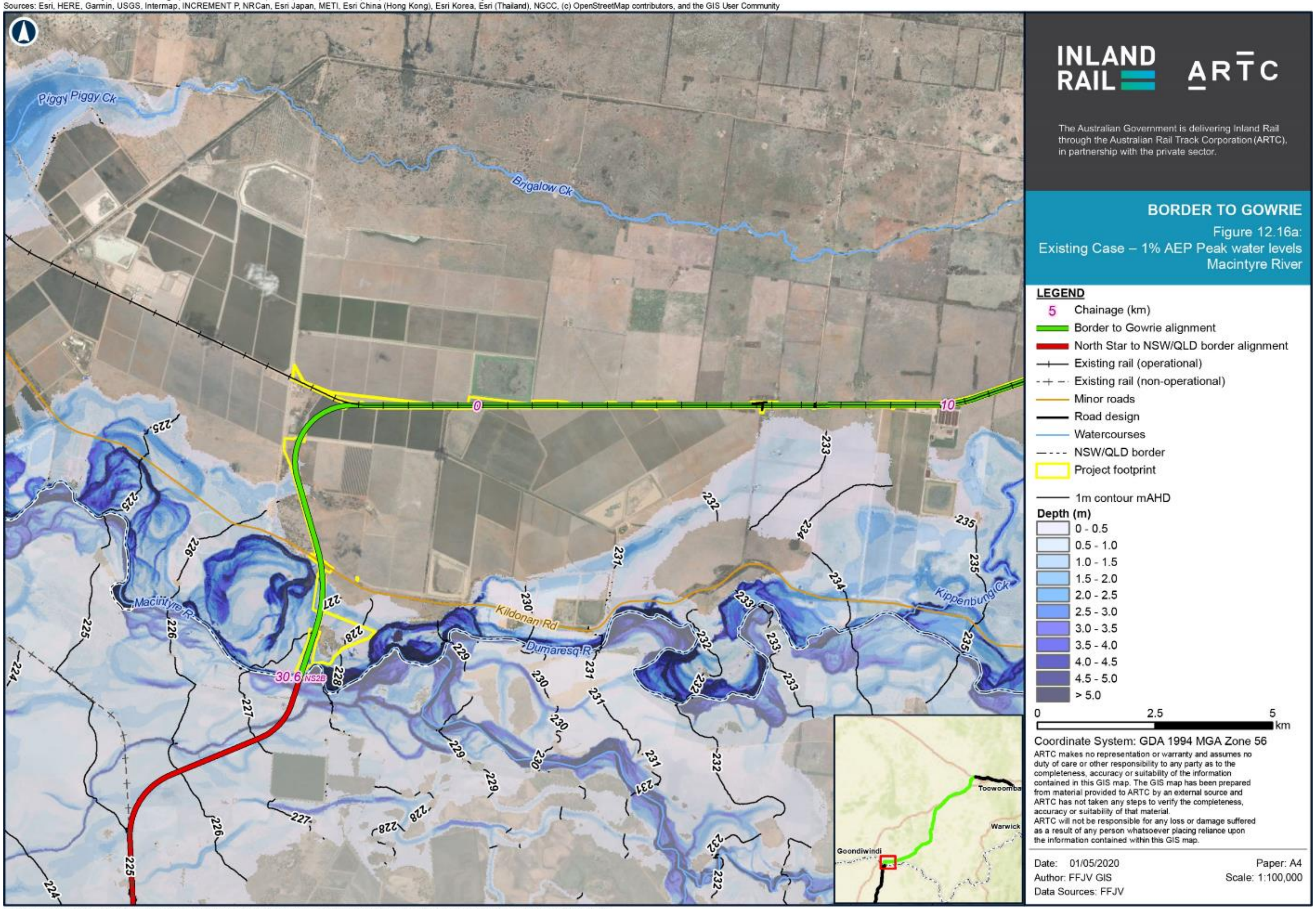

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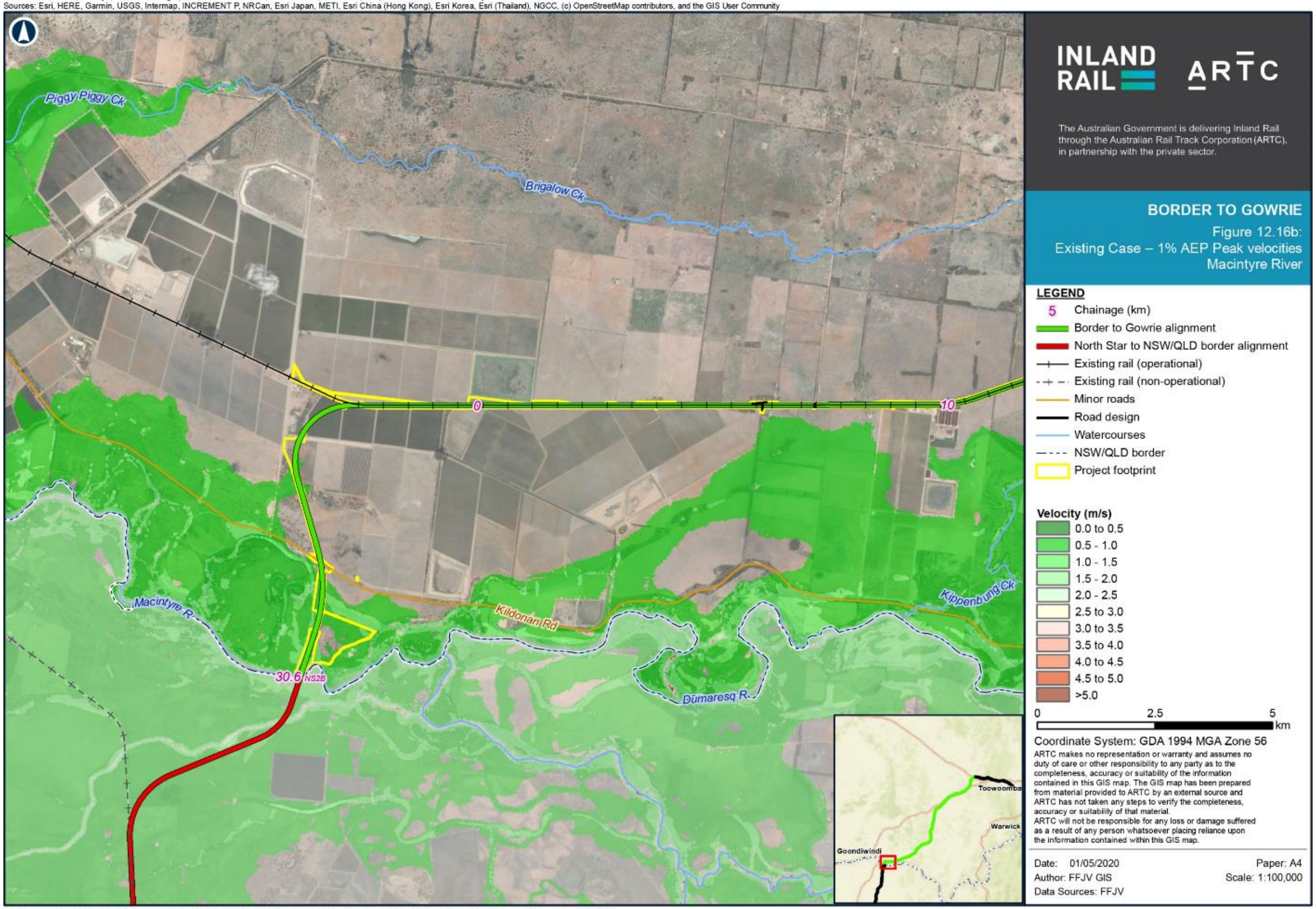

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12.8 Potential impacts

This section identifies and discusses the potential Project-related impacts associated with surface water and hydrology.

12.8.1 Surface water

12.8.1.1 Impacts to surface water quality

Potential impacts to surface water quality have been identified with reference to the existing EVs for surface waters within the impact assessment area (refer Section 12.5.1), including existing water quality and condition (refer Section 12.7.2) and the sensitivity of water quality receptors (refer Section 12.7.3 and Section 12.7.4).

The assessment of surface water quality impacts has also included consideration of the assimilative capacity of the receiving environment through historic and existing compliance with existing WQOs. Currently, the existing water-quality conditions do not meet all the WQO values for each water type zone; therefore, the qualitative risk of degradation of water quality (against WQO) from potential Project impacts has been assessed in regard to the assimilative capacity of waterways to identify the magnitude of potential impact.

It is generally considered likely that the assimilative capacity of waterways within the impact assessment area will be greater during higher-flow conditions (refer Appendix P: Surface Water Quality Technical Report). In contrast, the lowest assimilative capacity and highest realisation of impact would occur during periods of extended low flow (such as those currently experienced). Potential impacts from the Project are expected to have the highest risk during periods of higher flow condition; however, this aligns with the highest assimilative capacity of the waterway, reducing overall impact magnitude.

The following sections provide a summarised discussion of the potential direct and indirect impacts to surface water quality as a result of Project activities. Further information is available in Appendix P: Surface Water Quality Technical Report.

Construction impacts

Potential direct and indirect impacts to surface water quality that may arise due to construction activities for the Project are discussed in Table 12.51. Impacts include those to the water feature itself, in addition to receptors that may be indirectly impacted due to alterations in water quality, such as fish species, riparian vegetation etc.

TABLE 12.51 POTENTIAL CONSTRUCTION IMPACTS TO WATER QUALITY AND IMPACTING PROCESSES

Potential impact	Impacting process
Increased debris load in waterways, thereby reducing the aesthetic quality of downstream waterway systems. Debris may also impact on the health of aquatic and terrestrial fauna, particularly if ingested.	Potential for rubbish and debris from construction sites to be blown off or washed away from a construction area into nearby waterways, due to poor housekeeping or loss of containment.
Altered water quality, principally from increased water turbidity and sedimentation. Suspended sediments can clog fish and invertebrate gills, decrease light availability for aquatic plants and reduce visibility for fish. Furthermore, localised high sediment contamination can become a barrier to migration of some species that then decline in abundance due to restriction in range or loss of seasonal habitat above the contaminated reach (ANZECC & ARMCANZ, 2018).	Increased sediment loading of waterways may arise due to: ▸ Construction activities that involved the clearance of vegetation and disturbance of topsoil, thereby leaving subsoils exposed to erosional processes. In turn, this may result in elevated sediment concentrations in surface runoff. ▸ Construction works involving disturbance to the riparian corridor (e.g. removal of riparian vegetation, alterations to the profile of banks etc.) may indirectly result in erosion and scouring of streambanks ▸ Physical disturbance of stream beds and banks during the establishment of culverts and bridges, leading to a reduction in stability during construction of creek crossings ▸ Dewatering associated with the decommissioning of artificial waterbodies that intersect the Project alignment may cause an increase in erosion and sedimentation of waterways if the discharge of that water is not adequately managed.

Potential impact	Impacting process

Altered water chemistry, including an increase in salinity.
Alterations to water chemistry may impact on the aquatic ecosystem condition of the downstream waterway system, as well as affect the useability of downstream waters for purposes such as irrigation, farm supply, stock use, recreation etc.
	Water chemistry may be altered due to the following processes:
	▶ Salinity:
	  ▶ Disturbance and exposure of saline soils during construction, which could increase salinity in overland flows. The Project alignment directly intersects moderate-to-high salinity hazard rating areas (refer Figure 12.4), which may result in discharge of saline runoff into proximal waterways. The risk is considered to be low where there is existing disturbance at points where the Project alignment crosses the waterways, e.g. existing rail corridor.
	  ▶ Changes to riparian vegetation communities, stockpiling of sediment and Project-associated earthworks may result in saline discharge at drainage points into watercourses proximal to high salinity hazard areas.
	▶ Nutrient loading:
	  ▶ Nutrients may migrate into waterways with sediment lost from cleared areas and from stockpiles. This has the potential to:
	    – Change light conditions and water temperature
	    – Smother aquatic life and prevent photosynthesis for aquatic flora
	    – Affect downstream environments
	    – Impact on breeding and lifecycle of aquatic fauna.
	▶ Contaminants and toxicants:
	  ▶ Accidental spills and leaks of chemicals or fuels from construction equipment or fuel storages, which could introduce chemicals into overland flows
	  ▶ Chemical spills, due to inappropriate storage controls, resulting in an introduction into waterways of fuels and oils used for construction machinery
	  ▶ Contaminants may also leach from the following sources during construction:
	    – Residual heavy metals from rail grinding and welding
	    – Compounds adhered to ballast materials.
	  ▶ Dewatering activities leading to liberation of toxicants from potentially contaminated land
	  ▶ Contaminated land disturbance—if any nearby contaminated lands are disturbed near waterways, there is the potential for contamination from runoff on these waterways.

Wastewater consists of:

- Domestic wastewater, i.e. water used in toilets, showers, baths, kitchen sinks and laundries
- Industrial or trade waste, i.e. from manufacturing and industrial operations. This includes liquid waste from any process (e.g. water used to cool machinery or clean plant and equipment).
- Stormwater (including discharge from dewatering), i.e. water that would flow without intervention, untreated, into waterways.

Quantities of wastewater that may be generated during construction of the Project cannot be established, as the construction methodology is subject to confirmation. For example, volumes of wastewater generated through activities such as dewatering of excavations and pier holes will be dependent on the Principal Contractor's approach to constructing Project elements such as bridge piers. The following sections discuss each of the potential sources of wastewater during construction and provide details on the proposed management approach for each.

Domestic wastewater

Sources of domestic wastewater during construction will be restricted to the following:

- Toilets and kitchenette facilities provided in site office locations along the Project footprint
- Portaloos established at work fronts
- Operation of up to three non-resident workforce accommodation.

It is expected that each of these potential sources of domestic wastewater will be self-contained and will not require discharge of wastewater to sewer or to waterways.

Wastewater generated through the use of toilets and kitchenette facilities in office sites and work fronts will be captured and containerised. It is expected that this wastewater will be collected by a licensed waste contractor and taken offsite for disposal at an appropriately licensed wastewater facility.

Each non-resident workforce accommodation facility will have a 300-bed capacity, with occupancy expected to vary from 150 to 300 persons depending on the construction schedule. Based on an average dry weather flow (ADWF) sewage input of 150 litres per person per day (L/EP/d), between 22.5 and 45 kilolitres (kL) of wastewater may be generated on each non-resident workforce accommodation facility, per day. This ADWF volume is the lower end of the 150–275 L/EP/d suggested by the Water Services Association of Australia Sewerage Code (WSAA 2002); however, the lower ADWF value is considered appropriate for a non-resident workforce accommodation facility, as the residents will not be there during construction hours. Wastewater generated on non-resident workforce accommodation facilities will be treated in temporary package sewage treatment plants located onsite (estimated capacity of 300 equivalent population). Further details on the non-resident workforce accommodation are provided in Chapter 5: Project Description.

Industrial or trade waste

Sources of industrial or trade waste during construction will be limited, but may include:

- Precast concrete facility and concrete batch plant
- Vehicle and plant washdown facilities, located in laydown areas, non-resident workforce accommodation or concrete batching facilities.

Two locations have been identified for the temporary siting of a precast concrete facility and concrete batch plant for the Project (refer Table 12.52). While two locations have been nominated, only one plant is expected to be necessary to supplement the supply of concrete from established plants. The proposed locations are immediately north and south of the Condamine River floodplain outside the 1% AEP flood line.

TABLE 12.52 PRECAST CONCRETE FACILITY AND CONCRETE BATCH PLANT LOCATIONS

ID[1]	Location	Chainage	Description
B2G–LDN150.5	Gore Highway and Dieckmann Road	Ch 150.5 km	Precast concrete facility and concrete batch plant—north
B2G–LDN137.0	Gore Highway	Ch 137.0 km	Precast concrete facility and concrete batch plant—south

Table note:

1. Refer to drawings in Volume 3 of the draft EIS

Once appointed, the Principal Contractor will assess the need for a concrete batching facility and will be responsible for applying for and obtaining the necessary approvals to establish and operate the precast concrete facility and concrete batch plant.

Where industrial or trade waste may be generated by construction activities, the resultant wastewater will be captured and, where possible, recycled. Where recycling is not feasible, the captured wastewater will be collected by a licensed contractor and taken offsite for disposal at an appropriately licensed wastewater facility.

Stormwater

Sources of stormwater and other wastewater during construction may include:

- Stormwater runoff from construction sites
- Water that is discharged from dewatered excavations and trenches
- Water that accumulates in cuts due to groundwater seepage.

Temporary site drainage and water management controls will be installed in order to minimise the impacts of runoff and sedimentation from construction activities on adjacent receptors. Temporary site drainage and water runoff management will be in line with the *Best Practice Erosion and Sediment Control* (International Erosion Control Association, 2008) and will:

- Minimise runoff and sedimentation from Project activities to existing watercourses and drainage features
- Minimise disturbance to the water quality of existing watercourses and drainage features along the Project alignment.

The reference design includes 17 sediment basins, as identified in Table 12.53. All of the proposed sediment basins are passive, which allows surface runoff from a catchment to flow into the sediment basin without the need for pumping. The locations of sediment basins are shown in working plans and longitudinal sections presented in Volume 3 of the draft EIS.

The placement and sizing of sediment basins for the Project has been established based on the landform and earthworks required to construct the reference design; therefore, the placement and sizing of sediment basins will need to be reassessed and revised, as required, as part of the detail design process. Sufficient allowance has been included in the Project footprint for sediment basins to be relocated and/or resized, as required, to support the detail design.

TABLE 12.53 SEDIMENT BASINS FOR THE PROJECT

Sediment basin ID and chainage[1]	Catchment size (m^2)	Settling volume (m^3)	Total volume (m^3)
Sediment basin 1 (Ch.48.5 km)	35,175	409	613
Sediment basin 2 (Ch.73.7 km)	116,116	1,349	2,024
Sediment basin 3 (Ch.52.7 km)	88,708	1,031	1,546
Sediment basin 4 (Ch.55.5 km)	86,440	1,004	1,506
Sediment basin 5 (Ch.60.4 km)	85,664	995	1,493
Sediment basin 6 (Ch.61.5 km)	31,279	363	545
Sediment basin 7 (Ch.63.1 km)	27,150	315	473
Sediment basin 8 (Ch.73.6 km)	40,187	467	700
Sediment basin 9 (Ch.163.1 km)	20,571	239	359
Sediment basin 10 (Ch.170.6 km)	20,720	241	361
Sediment basin 11 (Ch.172.6 km)	82,424	958	1,436
Sediment basin 12 (Ch.179.9 km)	68,475	796	1,193
Sediment basin 13 (Ch.183.5 km)	41,256	479	719
Sediment basin 14 (Ch.191.8 km)	51,268	596	893
Sediment basin 15 (Ch.195.7 km)	67,138	780	1,170
Sediment basin 16 (Ch.204.4 km)	63,918	743	1,114
Sediment basin 17 (Ch.204.6 km)	7,425	86	129

Table note:
Refer to drawings in Volume 3 of the draft EIS

Other temporary stormwater retention structures, other than those listed in Table 12.53, may be required in order to prevent the direct discharge of stormwaters leaving the construction site directly into waterways.

In addition to sediment basins, construction sites will be set out, through a combination of landform and use of temporary erosion and sediment control measures, in a manner to minimise the volume of surface runoff that flows across the cleared areas within the construction footprint. Construction sites will also be established to ensure that potential sources of contamination (e.g. fuels and other hazardous materials) are appropriately stored and bunded.

In the first instance, stormwater and water that is dewatered from excavations (i.e. trenches and pits), or private storages within the Project footprint that are being decommissioned, will be directed to a temporary retention structure where the water will be retained in order to allow suspended solids to settle out of suspension and for evaporation to occur. If waters are to be discharged from site, either directly or indirectly, it will be done in a manner that ensures the discharged water is compliant with the relevant WQOs for the receiving waterway (refer Section 12.5).

Predictive modelling for groundwater seepage has determined that seepage may occur from the face of deep cuts (>10 m) where groundwater is intersected; however, the assessment has concluded that seepage water, in general, will evaporate due to local climate conditions and relatively small volumes when considered with the length of the cuts. For example, cut 310–C37 is predicted to encounter seepage volumes of 0.23 L/s and 3.3 L/s across the entire surface of a 2.29 km cut, to 29.7 m depth. As such, it is not anticipated that a means of capturing, treating and deposing of seepage water will be required there during construction. Further details are provided in Chapter 13: Groundwater.

Operation and maintenance impacts

Potential direct and indirect impacts to surface water quality that may arise due to operation and maintenance activities for the Project are discussed here. Impacts include those to the water feature itself, in addition to receptors that may be indirectly impacted due to alterations in water quality, such as fish species, riparian vegetation, etc. Many of the potential impacts and impacting processes are consistent with those that may occur during construction (refer Table 12.51) and full duplication of details has not been provided.

Operation and maintenance impacts to surface water quality may include:

- Increased debris due to rubbish and debris from operations blown off or washed away from the rail corridor into proximal watercourses
- Introduction of contaminants from a variety of sources during operation and maintenance due to:
  - Oil and grease spills—there is the potential for oil and grease from rollingstock to enter the waterways after heavy rainfall events
  - Residual heavy metals from maintenance rail grinding and welding
  - Leaching of compounds that are adhered to ballast materials
  - Leaching of materials from within the rail formation, if localised material encapsulation or embankment zoning were to fail
  - Accidental spills from freight carriages during routine operations
  - Chemicals, including fuels and oils, used for maintenance machinery.
- Structural failure—with the introduction of bridge or culverts within waterways, should these structures fail, there is the potential for impacts to water quality either from potential contaminants (debris) or from detained water flushing from collapsed structures. Furthermore, structural failure has the capacity to alter flow regimes and increase potential secondary salinity issues, with flow-on issues resulting in surface water quality degradation.
- Maintenance—maintenance of the rail line or machinery near waterways (such as the crossing loops associated with Macintyre Brook at approximate Ch 50.20 km to Ch 52.40 km) has the potential to mobilise sediments from disturbed areas and increase the potential for litter or rubbish to enter waterways. Furthermore, oils and greases and other contaminants, such as metals, have the potential to enter waterways from spills, and for impact from the use of environmental toxicants (such as biocides) to maintain operating infrastructure areas. These activities have the potential to impact nearby waterways through discharge points, without appropriate mitigation.
- Increase in rates of erosion and resultant sedimentation of waterways, due where soils are exposed as a result of unsuccessful site rehabilitation.

Operation phase wastewater volumes cannot be established, as the frequency and nature of maintenance activities, and rate of wastewater generation, will vary between Project components and be in response to asset age and condition. In any event, wastewater generated during operation and maintenance will be infrequent and small in volume.

Point source discharge of stormwater for the Project is anticipated only to occur where longitudinal drainage connects to location of cross-drainage. The purpose of longitudinal or track drainage is to remove water that has percolated through the track ballast, and to divert surface runoff to the nearest bridge or culvert location before it reaches the subgrade. Without adequate track drainage, the subgrade may become saturated, leading to weakening and subsequent failure of the subgrade.

Two types of track drainage are proposed:

- Embankment drains—longitudinal drains that run parallel to the railway and are located within the rail corridor, at the foot of the railway embankment
- Catch drains—longitudinal drains that run parallel to the railway and are located within the rail corridor, on the up-slope side of cuttings.

Track drainage is proposed at specific locations along the Project alignment where the gradient is steep enough to divert surface runoff to the nearest bridge or culvert location. The design and location of track drainage will be refined, if required, during the detail design phase.

Discharges of stormwater from the rail corridor are only likely to occur during weather events that contribute to inputs to the local waterway system from other sources at the same time, e.g. agricultural properties and road surfaces; therefore, the impact of stormwater discharges into the local water system during such events are likely to be negligible.

As a means of verifying this, theoretical stormwater quality modelling was undertaken using MUSIC modelling (Model for Urban Stormwater Improvement Conceptualisation) to compare the existing discharge conditions within the impact assessment area with the discharge conditions due to longitudinal drainage infrastructure included in the reference design. The modelling compared TSS, TP and TN levels in existing discharge conditions against stormwater discharged from longitudinal drains that were applied with 3.5 m buffer strips within 100 m swales before the point of discharge. Swales are grassed or vegetated broad, shallow channels used to collect and convey stormwater flows, promote infiltration, reduce stormwater peak flow rates and discharge volumes, and remove sediments. Swales use a combination of physical and biochemical processes to treat stormwater (Department of Water, 2011). Buffer strips are vegetated areas that reduce sediment loads from water flowing through them. Buffer strips are aligned perpendicular to the water flow. They are commonly used in conjunction with swales (Department of Water, 2011).

The modelling indicated that impacts to rural areas associated with potential stormwater discharges are expected to be negligible, with buffering from swales producing discharge of a better quality (reduced concentrations) than typical for rural areas; therefore, with proposed treatment measures in place, water quality leaving the rail corridor is expected to be similar to, or better than, runoff from the existing condition of the rural environments. The proposed Project treatment requirements are considered adequate for water quality receptors, provided sufficient buffer strips and swales are provided.

Modelled operational discharge along the Project alignment is predicted to contain suspended solids and nutrients in concentrations higher than forested conditions; however, these pollutant loads would be expected to be discharged from a comparable area of nearby rural catchment. It is expected that these will be contained within the areas of targeted rehabilitation zones and be limited in impact. Although impacts to water quality are theoretically possible, these will be mitigated with the provision of grassed rehabilitation strips along the length of the rail formation. Any impacts are likely to be minor and associated with highly constrained sites where buffer strips and swales cannot be provided.

12.8.1.2 Impacts to waterway morphology

The reference design does not require permanent diversion of any watercourses, as defined under the Water Act; however, three drainage features (not mapped watercourses under the Water Act) defined as waterways under the Fisheries Act are expected to require diversion based on the reference design (refer Section 12.7.1.2).

One trapezoidal diversion drain is required from Ch 120.77 km to Ch 121.92 km to divert runoff from the west away from the rail alignment, which is located in cut in this chainage range. The rail in cut intersects two waterway flow paths at Ch 120.77 km and Ch 121.43 km. The diverted flow returns to the original flow path 750 m downstream of the rail at Ch 120.77 km. The diversions from Ch 120.77 km to Ch 121.92 km are identified as low risk-of-impact waterways under the DAF *Queensland Waterways for Waterway Barrier Works* spatial mapping (DAF, 2020).

An additional trapezoidal diversion drain is proposed where the rail embankment overlays an existing flow path. This affected flow path runs for 150 m from Ch 190.66 km to Ch 190.81 km. The diversion from Ch 190.66 km to Ch 190.81 km is identified as a low risk-of-impact waterway under the DAF *Queensland Waterways for Waterway Barrier Works* spatial mapping. Where waterway diversions are necessary for unmapped waterways following the finalisation of design, a watercourse determination will need to be made in order to confirm approval requirements.

The level of risk relating to each waterway will be considered during detail design of all structures located within the bankfull width of waterways, such as culverts, bridges (piers and abutments) and other potential barriers. A list of cross-drainage infrastructure points along the Project alignment is provided in Appendix P: Surface Water Technical Report. Designs will need to be in accordance with the factsheet, *What is not a waterway barrier work?* (DAF, 2017c), or accepted development requirements for operational work that is constructing or raising waterway barrier works, or under a relevant development approval.

In-stream works will need to be undertaken in accordance with *Accepted Development Requirements for Operational Work that is Constructing or Raising Waterway Barrier Works* (DAF, 2018e) for lower-risk watercourses. In-stream works for higher-risk watercourses will be planned and undertaken in accordance with applicable assessment benchmarks for assessable development. Where in-stream works are developed in accordance with applicable accepted development requirements or acceptable outcomes within relevant codes, works are expected, at a minimum, to reduce increases in barriers for water movement during construction.

In-stream works will also need to be undertaken in accordance with the requirements of the *Riverine Protection Permit Exemption Requirements* (DNRME, 2018a). ARTC is an 'approved entity' for exemption from the requirement for Riverine Protection Permit applications. As such, activities associated with in-stream disturbance works will be exempt from requiring approval, as long as the exemption requirements are adhered to.

12.8.1.3 Impacts to surface water availability and users

Construction water requirements

Significant volumes of water will be required for various activities associated with construction of the Project, including for earthworks, concrete production, track works and the operation of non-resident accommodation. A summary of the estimated water requirement by construction activity is presented in Table 12.54. Further details on the estimated construction water demand, including the estimated construction water usage over time for the Project and the estimated water demand along the length of the Project alignment are presented in Chapter 5: Project Description.

TABLE 12.54 SUMMARY OF ESTIMATED WATER REQUIREMENT BY CONSTRUCTION ACTIVITY

Construction activity	Estimated water requirement (ML)
Rail	
Material conditioning	1,225
Dust suppression and revegetation[1]	613
Haul road and laydown area maintenance	490
Rail total:	**2,328**
Roads	
Material conditioning	110
Dust suppression and revegetation[1]	55
Haul road and laydown area maintenance	44
Roads total:	**209**

Construction activity	Estimated water requirement (ML)
Track works	
Dust suppression during ballast dropping	1.30
Dust suppression during tamping and regulating	0.86
Track works total:	**2.16**
Concrete[2, 3]	
Precast concrete	4.8
Wet (bulk) concrete	10.2
Concrete total:	**15.0**

Table notes:

1. This allowance covers the water required to re-establish vegetation on disturbed surfaces following the completion of works
2. Excludes concrete (insitu and precast) for culverts, which will all be supplied by existing commercial suppliers.
3. For insitu concrete required between Ch 138 km and Ch 165 km. Insitu concrete required outside of this chainage range will be supplied by existing commercial concrete batching plants.

The total daily water usage on non-resident workforce accommodation is a factor of a site's occupancy numbers and includes water used for the following purposes:

- Toilets
- Showers
- Laundry
- Food preparation
- Cleaning.

The average daily water use per person recorded by TRC in February 2020 was 120 L per person per day (L/p/d), with a maximum of 322 L/p/d (Millmerran) and a minimum of 44 L/p/d (Haden) (TRC, 2020). Based on this data, a conservative daily volume of 340 L/p/d has been adopted to estimate the water usage for non-resident workforce accommodation. For three non-resident workforce accommodation sites operating at full capacity (300 beds) over a 58-month period, a total conservative water usage of 540 ML is estimated. A breakdown of this total volume is presented in Table 12.55.

TABLE 12.55 ESTIMATED WATER USAGE FOR NON-RESIDENT WORKFORCE ACCOMMODATION

Rate of water usage (L/p/d)	Occupants per non-resident workforce accommodation facility	Daily water usage (kL/day/facility)	Days of operation[1]	Total water usage per non-resident workforce accommodation facility (ML)	Number of non-resident workforce accommodation facility	Total water usage (ML)
340	300	102	1,765	180.03	3	540.09

Table notes:

1. Based on 58 months of non-resident workforce accommodation operation

Construction water sources

ARTC recognises water sourcing and availability is critical to supporting the construction program for the Project. Sources of construction water will be finalised as the construction approach is refined during the detail design phase of the Project (post-EIS). Through this process, detailed water demand planning will be undertaken, including detailed contingency options, in the event that protracted dry seasonal conditions prevail and water supply options become unavailable.

The ultimate water sourcing strategy for the Project will be documented in a Construction Water Plan and be dependent on:

- Climatic conditions in the lead up to construction
- Confirmation of private water sources made available to the Project by landowners under private agreement and in consultation with DNRME
- Confirmation of access agreements with local governments for sourcing of mains water
- Consultation with the state regarding access to water via markets, water licenses and water permits.

Options for the sourcing of construction water, subject to availability, are anticipated to be as follows:

- Commercial, licensed water supplies where capacity exists
- Public surface water storages, i.e. dams and weirs
- Permanently (perennial) flowing watercourses
- Privately held water storages, i.e. dams or ring tanks, under private agreement
- Existing registered and licensed bores
- Treated water, e.g. from wastewater treatment plants
- New bores established to service the Project under appropriate water licence or entitlement (least preferred option).

An assessment of the suitability of each source will need to be made for each construction activity requiring water, based on the following considerations:

- Legal access
- Volumetric requirement for the activity
- Water quality requirement for the activity, e.g. non-resident workforce accommodation will need potable water
- Source location relative to the location of need.

Dams and weirs that are located in the vicinity of the Project are listed in Table 12.12. These dams have, subject to climatic conditions, the ability to supply the required volume for construction water for the Project; however, the transportation cost of sourcing all construction water from these locations is prohibitive. Therefore, other sources will need to be accessed to meet the full construction water demand for the Project.

Surface water storages, identified in Table 12.12 or otherwise, may be accessed for the sourcing of construction water, subject to obtaining the appropriate water allocation or licence under the Water Act.

Current dam levels are reflective of the prolonged drought conditions in Queensland. The availability of water from these sources will continue to be dependent on climatic conditions prior to and during construction.

Consultation with the Dumaresq–Barwon Border Rivers Commission, Sunwater, GRC and TRC during the detail design process will be required to establish the availability of water from dams and weirs in proximity to the Project.

The following perennial watercourses are in proximity to the Project:

- Oakey Creek
- Hodgson Creek
- Condamine River North Branch
- Condamine River
- Canning Creek
- Macintyre Brook
- Brigalow Creek
- Macintyre River.

Extraction of water from a watercourse typically requires:

- A water allocation, water licence or water permit. Applications for resource entitlements are assessed against relevant criteria in the Water Act and relevant water resource plan and resource operations plan.
- A development permit for use of water that is assessable development under the Planning Act.

The DNRME maintains *Exemption requirements for constructing authorities for the take of water without a water entitlement* (WSS/2013/666) (DNRME, 2020b). These exemption requirements may only be used by a constructing authority defined under Schedule 2 of the *Acquisition of Land Act 1967* (Qld) (AL Act) and includes State government departments and local governments. At present, these guidelines do not directly apply to ARTC; however, ARTC's eligibility to operate under the exemption requirements will be reassessed prior to the commencement of construction.

If ARTC and its contractors remain ineligible to operate under the exemption requirements, or are unable to comply with the requirements, then a temporary water permit would be required before taking any water for construction purposes.

Other opportunities for potential sources of water for the Project are as follows:

- Recycled water: a 97-km pipeline currently transfers water from the Wetalla Water Treatment Plant in Toowoomba to the Millmerran Power Station. This potential water source could be further investigated through consultation with the operators of the Millmerran Power Station, Intergen, during the detail design process (post-EIS) to determine if there is unused capacity that may be suitable for construction water.
- Commodore Mine: water is supplied to the Commodore Mine. Wastewater is also generated through the mine's operations. These potential water sources could be further investigated through consultation with the operators of the mine, Intergen, during the detail design process (post-EIS) to determine if there is unused capacity that may be suitable for construction water.
- Privately owned water storages: smaller dams located on private properties along the Project alignment may be suitable as a source of construction water. Accessing such water would require private agreement between ARTC and the relevant landowner.

The quality characteristics of water used by the Project during construction will be dependent on its intended use. The water quality requirements for the various activities associated with construction of the Project are summarised in Table 12.56.

TABLE 12.56 WATER QUALITY REQUIREMENTS FOR CONSTRUCTION ACTIVITIES

Activity	Water quality requirement
Earthworks	No specific quality criteria
Concrete batching	Specified in *AS 1379: Specification and supply of concrete* (Standards Australia, 2007)
Track works	No specific quality criteria
Non-resident workforce accommodation	Potable water will need to achieve the quality requirements specified in the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2011)
Vegetation establishment, landscaping and rehabilitation	Water should be consistent with the quality requirements specified for irrigation and general water use in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2018)

Licensed water users

Extraction of water from a watercourse typically requires:

- A water entitlement, water allocation, water licence or water permit. Applications for resource entitlements are assessed against relevant criteria in the Water Act and relevant water resource plan and resource operations plan.
- A development permit for use of water that is assessable development under the Planning Act.

Water allocation licence data indicates that 285,999 ML per year is allocated within several management areas (under Water Regulation 2016) that intersect the impact assessment area. For further information regarding surface water licencing within the impact assessment area, refer to Appendix P: Surface Water Quality Technical Report.

There is the potential to impact on licenced users of surface water if the quality of water or the flow of water changes within offtake locations on or associated with:

- Canning Creek
- Condamine River
- Macintyre River
- Westbrook Creek
- Oakey Creek.

In a worst case, impacts to water quality as a result of Project activities during construction may have temporary impacts to local water users, potentially restricting access to human drinking water, stock water and crop irrigation.

Aquatic ecosystems have the most stringent WQOs of the EVs that are of relevance to the impact assessment area; therefore, implementing mitigation measures to ensure protection of aquatic ecosystems, protection of other EVs and water users downstream of the Project will be achieved.

The detail design will be developed to ensure that, where possible:

- Private water storages are avoided
- Affected landowners retain access to existing natural resources.

If impacts to either of the above cannot be avoided through design, appropriate compensation arrangements will be discussed and agreed with the relevant impacted landowner.

12.8.2 Hydrology and flooding

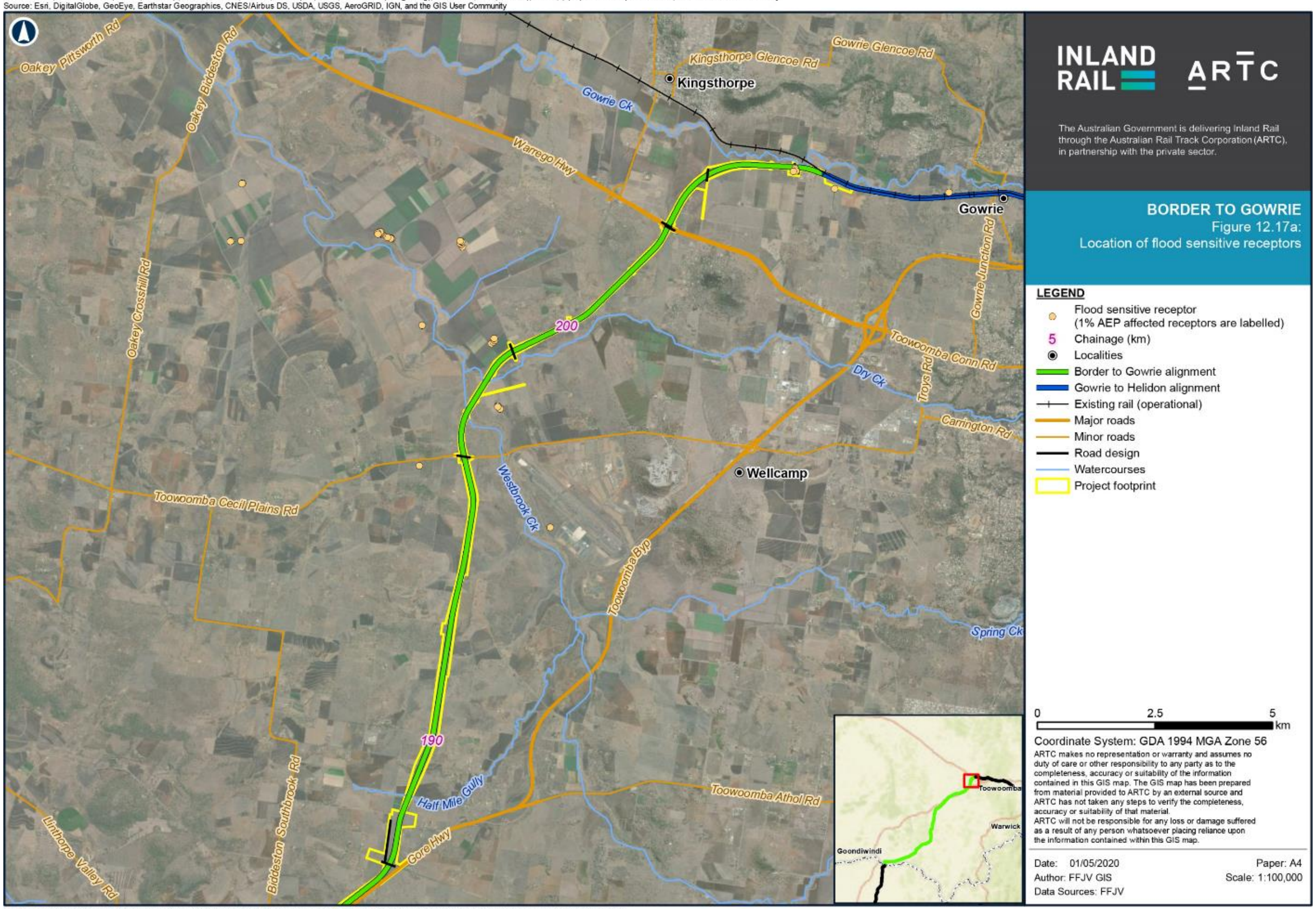
Flood-sensitive receptors were identified from aerial and satellite imagery and ground-truthed, where possible, during site visits. In certain cases, such as the Condamine River floodplain, flood-sensitive receptors were confirmed with affected landowners. Flood-sensitive receptors include dwellings, sheds, commercial properties (such as petrol filling stations and shops), silos, hospitals, roads, rail lines, airports, etc. A total of 545 flood-sensitive receptors were identified within the impact assessment area, as shown in Figure 12.17a–k.

In terms of the flooding regime, the potential impacts associated with the construction and operation phases of the project are similar. These impacts may affect all flood-sensitive receptors, and include:

- Changes in peak water levels and associated areas of inundation
- Concentration of flows, redirection of flows and/or changes to flood flow patterns
- Increased velocities leading to localised scour and erosion
- Changes to duration of inundation, and subsequent impacts to the design life of existing assets and the viability and tolerance of crops
- Increased depth of water affecting trafficability of roads and tracks.

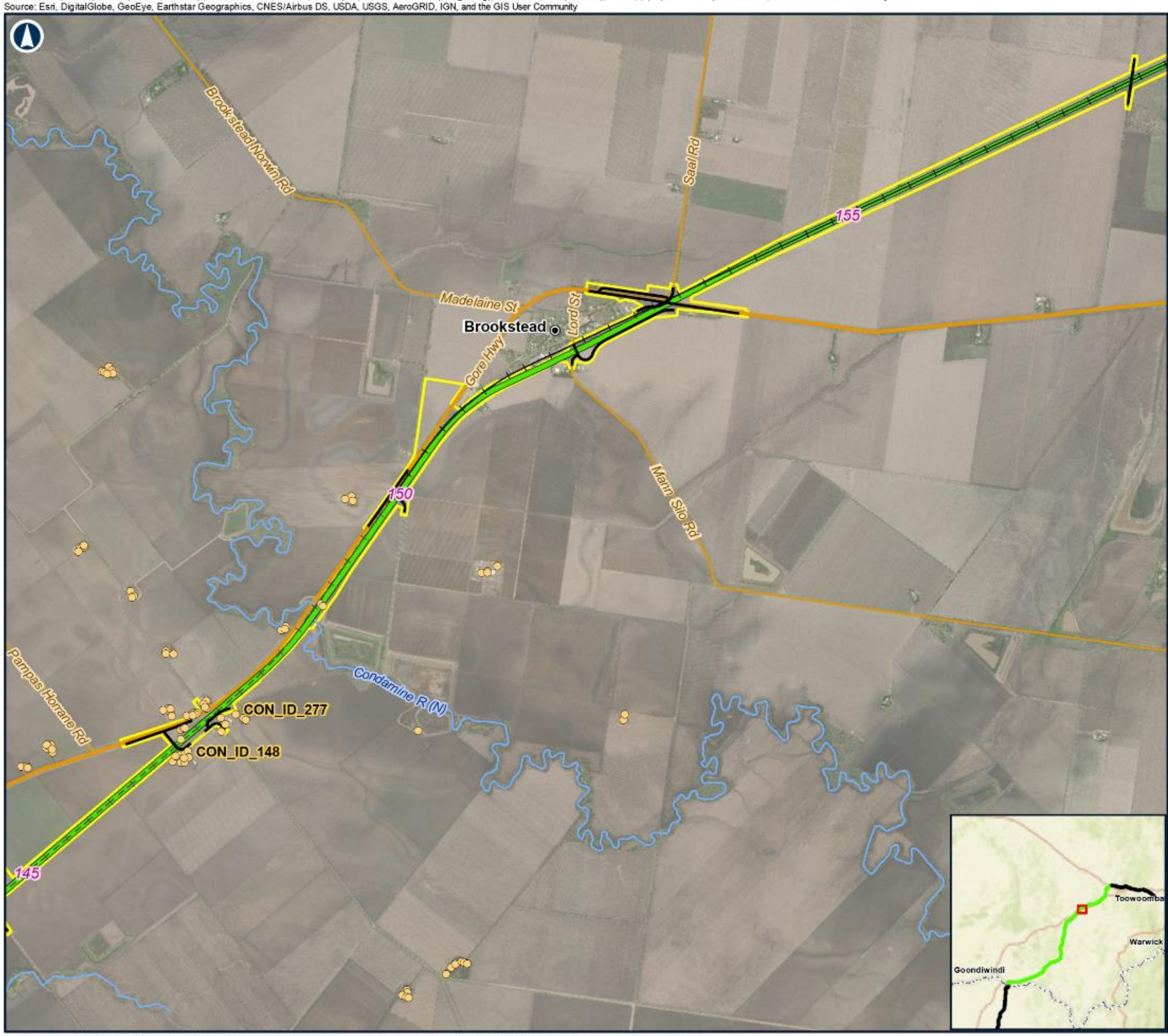
The quantified flooding impacts associated with the Project alignment and drainage structures are detailed in Section 12.10.2.

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: MF/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202005121229_SurfaceWaterEIS\310-IHY-202005121229_ARTC_Fig12-17x_SensitiveR.mxd Date: 8/06/2020 18:09

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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 12.17b:
Location of flood sensitive receptors

LEGEND
- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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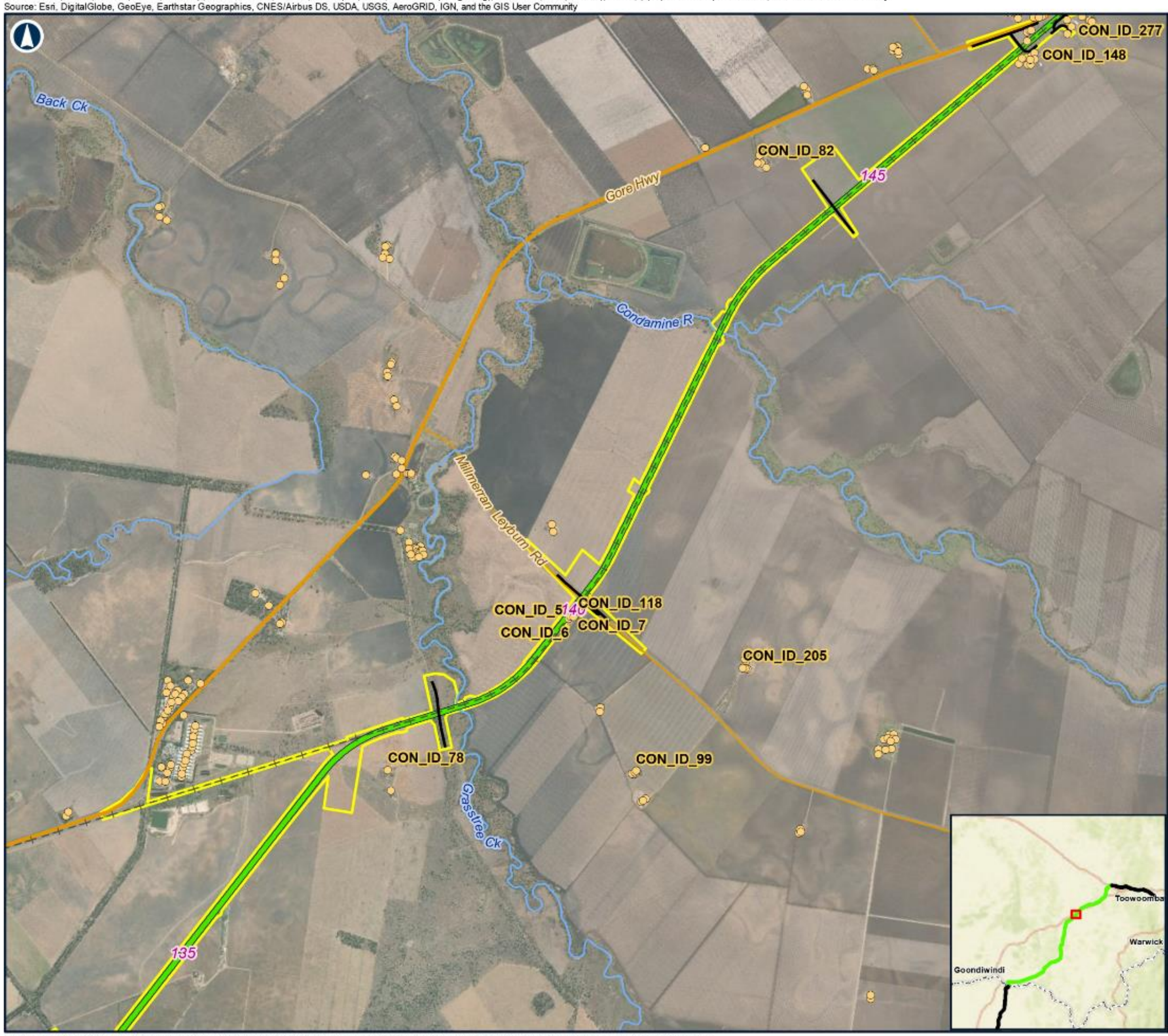

INLAND RAIL
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BORDER TO GOWRIE
Figure 12.17c:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 01/05/2020
Author: FFJV GIS
Data Sources: FFJV

Paper: A4
Scale: 1:50,000

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BORDER TO GOWRIE
Figure 12.17d:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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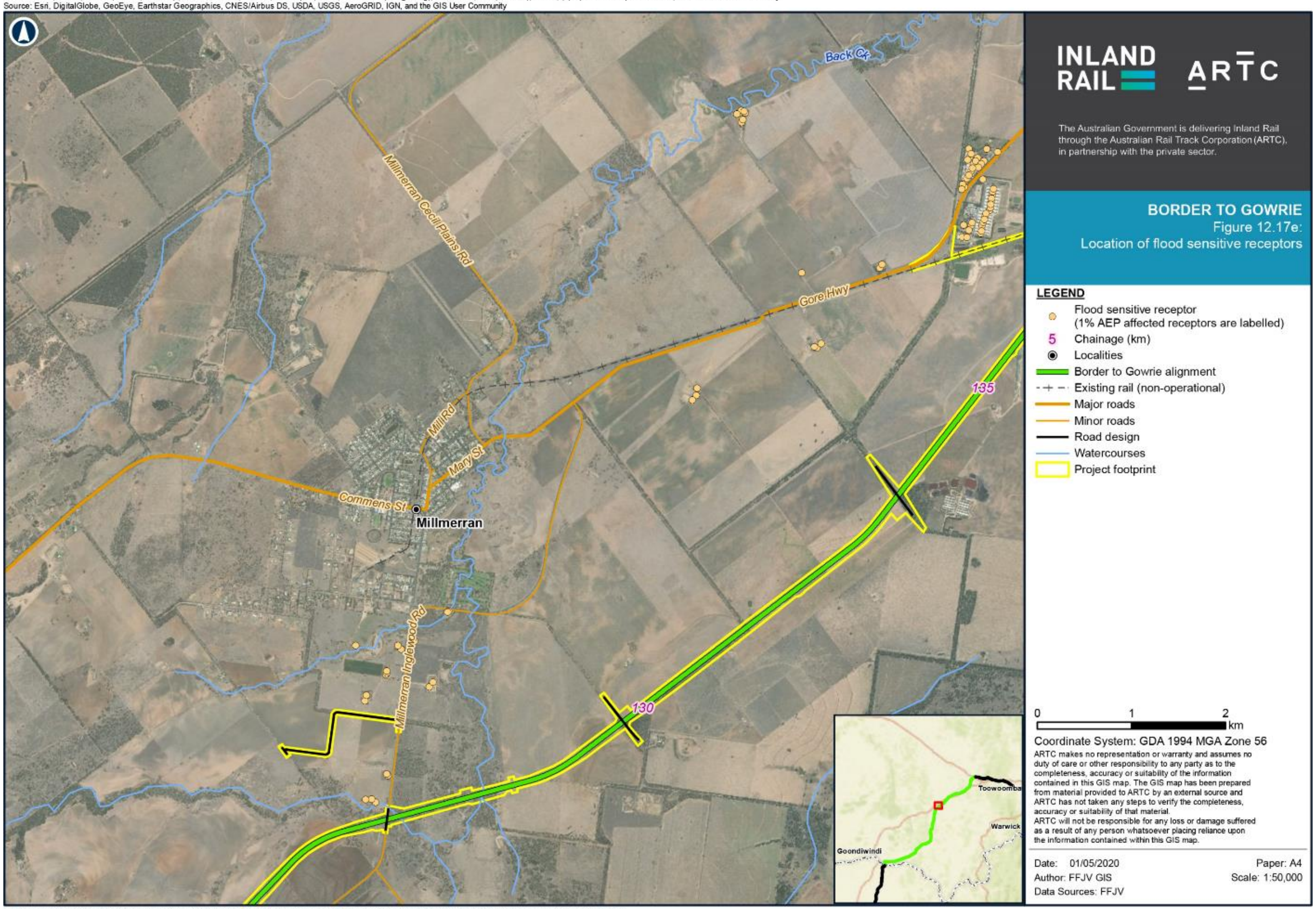

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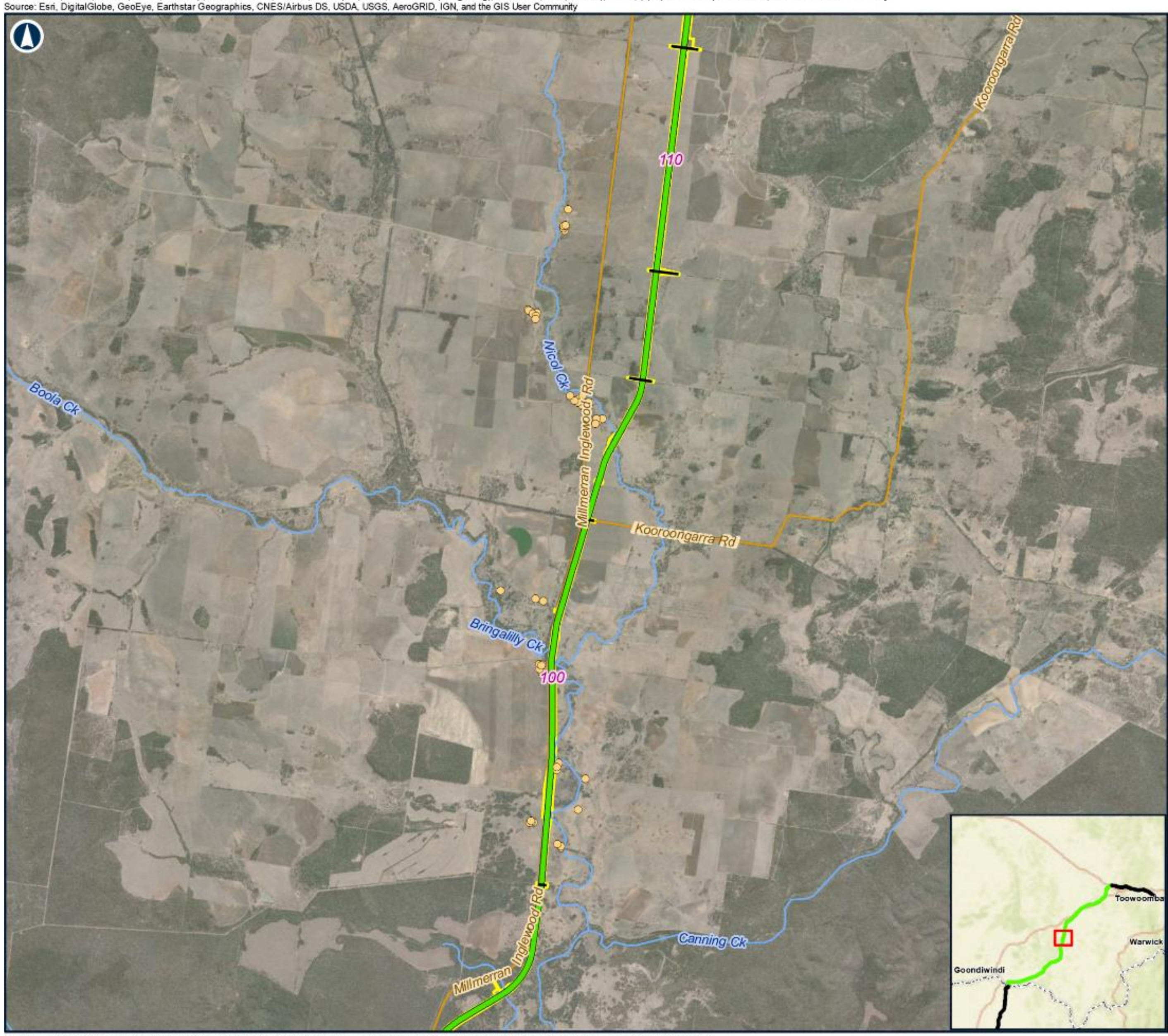

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BORDER TO GOWRIE
Figure 12.17f:
Location of flood sensitive receptors

LEGEND
- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:100,000
Data Sources: FFJV

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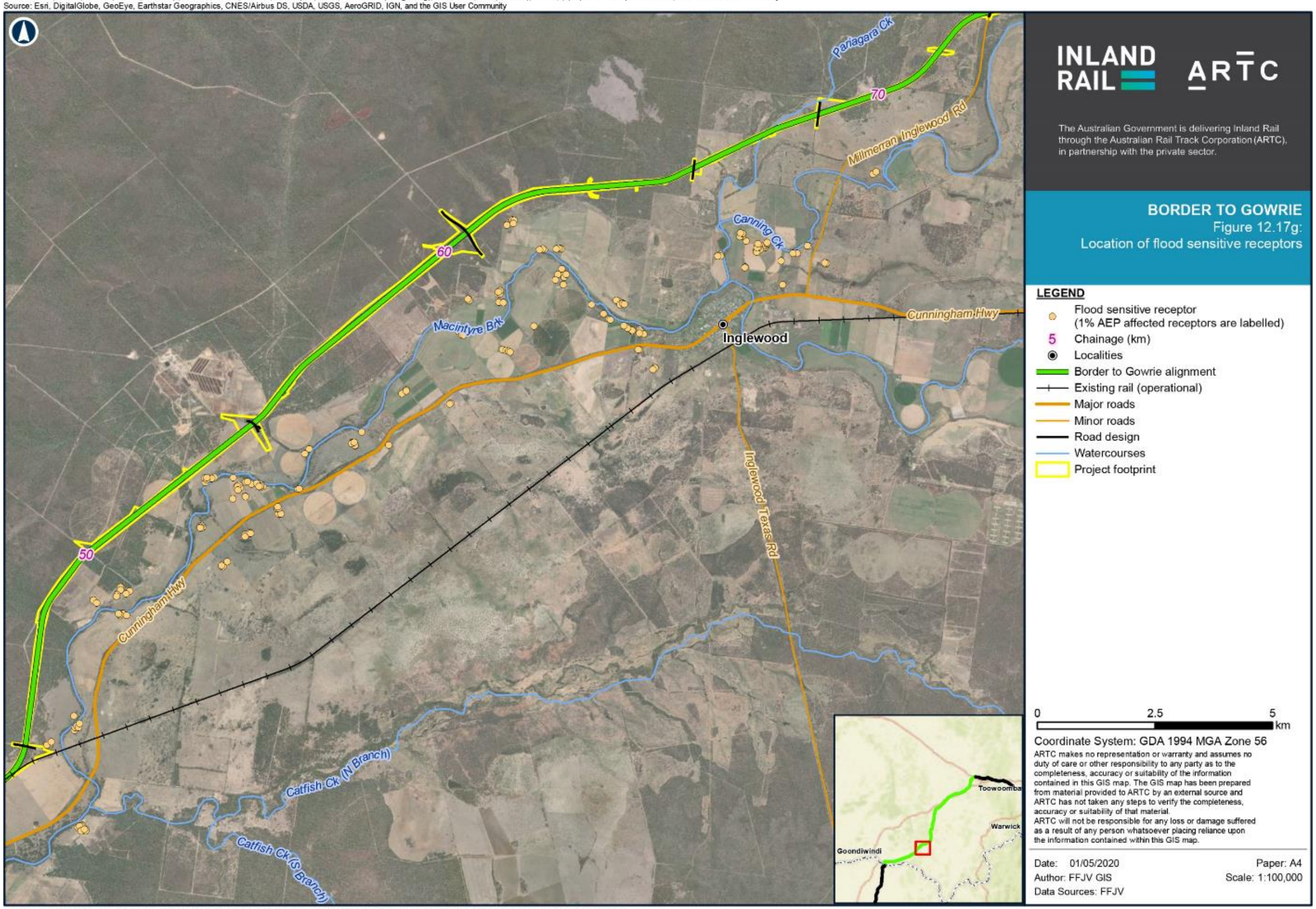

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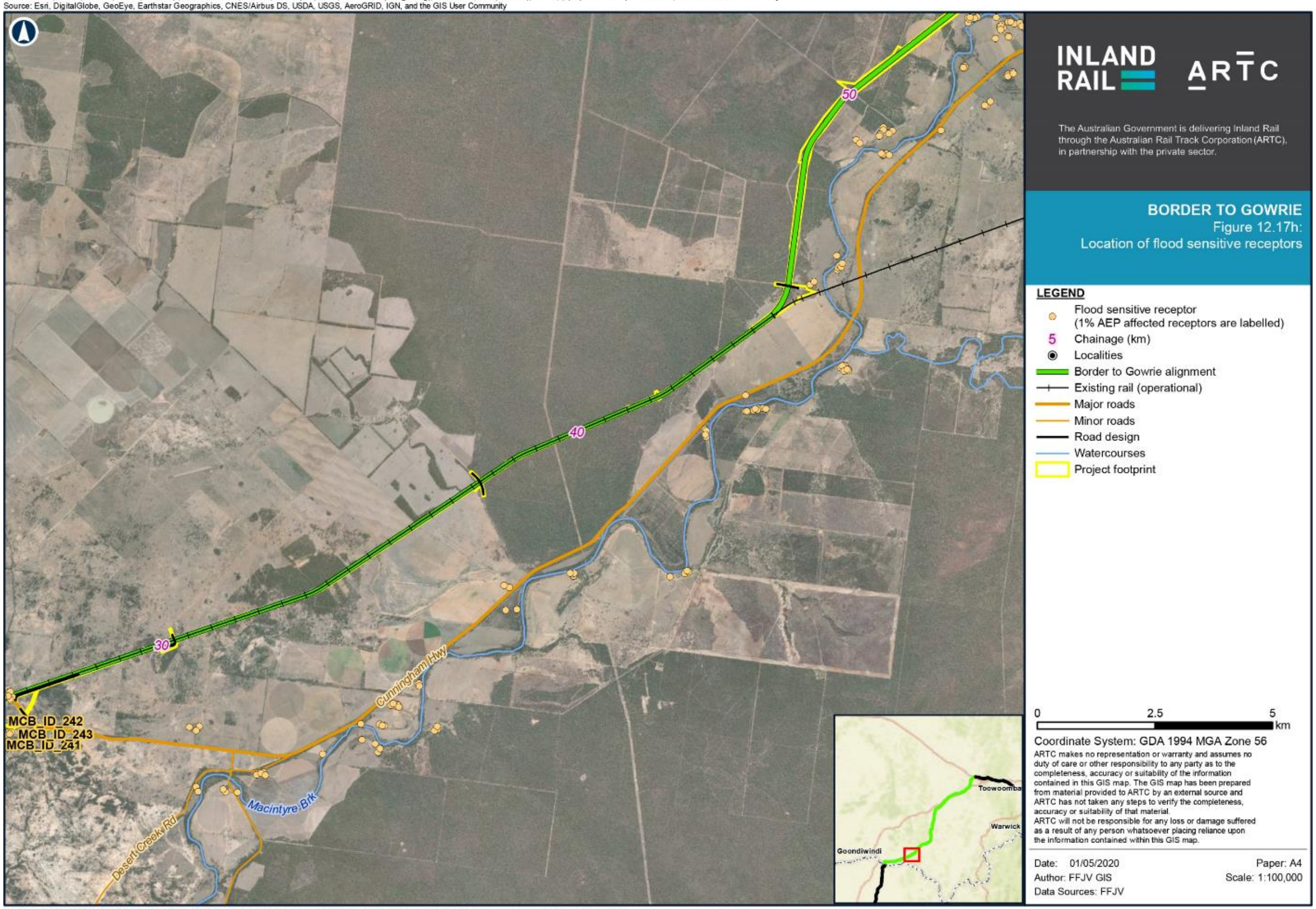

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BORDER TO GOWRIE

Figure 12.17i:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE
Figure 12.17j:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV

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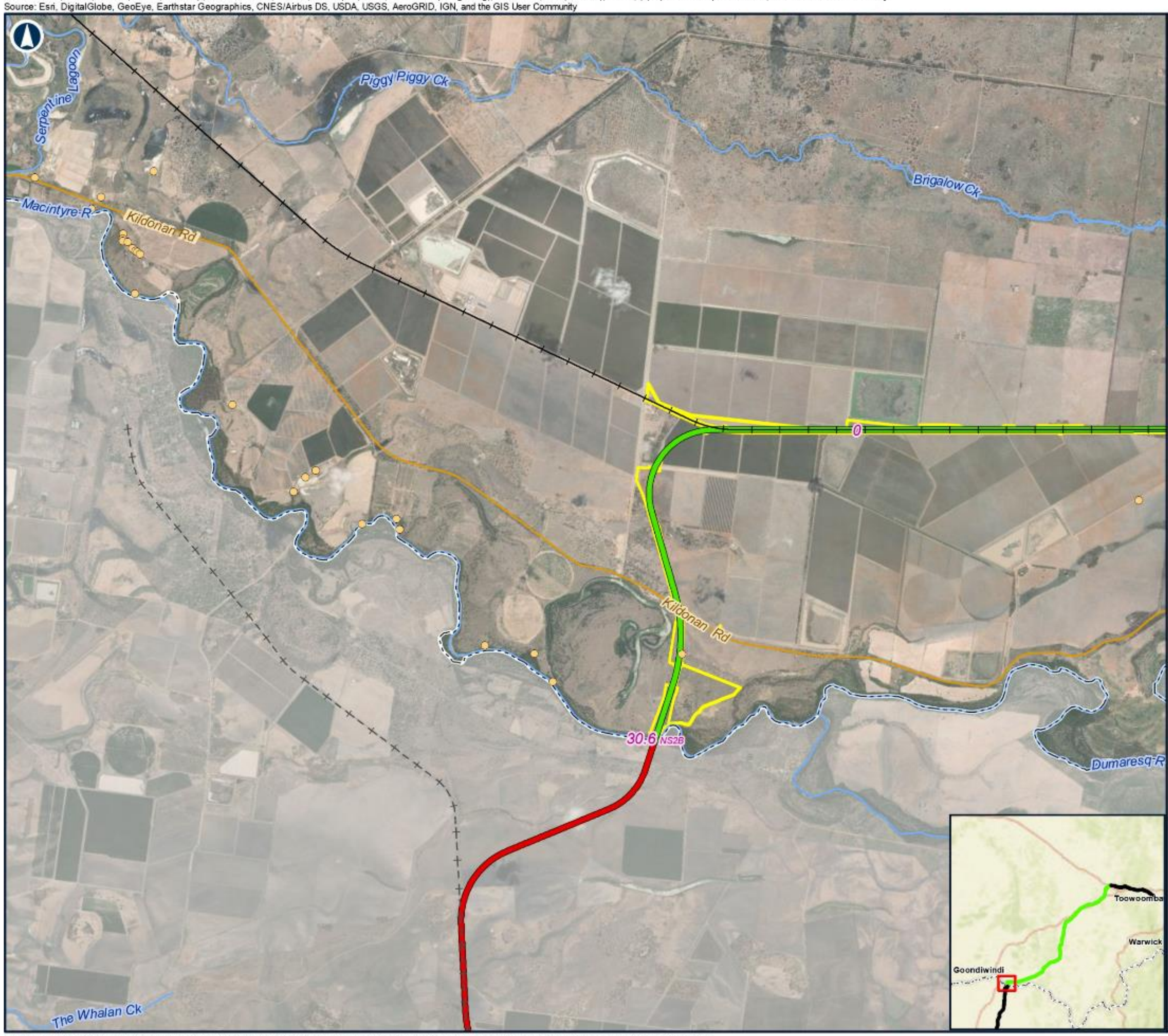

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BORDER TO GOWRIE
Figure 12.17k:
Location of flood sensitive receptors

LEGEND

- Flood sensitive receptor (1% AEP affected receptors are labelled)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Minor roads
- Watercourses
- NSW/QLD border
- Project footprint

0 2.5 5 km

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12.9 Mitigation measures

This section provides discussion of mitigation measures and controls that have been incorporated into the reference design development process, as appropriate and where possible (refer Section 12.9.1.1 and Section 12.9.2.1), as well as those measures that are proposed to be adopted for future phases of Project delivery (refer Section 12.9.1.2 and Section 12.9.2.2).

12.9.1 Surface water quality

12.9.1.1 Mitigation through the reference design phase

Development of the reference design for the Project has progressed in parallel with the impact assessment process. As a result, design solutions for avoiding, minimising or mitigating impacts have been incorporated into the reference design as appropriate and where possible.

Mitigation measures and controls that have been factored into the design, or otherwise implemented during the reference design phase for impacts to surface water quality and resources, are as follows:

- The Project uses the existing South Western Line and Millmerran Branch Line rail corridors as much as possible to avoid introducing a new linear infrastructure corridor across watercourses and floodplains, where possible
- The reference design has been developed to minimise impacts to watercourses, riparian vegetation and in-stream flora and habitats by adopting a crossing structure hierarchy where bridges are preferred to culverts
- Watercourse crossing structures (including culverts and bridges) are designed to minimise the need for ongoing maintenance and inspection to maintain aquatic fauna passage (e.g. fish and turtles) and minimise the risk of blockages in reference to *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e)
- Bridges and waterway crossings are designed to minimise impacts to bed, banks and environmental flows, in accordance with relevant regulatory requirements (as per requirements of DAF and the Fisheries Act)
- The reference design has been developed to avoid the need to permanently divert watercourses, as defined and mapped under the Water Act
- Three drainage features (not mapped watercourses under the Water Act) defined as waterways under the Fisheries Act are expected to require diversion based on the reference design
- Bridge structures are provided in the reference design over the following watercourses, to minimise disturbance of aquatic habitats:
  - Macintyre River
  - Macintyre Brook
  - Pariagara Creek
  - Cattle Tree Creek
  - Native Dog Creek
  - Bringalily Creek
  - Nicol Creek
  - Back Creek
  - Grasstree Creek
  - Condamine River
  - Condamine River north branch
  - Westbrook Creek
  - Dry Creek.

- Scour protection measures have been included around culvert entrances and exits, on disturbed stream banks and on land bound by a watercourse to avoid erosion. Scour protection or energy dissipation measures have been specifically designed and sized for each culvert location, in accordance with the *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (AGRD) (Austroads, 2013b) with consideration for flow velocity, soil type and vegetation cover. Scour protection measures incorporated into the reference design for culverts include:
  - Concrete apron
  - Concrete wingwalls
  - Rock mattress scour protection, with geotextile underlay.
- Scour protection measures for culvert outlets have been designed to ensure that the maximum allowable flow velocities in a 1% AEP, as specified in Table 3.1 of AGRD, are not exceeded. Maximum allowable flow velocities in Table 3.1 of AGRD are specific to the soil type at each culvert location, as follows:
  - Stable rock—4.5 m/s
  - Stones 150 mm diameter or larger—3.5 m/s
  - Gravel 100 mm or grass cover—2.5 m/s
  - Firm loam or stiff clay—1.2 to 2 m/s
  - Sandy or silty clay—1.0 to 1.5 m/s.
- The scour protection length and minimum rock size (d50) have been determined from Figure 3.15 and Figure 3.17 in AGRD. All required scour lengths are predicted to fit within the rail corridor.
- The reference design includes 17 sediment basins. All sediment basins are passive, which allows surface runoff from a catchment to flow into the sediment basin without the need for pumping.
- Longitudinal drains have been designed to include 3.5 m buffer strips within 100 m swales before the point of discharge into the local waterway system.

12.9.1.2 Proposed mitigation measures

In order to manage and mitigate potential impacts associated with the Project, several mitigation measures have been proposed for implementation in future phases of Project delivery. These proposed mitigation measures have been identified to address Project-specific issues and opportunities.

Table 12.57 identifies the relevant Project phase, the aspect to be managed and the proposed mitigation measure. The mitigation measures presented in Table 12.57 have then been factored into the assessment of residual impact significance, as documented in Table 12.59.

A Surface Water Management Sub-plan has been proposed as part of the suite of mitigation measures indicated in Table 12.57.

As part of the detail design stage, when finalised positions of infrastructure elements (e.g. abutments/piers, etc.) are known and detailed soil studies are complete, geomorphological assessment of identified risk locations will be undertaken.

Chapter 22: Outline Environmental Management Plan provides further context and the framework for implementation of these proposed mitigation and management measures.

TABLE 12.57 SURFACE WATER MITIGATION MEASURES FOR FUTURE PHASES OF PROJECT DELIVERY

Delivery phase	Aspect	Mitigation and management measures
Detail design	Erosion and sediment control	▶ Develop a Soil Management Sub-plan that includes the following procedures and protocols relevant to potential impacts on land resources: ▶ Soil/land conservation objectives for the Project ▶ Management of problem soils, such as: – Acid sulfate soils, which may occur in proximity to wetland features and water storages – Erosive or dispersive soils, such as sodosols, which are expected to be encountered between the Macintyre River and Yelarbon as well as along the fertile lands north of Inglewood, to the west of Kooroongarra – Cracking clays (vertosols) that are expected to be encountered between Koorongarra and Millmerran and from Yandilla to Gowrie – Saline soils, particularly in high-salinity hazard areas such as between Kurumbul and Yelarbon. ▶ Specification of the type and location of erosion and sediment controls. The erosion and sediment control measures will be developed by a certified professional in erosion and sediment control and be in accordance with the *Best Practice Erosion and Sediment Control* (International Erosion Control, 2008). The Soil Management Sub-plan will include: – Locations for specific temporary/permanent erosion and sediment control measures, such as: (1) Sediment retention basins (2) Scour protection (included in the reference design) (3) Sediment fencing (4) Berms and other surface flow diversions. – Nomination of location-specific erosion controls will include consideration of site conditions, proximity to environmental receptors, adjoining land uses, climatic and seasonal factors, and will be based on an erosion risk assessment – Minimise the area of disturbance during each stage to that required to enable the safe construction, operation and maintenance of the rail corridor – Scheduling of works with consideration to periods of higher rainfall (summer months) – Establish and specify the monitoring and performance objectives for handover on completion of construction – Stockpiling and management/segregation of topsoil where it contains native plants, seedbank or weed material – Vehicle, machinery and imported fill hygiene protocols and documentation, in accordance with the requirements of the *Biosecurity Act 2014* (Qld). ▶ Requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.

Delivery phase	Aspect	Mitigation and management measures

Detail design (continued)	Interference with existing surface water	▶ The detail design will be developed to ensure that the potential for diversion of watercourses, (as defined under the Water Act), and waterways (as defined under the Fisheries Act) are minimised.
		▶ The detail design will continue to be developed to minimise the extent of impacts to waterways, riparian vegetation and in-stream flora and habitats, in accordance with the intent of:
		  ▶ *Riverine protection permit exemption requirements* (WSS/2013/726) (DNRME, 2018a)
		  ▶ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e).
		▶ Where the Project is unable to comply with the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e), a development approval for operational work that is constructing or raising waterway barrier works will be required
		▶ Where the Project is unable to comply with the exemption requirements, a riverine protection permit will be required for works within a watercourse.

	Water quality	▶ A Surface Water Management Sub-plan will be developed as a component of the CEMP. The sub-plan will provide a surface water monitoring framework for the Project that establishes:
		  ▶ Additional monitoring and sampling required to establish baseline water-quality conditions, as a continuation of data collected during development of the draft EIS. Baseline water-quality conditions will preferentially use water-quality monitoring sites used within the draft EIS, with consideration of construction activities, seasonality and watercourse sensitivity. These will be monitored monthly, at a minimum, for a period of 12 months prior to commencement of construction, to determine baseline conditions as a reference for monitoring of impact (as per QWQG).
		  ▶ Watercourse-specific water-quality values, based on baseline data, ANZG, QWQG and relevant WQOs
		  ▶ Frequency and location of surface water sampling during construction of the Project, with consideration for:
		    – Construction activities with potential to impact water quality
		    – Seasonality
		    – Sensitivity of receiving watercourse.
		  ▶ In-situ water-quality parameters (pH, EC, dissolved oxygen, temperature, oxygen reduction potential (ORP) and TDS) and laboratory analysis required for samples collected at each sampling location
		  ▶ Quality assurance/quality control (QA/QC) requirements for surface water sampling and analysis
		  ▶ A risk management framework for evaluation of the risks to surface water quality and ecosystems in the receiving environment
		  ▶ Responses to impact threshold exceedances (to be determined after the establishment of baseline water quality conditions)
		  ▶ Data management and reporting requirements.
		▶ The Surface Water Management Sub-plan will be developed in consultation with DNRME and DES prior to implementation for construction, after the establishment of location-specific impact thresholds.

<table>
<tr><th>Delivery phase</th><th>Aspect</th><th>Mitigation and management measures</th></tr>
<tr><td>Detail design (continued)</td><td>Availability of water to users</td><td>

The detail design will be developed to ensure that, where possible, private water storages are avoided and that affected landowners retain access to existing natural resources
If impacts to access to existing natural resources cannot be avoided through design, appropriate compensation arrangements will be discussed and agreed with the relevant impacted landowner
Where the Project will result in disturbance to private surface water storages (e.g. dams), ARTC will consult with the owners of relevant, legal storage structures prior to works commencing to agree an approach to decommissioning or relocation of the structure. This may also include the usage or relocation of stored water and compensation (if applicable).
</td></tr>
<tr><td></td><td>Construction water</td><td>

The construction water requirements (volumes, quality, demand curves, approvals requirements and lead times) will be confirmed through the construction approach refinement process. The refinement process will use a hierarchical approach to confirming the suitability of water sources, with a focus on using existing sustainable allocated water entitlements from private water holders. The ultimate water-sourcing strategy for the Project will be documented in a construction water plan and be dependent on:

Climatic conditions in the lead up to construction
Confirmation of private water sources made available to the Project by landowners under private agreement
Confirmation of access agreements with local governments for sourcing of mains water.

Licenses, approvals and agreements to access water from sources identified in the finalised construction water plan will be obtained. These may include water licenses under the Water Act or access agreements with bulk water suppliers or private landowners.
ARTC to review the ability for the take of water to be done in accordance with the Exemption requirements for constructing authorities for the take of water without a water entitlement (DNRME, 2020b).
</td></tr>
<tr><td></td><td>Rehabilitation</td><td>

A Rehabilitation and Landscaping Management Sub-plan will be developed for the Project, as a component of the CEMP. This sub-plan will be based on the Inland Rail Landscape and Rehabilitation Strategy, in addition to location- and property-specific reinstatement commitments. The plan will include and clearly identify:

Location-specific objectives for rehabilitation, reinstatement and/or stabilisation
Objectives and timeframes for rehabilitation and/or reinstatement/stabilisation works (including biodiversity, vegetation establishment and erosion and sediment control outcomes to be achieved)
Details of the actions and responsibilities to progressively rehabilitate, regenerate, and/or revegetate areas, while minimising the duration of exposure in disturbed areas
Include rehabilitation requirements such as:

Milling and removal of bitumen pavement
Removal of any decommissioned culverts
Tyning and ripping of base and sub-base material
Application of soil ameliorants
Topsoiling and/or compost blanket
Stabilisation and rehabilitation (e.g. planting and or seeding).

</td></tr>
</table>

Delivery phase	Aspect	Mitigation and management measures
Detail design (continued)		- Consideration for maintenance or performance issues of rehabilitation - Obtaining water for rehabilitation and landscaping purposes from a sustainable source, under applicable permits or licences, or in accordance with exemption requirements - Procedures, timeframes, measurable performance objectives and responsibilities for monitoring the success of rehabilitation and/or reinstatement/stabilisation areas - Corrective actions if the outcomes of rehabilitation and/or reinstatement/stabilisation are not achieved. - Where temporary construction facilities/borrow pits are required, land will be returned to a stable condition that complies with the conditions of applicable landowner agreements and regulatory approvals (e.g. development approval and/or Environmental Authority (EA)).
Pre-construction	Erosion and sediment control	- Install initial erosion and sediment controls in support of pre-construction minor civil works, e.g. establishing laydown areas, in accordance with the Soil Management Sub-plan.
Construction	Erosion and sediment control	- Implement the Soil Management Sub-plan, including erosion and sediment controls - Install permanent erosion-control measures, such as sediment retention basins and scour protection, in accordance with the detail design and erosion and sediment control plans - Monitor the effectiveness of erosion controls installed as part of the environmental inspection schedule for the Project, as prescribed in the CEMP - Controls that are found to be failing or not performing as intended will either be modified or replaced, as required - Clearing extents are limited to the Project footprint, and clearing is scheduled to minimise the exposure time of unprotected earth to prevent sedimentation of receiving waterways - Where practical, vegetation clearing and ground-disturbing works will be staged sequentially across the Project to minimise areas exposed to erosion and sediment risk of receiving waterways.
	Dewatering	- Where the dewatering of excavations (e.g. trenches, pier holes etc.) is required, water will need to meet the established WQOs for receiving waterways before being released/discharged into local waterways - If dewatering of existing storages is required, dewatering strategies will be required to comply with the *Biosecurity Act 2014* (Qld) to take reasonable measures to avoid the spread of pest species, e.g. screening of pump intake.
	Construction water	- The extraction of water will occur in accordance with licenses, approvals and/or agreements - Volume monitoring during extraction will be required for each source point, with extraction logs maintained - If the *Exemption requirements for constructing authorities for the take of water without a water entitlement* (DNRME, 2020b) are considered to be applicable to ARTC and the Project, then the take of water will occur in accordance with the exemption requirements - Extraction reporting will occur, as required, in accordance with requirements of relevant licenses, approvals and/or agreements obtained to cover this activity.

Delivery phase	Aspect	Mitigation and management measures

Construction (continued)	Water quality	▶ Implementation of the Surface Water Management Sub-plan (refer above)
		▶ Water will need to meet the established WQOs for receiving waterways before being released/discharged into local waterways. Water that does not comply with relevant WQOs will either be:
		  ▶ Treated onsite to enable discharge
		  ▶ Used for construction water purposes that are not quality dependent, if safe to do so (e.g. dust suppression)
		  ▶ Removed from site for disposal at an appropriately licensed facility.
		▶ Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social and environmental receptors such that offsite impacts or risks from any foreseeable hazard scenario will not exceed the dangerous dose for the defined land-use zone, i.e. either sensitive, commercial/community, or industrial, in accordance with the intent of the SPP.
		▶ Licensed transporters operating in compliance with the *Australian Code for the Transport of Dangerous Goods by Road & Rail* (National Transport Commission, 2018) will be used for the transportation of dangerous goods.
		▶ Chemicals stored and handled as part of construction activities will be managed in accordance with:
		  ▶ The *Work Health Safety Act 2011* (Qld) and Regulation
		  ▶ AS 2187.1:1998 *Explosives—storage, transport and use: Storage* (Standards Australia, 1998a)
		  ▶ AS 2187.2:2006 *Explosives—storage, transport and use: Use of explosives* (Standards Australia, 2006)
		  ▶ AS 1940:2017 *Storage and Handling of Flammable and Combustible Liquids* (Standards Australia, 2017a)
		  ▶ AS 3780:2008 *The Storage and Handling of Corrosive Substances* (Standards Australia, 2008a)
		  ▶ The requirements of chemical safety data sheets.
		▶ Procedures will be established for safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas. The bunding will have floors and walls that are lined with an impermeable material, to prevent leaching and spills.
		▶ 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 Service (QFES).
		▶ Laydown areas and other construction facilities that are located within the 1% AEP will be temporary. Their planning and function in supporting construction will reflect the local flood risk, e.g. hazardous goods will not be bulk stored in these locations.
		▶ Mobile plant will not be stored in the 1% AEP when not scheduled to be in use for construction purposes
		▶ Plant maintenance and refuelling will be carried out a minimum of 50 m from riparian vegetation and waterways, with appropriate interception measures in place to avoid impacts to waterways, aquatic habitats, and groundwater. Appropriate spill-control materials, including booms and absorbent materials, will be onsite at refuelling facilities at all times.
		▶ Appropriate waste bins will be located in laydown areas to facilitate segregation and appropriate containment of waste materials

Delivery phase	Aspect	Mitigation and management measures
Construction (continued)	Rehabilitation	▸ Reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively, consistent with the Rehabilitation and Landscaping Management Sub-plan.
Operation	Water quality	▸ Cross-drainage structures will be inspected to assess physical condition and performance, structural integrity and corrective measures in accordance with ARTC's *Structures Inspection Engineering Code of Practice* (ETE-09-01) ▸ Plant maintenance and refuelling will be carried out in accordance with ARTC work instructions, with appropriate interception measures in place to avoid impacts to waterways, aquatic habitats, and groundwater.
	Erosion and sediment control	▸ The effectiveness of permanent erosion controls (e.g. scour protection or vegetated swales) will be monitored as part of the maintenance inspection schedule for the Project, as prescribed in the Operation EMP ▸ Controls that are found to be failing or not performing as intended will either be modified or replaced, as required ▸ The integrity of rail embankments will be maintained to prevent slope face scour and degradation ▸ Maintenance of surface and subsurface drains will be required to ensure continued effectiveness and to minimise risk of impact to surrounding and downstream environments and structures.

12.9.1.3 Baseline monitoring

Additional monitoring and sampling of surface water within the impact assessment area will be conducted prior to the commencement of construction to:

- Determine baseline conditions as a reference for monitoring of impact
- Enable location-specific guideline values to be developed
- Inform finalisation of the Surface Water Management Sub-plan.

Baseline water-quality conditions will preferentially be undertaken at water-quality monitoring sites previously monitored for development of the EIS (refer Table 12.6). These will be monitored at quarterly intervals (minimum), for a period of 12 months prior to commencement of construction (as per QWQG). Additional monitoring and sampling may also be undertaken in response to large rain events.

Surface water quality data will be collected at accessible sites in accordance with the *Monitoring and Sampling Manual* (DES, 2018a).

At each sampling location, the following in-situ parameters will be recorded:

- Dissolved oxygen (mg/L) and saturation (per cent)
- pH
- Electrical conductivity (µs/cm)
- Temperature (°C)
- Turbidity (NTU)
- Total dissolved solids (ppm)
- Oxidation reduction potential (mV).

Samples will also be collected from each site for laboratory analysis for the following analytes:

- Conductivity and salinity
- TSS
- Total hardness as $CaCO_3$ (Alkalinity)
- Nutrient suite (ammonia, nitrite, nitrate, total nitrogen, TKN, nitrogen oxides, reactive P and total P)
- Organic nitrogen
- Dissolved metals (eight metals suite: arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury)
- PAHs
- Chlorophyll *a*.

Samples will be submitted for analysis to a National Association of Testing Authorities (NATA) accredited laboratory.

12.9.2 Hydrology and flooding

12.9.2.1 Mitigation through the reference design phase

The Project has been designed to achieve the hydraulic design criteria (Table 12.7) including 1% AEP flood immunity to rail formation level. At the same time, the design seeks to avoid impacts that do not meet the flood-impact objectives (Table 12.8) for the flooding and drainage regime.

Key strategies that have been adopted in developing the reference design are as follows:

- The Project has been designed to achieve the hydraulic design criteria (refer Table 12.7), which includes:
  - 50-year design life for formation and embankment performance
  - Track drainage ensures that the performance of the formation and track is not affected by water
  - Earthworks designed to ensure that the rail formation is not over-topped during a 1% AEP flood event
  - Embankment cross section can sustain flood levels up to the 1% AEP
  - Bridges are designed to withstand flood events up to and including 0.05% AEP (2,000-year event).
- Flood models were developed in consultation with stakeholders and, where possible, models were calibrated and validated using stakeholder-supplied information.

- The Project uses the existing South Western Line and Millmerran Branch Line rail corridors as much as possible to avoid introducing a new linear infrastructure corridor across floodplains. This means that 71.2 km of the total 216.2 km Project length is located within existing rail corridor.
- The Project incorporates bridge and culvert structures to maintain existing flow paths and flood-flow distributions, such as across the Condamine River floodplain, where six bridges have been incorporated into the design with a combined opening width of > 6 km
- Bridge and culvert structures have been located and sized to avoid increases in peak water levels, flow distribution, velocities and duration of inundation in accordance with the flood-impact objectives (Section 12.6.3.2)
- Progressive refinement of bridge location/extents and culvert banks (location, number of barrels and dimensions) has been undertaken as the Project design has evolved. This refinement process has considered engineering requirements, as well as input and feedback from stakeholders, to achieve acceptable outcomes that address the flood-impact objectives.
- Stakeholder concerns regarding the dispersive nature of soils in floodplains were addressed in the reference design by incorporating scour and erosion protection measures into the design in areas determined to be at risk, such as around culvert headwalls, drainage discharge pathways and bridge abutments (refer Section 12.9.1.1)
- The reference design includes the option to modify the existing Yelarbon flood levee to increase the flood immunity for the township of Yelarbon with the addition of the Project
- A climate change assessment has been incorporated into the design of cross-drainage structures for the local drainage catchments for the 1% AEP design event. This assessment was in accordance with the *Australian Rainfall and Runoff Guidelines* (Book 1, Chapter 6) (Ball et al., 2016) and was used to determine the sensitivity of the design to the potential increase in rainfall intensity.
- Potential blockage of hydraulic structures caused by floodplain debris, as highlighted by stakeholders, has been factored into the reference design by allowing an additional 25 per cent flow capacity in culverts, and by placing bridges over major debris transportation paths
- Flood-sensitive receptors and corresponding acceptable design outcomes have been identified through discussions with potentially affected landowners, where possible.

Details of the reference design's performance against the flood-impact objectives is provided in Section 12.10.2. For further details regarding the hydrologic and hydraulic modelling approach and design outcomes, refer to Appendix Q1/Q2: Hydrology and Flooding Technical Report, and for further details on engagement with stakeholders regarding hydrology, refer to Appendix C: Stakeholder Engagement Report.

12.9.2.2 Proposed mitigation measures

In order to manage and mitigate potential impacts associated with the Project, several mitigation measures have been proposed for implementation in future phases of Project delivery. These proposed mitigation measures have been identified to address Project-specific issues and opportunities.

Table 12.58 identifies the relevant Project phase, the aspect to be managed and the proposed mitigation measure.

TABLE 12.58 HYDROLOGY AND FLOODING MITIGATION MEASURES FOR FUTURE PHASES OF PROJECT DELIVERY

Delivery phase	Aspect	Proposed mitigation measure
Detail design	Flooding	▸ The Project has been designed to achieve a 1% AEP flood immunity to rail formation level and to meet the flood-impact objectives detailed in Table 12.8. These same design principles will apply to the detail design of the Project. ▸ Design modifications during the detail design phase will be subject to re-runs of the existing flood models, to demonstrate continued compliance with the design objectives of the Project, including for extent and duration of inundation, afflux and flow velocities ▸ ARTC will continue to consult with impacted landowners in regard to the results of local catchment modelling through finalisation of the EIS and development of the detail design. The purpose of this consultation will be to ensure that impacts to property-scale water balance features, such as irrigation channels and dams, are appropriately considered in the EIS and Project design. Feedback from this consultation will be used to update flood modelling for the Project, if appropriate to do so. Outcomes of this consultation and revised local catchment modelling will be incorporated into the Final EIS. ▸ Hydrology and flooding impacts due to the alteration of design will be communicated to affected landowners

Delivery phase	Aspect	Proposed mitigation measure
		▶ Consultation with impacted stakeholders will continue through detail design to ensure that alterations to the design and its impacts are communicated back to landowners ▶ The design requirements for modifying the existing Yelarbon levee will be confirmed through further consultation with GRC and incorporated into the detail design. It is anticipated that the modified levee would be considered a Category 2 levee (Schedule 10 of the Water Regulation 2016). This levee modification would constitute code assessable development, with GRC as the assessment manager. Development approval for the modification of Yelarbon levee will be obtained prior to the commencement of any modification works.
Pre-construction	Flooding	▶ Impacts must be determined at all drainage structures and waterways affected by construction works. The change in flood levels and impacts on infrastructure and properties outside the rail corridor must be justified for a range of events up to and including the 1% AEP event.
Construction	Flooding	▶ 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 QFES. ▶ Laydown areas and other temporary construction facilities that are located within the 1% AEP event inundation extents will be short term in use. Their planning and function in supporting construction will reflect the local flood risk, e.g. hazardous goods will not be bulk stored in these locations. ▶ Mobile plant will not be stored in the 1% AEP when not scheduled or in use for construction purposes.
Operation	Flooding	▶ Inspections will be carried out in accordance with ARTC's *Structures Inspection Engineering Code of Practice* (ETE-09-01) to identify defects and conditions that may affect waterway and drainage system capacity or indicate increased risk of flooding, such as: ▸ Scour ▸ Blockages due to debris build up ▸ Indication of floods overtopping a structure ▸ Culvert or drain damage or collapse. ▶ Where defects are identified and corrective actions are required, these works will be completed in accordance with the Operation EMP for the Project ▶ Asset inspections will be completed as soon as safe access can be achieved following a flood event.

12.10 Impact assessment summary

12.10.1 Surface water quality impact assessment

Potential impacts on surface water in the construction and operation phases of the Project are outlined in Table 12.59. These impacts have been subjected to significance assessment as per the methodology introduced in Chapter 4: Assessment Methodology and discussed in Section 12.6.2.1.

The initial impact assessment is undertaken on the assumption that the design considerations (or initial mitigation measures) factored into the reference design phase (refer Section 12.9.1.1) have been implemented.

Additional mitigation and management measures (refer Table 12.57) were then applied to future phases of the Project to further reduce the level of potential impact and derive a residual significance of impact.

The initial and residual significance of potential impacts are presented in Table 12.59 to demonstrate the effectiveness of mitigation measures. Each potential impact is assessed for moderate and high sensitivity receptors. High sensitivity receptors are waterways with habitat values that support MNES and MSES, i.e. sections of Macintyre River, Macintyre Brook, Canning Creek and the Condamine River that intersect with the Project footprint. All other waterways are regarded as moderate sensitivity receptors.

Impacts on water quality are based on a model of expected occurrences regarding projected impacts (potential and specific) from Project activities. As such, critical failure of infrastructure is not considered a viable impact for impact significance assessment.

TABLE 12.59 INITIAL AND RESIDUAL IMPACT SIGNIFICANCE ASSESSMENT FOR SURFACE WATER

					Initial impact significance[1]		Residual impact significance of risk[2]	
Aspect	Potential impact	Specific impact	Phase	Sensitivity	Magnitude	Significance	Magnitude	Significance
Erosion and sediment control	Increased debris	Contamination of waterway from debris from the Project to be blown or washed into waterway	Pre-construction and construction Operation	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction Operation	High[3]	Low	Moderate	Negligible	Low
		Restriction of flow within the waterways if too much debris is introduced to waterway or is stuck in culverts or creek crossings	Pre-construction and construction Operation	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction Operation	High[3]	Moderate	High	Negligible	Low
Water quality Waterways	Changes to receiving water quality and hydrology	Changes to receiving water quality from dewatering of artificial waterbodies	Pre-construction and construction	Moderate	Low	Moderate	Low	Low
Erosion and sediment control Water quality	Increase in salinity	Increased salinity in proximal watercourses from land disturbance	Pre-construction and construction	Moderate	High	High	Negligible	Low
				High[3]	High	Major	Negligible	Low

Aspect	Potential impact	Specific impact	Phase	Sensitivity	Initial impact significance[1]		Residual impact significance of risk[2]	
					Magnitude	Significance	Magnitude	Significance
Erosion and sediment control Water quality Waterways	Increase in contaminants	Contamination of waterway from inadequate storage of fuels, oils and contaminants	Pre-construction and construction Operation	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction Operation	High[3]	Low	Moderate	Negligible	Low
		Runoff from areas of disturbed contaminated lands near waterways	Pre-construction and construction	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Low	Moderate	Negligible	Low
		Introduction of contaminants from stockpiled areas	Pre-construction and construction	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Low	Moderate	Negligible	Low
		Contaminants can enter waterways after rainfall events from rolling stock or after weed control activities	Operation	Moderate	Moderate	Moderate	Negligible	Low
			Operation	High[3]	Moderate	High	Negligible	Low
		Potential contamination of waterways from failed equipment or from failed infrastructure	Pre-construction and construction Operation	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction Operation	High[3]	Moderate	High	Negligible	Low

					Initial impact significance[1]		Residual impact significance of risk[2]	
Aspect	**Potential impact**	**Specific impact**	**Phase**	**Sensitivity**	**Magnitude**	**Significance**	**Magnitude**	**Significance**
Erosion and sediment control General interference with existing surface water	Increases in erosion and sedimentation	Disturbance of the bed, banks and riparian zone of waterways	Pre-construction and construction	Moderate	High	High	Negligible	Low
			Operation		Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	High	Major	Negligible	Low
			Operation		Moderate	High	Negligible	Low
		Increased turbidity and sedimentation; and potential mobilisation of contaminants through erosion from disturbance activities near waterways	Pre-construction and construction	Moderate	High	High	Negligible	Low
			Operation		Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	High	Major	Negligible	Low
			Operation		Moderate	High	Negligible	Low
		Increased turbidity and potential mobilisation of contaminants from stockpiled areas	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
		Increased turbidity and potential mobilisation of contaminants from dewatering activities near excavations	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
		Increased sedimentation can impact the function of culverts/creek crossing and impede flow of the waterway	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation		Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation		Low	Moderate	Negligible	Low

Aspect	Potential impact	Specific impact	Phase	Sensitivity	Initial impact significance[1]		Residual impact significance of risk[2]	
					Magnitude	Significance	Magnitude	Significance
Erosion and sediment control	Exacerbation of listed impacts above, from inadequate rehabilitation processes	Potential for sedimentation and increased turbidity within waterways if areas are either not rehabilitated or inadequate rehabilitation occurs	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation					
		Inadequate rehabilitation increasing erosion and sedimentation within waterways impacting the function of culverts/creek crossing and impeding flow of the waterway	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation					
Waterway morphology	Alteration to the structure and function of waterways	Alteration to the structure of waterways, through diversions or introduction of infrastructure elements into the bankfull width, has potential to impact the physical characteristic of a waterway	Pre-construction and construction	Moderate and High[3]	Moderate	High	Negligible	Low
			Operation		N/A	N/A	N/A	N/A
Water availability	Extraction of water for construction	Extraction of water, from multiple surface water sources, for the purpose of supporting construction activities has the potential to reduce the availability of water for other users within the relevant basins, if not planned and managed appropriately	Pre-construction and construction	Moderate and High[3]	Moderate	High	Negligible	Low
			Operation		N/A	N/A	N/A	N/A

Table notes:

1. Includes implementation of design mitigation specified in Section 12.8.1.1
2. Includes proposed mitigation measures specified in Table 12.57
3. Macintyre River, Macintyre Brook, Canning Creek and the Condamine River

12.10.2 Hydrology and flooding

The existing flood regime without the Project, or Existing Case, was modelled for floodplain through which the Project is aligned, with results presented in Section 12.7.6.2.

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 (refer Figure 12.17a–k).

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 flood impact objectives listed in Table 12.8. 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, riparian vegetation (and associated bank morphology) or otherwise impact aquatic ecosystems.

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 Q1/Q2: Hydrology and Flooding Technical Report.

12.10.2.1 Gowrie Creek

On the Gowrie Creek floodplain, the Project design includes:

- Nine RCP locations (a total of 51 cells)
- One RCBC location (a total of 16 cells).

Details of the floodplain structures required to convey Gowrie Creek flood flows are presented in Table 12.60 with structure locations presented in Figure 12.18a. Figure 12.18a also presents the location of 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 12.60 GOWRIE CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS

Approximate chainage (km)	Structure ID	Structure type	No. of cells	Diameter/width x height (m)[1]
203.17	C203.17	RCP	2	1.05
204.92	C204.92	RCP	2	1.05
205.09	C205.09	RCP	12	1.05
205.14	C205.14	RCP	2	1.05
205.30	C205.30	RCP	4	1.05
205.37	C205.37	RCP	15	1.05
205.47	C205.47	RCP	5	1.05
205.60	C205.60	RCP	2	1.05
205.87	C205.87	RCP	7	1.05
206.95	C206.95	RCBC	16	2.40 x 1.20

Table notes:
1. For RCP height equals diameter

Change in peak water levels

Figure 12.18b presents the change in peak water levels under the 1% AEP event and Table 12.61 presents details of where the change in peak water levels lie outside the flood-impact objectives. Except for these locations, the change in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.61 GOWRIE CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water levels (mm)	Comments
Draper Road	206.90	Roadway	≤100 mm	+230	The change in peak water levels on Draper Road is localised, contained in the Project corridor and occurs directly upstream of the existing QR culvert. ToS remains unchanged for events up to 1% AEP; however, AAToS increases by up to 0.56 hours per year due to extreme event impacts.
Private land outside Project footprint[1]	206.65 to 206.95	Agricultural (cropping)	≤100 mm (up to 400 mm)	+410	1.4 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm
Private land outside Project footprint	205.85 to 206.05	Agricultural (cropping)	≤100 mm (up to 400 mm)	+200	0.2 ha in total affected by afflux > 10 mm
Private land outside Project footprint	205.30 to 205.85	Agricultural (cropping)	≤100 mm (up to 400 mm)	+260	2.9 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm
Private land outside Project footprint	204.50 to 205.30	Agricultural (cropping)	≤100 mm (up to 400 mm)	+6842	6.8 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm

Table notes:

1. Project footprint is indicated in Figure 12.18b
2. Area affected by change in peak water levels between 200 mm and 684 mm is contained in a small area within an existing creek channel

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with noticeable floodplain inundation starting under the 20% AEP event.

For events exceeding the 10% AEP event, minor changes in peak water levels occur near Chamberlain Road adjacent to the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood events within the Gowrie Creek floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

With the exception of Draper Road (as reported in Table 12.61) there are no roads within the Gowrie Creek modelling extent that are impacted by changes in duration of inundation for a 1% AEP event.

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.

Velocities

Figure 12.18f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Gowrie Creek main channels are negligible.

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* (Austroads, 2013a). 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.

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. Figure 12.18c to Figure 12.18e presents the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.62 outlines the changes in peak water levels 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 in such a rare event.

TABLE 12.62 GOWRIE CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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_1	-	-	+39	0.14	+77	0.75
GOW_ID_4	-	-	-	-	+264	0.74
GOW_ID_5	-	-	-	-	+240	0.15
GOW_ID_6	-	-	-	-	+96	0.21
GOW_ID_7	-	-	-	-	+51	0.07
Kingsthorpe–Tilgonda Road	+52	2.47	+161	3.42	+449	4.98
Leesons Road	+17	2.80	+202	4.11	+308	6.10
Tilgonda–Kingsthorpe Road	-	2.17	+21	2.63	+432	3.90
Draper Road	+549	1.31	+699	1.62	+517	3.09
Kingsthorpe–Haden Road	+15	5.45	+1	6.25	-30	8.02
Chamberlain Road	+281	0.42	+295	1.16	+1,898	3.00

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 12.63 outlines the overtopping locations and depths.

TABLE 12.63 GOWRIE CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
205.87	-	-	1.5
206.95	-	-	0.8

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.

Climate change

The climate change guidelines set out in ARR 2016 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 (RCP) 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 Q2: Hydrology and Flooding Technical Report 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 rail formation level is higher than the 1% AEP climate change water level.

Table 12.64 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.64 GOWRIE CREEK—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood sensitive receptor ID	Change in peak water level (mm)	Existing case flood depth[2] (m)
Draper Road[1]	+332	1.07
Kingsthorpe–Haden Road[1]	+37	4.95
Chamberlain Road[1]	+285	0.40

Table notes:

1. These roads are affected by climate change regardless of the Project and so the amenity of the roads is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

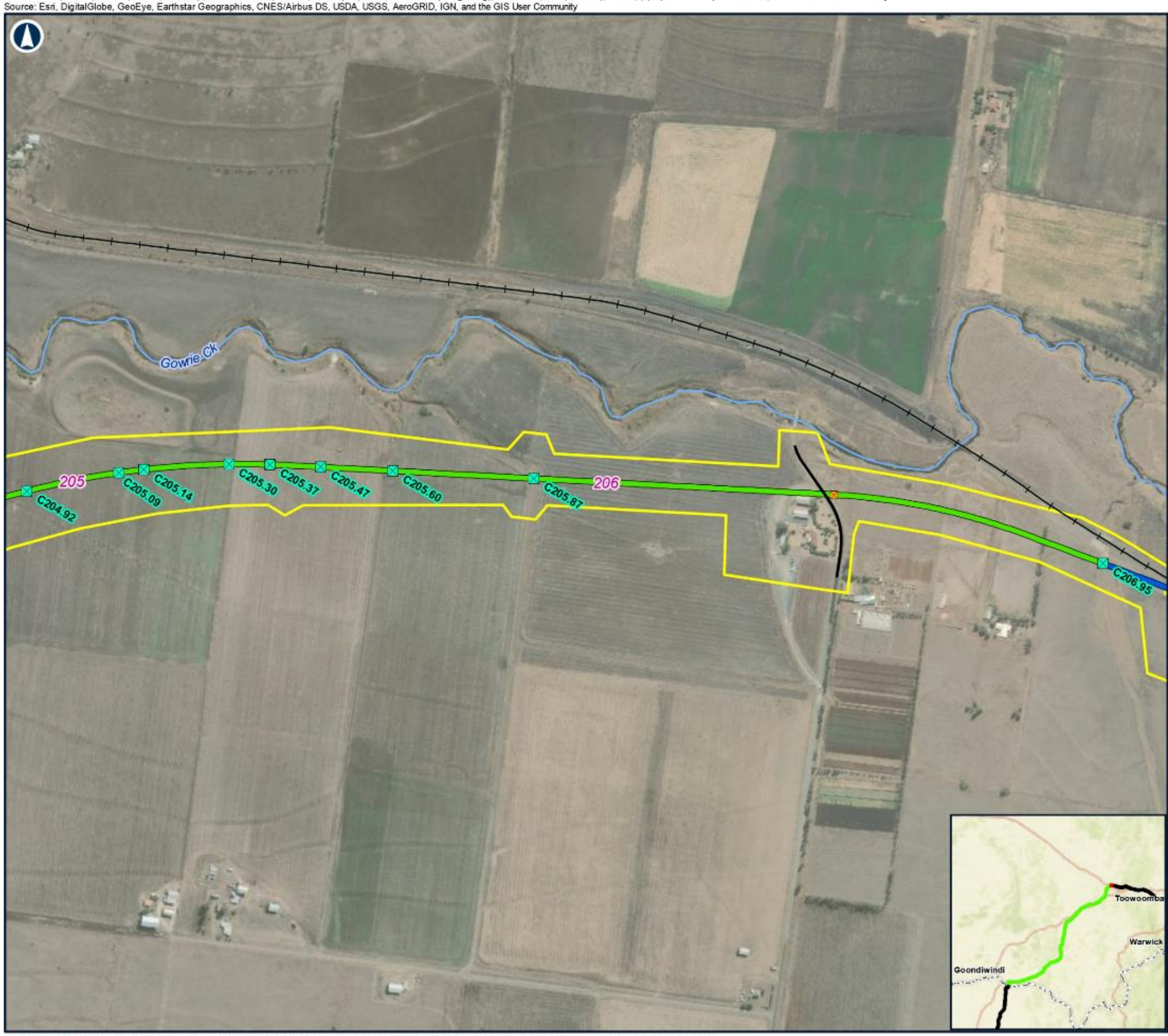
During detail design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in varied and/or lower blockage factors being applied along the Project alignment.

Table 12.65 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.65 GOWRIE CREEK—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood-sensitive receptor ID	Existing Case flood depth (m)	Change in peak water level (mm)
Draper Road	1.07	+260
Kingsthorpe–Haden Road	4.95	+10
Chamberlain Road	0.40	+280

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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BORDER TO GOWRIE
Figure 12.18a:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Local drainage culvert

0 0.25 0.5 km

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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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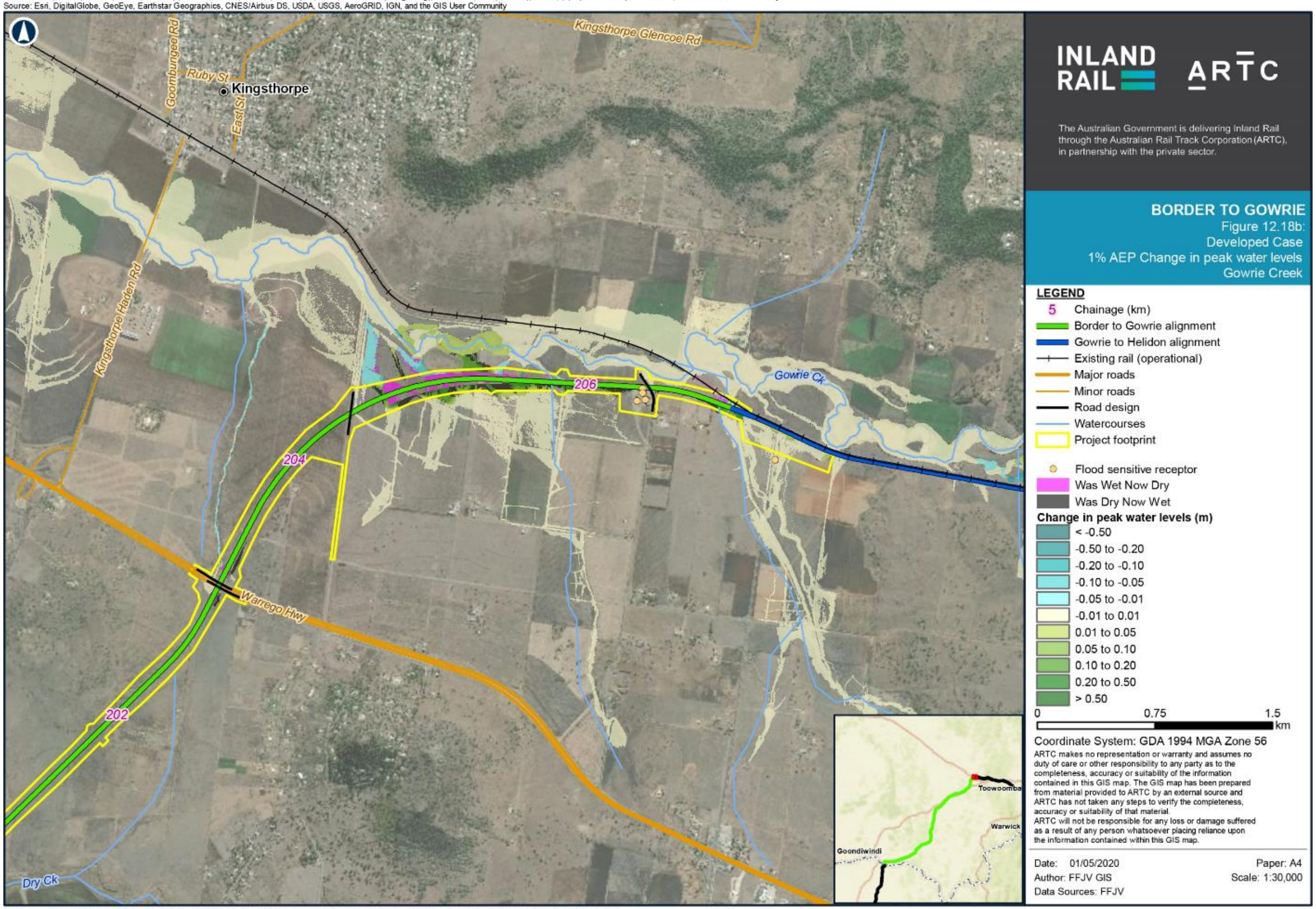

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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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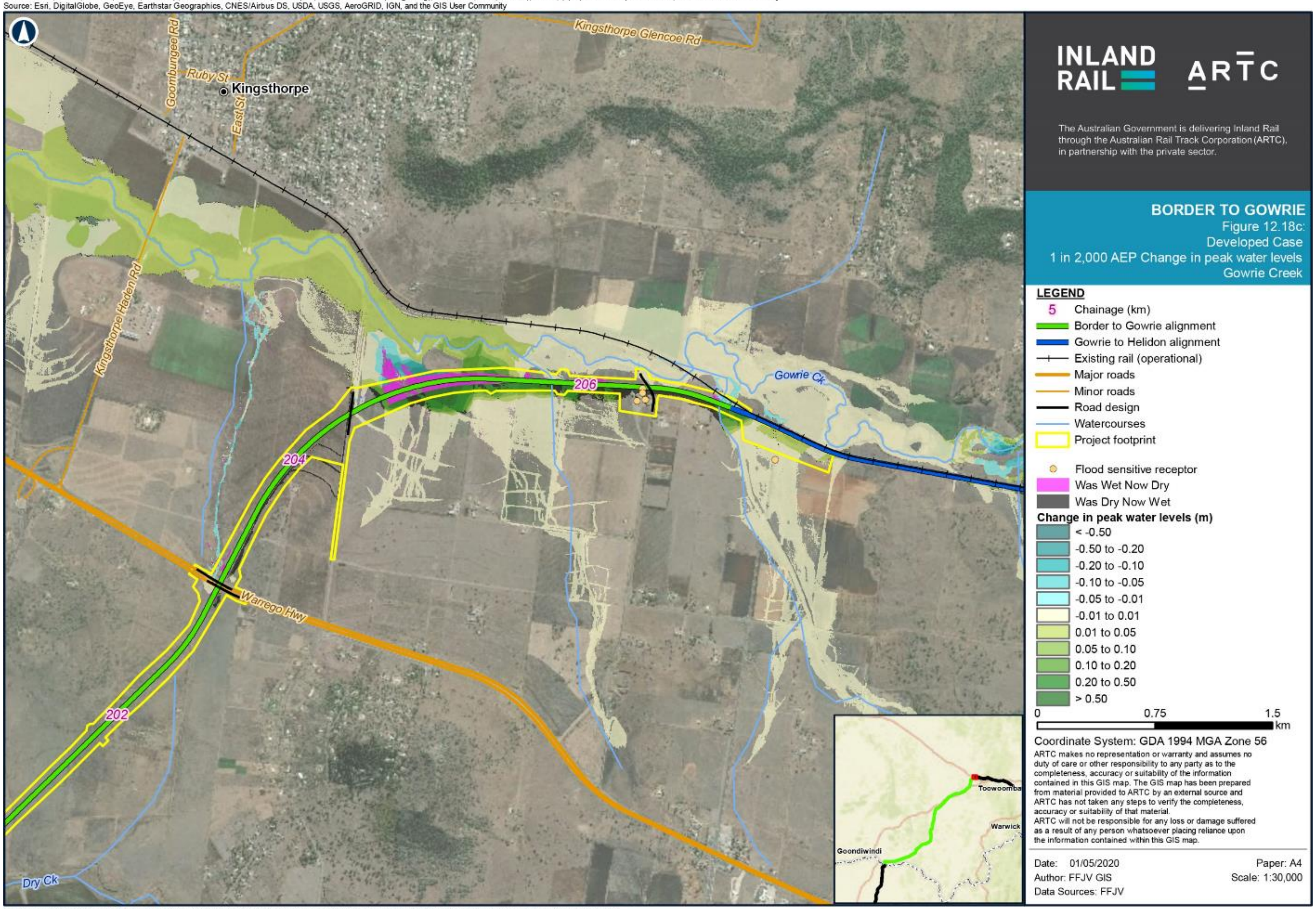
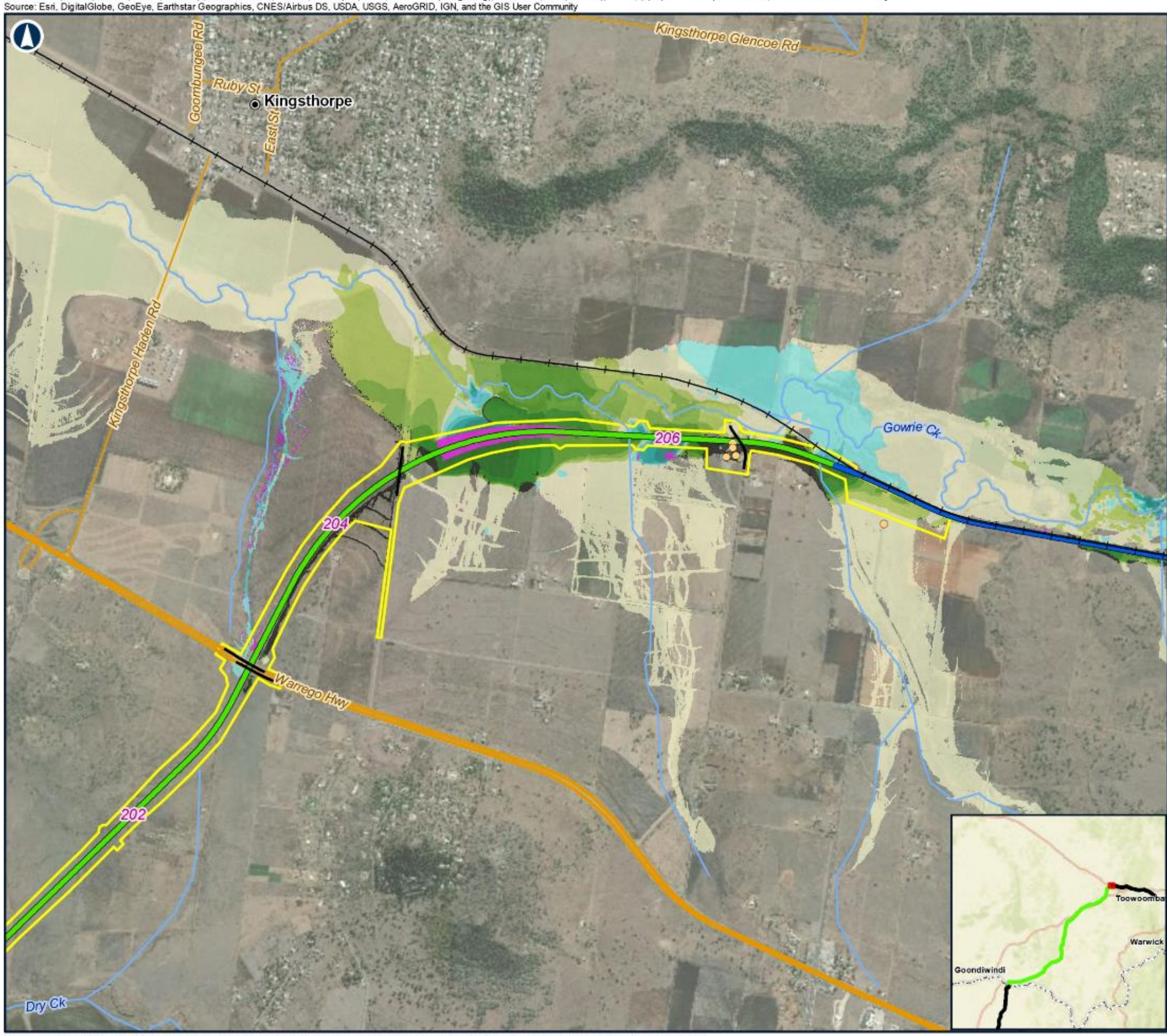


Map by: MF/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202005121229_SurfaceWaterEIS\310-IHY-202005121229_ARTC_Fig12-Xbcde_Afflux.mxd Date: 8/06/2020 18:33

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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BORDER TO GOWRIE
Figure 12.18d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Gowrie Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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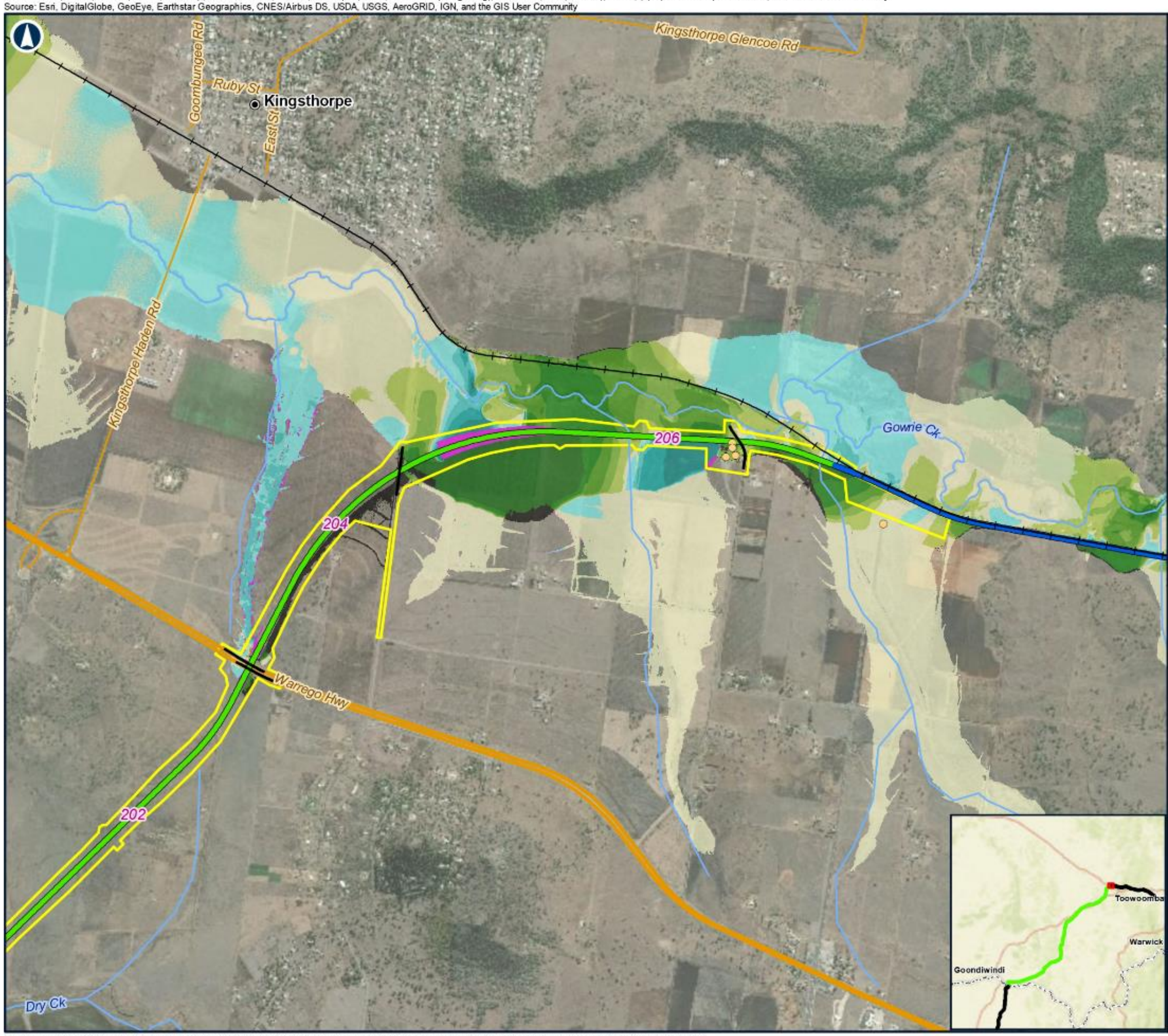
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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BORDER TO GOWRIE
Figure 12.18e:
Developed Case
PMF Change in peak water levels
Gowrie Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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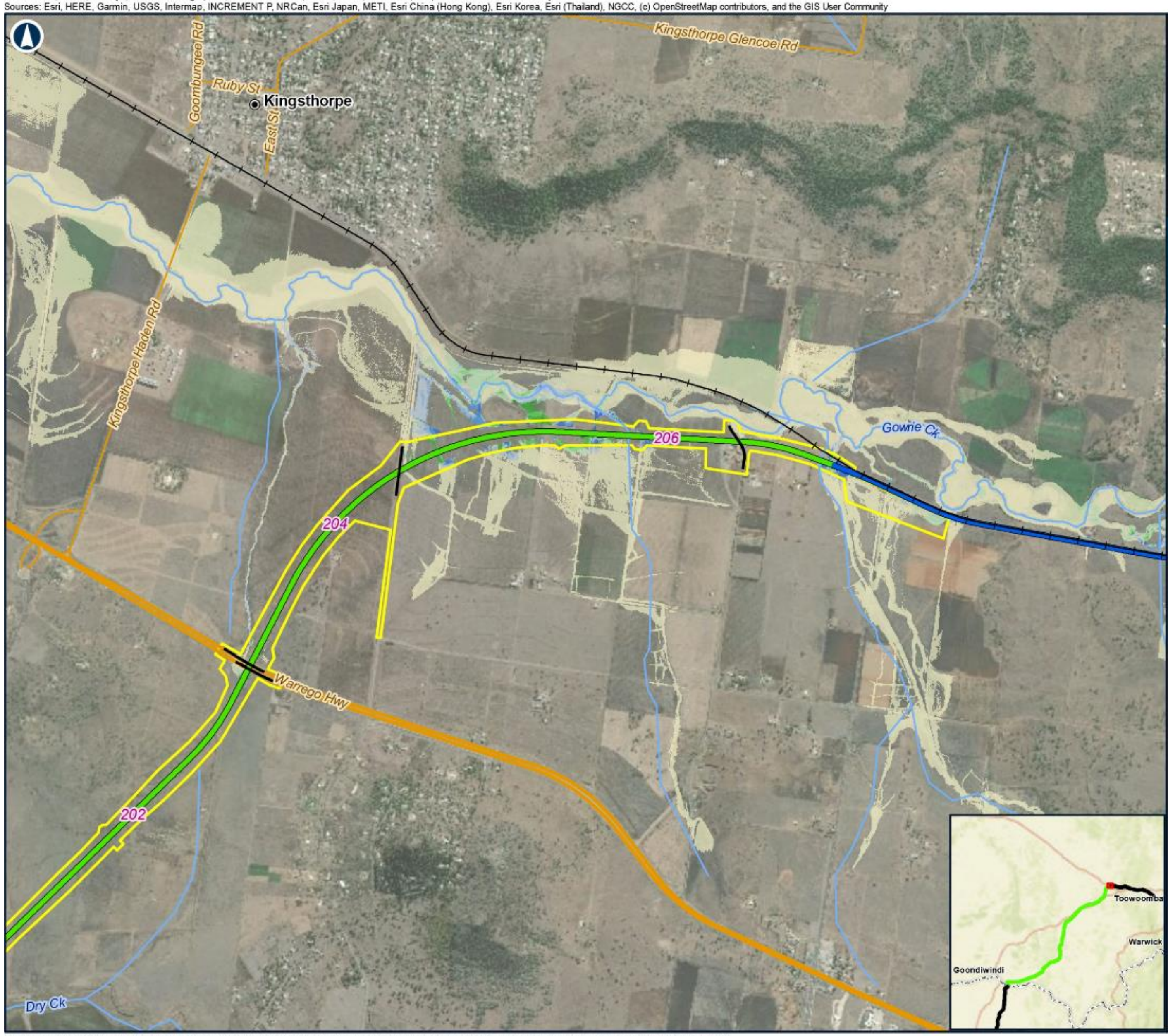

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BORDER TO GOWRIE
Figure 12.18f:
Developed Case
1% AEP Change in peak velocities
Gowrie Creek

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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12.10.2.2 Westbrook Creek and Dry Creek

On the Westbrook/Dry Creek floodplain, the Project design includes:

- Two bridges
- Ten reinforced concrete pipe (RCP) locations (a total of 94 cells)
- Two reinforced concrete box culvert (RCBC) location (a total of 13 cells).

Details of the floodplain structures required to convey Westbrook Creek and Dry Creek flood flows are presented in Table 12.66 and Table 12.67, with structure locations presented in Figure 12.19a. Figure 12.19a also presents the location of local catchment drainage structures.

TABLE 12.66 WESTBROOK CREEK AND DRY CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Structure name	Soffit level (m AHD)	Bridge length (m)
197.26	310-BR31	Bridge	Westbrook Creek Bridge	430.3	230
197.96	310-BR32	Bridge	Dry Creek Bridge	428.7	184

TABLE 12.67 WESTBROOK CREEK AND DRY CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
188.72	C188.72	RCBC	11	1.80 x 1.20
191.83	C191.83	RCP	5	2.70
193.38	C193.38	RCBC	2	1.50 x 0.90
193.41	C193.41	RCP	3	1.05
195.64	C195.64	RCP	14	1.05
195.93	C195.93	RCP	2	1.05
196.03	C196.03	RCP	2	1.05
197.42	C197.42	RCP	15	2.40
197.49	C197.49	RCP	11	1.50
197.53	C197.53	RCP	10	1.20
197.71	C197.71	RCP	17	1.05
198.26	C198.26	RCP	15	1.05

Table notes:

1. For RCP height equals diameter

Change in peak water levels

Figure 12.19b presents the change in peak water levels under the 1% AEP event and Table 12.68 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.68 WESTBROOK CREEK AND DRY CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside Project footprint[3]	198.90–199.00	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+110	2.4 ha in total affected by afflux > 10 mm
Private land outside Project footprint	197.85–198.70	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+300	6.1 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm
Private land outside Project footprint	197.50–197.80	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+440	6.5 ha in total affected by afflux > 10 mm 2.3 ha affected by afflux > 200 mm
Private land outside Project footprint	197.50	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+380	4.3 ha in total affected by afflux > 10 mm 0.6 ha affected by afflux > 200 mm
Private land outside Project footprint	197.20–197.50	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+380	11.4 ha in total affected by afflux > 10 mm 1 ha affected by afflux > 200 mm
Private land outside Project footprint	197.15	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+140	2.8 ha in total affected by afflux > 10 mm
Private land outside Project footprint	196.15–196.70	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+440	6.52 ha in total affected by afflux > 10 mm 0.5 ha affected by afflux > 200 mm
Private land outside Project footprint	195.50–195.90	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+760[1]	2.9 ha in total affected by afflux > 10 mm 1.2 ha affected by afflux > 200 mm
Private land outside Project footprint	195.50–195.90	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+110	2.8 ha in total affected by afflux > 10 mm
Private land outside Project footprint	193.40	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+440[2]	0.2 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm
Private land outside Project footprint	191.80	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+160[2]	0.2 ha in total affected by afflux > 10 mm
Private land outside Project footprint	188.70	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+250[2]	0.4 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm

Table notes:
1. Change in peak water levels at this location is localised and directly adjacent to the Project alignment
2. Change in peak water levels at these locations are confined to existing creek channels
3. Project footprint is indicated in Figure 12.19b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with noticeable floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur south of Toowoomba–Cecil Plains Road and upstream of the proposed Dry Creek bridge. These localised increases in peak water levels gradually spread as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Westbrook Creek and Dry Creek floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

Toowoomba–Cecil Plains Road currently floods to a depth of up to 110 mm in a 10% AEP event and up to 330 mm in a 1% AEP event. The total length of road inundated during a 10% AEP event is 251 m and in a 1% AEP a 533-m long section of road is affected by flooding. The maximum ToS in a 10% AEP event is 3.3 hours and in a 1% AEP event the maximum ToS is 3.7 hours.

The Project is expected to increase peak water levels on Toowoomba–Cecil Plans Road by up to 70 mm in a 1% AEP, but no increases are expected for events < 1% AEP. ToS is expected to increase by up to 1.1 hour (0 hours to 1.1 hours at a certain location) in a 1% AEP event; however, the road is already cut elsewhere and so the road amenity is not detrimentally impacted. The change in AAToS on Toowoomba–Cecil Plans Road is only 0.2 hours per year.

Brimblecombe Road would experience an even lower change and is therefore not reported.

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.

Velocities

Figure 12.19f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Westbrook Creek and Dry Creek main channels are negligible.

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* (Austroads, 2013b). 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.

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. Figure 12.19c to Figure 12.19e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.69 outlines the changes in peak water levels 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.

TABLE 12.69 WESTBROOK AND DRY CREEKS—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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	+4	0.52	+128	1.17	+846	2.93
WES_ID_2	+19	0.28	+235	0.98	+964	2.79
WES_ID_3	+11	0.38	+214	1.04	+947	2.82
Omara Road	-	3.01	+1	3.11	+19	3.88
Brimblecombe Road	+68	1.26	+110	1.48	+479	2.11
Athol School Road	-	0.57	+2,912	0.76	+3,737	1.13
F G G Couper Road	+1	3.70	+15	5.06	+4	7.38

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 12.70 outlines the overtopping locations and depths.

TABLE 12.70 WESTBROOK AND DRY CREEKS—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
197.55	-	-	0.01
188.32	-	0.15	0.49
193.01	-	-	0.11
197.09	-	-	0.53
197.13	-	-	0.72
197.31	-	-	1.78

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 21 per cent across the Westbrook Creek and Dry Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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 0.6 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 12.71 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.71 WESTBROOK AND DRY CREEKS—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

Flood sensitive receptor ID	1% AEP climate change event	
	Change in peak water level (mm)	Existing case flood depth[2] (m)
Brimblecombe Road[1]	+45	1.12

Table notes:

1. Brimblecombe Road is affected by climate change regardless of the Project and so the amenity of this road is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 notes that there are limited instances of multiple-span bridges being observed with blockages similar to those seen at single-span bridges or culverts.

The blockage assessment, therefore, resulted in no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

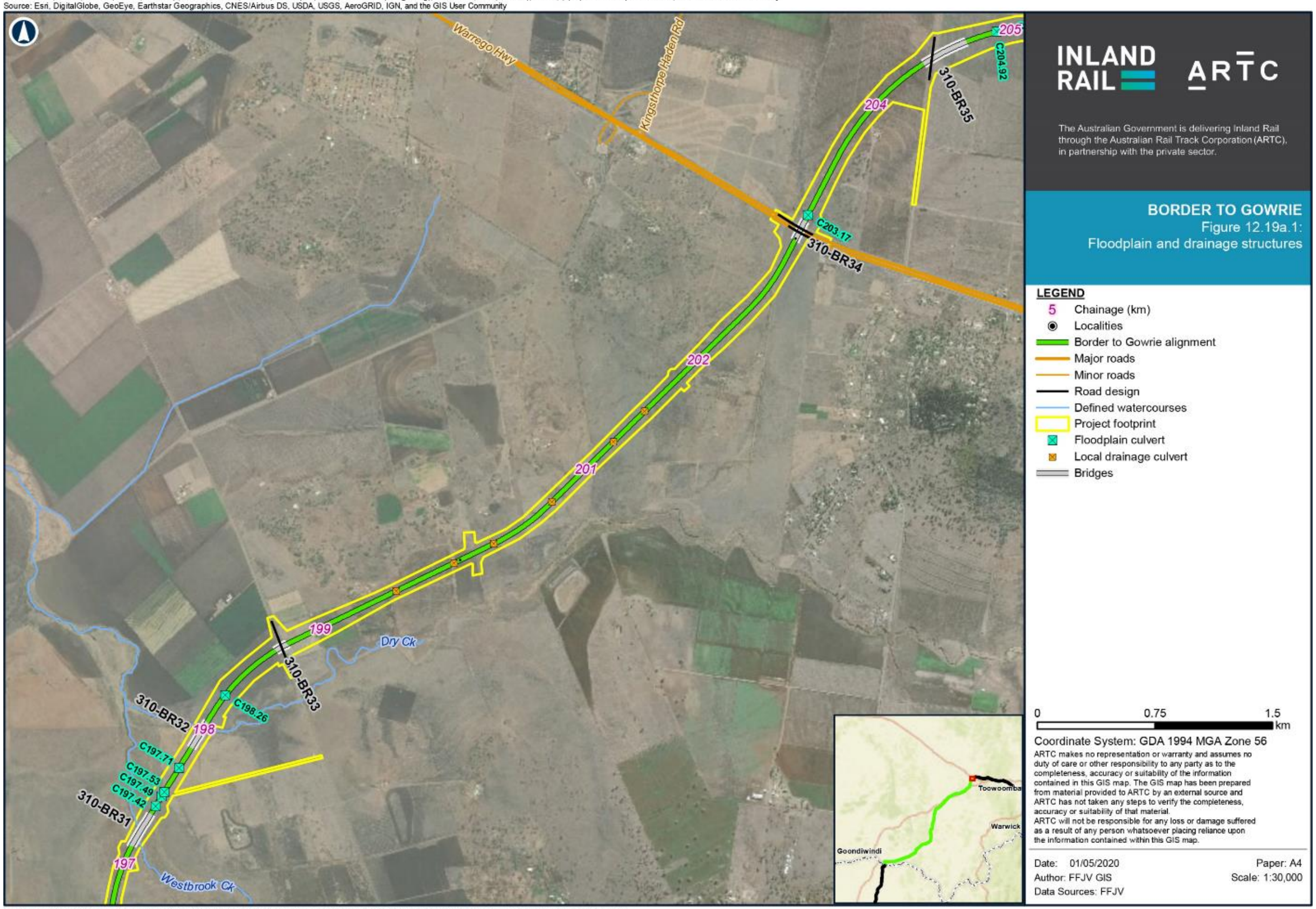
During detail design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in a varied and/or lower blockage factors being applied along the Project alignment.

Table 12.72 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.72 WESTBROOK AND DRY CREEKS—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
Brimblecombe Road	1.12	+34

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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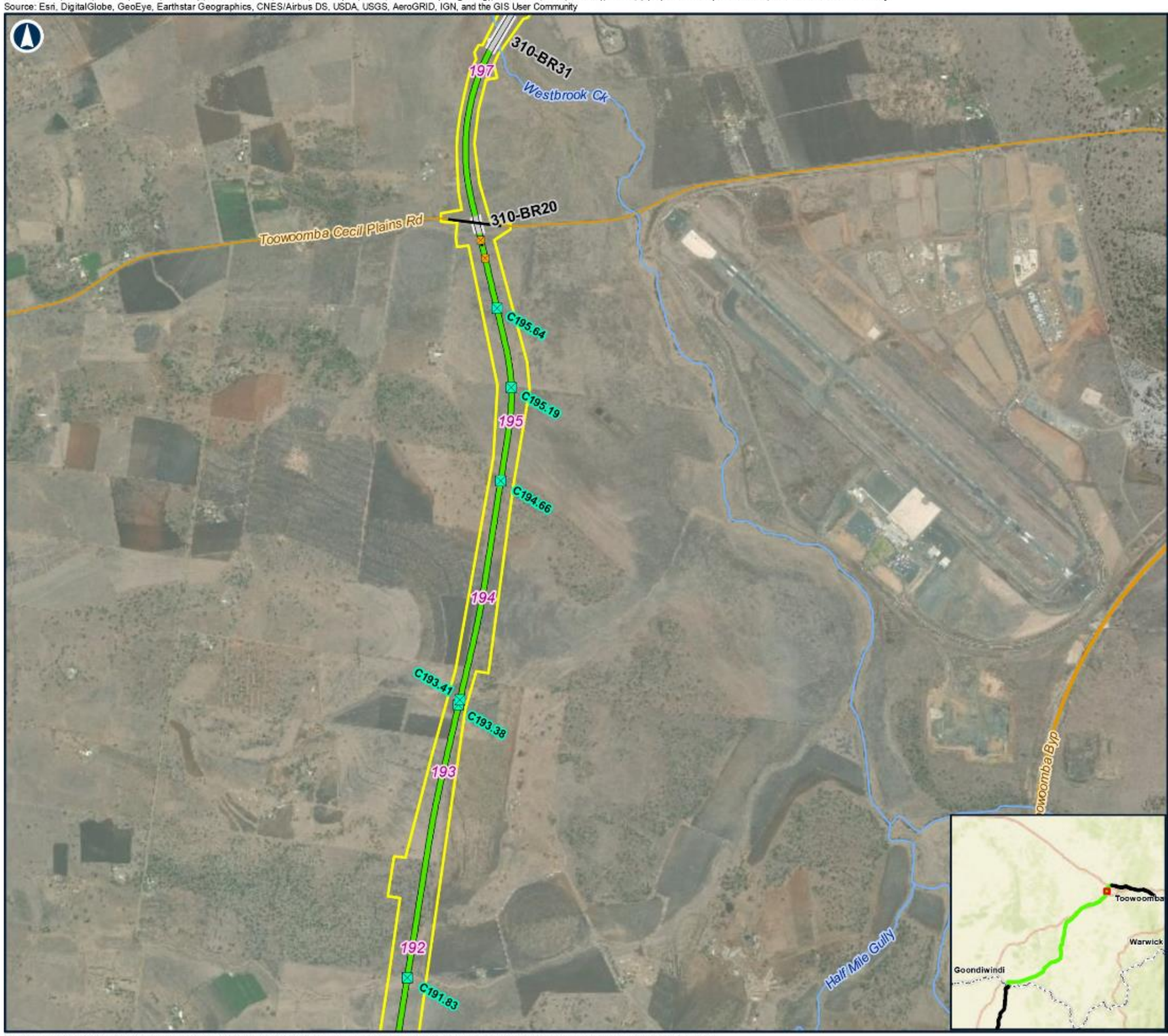

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BORDER TO GOWRIE
Figure 12.19a.2:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV

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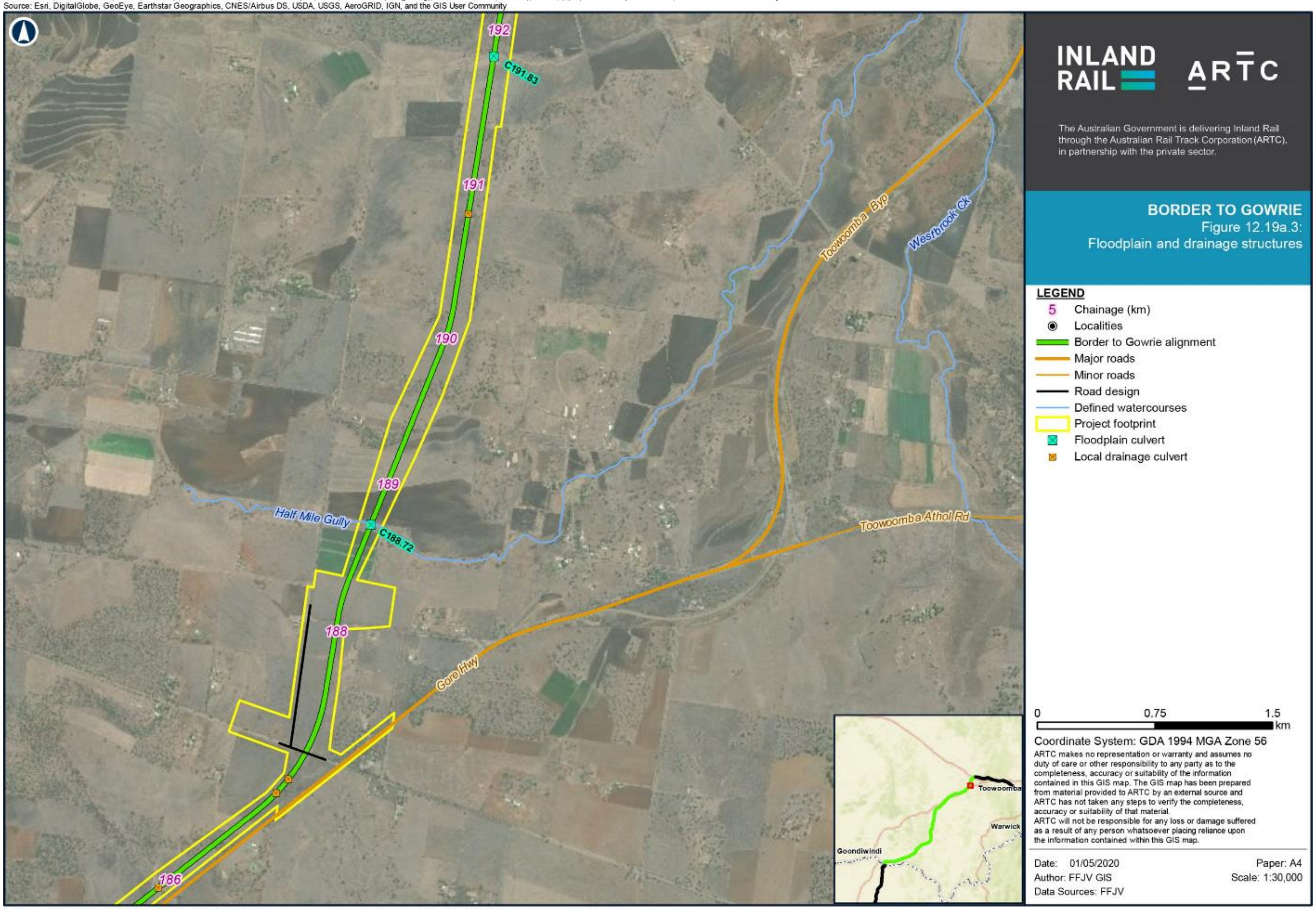

BORDER TO GOWRIE
Figure 12.19a.3:
Floodplain and drainage structures

Map by: MF/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202005121229_SurfaceWaterEIS\310-IHY-202005121229_ARTC_Fig12-Xa_Structures30.mxd Date: 8/06/2020 20:38

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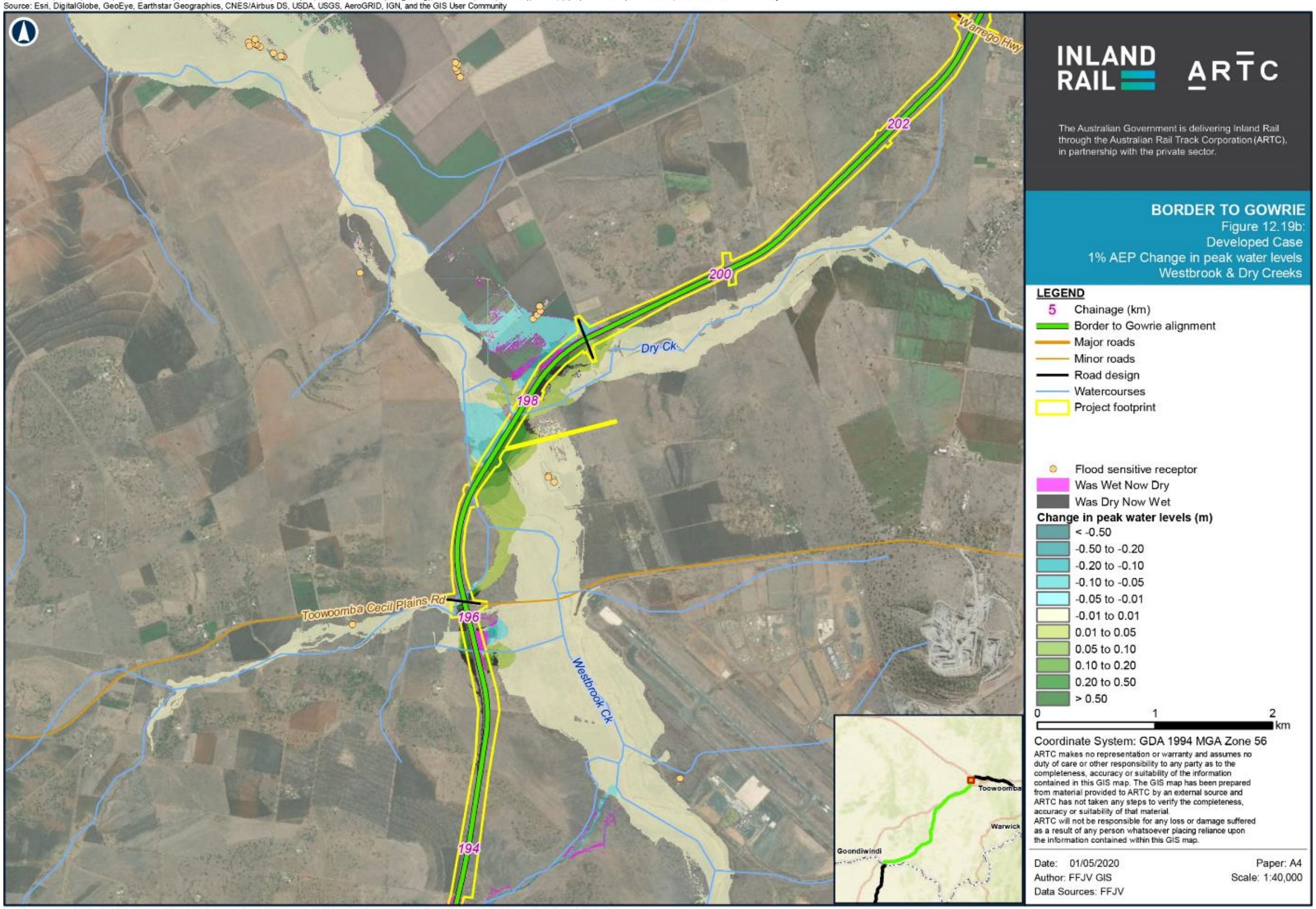

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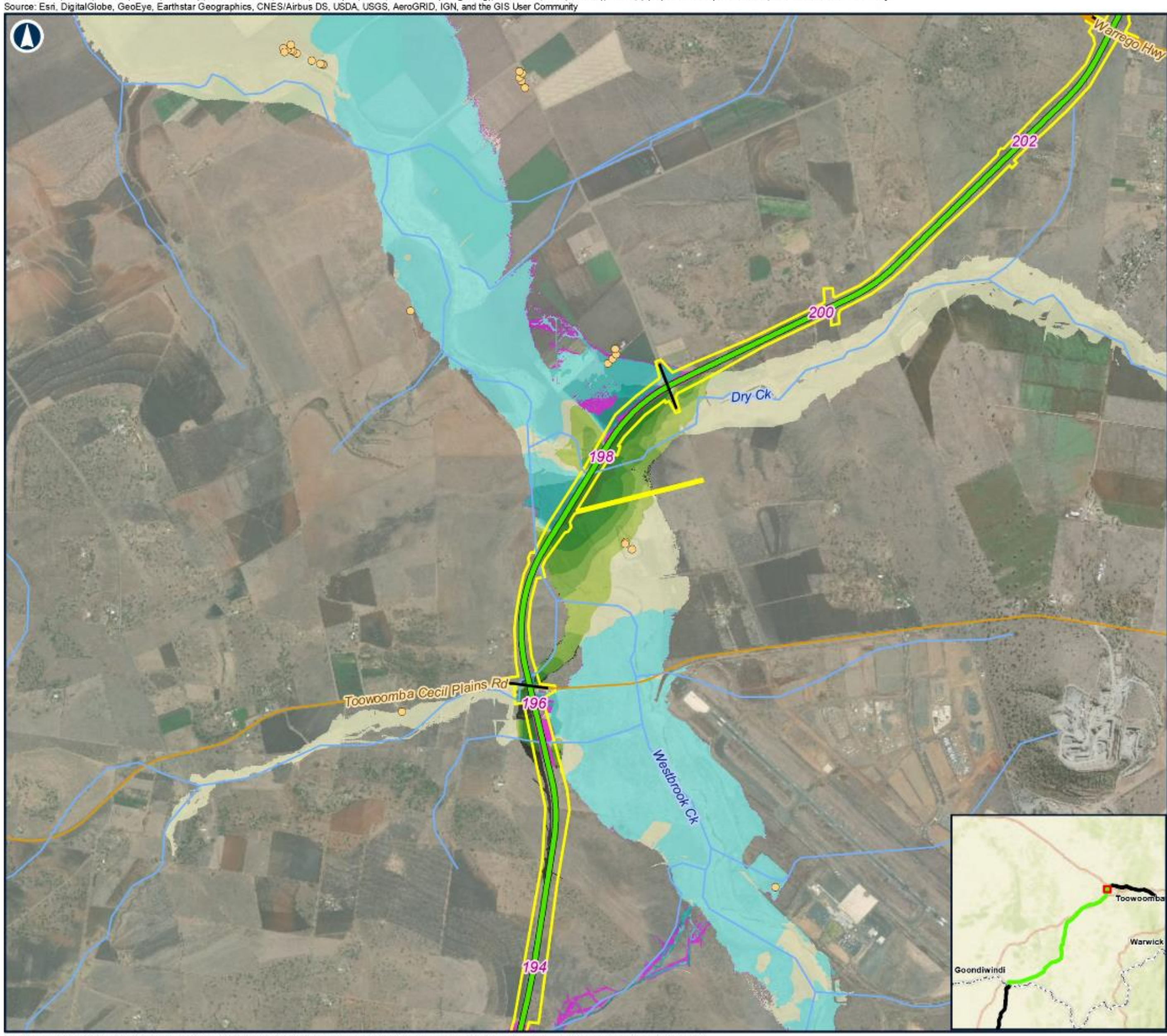

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BORDER TO GOWRIE
Figure 12.19c:
Developed Case
1 in 2,000 AEP Change in peak water levels
Westbrook & Dry Creeks

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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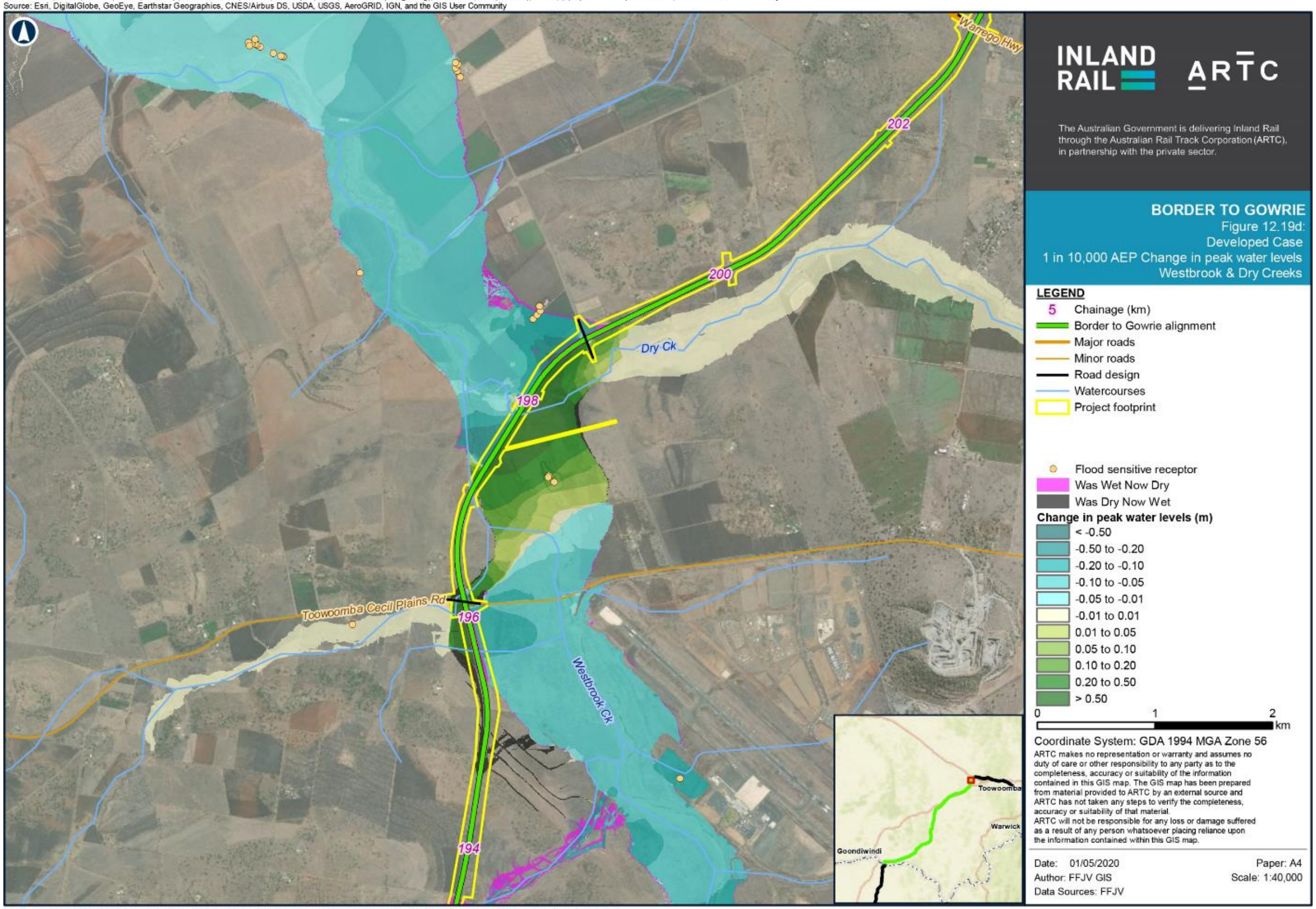

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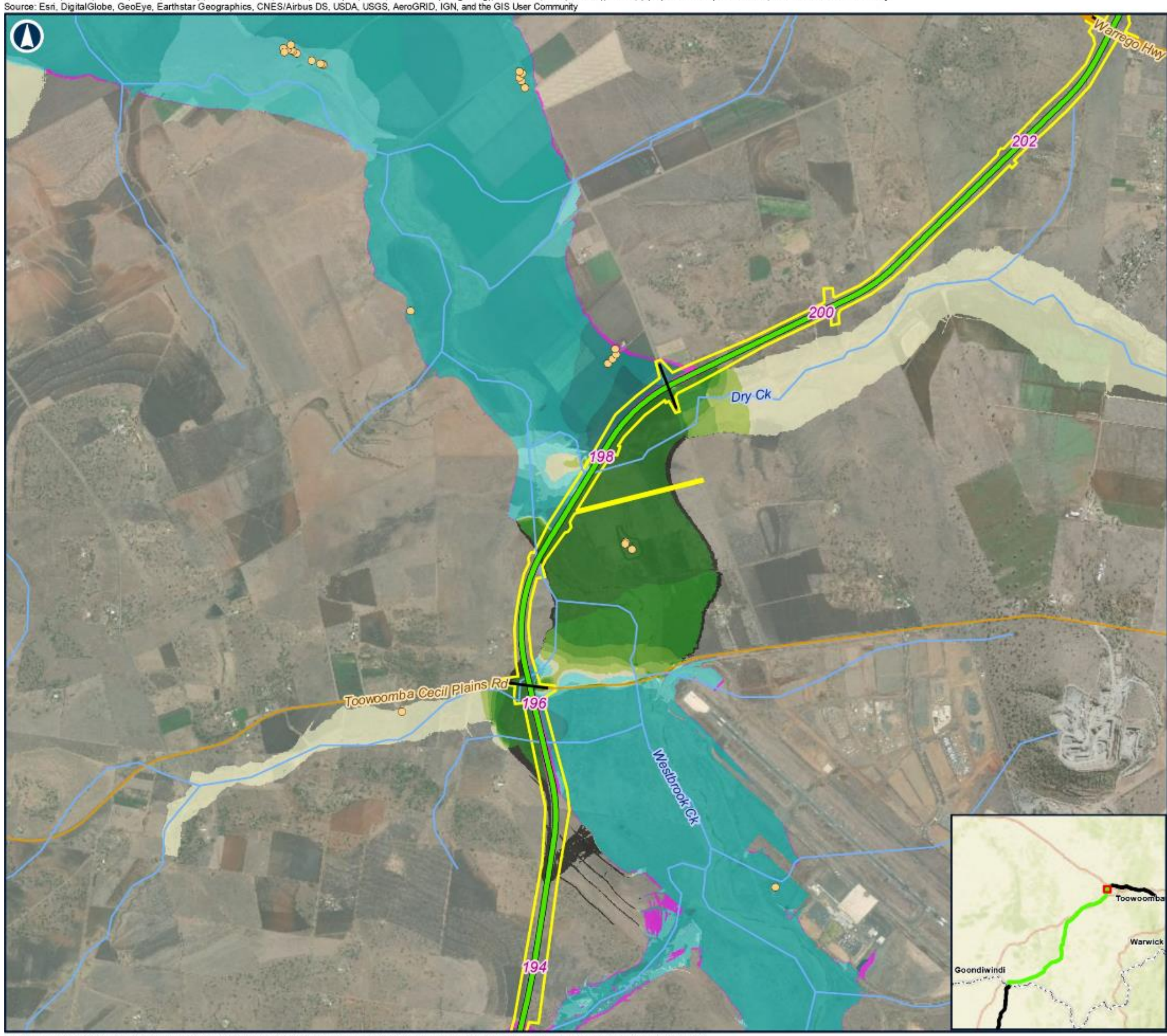

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BORDER TO GOWRIE
Figure 12.19e:
Developed Case
PMF Change in peak water levels
Westbrook & Dry Creeks

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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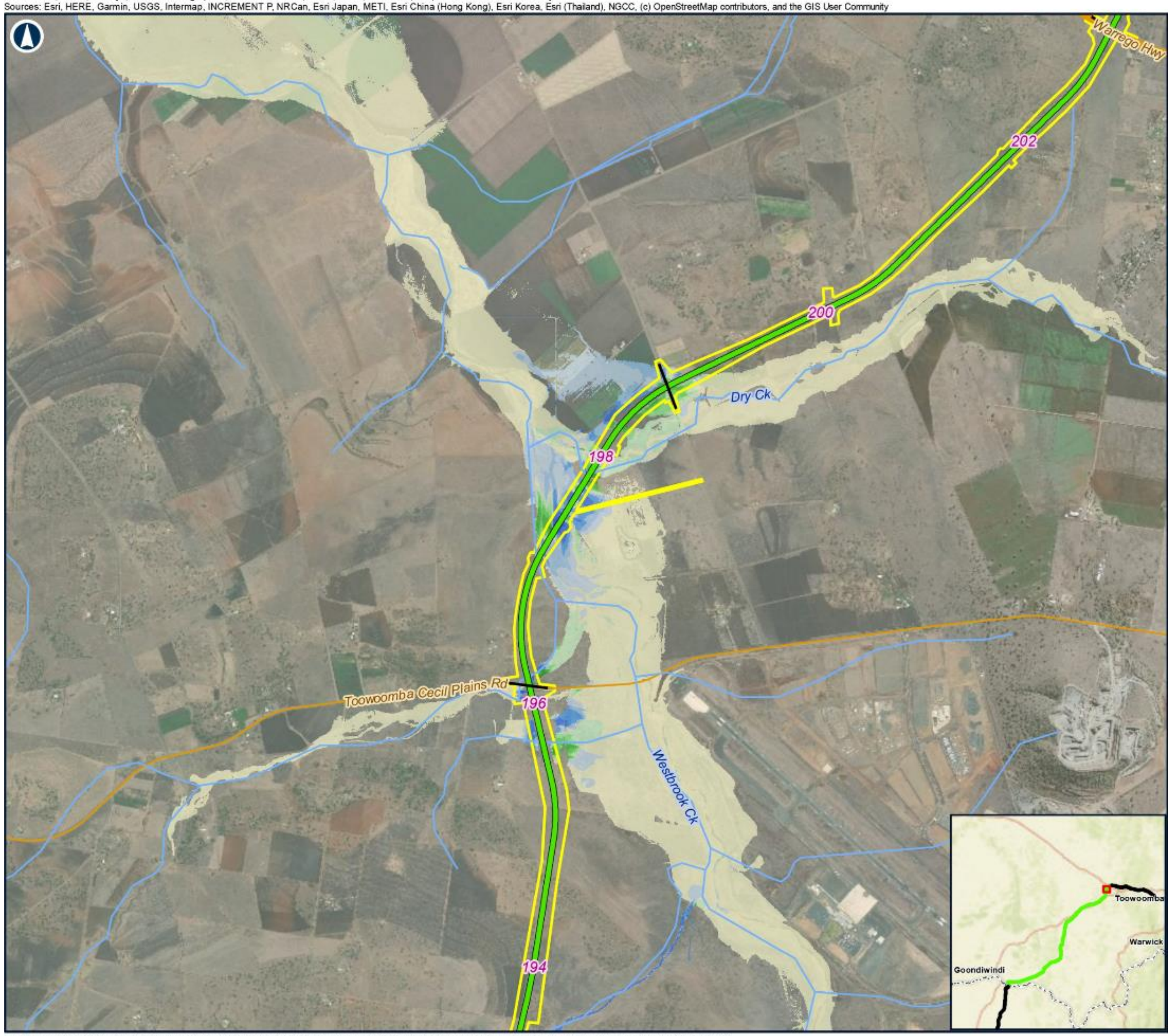

INLAND RAIL

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BORDER TO GOWRIE
Figure 12.19f:
Developed Case
1% AEP Change in peak velocities
Westbrook & Dry Creeks

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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12.10.2.3 Condamine River

On the Condamine River floodplain, the Project design includes:

- Six bridges (at four main locations)
- 71 RCP locations (a total of 452 cells)
- 14 RCBC locations (a total of 76 cells).

Details of the floodplain structures required to convey Condamine River flood flows are presented in Table 12.73 and Table 12.74, with structure locations presented in Figure 12.20a. Figure 12.20a also presents the location of local catchment drainage structures.

TABLE 12.73 CONDAMINE RIVER—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Structure name	Soffit level (m AHD)	Bridge length (m)
138.01	310-BR21	Bridge	Grasstree Creek #1 Rail Bridge	382.05	336
138.78	310-BR22	Bridge	Grasstree Creek #2 Rail Bridge	382.05	952
141.34	310-BR24	Bridge	Condamine River #1 Rail Bridge	382.06	658
142.60	310-BR25	Bridge	Condamine River #2 Rail Bridge	382.06	1,918
144.54	310-BR26	Bridge	Condamine River #3 Rail Bridge	382.06	602
147.78	310-BR27	Bridge	Condamine River North Branch Rail Bridge	383.79	1,568

TABLE 12.74 CONDAMINE RIVER—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
131.39	C131.39	RCP	1	2.10
131.49	C131.49	RCP	1	2.10
137.83	C137.83	RCP	8	1.35
137.88	C137.88	RCP	11	1.65
137.92	C137.92	RCP	8	1.80
139.37	C139.37	RCP	11	1.80
139.44	C139.44	RCP	8	2.10
139.50	C139.5	RCP	8	2.10
139.56	C139.56	RCP	11	1.80
139.71	C139.71	RCP	9	1.65
139.73	C139.73	RCBC	4	2.4 x 1.8
139.78	C139.78	RCP	10	2.10
140.09	C140.09	RCP	7	1.80
140.11	C140.11	RCP	7	1.80
140.17	C140.17	RCP	6	2.10
140.21	C140.21	RCP	6	2.10
140.23	C140.23	RCP	6	2.10
140.25	C140.25	RCP	6	2.10
140.27	C140.27	RCP	6	2.10
140.32	C140.32	RCP	6	2.10
140.38	C140.38	RCP	6	2.10
140.40	C140.4	RCP	6	2.10

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
140.43	C140.43	RCP	7	1.80
140.46	C140.46	RCP	5	2.10
140.49	C140.49	RCP	6	2.10
140.51	C140.51	RCP	6	2.10
140.55	C140.55	RCP	5	2.10
140.59	C140.59	RCP	5	2.10
140.64	C140.64	RCP	6	2.10
140.67	C140.67	RCP	5	2.10
140.78	C140.78	RCP	6	2.10
140.83	C140.83	RCP	6	2.10
140.87	C140.87	RCP	4	2.10
140.91	C140.91	RCP	6	2.10
140.98	C140.98	RCP	6	2.10
141.03	C141.03	RCP	4	2.10
141.07	C141.07	RCP	6	2.10
141.11	C141.11	RCP	6	2.10
141.20	C141.2	RCP	6	2.10
141.24	C141.24	RCP	6	2.10
141.29	C141.29	RCP	6	2.10
141.32	C141.32	RCP	4	2.10
142.02	C142.02	RCP	6	2.10
142.04	C142.04	RCP	6	2.10
142.08	C142.08	RCP	6	2.10
142.13	C142.13	RCP	6	2.10
142.15	C142.15	RCP	6	2.10
142.19	C142.19	RCP	6	2.10
142.22	C142.22	RCP	6	2.10
142.25	C142.25	RCP	6	2.10
142.28	C142.28	RCP	5	2.10
142.36	C142.36	RCP	6	2.10
142.41	C142.41	RCP	6	2.10
142.44	C142.44	RCP	6	2.10
142.48	C142.48	RCP	6	2.10
142.50	C142.5	RCP	5	2.10
142.54	C142.54	RCP	4	2.10
142.58	C142.58	RCP	5	2.10
145.16	C145.16	RCBC	4	1.20 x 0.90
145.21	C145.21	RCBC	4	1.20 x 0.90
145.25	C145.25	RCBC	4	1.20 x 0.90
145.32	C145.32	RCBC	2	1.20 x 0.90
145.40	C145.4	RCBC	6	1.20 x 0.90

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
145.72	C145.72	RCBC	10	1.50 x 0.90
145.83	C145.83	RCBC	4	1.20 x 0.90
145.89	C145.89	RCBC	10	1.50 x 0.90
145.92	C145.92	RCBC	4	1.20 x 0.90
145.98	C145.98	RCBC	4	1.20 x 0.90
146.03	C146.03	RCBC	10	1.50 x 0.90
146.56	C146.56	RCBC	6	1.20 x 0.60
146.62	C146.62	RCBC	4	1.20 x 0.60
147.58	C147.58	RCP	6	1.05
147.63	C147.63	RCP	6	1.05
147.66	C147.66	RCP	6	1.05
147.73	C147.73	RCP	7	1.05
149.39	C149.39	RCP	10	1.35
149.42	C149.42	RCP	12	1.20
149.45	C149.45	RCP	3	1.35
149.76	C149.76	RCP	8	1.20
149.80	C149.8	RCP	8	1.20
149.83	C149.83	RCP	8	1.20
149.87	C149.87	RCP	6	1.35
149.91	C149.91	RCP	6	1.35
149.96	C149.96	RCP	8	1.20
150.01	C150.01	RCP	8	1.05

Table notes:

1. For RCP, height equals diameter

Change in peak water levels

Figure 12.20b presents the change in peak water levels under the 1% AEP event and Table 12.75 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.75 CONDAMINE RIVER—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Flood sensitive receptor ID	Approximate chainage (km)	Existing land use	Flood impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
House	CON_ID_78	137.70	Dwelling	≤ 10 mm	+42	Existing 1% AEP flood depth: 441 mm
House	CON_ID_99	139.30	Dwelling	≤ 10 mm	+16	Existing 1% AEP flood depth: 19 mm
House	CON_ID_205	140.30	Dwelling	≤ 10 mm	+16	Existing 1% AEP flood depth: 767 mm
House	CON_ID_148	146.90	Dwelling	≤ 10 mm	+26	Existing 1% AEP flood depth: 148 mm
House	CON_ID_277	147.45	Dwelling	≤ 10 mm	+36	Existing 1% AEP flood depth: 98 mm
Shed	CON_ID_118	140.00	Outbuilding	≤ 100 mm	+136	Existing 1% AEP flood depth: 95 mm
Silos	CON_ID_6	139.90	Commercial	≤ 100 mm	+117	Existing 1% AEP flood depth: 333 mm
Silos	CON_ID_5	139.90	Commercial	≤ 100 mm	+147	Existing 1% AEP flood depth: 80 mm
Silos	CON_ID_7	139.90	Commercial	≤ 100 mm	+160	Existing 1% AEP flood depth: 173 mm
Private land outside Project footprint[2]	-	131.10 to 133.40	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+900[1]	1.5 ha in total affected by afflux > 10 mm < 1 ha affected by afflux > 200 mm
Private land outside Project footprint	-	138.55 to 140.10	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+117	279 ha in total affected by afflux > 10 mm
Private land outside Project footprint	-	140.10 to 141.30	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+128	227 ha in total affected by afflux > 10 mm
Private land outside Project footprint	-	145.20 to 146.10	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+295	183 ha in total affected by afflux > 10 mm
Private land outside Project footprint	-	146.15 to 146.80	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+138	20 ha in total affected by afflux > 10 mm
Private land outside Project footprint	-	149.15 to 150.30	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+139	12 ha in total affected by afflux > 10 mm

Table notes:
1. Change in peak water levels at this location are extremely localised and directly adjacent to the Project alignment
2. Project footprint is indicated in Figure 12.20b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur near Millmerran Leyburn Road, downstream of Gilgai Lane and to the northeast of Pampas, adjacent to the Project alignment. These localised increases in peak water levels gradually spread as the flood magnitude increases.

An assessment was undertaken to determine impacts to additional flood-sensitive receptors not impacted by the 1% AEP event, for events < 1% AEP. It was found that in a 20% AEP event, flood-sensitive receptor CON_ID_82 is impacted by afflux of 12 mm.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. A 'change in time of inundation' map is presented in Appendix Q2: Hydrology and Flooding Technical Report.

The change in ToS for the 1% AEP event is presented in Table 12.76 for locations within the Condamine River floodplain where changes in ToS lie outside the flood-impact objectives.

TABLE 12.76 CONDAMINE RIVER—1% AEP EVENT—CHANGE IN DURATION OF INUNDATION

Location	Approximate chainage (km)	Existing land use	Flood impact objectives for 1% AEP event	Maximum change in duration of inundation (hrs)	Comment
Private land outside Project footprint	142.95–144.50	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+1	2.85 ha in total affected by changes in duration of inundation
Private land outside Project footprint	144.55–146.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+3.9	2.05 ha in total affected by changes in duration of inundation
Private land outside Project footprint	144.85–145.25	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+15	0.69 ha in total affected by changes in duration of inundation
Private land outside Project footprint	145.25–145.60	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+2.5	3.73 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.80–148.28	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-3.4	4.88 ha in total affected by changes in duration of inundation
Private land outside Project footprint	146.20–146.80	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-3.9	6.27 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.42–147.52	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+5.4	0.85 ha in total affected by changes in duration of inundation
Private land outside Project footprint	139.85–140.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+10	0.50 ha in total affected by changes in duration of inundation[1]
Private land outside Project footprint	145.60–146.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-3.1	11.68 ha in total affected by changes in duration of inundation
Private land outside Project footprint	138.55–140.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+1.1	19.00 ha in total affected by changes in duration of inundation
Private land outside Project footprint	146.70–147.20	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-1.9	0.60 ha in total affected by changes in duration of inundation

Location	Approximate chainage (km)	Existing land use	Flood impact objectives for 1% AEP event	Maximum change in duration of inundation (hrs)	Comment
Private land outside Project footprint	146.20 to 147.20	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+1.3	9.31 ha in total affected by changes in duration of inundation
Private land outside Project footprint	146.30 to 147.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-1.5	4.46 ha in total affected by changes in duration of inundation
Private land outside Project footprint	146.40 to 147.00	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-1.1	0.75 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.10 to 147.90	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-2.4	0.33 ha in total affected by changes in duration of inundation
Private land outside Project footprint	146.20 to 147.20	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-2.2	3.78 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.20 to 147.80	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-2.3	0.25 ha in total affected by changes in duration of inundation
Private land outside Project footprint	149.15 to 149.75	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+1.2	0.35 ha in total affected by changes in duration of inundation
Private land outside Project footprint	141.35 to 142.88	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-6.8	0.80 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.30 to 147.80	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-3.4	6.24 ha in total affected by changes in duration of inundation
Private land outside Project footprint	145.90 to 146.10	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+3.6	0.21 ha in total affected by changes in duration of inundation
Private land outside Project footprint	150.00 to 151.50	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	+1.2	3.74 ha in total affected by changes in duration of inundation
Private land outside Project footprint	147.30 to 147.80	Agricultural (cropping)	>+/- 1hr change and > 0.2 ha affected	-1.8	20.23 ha in total affected by changes in duration of inundation

Table notes:

1. Affected area of less than 0.1 ha directly upstream of the Project alignment
2. Project footprint is indicated in Figure 12.20b

The Gore Highway between Pampas and Millmerran currently floods to a depth of up to 100 mm in a 10% AEP event and up to 390 mm in a 1% AEP event. The total length of road inundated between Pampas and Millmerran during a 10% AEP event is 5.4 km, and in a 1% AEP event a 7.6 km section of the road becomes inundated. The maximum ToS along this stretch of road in a 10% AEP event is 54 hrs, and 84 hrs in a 1% AEP event.

The Gore Highway between Brookstead and Pampas does not currently flood in a 10% AEP event but in a 1% AEP event it floods to a maximum depth of 110 mm. The total length of road inundated between Brookstead and Pampas during a 1% AEP event is 650 m. The maximum ToS along this stretch of road is 64 hrs in a 1% AEP event.

The Project is not expected to increase peak water levels on the Gore Highway up to a 1% AEP; however, ToS is expected to increase by up to 1 hr (59 hrs to 60 hrs) in a 5% AEP event, and up to 12 hrs in a 1% AEP event. The change in AAToS on the Gore Highway, however, is only 0.4 hours per year.

ToS on Millmerran–Leyburn Road downstream of the Project for frequent events (20% AEP, 10% AEP and 5% AEP) is expected to increase as a result of the Project but decrease for events exceeding the 5% AEP. AAToS for Millmerran–Leyburn Road is expected to increase by 21.4 hrs/yr. This increase is due to the increased conveyance area under the proposed rail alignment in comparison to the existing rail alignment. The effects are noticeable in the smaller events as flow is able to pass through the proposed rail alignment far easier than the existing rail alignment, which acts as a weir in smaller events. Difference in larger events are negligible as the existing rail alignment is overtopped. It should be noted, however, that Millmerran–Inglewood Road becomes cut by floodwater upstream of the Project anyway and, as such, the increased AAToS downstream of the Project does not detrimentally affect the amenity of the road.

Potential impacts to other roads in the Condamine River floodplain are reported in Appendix Q1/Q2: Hydrology and Flooding Technical Report.

Flood flow distribution

To understand the magnitude of these flowpaths, flows were extracted from the hydraulic model at key locations. The difference between the Existing Case and Developed Case was considered and reported in Table 12.77.

Figure 12.20g presents the selected flowpath comparison locations. The flow is calculated across the length of the line; therefore, the lines presented are either calculating the flow across the width of the floodplain (for the longer flow lines) or the main flowpath of the waterways (generally for smaller flow lines).

TABLE 12.77 CONDAMINE RIVER—FLOW COMPARISON

	10% AEP event			1% AEP event		
Location ID	Existing Case flow (m^3/s)	Developed Case flow (m^3/s)	% Change	Existing Case flow (m^3/s)	Developed Case flow (m^3/s)	% Change
	1,516	1,541	+2%	3,739	3,703	-1%
2	317	311	-2%	1,021	1,014	-1%
3	1,262	1,236	-2%	2,724	2,714	-
4	434	438	+1%	1,193	1,169	-2%
5	116	127	+8%	247	276	+10%
6	882	872	-1%	1,512	1,474	-3%
7	21	21	+1%	140	150	+6%
8	1,475	1,470	-	3,672	3,661	-
9	62	63	+1%	200	192	-4%

Velocities

Figure 12.20f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Condamine River main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.20c to Figure 12.20e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.78 outlines the changes in peak water levels 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.

TABLE 12.78 CONDAMINE RIVER—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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	+224	1.09	+282	2.06	+91	3.46
CON_ID_5	+232	1.05	+304	2.02	+101	3.43
CON_ID_6	+232	1.08	+304	2.05	+98	3.47
CON_ID_7	+235	1.03	+304	2.0	+101	3.41
CON_ID_8	+225	1.28	+282	2.25	+91	3.66
CON_ID_9	+223	1.22	+280	2.19	+91	3.60
CON_ID_10	+221	1.34	+279	2.30	+92	3.71
CON_ID_68	+99	1.41	+168	2.38	+153	3.79
CON_ID_78	+110	1.31	+186	2.27	+169	3.69
CON_ID_79	+10	1.23	+19	2.09	+10	3.40
CON_ID_80	+12	1.16	+22	2.01	+10	3.32
CON_ID_81	+14	0.89	+23	1.72	+10	3.02
CON_ID_82	+12	1.37	+21	2.22	+10	3.53
CON_ID_96	+65	0.49	+121	1.46	+82	2.91
CON_ID_97	+62	0.76	+120	1.72	+83	3.17
CON_ID_98	+62	0.62	+120	1.58	+82	3.03
CON_ID_99	+81	0.86	+133	1.86	+86	3.31
CON_ID_100	+81	1.03	+132	2.03	+86	3.48
CON_ID_101	+81	1.29	+132	2.29	+86	3.75
CON_ID_102	+81	1.33	+133	2.33	+87	3.79
CON_ID_103	+81	0.93	+133	1.93	+86	3.39
CON_ID_104	+82	0.95	+133	1.95	+86	3.41
CON_ID_118	+235	1.09	+314	2.06	+93	3.47
CON_ID_119	+106	1.34	+161	2.33	+92	3.77
CON_ID_120	+109	1.33	+164	2.32	+92	3.76
CON_ID_146	+133	0.48	+157	1.03	+73	1.87
CON_ID_147	+134	0.54	+152	1.08	+66	1.92
CON_ID_148	+131	0.54	+149	1.08	+63	1.92
CON_ID_149	+134	0.30	+184	0.86	+111	1.70
CON_ID_153	+12	1.15	+18	2.03	+10	3.35
CON_ID_154	-100	0.93	-67	1.77	+11	3.07
CON_ID_155	-108	0.97	-72	1.82	+11	3.11
CON_ID_156	-108	1.03	-73	1.87	+11	3.17
CON_ID_157	+70	0.08	+190	0.46	+107	1.27
CON_ID_158	+82	0.04	+187	0.42	+112	1.25
CON_ID_159	+2	1.92	+24	2.30	+50	3.21
CON_ID_160	+24	0.46	+84	0.89	+75	1.72
CON_ID_161	+25	0.63	+86	1.06	+77	1.89
CON_ID_162	+25	0.62	+85	1.05	+77	1.88
CON_ID_163	-	0.08	+20	0.28	+25	0.83

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_164	-	0.09	+19	0.28	+24	0.83
CON_ID_165	+1	0.09	+19	0.23	+24	0.80
CON_ID_166	-	0.09	+4	0.94	+10	2.12
CON_ID_167	-	0.03	+3	0.70	+10	1.88
CON_ID_168	-	0.01	+3	0.76	+10	1.94
CON_ID_169	-	0.09	+3	0.81	+10	1.98
CON_ID_170	-	0.12	+3	0.81	+10	1.99
CON_ID_171	-	0.25	+3	1.00	+10	2.18
CON_ID_172	-	0.30	+3	1.04	+10	2.21
CON_ID_173	-	0.28	+4	1.04	+10	2.23
CON_ID_186	-155	0.79	-86	1.64	+12	2.93
CON_ID_187	-169	0.81	-92	1.67	+11	2.96
CON_ID_188	-168	0.76	-91	1.61	+12	2.90
CON_ID_189	-163	0.83	-89	1.68	+12	2.97
CON_ID_190	-165	0.78	-88	1.63	+12	2.91
CON_ID_191	-158	0.64	-86	1.48	+12	2.77
CON_ID_192	-155	0.67	-85	1.52	+12	2.81
CON_ID_193	+1	1.21	+10	1.82	+17	2.85
CON_ID_194	+1	1.32	+10	1.92	+17	2.95
CON_ID_195	+1	1.37	+9	1.97	+16	3.00
CON_ID_196	+1	1.28	+10	1.88	+17	2.89
CON_ID_197	+1	1.20	+9	1.80	+17	2.82
CON_ID_198	-	-	+12	0.13	+10	1.21
CON_ID_199	-	-	+13	0.29	+10	1.36
CON_ID_200	-	-	+13	0.32	+10	1.31
CON_ID_201	-	-	+14	0.38	+10	1.34
CON_ID_202	-	-	+14	0.20	+9	1.17
CON_ID_203	+71	1.24	+125	2.22	+70	3.65
CON_ID_204	+72	1.54	+126	2.52	+70	3.95
CON_ID_205	+72	1.59	+126	2.57	+70	4.00
CON_ID_206	+72	1.34	+127	2.32	+70	3.75
CON_ID_207	+72	1.63	+127	2.60	+70	4.03
CON_ID_208	+24	0.49	+72	1.45	+54	2.91
CON_ID_209	+27	0.53	+73	1.53	+54	3.00
CON_ID_210	+23	0.46	+71	1.43	+53	2.89
CON_ID_211	+12	0.33	+82	0.81	+152	1.68
CON_ID_212	+9	0.28	+74	0.67	+142	1.39
CON_ID_213	+10	0.51	+78	0.98	+147	1.85
CON_ID_214	+10	0.62	+76	1.09	+146	1.96
CON_ID_215	+20	1.14	+63	2.13	+46	3.58
CON_ID_216	+20	1.43	+64	2.41	+46	3.86

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_217	+20	1.21	+64	2.18	+46	3.63
CON_ID_218	+20	1.06	+63	2.04	+46	3.48
CON_ID_219	+20	1.10	+63	2.08	+46	3.52
CON_ID_220	+20	0.91	+62	1.90	+45	3.34
CON_ID_221	+20	0.91	+62	1.90	+45	3.35
CON_ID_222	+20	0.87	+61	1.86	+44	3.32
CON_ID_223	+20	1.00	+62	1.99	+45	3.44
CON_ID_224	+20	0.83	+61	1.84	+44	3.29
CON_ID_225	+20	1.07	+62	2.07	+45	3.52
CON_ID_231	-12	0.11	+34	0.31	+27	1.26
CON_ID_232	-12	0.09	+33	0.35	+29	1.27
CON_ID_233	-12	0.16	+31	0.42	+30	1.33
CON_ID_234	-10	0.11	+36	0.37	+22	1.36
CON_ID_235	-12	0.23	+32	0.50	+31	1.42
CON_ID_236	-12	0.05	+28	0.30	+28	1.19
CON_ID_237	-	0.71	+4	1.47	+10	2.65
CON_ID_238	-	0.75	+4	1.50	+10	2.69
CON_ID_239	-	0.73	+4	1.48	+10	2.66
CON_ID_242	-	0.91	+4	1.67	+10	2.86
CON_ID_243	-	0.76	+4	1.52	+10	2.71
CON_ID_244	+205	0.40	+202	0.95	+70	1.83
CON_ID_245	+202	0.28	+189	0.84	+68	1.69
CON_ID_246	+167	0.54	+175	1.10	+71	1.97
CON_ID_247	+147	0.65	+167	1.20	+72	2.07
CON_ID_248	+145	0.46	+163	1.00	+70	1.85
CON_ID_256	-	0.85	+4	1.37	+12	2.30
CON_ID_257	-	1.17	+4	1.66	+12	2.56
CON_ID_258	-	0.82	+3	1.31	+12	2.20
CON_ID_259	-	0.90	+3	1.38	+11	2.26
CON_ID_260	-	0.96	+3	1.43	+11	2.30
CON_ID_261	-	0.87	+3	1.34	+11	2.21
CON_ID_268	-6	0.16	+31	0.45	+39	1.21
CON_ID_269	-6	0.36	+31	0.65	+39	1.41
CON_ID_270	-7	0.50	+31	0.80	+41	1.57
CON_ID_271	-15	0.23	+79	0.52	+75	1.47
CON_ID_272	-36	0.05	+36	0.39	+65	1.31
CON_ID_273	-18	0.16	+39	0.50	+70	1.44
CON_ID_274	-22	0.49	+20	0.86	+60	1.76
CON_ID_275	+61	0.06	+170	0.41	+110	1.26
CON_ID_276	+60	0.02	+161	0.27	+107	1.12
CON_ID_277	+77	0.30	+193	0.63	+118	1.47

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_278	-7	1.06	+48	1.38	+84	2.12
CON_ID_280	-14	0.13	+47	0.44	+54	1.45
CON_ID_281	-13	0.09	+77	0.45	+69	1.44
CON_ID_282	-16	0.04	+54	0.37	+71	1.38
CON_ID_283	-14	0.10	+48	0.44	+70	1.43
CON_ID_284	-13	0.12	+46	0.48	+73	1.48
CON_ID_300	-	-	-	-	+32	0.76
CON_ID_301	-	-	-	-	+33	0.17
CON_ID_302	+2	0.25	+15	0.91	+26	2.15
CON_ID_303	+2	0.41	+16	1.10	+27	2.35
Bellevue Road	+14	1.68	+44	2.53	+45	3.90
Brose Lane	+13	2.13	+19	3.11	+10	4.46
Crank Road	-	1.66	+3	2.39	+10	3.57
Elsden Road	+145	2.63	+396	3.01	+587	3.79
Fysh Road	+112	2.09	+189	2.80	+113	3.90
Gibbs Road	+52	1.14	+169	1.59	+243	2.40
Gilgai Lane	+155	3.24	+239	4.03	+134	5.29
Gore Highway (Toowoomba–Millmerran)	+89	2.36	+313	3.25	+122	4.55
Grasstree Reserve Road	+2	2.37	+14	3.08	+24	4.32
Hall Road	+175	4.35	+234	5.30	+155	6.70
King Road	+1	2.43	1+0	3.14	+18	4.38
Lovell Road	+1,080	0.58	+1,209	0.67	+1,429	0.77
Mann Silo Road	-	0.88	+4	1.05	+98	1.34
Millmerran–Leyburn Road	+177	3.59	+268	4.42	+90	5.61
Missen Road	+1	1.38	+23	2.17	+33	3.37
Pampas–Horrane Road	-	1.80	+1	2.80	+14	3.99
Pampas Pit Road	+79	1.40	+204	1.78	+127	2.56
Pampas Road	+3	0.89	+124	1.97	+87	3.20
Reichle Road	+11	4.83	+49	5.59	+41	6.90
Yarramalong Road	-	6.20	+7	6.81	+57	7.76

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 12.79 outlines the overtopping locations and depths.

TABLE 12.79 CONDAMINE RIVER—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
132.00–132.94	-	0.18	0.27
137.93–138.00	-	0.17	1.47
138.18	-	-	1.55
139.35–141.27	-	0.28	1.56
141.67	-	-	0.50
142.00–142.58	-	-	1.12
144.88	-	-	0.34
145.24–147.50	-	0.42	1.12

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.

Climate change

The climate change guidelines set out in ARR 2016 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 20.8 per cent across the Condamine River basin area.

Appendix Q1/Q2: Hydrology and Flooding Technical Report 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 90 mm in the vicinity of the Project under the 1% AEP event. The Project formation level is higher than the 1% AEP climate change water level at these locations.

Table 12.80 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.80 CONDAMINE RIVER—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood sensitive receptor ID	Change in peak water level (mm)	Existing case flood depth[2] (m)
CON_ID_4	+168	0.74
CON_ID_5	+181	0.69
CON_ID_6	+183	0.72
CON_ID_7	+185	0.67
CON_ID_8	+170	0.92
CON_ID_9	+167	0.87
CON_ID_10	+163	0.99
CON_ID_13	+17	0.11
CON_ID_14	+17	0.07
CON_ID_15	+13	0.20
CON_ID_16	+69	0.04
CON_ID_68	+57	1.06

Flood sensitive receptor ID	1% AEP climate change event	
	Change in peak water level (mm)	Existing case flood depth[2] (m)
CON_ID_78	+64	0.95
CON_ID_96	+28	0.17
CON_ID_97	+24	0.46
CON_ID_98	+24	0.31
CON_ID_99	+48	0.48
CON_ID_100	+47	0.65
CON_ID_101	+48	0.91
CON_ID_102	+48	0.95
CON_ID_103	+48	0.55
CON_ID_104	+49	0.57
CON_ID_118	+186	0.73
CON_ID_119	+66	0.98
CON_ID_120	+69	0.96
CON_ID_146	+66	0.29
CON_ID_147	+67	0.35
CON_ID_148	+68	0.35
CON_ID_149	+59	0.11
CON_ID_157	+50	0.04
CON_ID_158	+51	0.01
CON_ID_160	+10	0.35
CON_ID_161	+11	0.51
CON_ID_162	+10	0.50
CON_ID_203	+40	0.87
CON_ID_204	+40	1.17
CON_ID_205	+40	1.22
CON_ID_206	+40	0.97
CON_ID_207	+41	1.26
CON_ID_244	+100	0.22
CON_ID_245	+91	0.11
CON_ID_246	+76	0.35
ID CON__247	+67	0.46
CON_ID_248	+68	0.27
CON_ID_275	+47	0.03
CON_ID_277	+52	0.24
Elsden Road[1]	+71	2.53
Fysh Road[1]	+99	1.85
Gibbs Road[1]	+26	0.99
Gilgai Lane[1]	+112	2.96
Gore Highway (Toowoomba-Millmerran)[1]	+66	2.04

	1% AEP climate change event	
Flood sensitive receptor ID	**Change in peak water level (mm)**	**Existing case flood depth[2] (m)**
Hall Road[1]	+92	4.00
Lovell Road[1]	+815	0.52
Millmerran-Leyburn Road[1]	+130	3.23
Pampas Pit Road[1]	+54	1.30

Table notes:

1. These roads are affected by climate change regardless of the Project and so the amenity of the roads is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

During detail 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.

Table 12.81 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.81 CONDAMINE RIVER—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood-sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
CON_ID_4	0.74	+126
CON_ID_5	0.69	+178
CON_ID_6	0.72	+187
CON_ID_7	0.67	+183
CON_ID_8	0.92	+130
CON_ID_9	0.87	+127
CON_ID_10	0.99	+117
CON_ID_68	1.06	+41
CON_ID_78	0.95	+45
CON_ID_99	0.48	+20
CON_ID_100	0.65	+30
CON_ID_101	0.91	+31
CON_ID_102	0.95	+31
CON_ID_103	0.55	+29
CON_ID_104	0.57	+21
CON_ID_118	0.73	+180
CON_ID_119	0.98	+45
CON_ID_120	0.96	+50
CON_ID_146	0.29	+27
CON_ID_147	0.35	+27
CON_ID_148	0.35	+28
CON_ID_149	0.11	+23
CON_ID_158	0.01	+44
CON_ID_203	0.87	+21
CON_ID_204	1.17	+21
CON_ID_205	1.22	+21
CON_ID_206	0.97	+21
CON_ID_207	1.26	+21
CON_ID_229	0.27	+11
CON_ID_244	0.22	+14
CON_ID_246	0.35	+15
CON_ID_247	0.46	+27
CON_ID_248	0.27	+23
CON_ID_275	0.03	+36
CON_ID_277	0.24	+41
Fysh Road	1.85	+91
Gilgai Lane	2.96	+75
Gore Highway	2.04	+26
Hall Road	4.00	+76
Lovell Road	0.52	+780
Millmerran–Leyburn Road	3.23	+102
Pampas Pit Road	1.30	+42

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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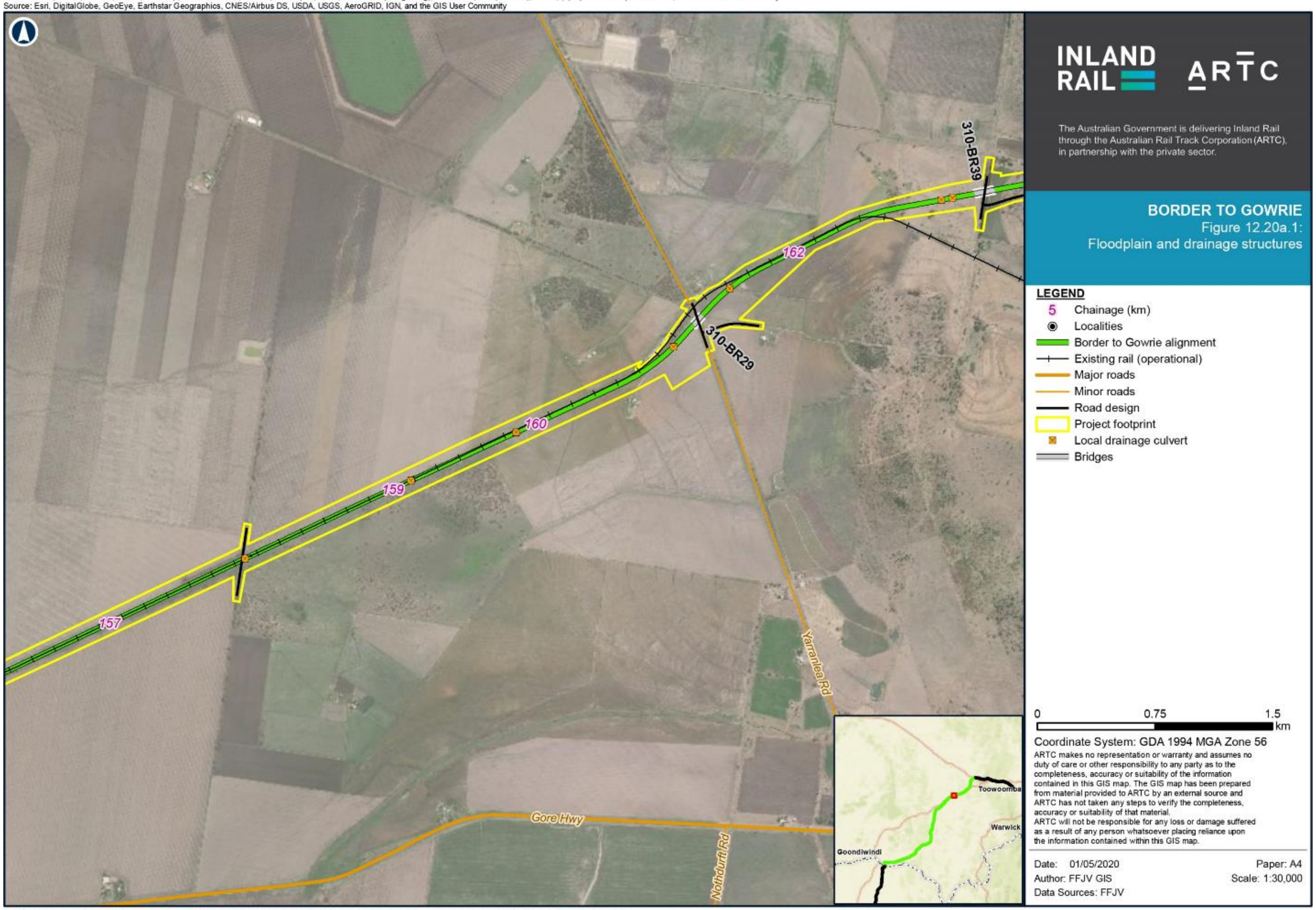

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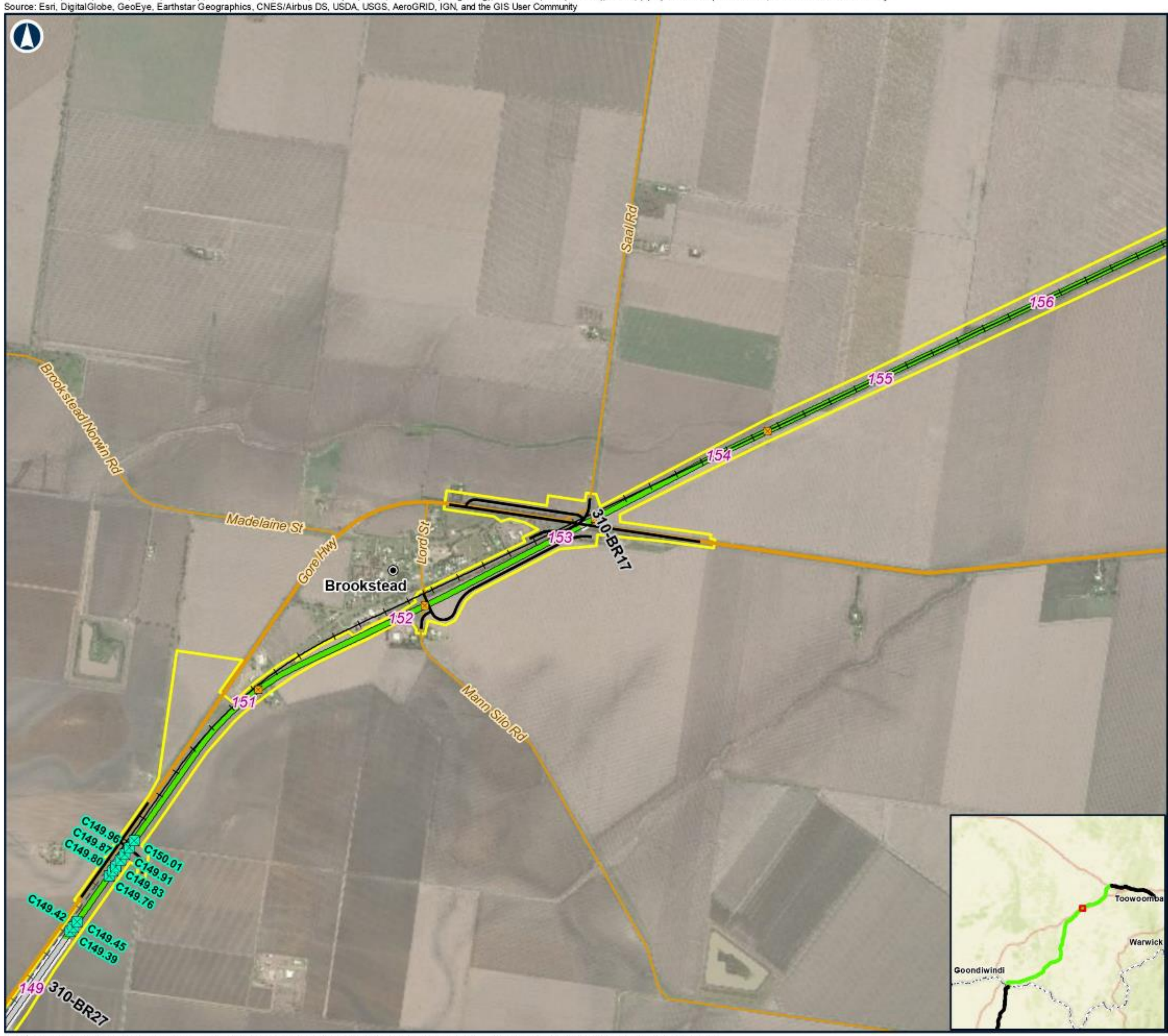

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BORDER TO GOWRIE
Figure 12.20a.2:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 01/05/2020 Paper: A4
Author: FFJV GIS Scale: 1:30,000
Data Sources: FFJV

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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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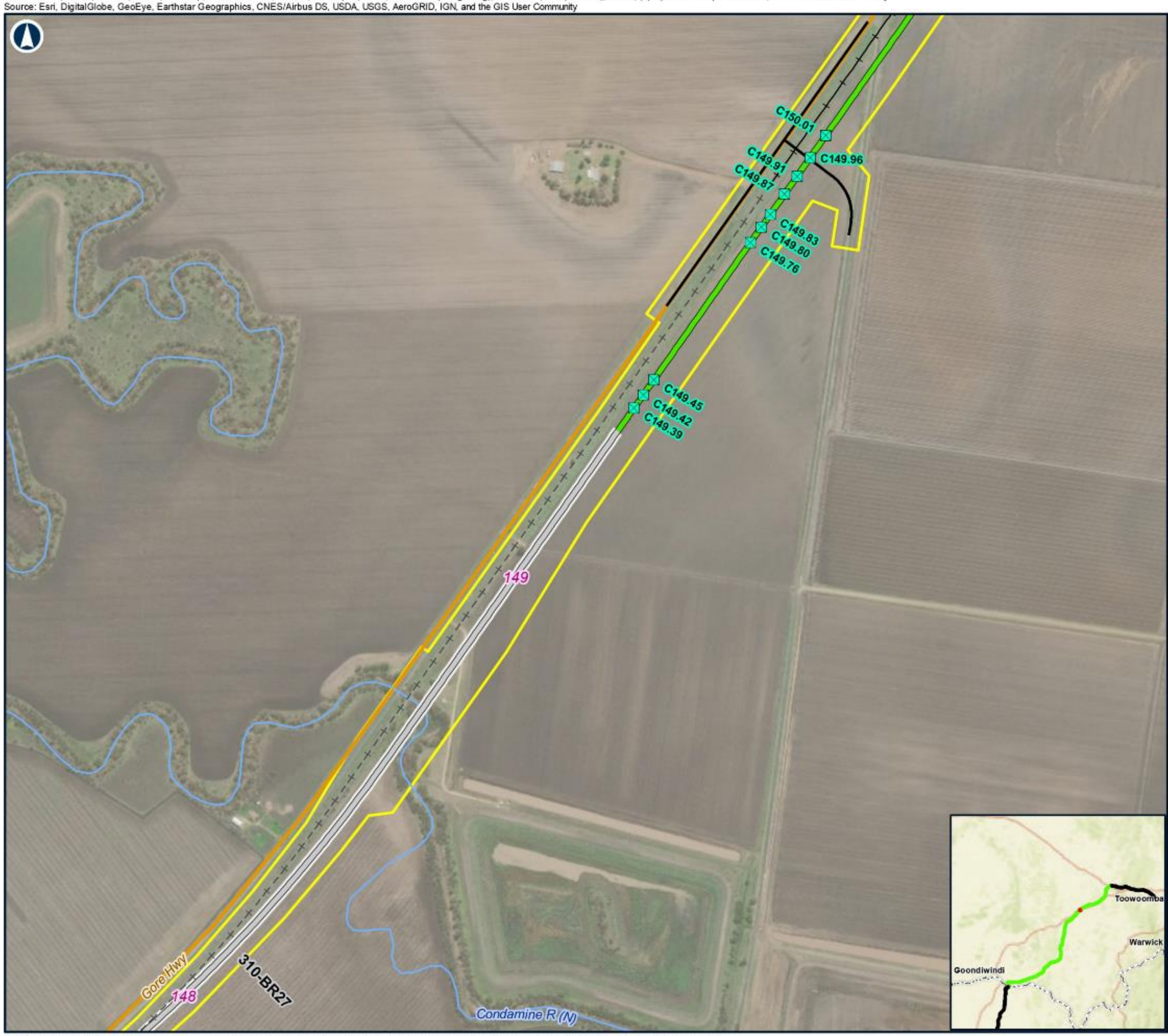

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BORDER TO GOWRIE

Figure 12.20a.3: Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Bridges

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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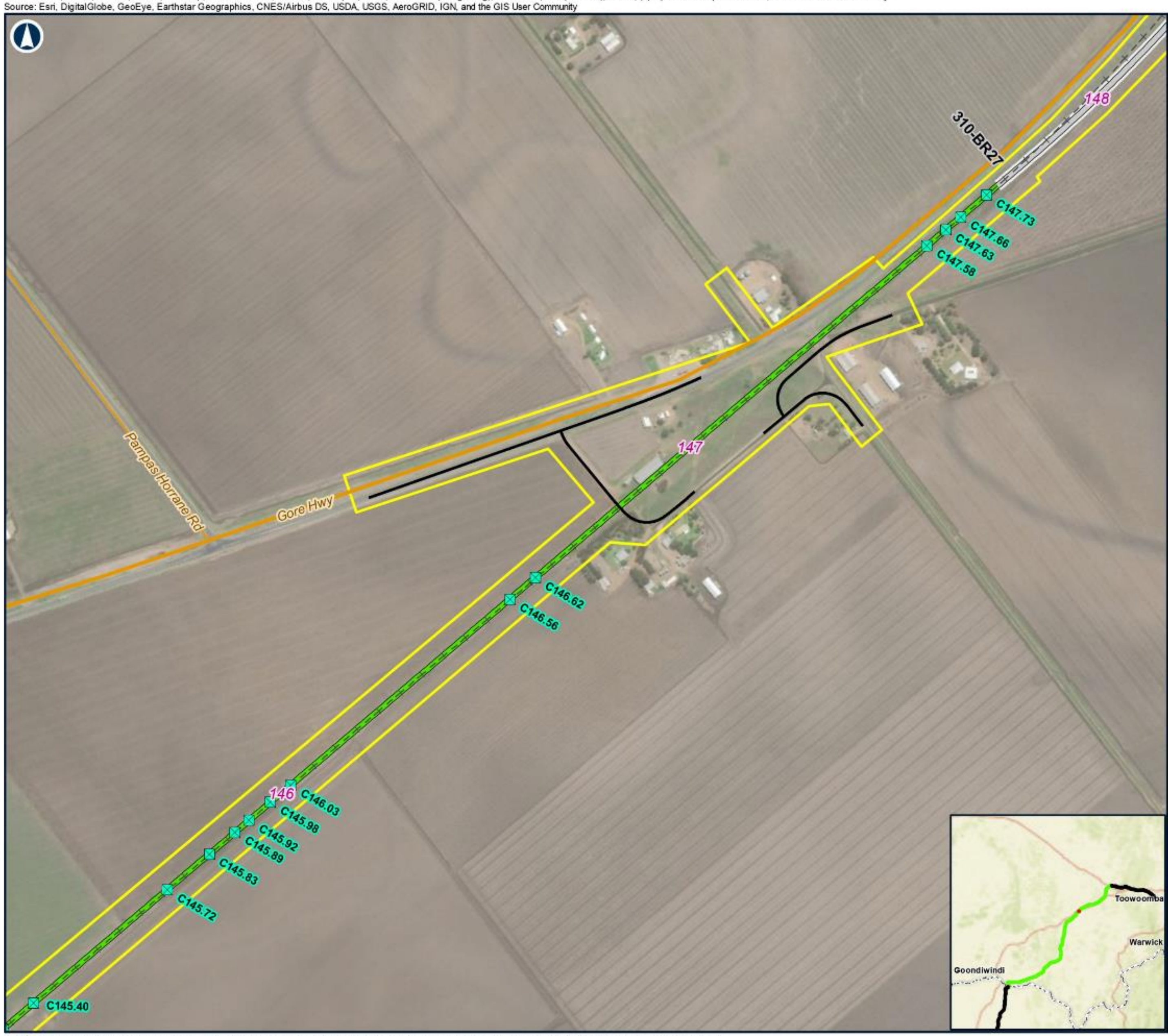

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BORDER TO GOWRIE
Figure 12.20a.4:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Bridges

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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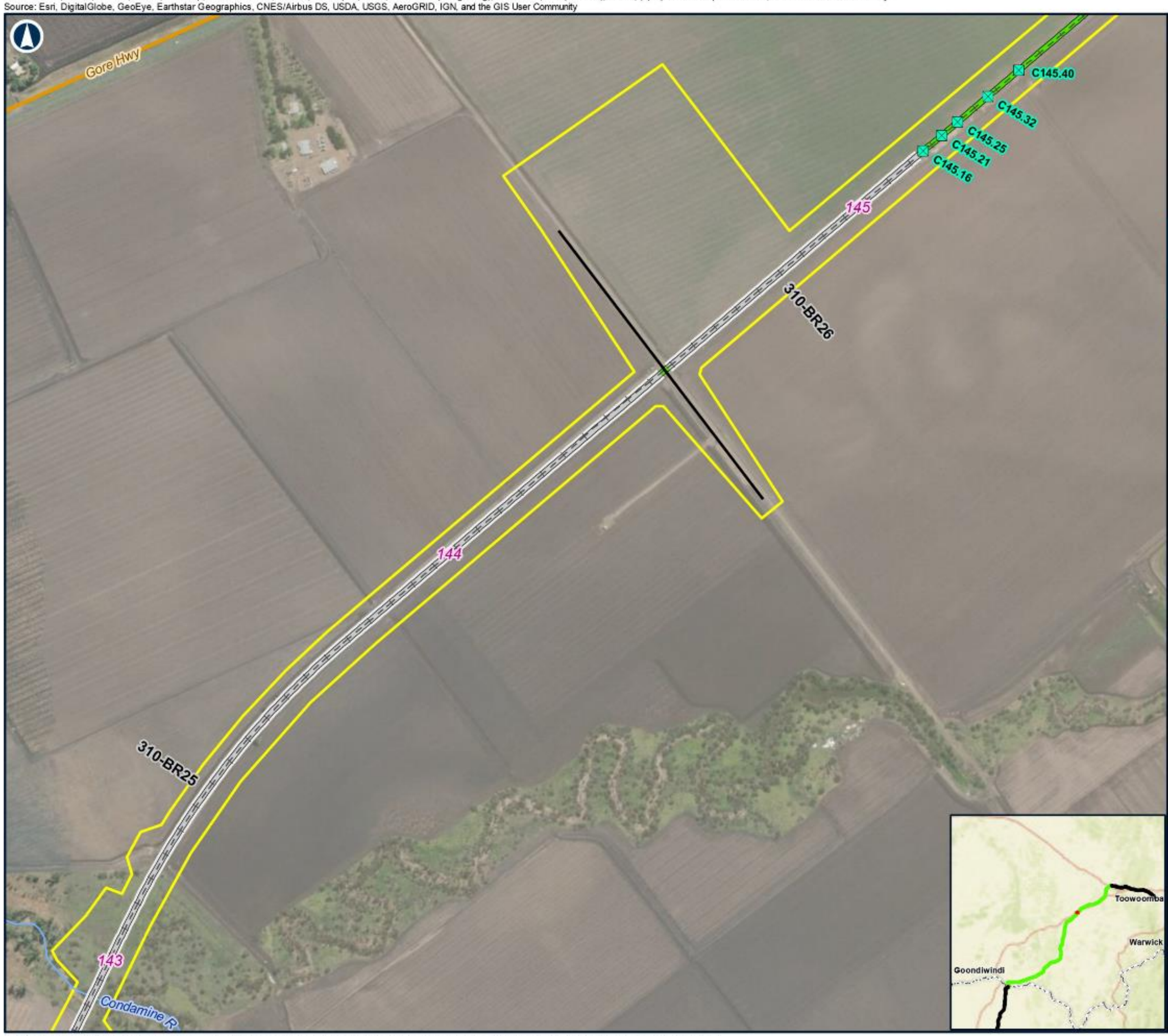

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BORDER TO GOWRIE
Figure 12.20a.5:
Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Major roads
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Bridges

0 0.25 0.5 km

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Author: FFJV GIS Scale: 1:10,000
Data Sources: FFJV

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BORDER TO GOWRIE
Figure 12.20a.6:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Bridges

0 0.25 0.5 km

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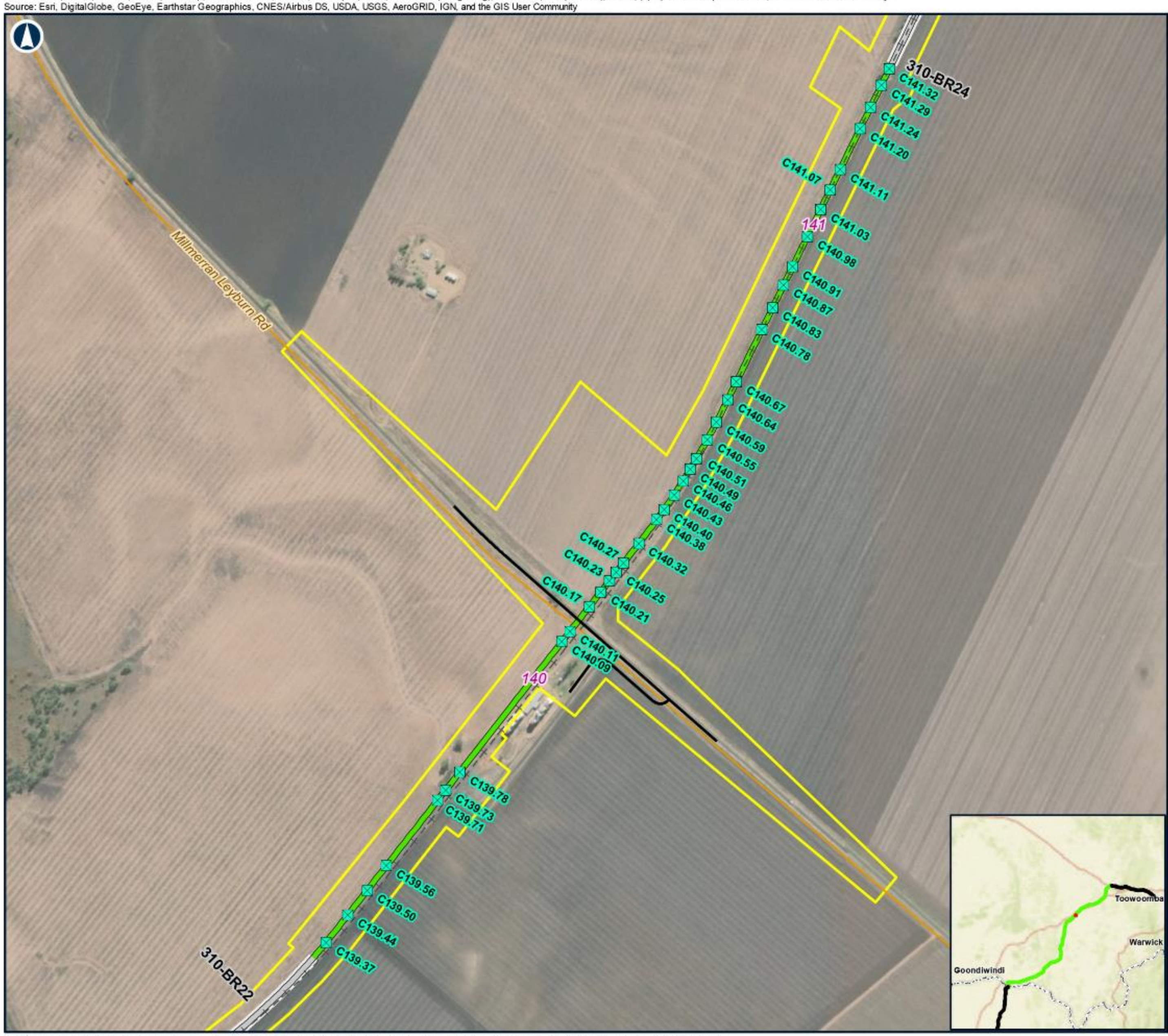

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BORDER TO GOWRIE
Figure 12.20a.7:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (non-operational)
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Bridges

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:10,000
Data Sources: FFJV

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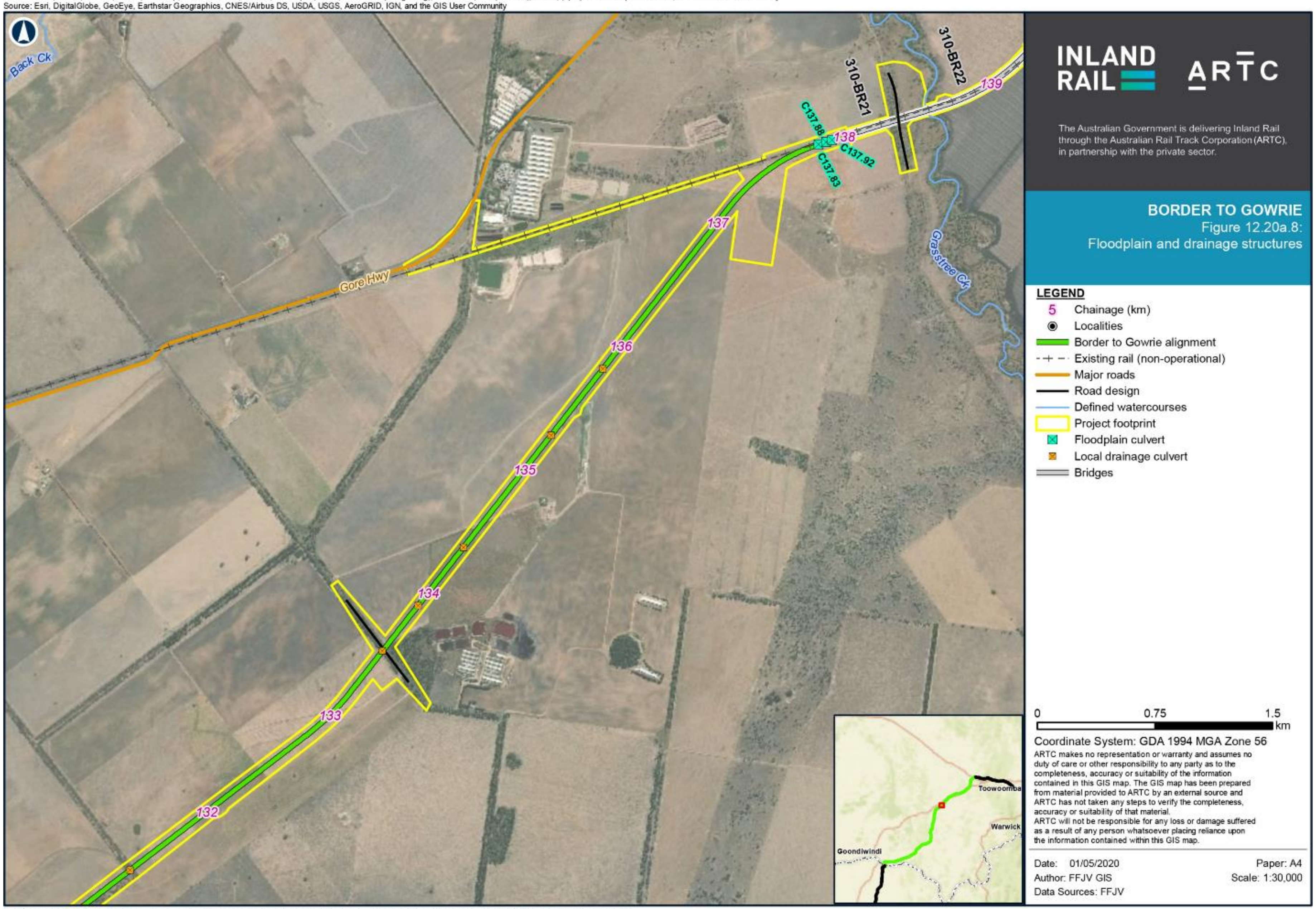

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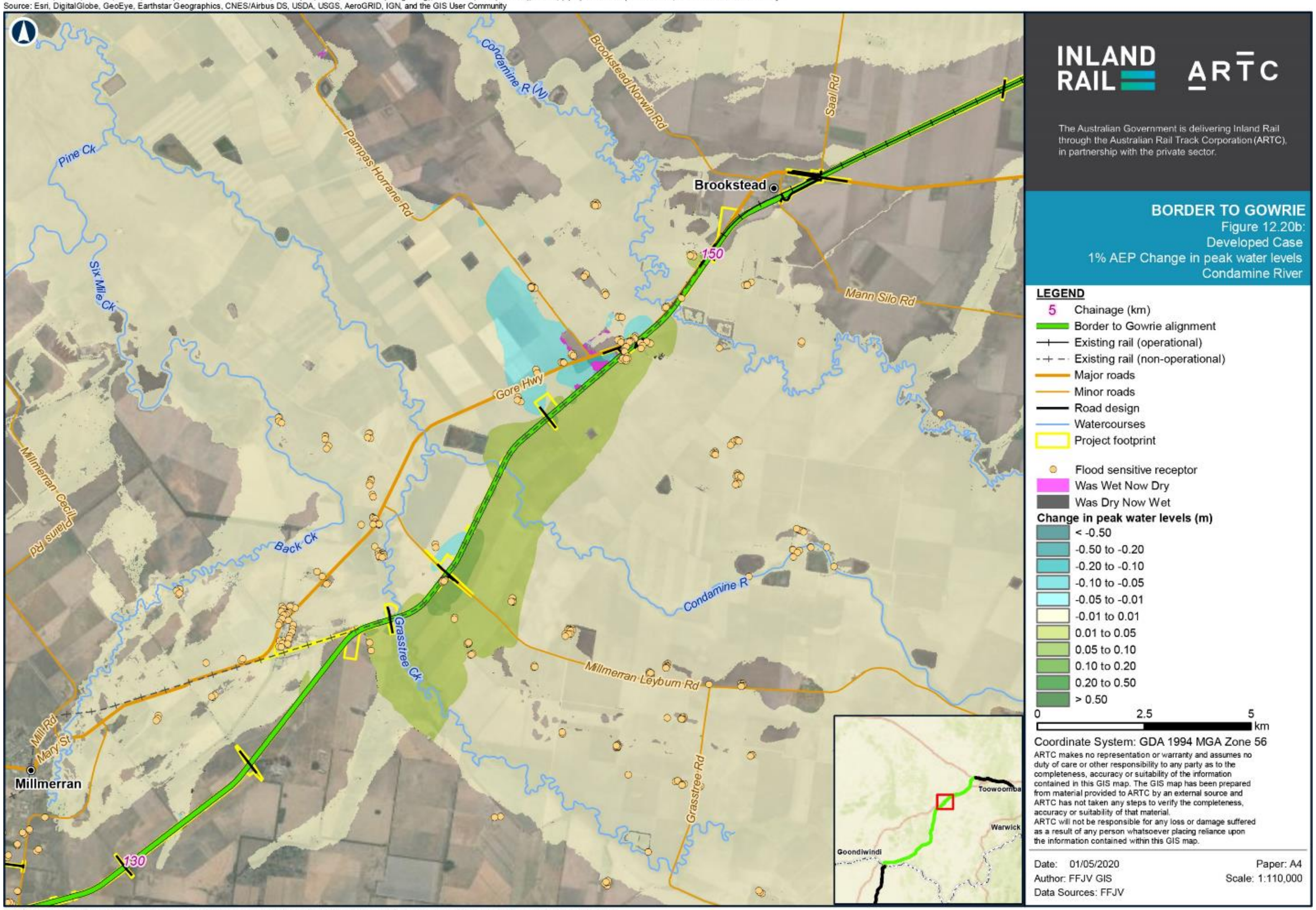

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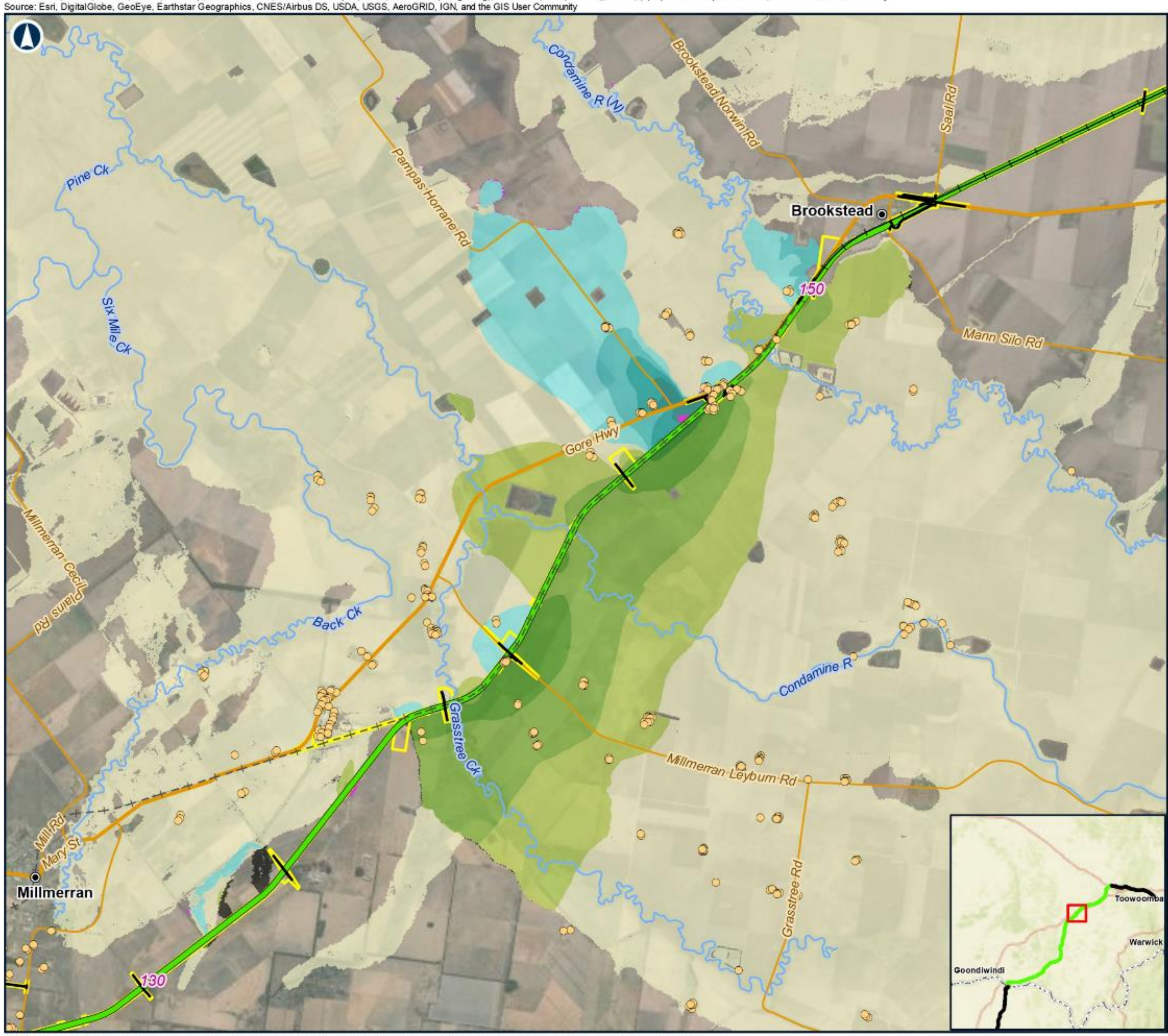

INLAND RAIL ARTC

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BORDER TO GOWRIE
Figure 12.20c:
Developed Case
1 in 2,000 AEP Change in peak water levels
Condamine River

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:110,000
Data Sources: FFJV

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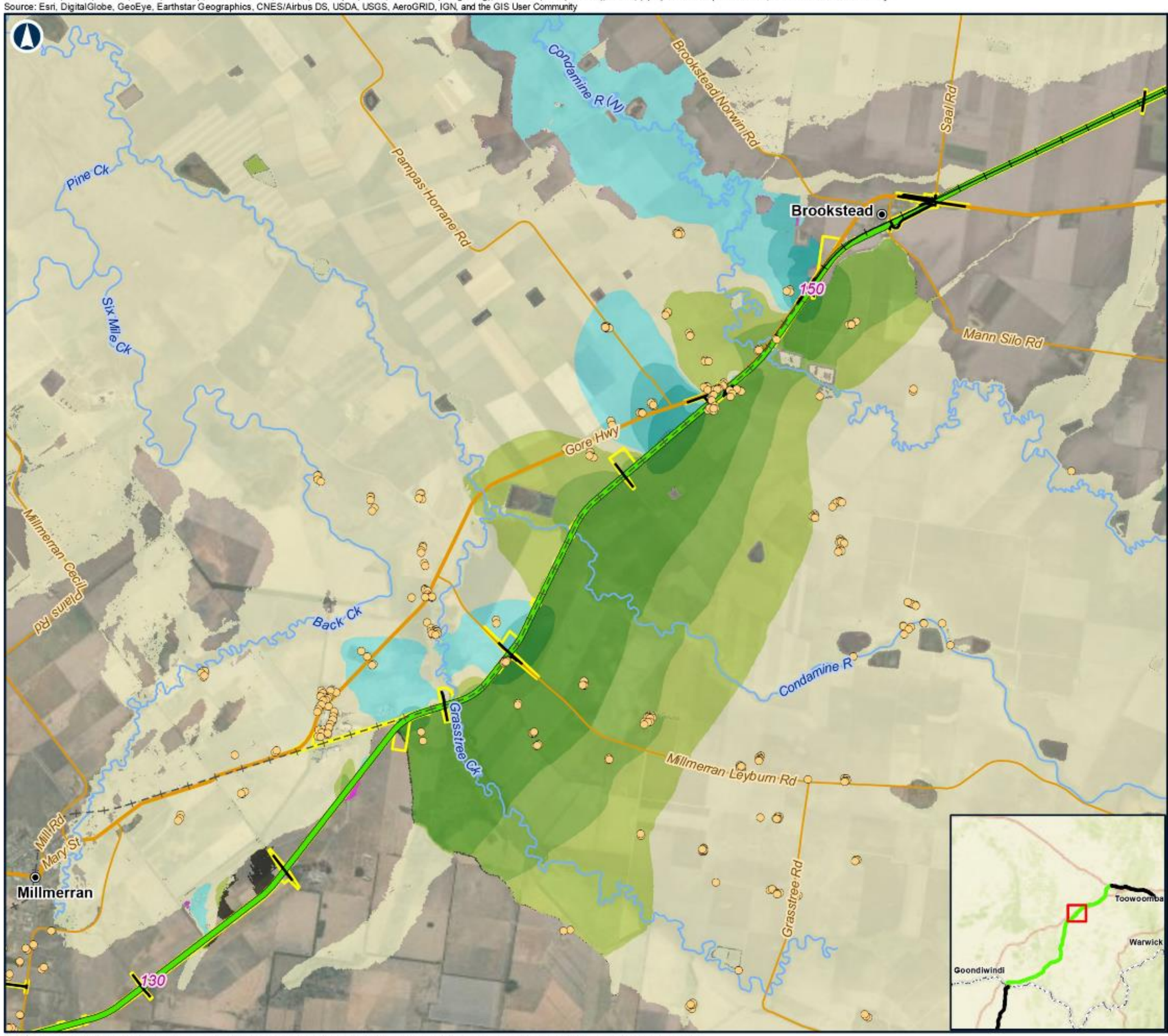

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BORDER TO GOWRIE
Figure 12.20d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Condamine River

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV

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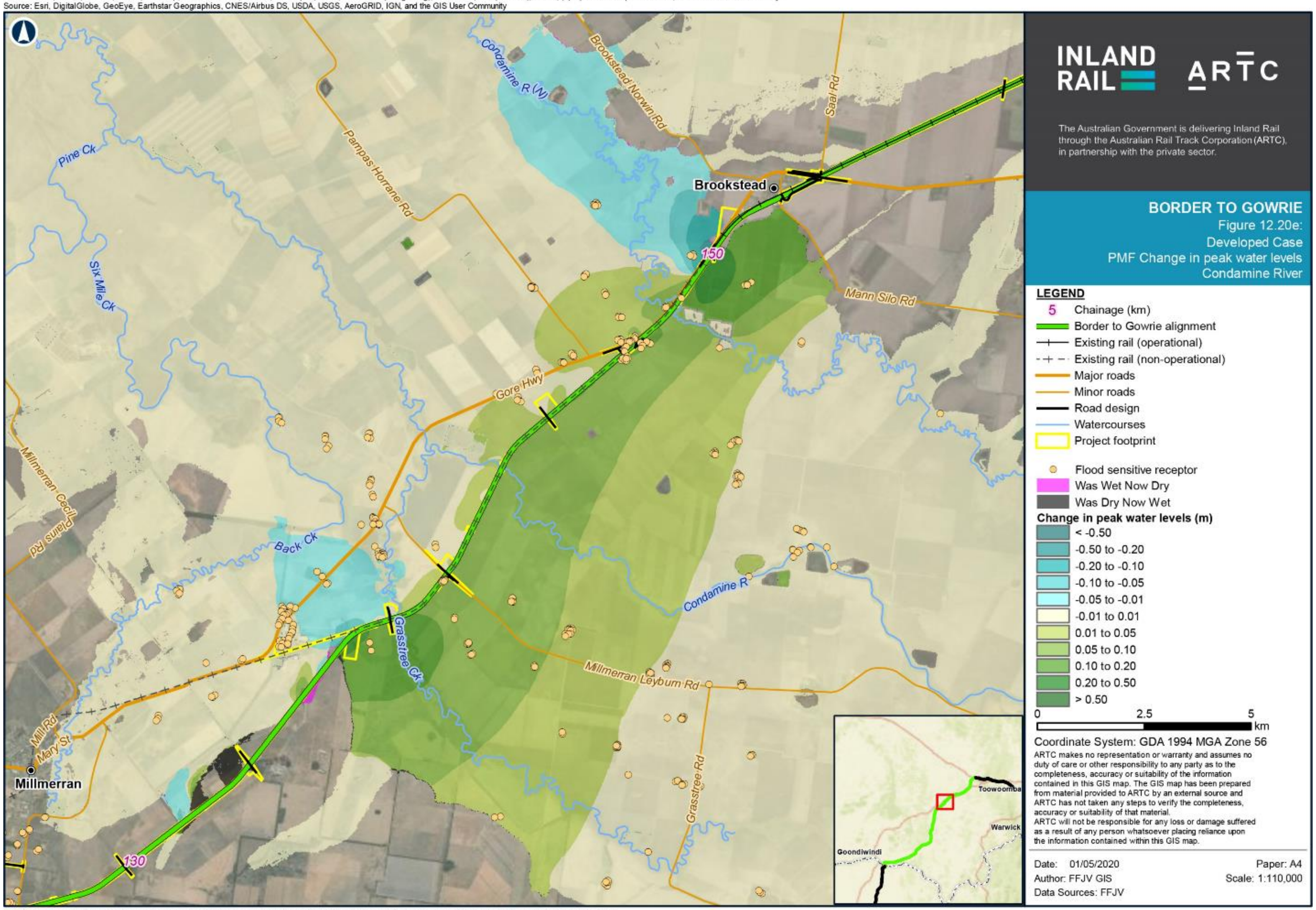

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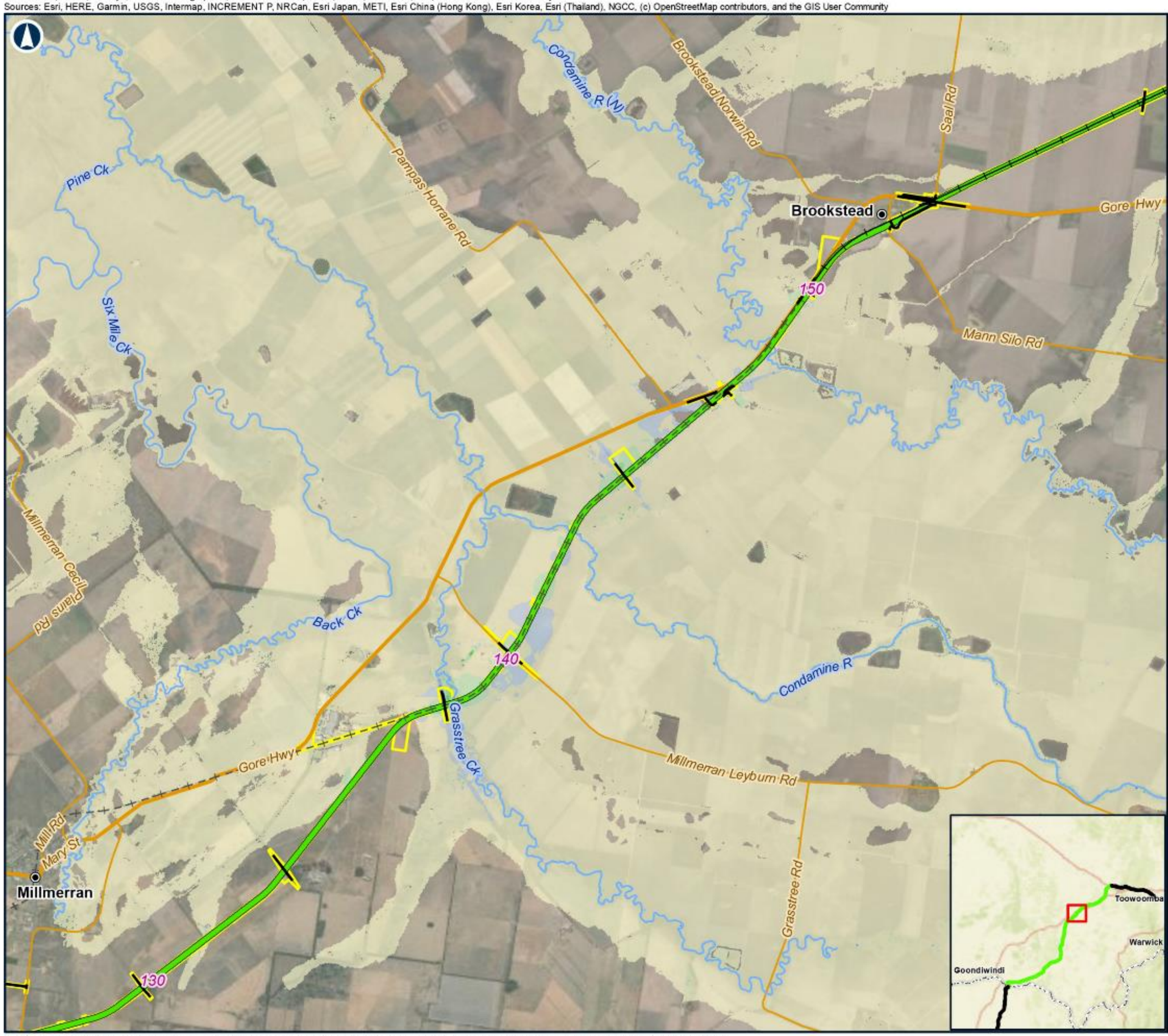

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BORDER TO GOWRIE
Figure 12.20f:
Developed Case
1% AEP Change in peak velocities
Condamine River

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV
Paper: A4
Scale: 1:110,000

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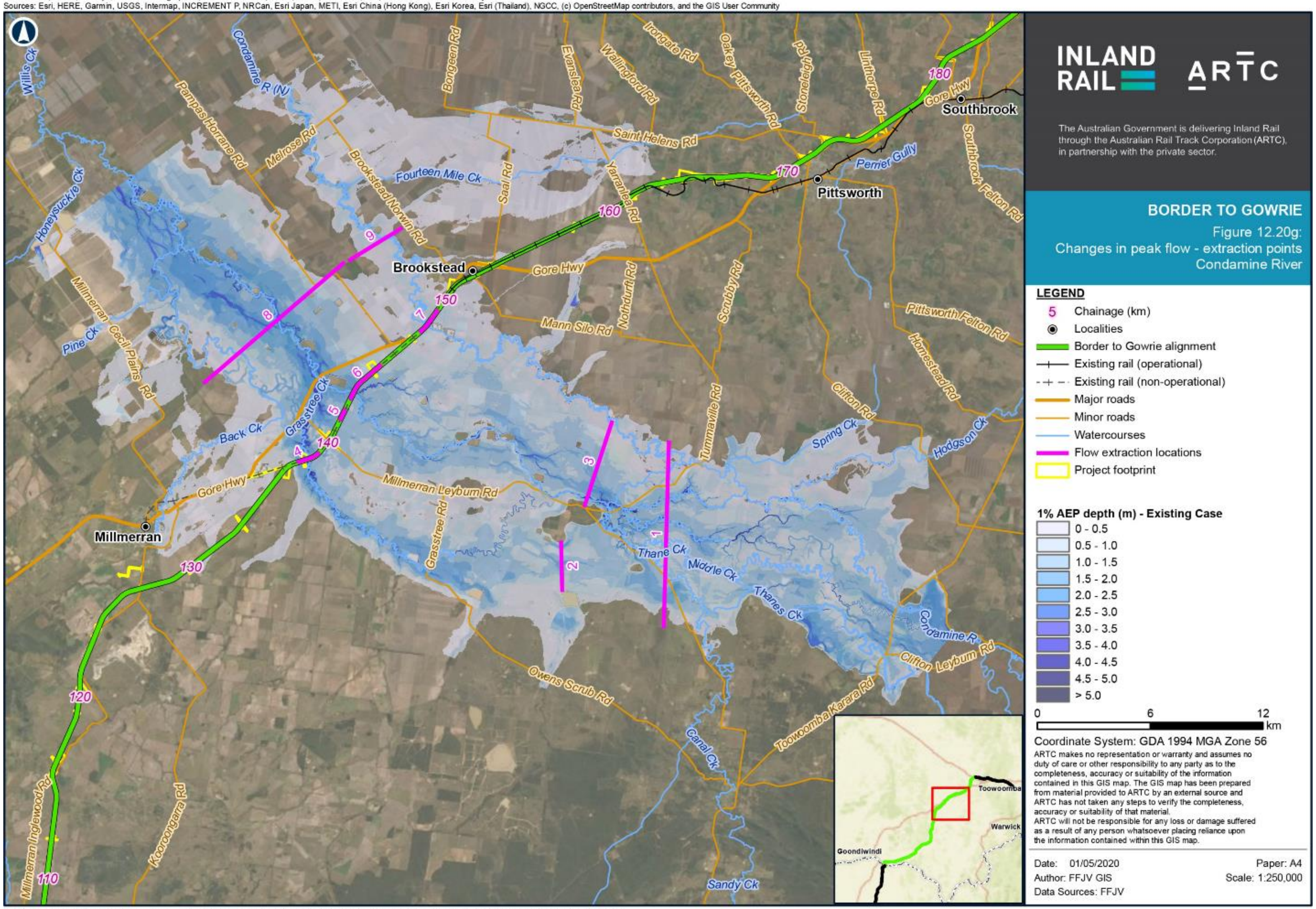

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12.10.2.4 Back Creek

On the Back Creek floodplain the Project design includes:

- Two bridges
- Two RCP locations (a total of 24 cells).

Details of the floodplain structures required to convey Back Creek flood flows are presented in Table 12.82 and Table 12.83, with structure locations presented in Figure 12.21a. Figure 12.21a also presents the location of local catchment drainage structures.

TABLE 12.82 BACK CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
126.97	310-BR37[1]	Bridge	419.0	167.0
128.06	310-BR38	Bridge	409.0	230.0

Table note:
1. 310-BR37 is also a rail bridge, and spans across Millmerran–Inglewood Road

TABLE 12.83 BACK CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No. of cells	Diameter (m)
126.76	C126.76	RCP	12	2.10
126.80	C126.80	RCP	12	2.10

Change in peak water levels

Figure 12.21b presents the change in peak water levels under the 1% AEP event and Table 12.84 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.84 BACK CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Impact type	Approximate chainage (km)	Existing land use	Flood impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside Project footprint[1]	126.50 to 126.90	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+120	2.9 ha in total affected by afflux > 10 mm
Private land outside Project footprint	127.40 to 127.95	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+290	28 ha in total affected by afflux > 10 mm 3.1 ha affected by afflux > 200 mm
Private land outside Project footprint	128.20	Agricultural (cropping)	≤ 100 mm (up to 400 mm)	+260	3.9 ha in total affected by afflux > 10 mm 2.6 ha affected by afflux > 200 mm

Table note:
1. Project footprint is indicated in Figure 12.21b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with noticeable floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur near Millmerran–Inglewood Road, adjacent to the Project alignment. This localised increase in peak water levels gradually spreads and expands to include the area upstream of the main Back Creek channel as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Back Creek floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

Millmerran–Inglewood Road currently floods to a depth of up to 110 mm in a 10% AEP event and up to 240 mm in a 1% AEP event. The total length of road inundated during a 10% AEP event is 92 m and in a 1% AEP a 271-m long section of road is affected by flooding. The maximum ToS in a 10% AEP event is 17.5 hrs and in a 1% AEP event the maximum ToS is 10.1 hrs.

The Project is expected to increase peak water levels on Millmerran–Inglewood Road by up to 10 mm in a 10% AEP as well as a 1% AEP event. ToS is expected to increase by up to 4.8 hr (17.5 hrs to 22.3 hrs) in a 10% AEP event, and up to 0.1 hrs in a 1% AEP event. The change in AAToS on Millmerran–Inglewood Road is 2.6 hours per year.

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.

Velocities

Figure 12.21f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Back Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.21c to Figure 12.21e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.85 outlines the changes in peak water levels 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.

TABLE 12.85 BACK CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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)
BAC_ID_1	-	-	-	-	+51	0.72
BAC_ID_2	-	-	+4	0.15	+47	0.85
BAC_ID_3	-	-	+45	0.28	+215	0.98
BAC_ID_4	-	0.26	+35	0.53	+172	1.23
BAC_ID_5	-	0.19	+36	0.57	+164	1.32
Kooroongarra Road	-	2.80	+6	3.60	+221	5.20
Millmerran–Inglewood Road	+247	2.03	+173	2.58	+237	3.23
Unnamed Road	+182	0.31	+249	0.44	+204	0.98
Schwartens Road	+69	1.66	+90	2.31	+39	3.25

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 12.83 outlines the overtopping locations and depths.

TABLE 12.86 BACK CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
125.65 to 126.75	0.03	0.04	0.04
126.85 to 127.05	0.89	1.30	1.86
127.95 to 128.15	2.08	2.93	4.49
128.15 to 129.25	-	-	1.42

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23.9 per cent across the Back Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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.

Table 12.87 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.87 BACK CREEK—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood sensitive receptor ID	Change in peak water level (mm)	Existing case flood depth[2] (m)
Kooroongarra Road[1]	+184	2.50
Millmerran–Inglewood Road[1]	+195	1.90
Unnamed road[1]	+64	0.29
Schwartens Road[1]	+128	1.56

Table notes:

1. These roads are affected by climate change regardless of the Project and so the amenity of the roads is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

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

Table 12.88 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP), where the increase exceeds 10 mm.

TABLE 12.88 BACK CREEK—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
Millmerran–Inglewood Road[1]	1.90	+298.0
Unnamed Road[1]	0.29	+34.0
Schwartens Road[1]	1.56	+77.0

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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BORDER TO GOWRIE
Figure 12.21a:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Defined watercourses
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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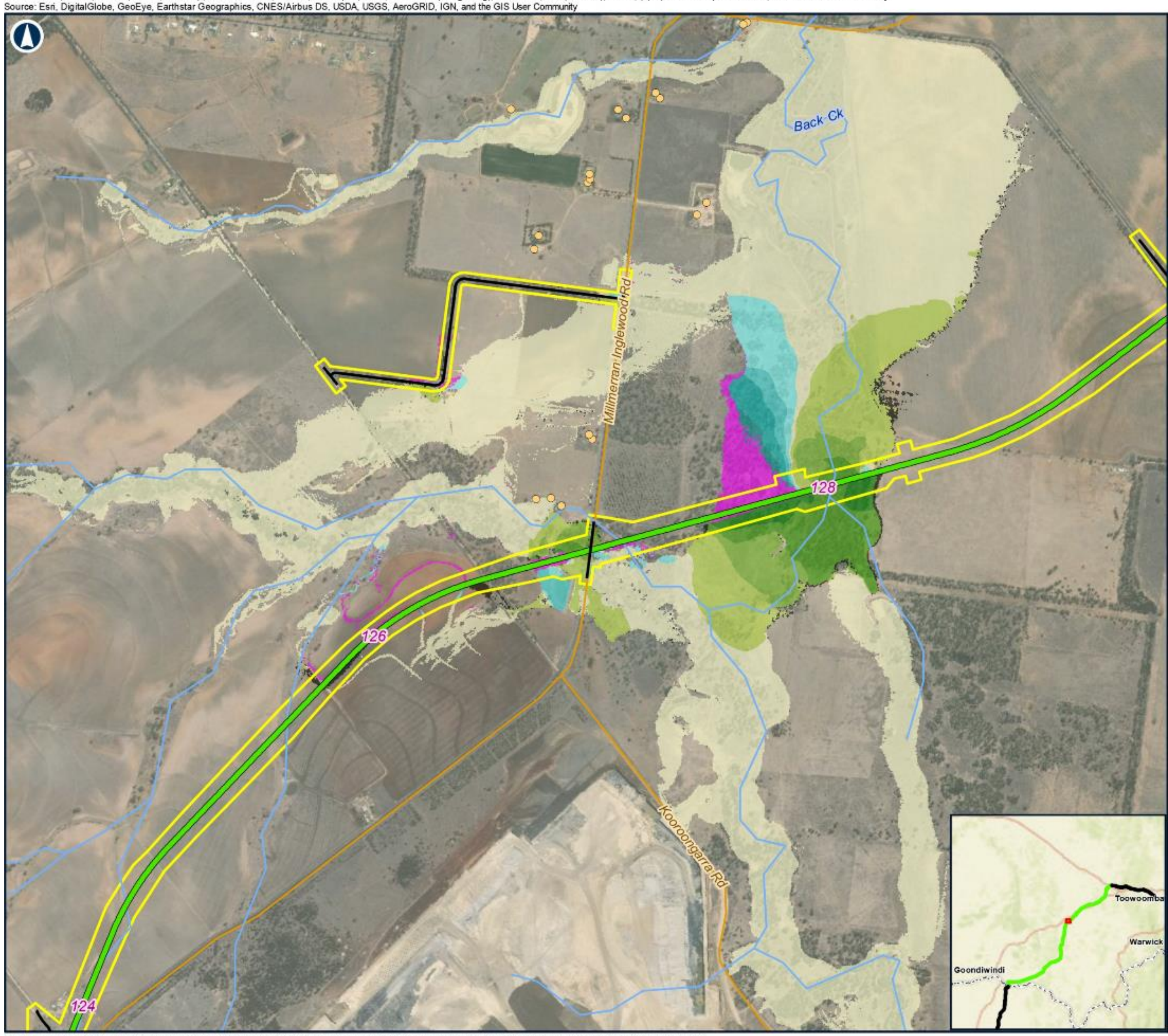

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BORDER TO GOWRIE
Figure 12.21b:
Developed Case
1% AEP Change in peak water levels
Back Creek

LEGEND
5 Chainage (km)
Border to Gowrie alignment
Minor roads
Road design
Watercourses
Project footprint
Flood sensitive receptor
Was Wet Now Dry
Was Dry Now Wet

Change in peak water levels (m)
< -0.50
-0.50 to -0.20
-0.20 to -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 to 0.20
0.20 to 0.50
> 0.50

0 0.55 1.1 km

Coordinate System: GDA 1994 MGA Zone 56

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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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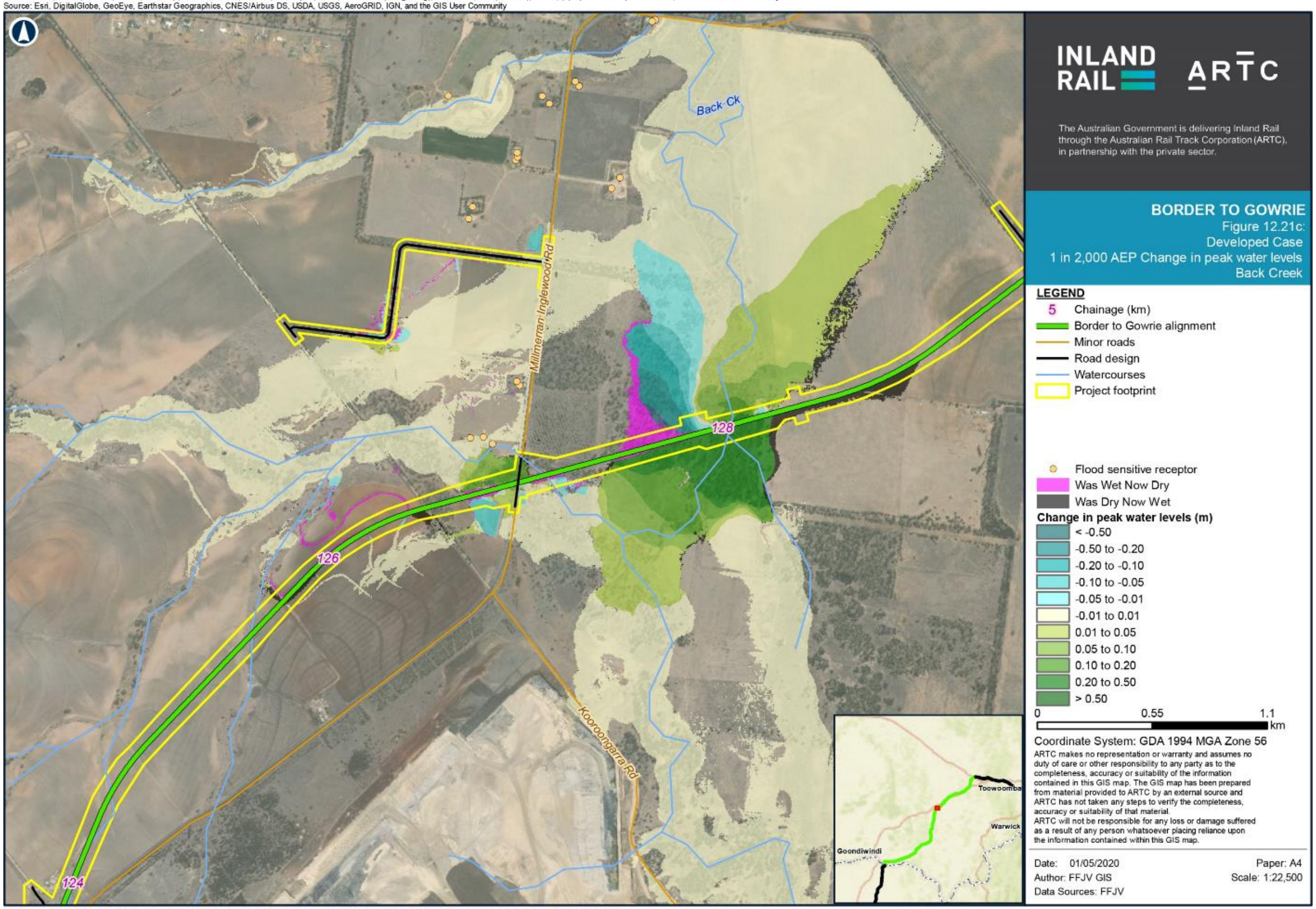

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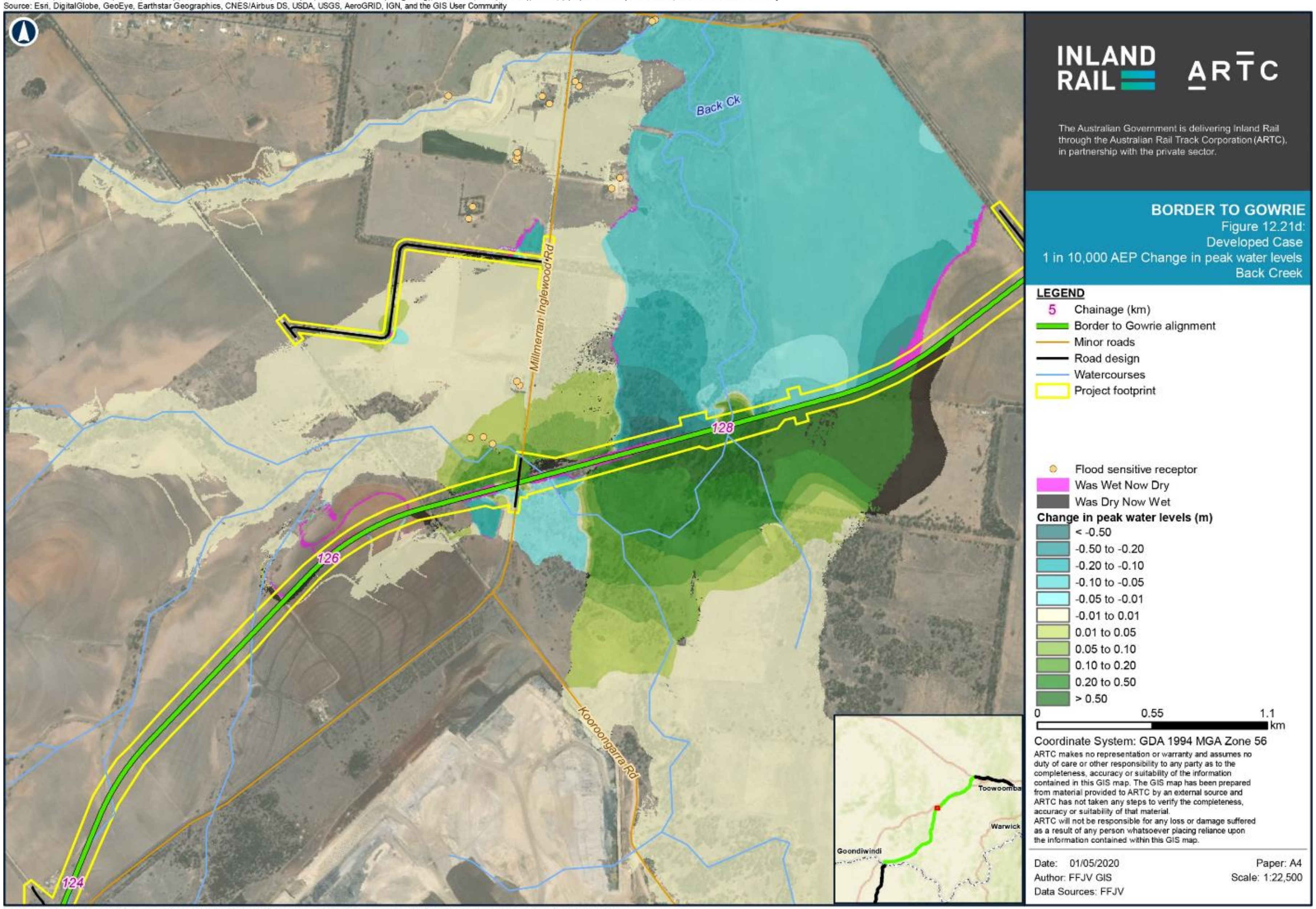
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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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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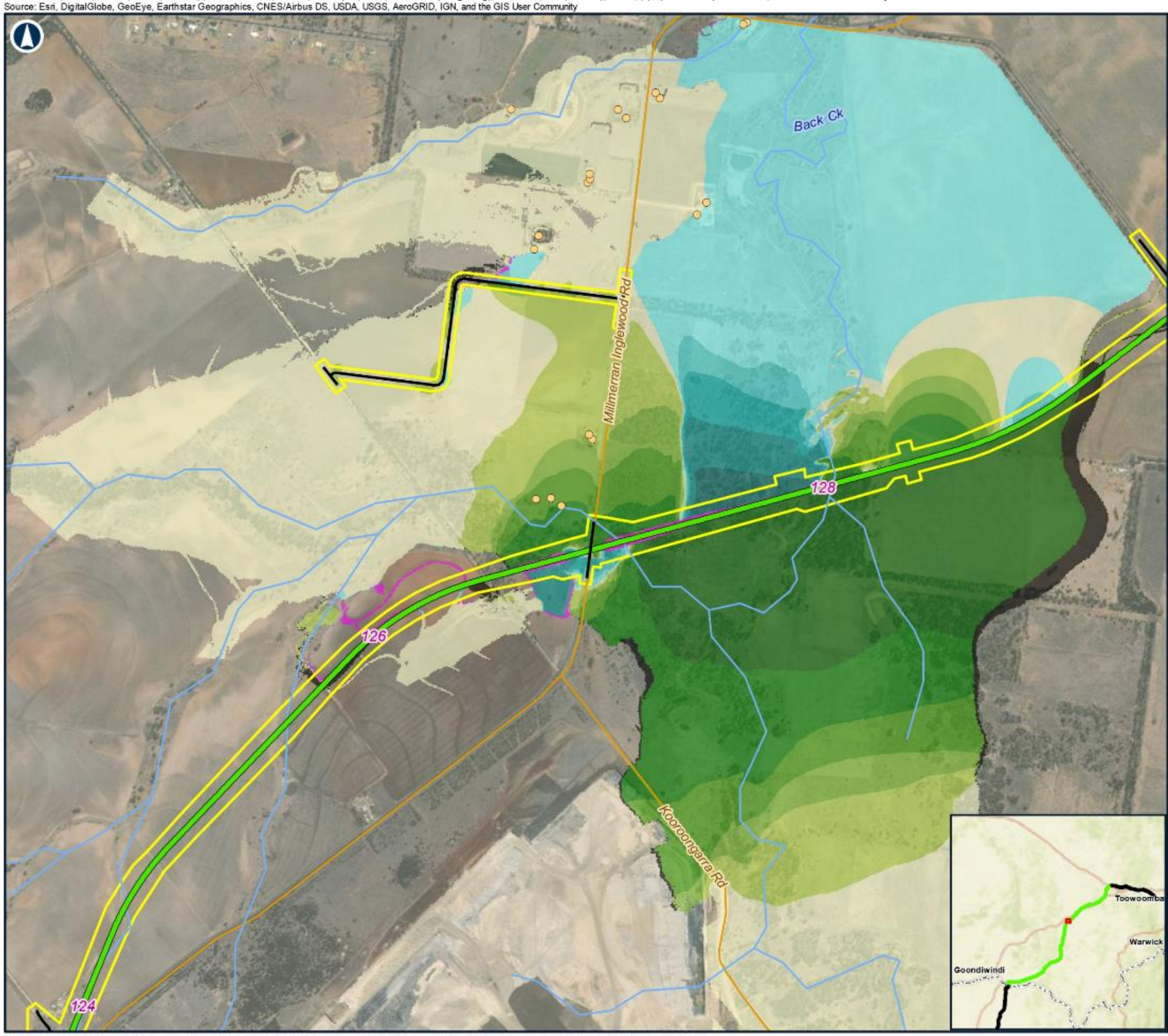

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BORDER TO GOWRIE

Figure 12.21e:
Developed Case
PMF Change in peak water levels
Back Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.55 1.1 km

Coordinate System: GDA 1994 MGA Zone 56

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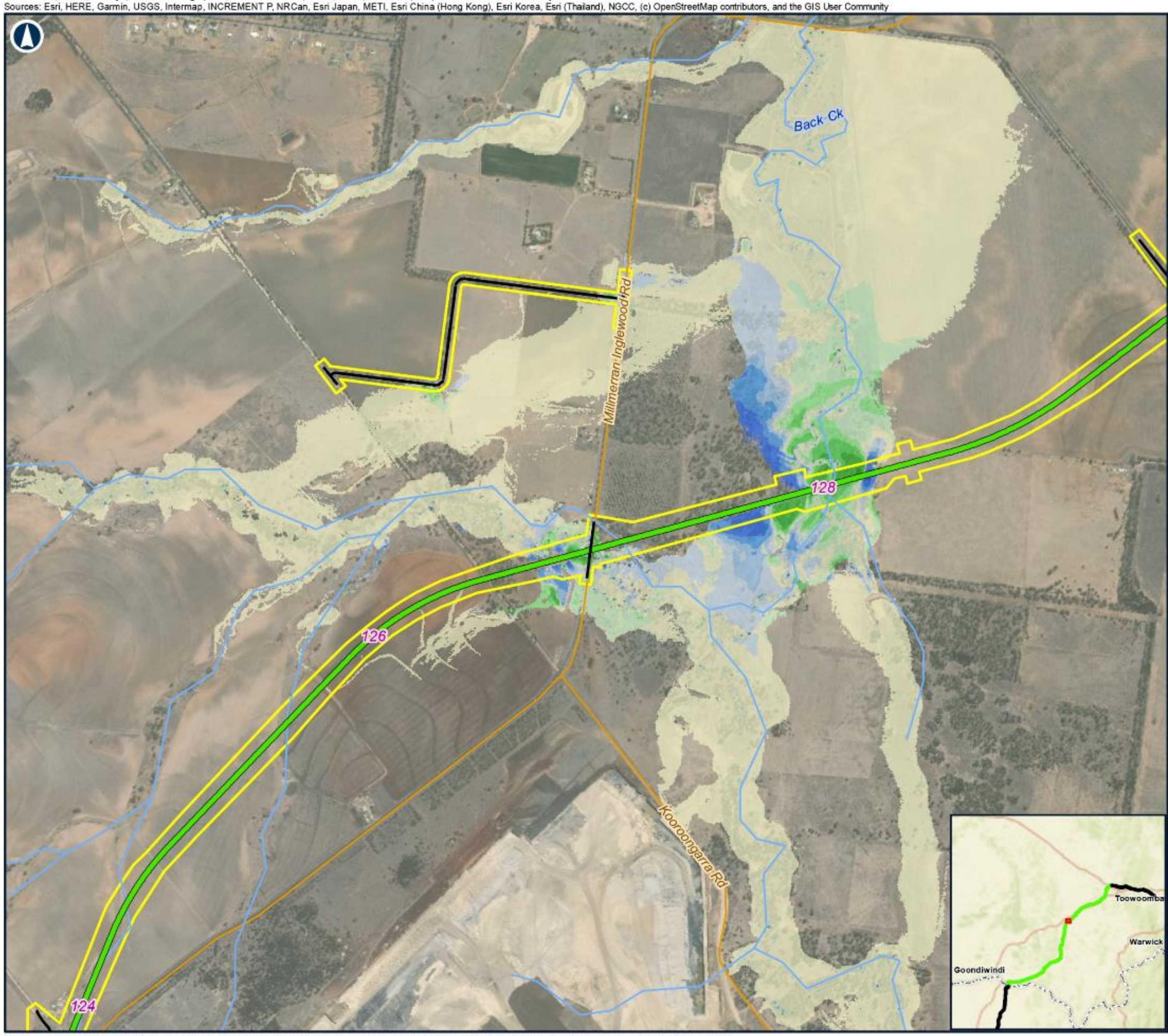

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BORDER TO GOWRIE
Figure 12.21f:
Developed Case
1% AEP Change in peak velocities
Back Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.55 1.1 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 01/05/2020 Paper: A4
Author: FFJV GIS Scale: 1:22,500
Data Sources: FFJV

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12.10.2.5 Nicol Creek

In the Nicol Creek floodplain, the Project design includes:

- One bridge
- Four RCP locations (a total of 36 cells).

Details of the floodplain structures required to convey Nicol Creek flood flows are presented in Table 12.89 and Table 12.90, with structure locations presented in Figure 12.22a. Figure 12.22a also presents the location of local catchment drainage structures.

TABLE 12.89 NICOL CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
104.39	310-BR11	Bridge	354.5	92.0

TABLE 12.90 NICOL CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of 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

Change in peak water levels

Figure 12.22b presents the change in peak water levels under the 1% AEP event and Table 12.91 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.91 NICOL CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside Project footprint[1]	104.90 to 105.20	Agricultural (cropping)	≤1 00 mm (up to 400 mm)	+126	0.4 ha in total affected by afflux > 10 mm

Table note:
1. Project footprint is indicated in Figure 12.22b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with noticeable floodplain inundation starting under the 20% AEP event. The floodplain does not significantly increase from a 20% to a 1% AEP event.

For events exceeding the 2% AEP event, minor changes in peak water levels occur to the east of Millmerran–Inglewood Road adjacent to the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Nicol Creek floodplain are negligible, as demonstrated in the 'change in time of inundation map' in Appendix Q2: Hydrology and Flooding Technical Report.

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.

Velocities

Figure 12.22f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Nicol Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.22c to Figure 12.22e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.92 outlines the changes in peak water levels 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.

TABLE 12.92 NICOL CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	**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_10	-	-	-	0.62	+15	2.10
NIC_ID_11	-	-	-	0.33	+15	1.74
NIC_ID_12	-	0.08	+16	0.67	+449	2.06
NIC_ID_13	-	-	+27	1.17	+424	2.65
NIC_ID_14	-	-	+8	0.70	+208	2.25
NIC_ID_15	-	-	-	-	+161	0.29
NIC_ID_16	-	-	-	0.34	+13	1.76
Millmerran–Inglewood Road	-	3.03	-	3.89	+22	5.59
Paton Road	-	0.16	-	0.50	+66	2.42

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 12.93 outlines the overtopping locations and depths.

TABLE 12.93 NICOL CREEK—PROJECT ALIGNMENT—EXTREME EVENT OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
103.95 to 104.35	-	-	0.90
104.35 to 104.45	1.80	3.10	5.10
104.45 to 105.15	-	-	1.30

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23.9 per cent across the Nicol Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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.

No flood-sensitive flood receptors are detrimentally affected by the climate change scenario.

The downstream extents of these impacts are similar to those under the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

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

There are no changes to impacts on flood-sensitive receptors under the blockage scenarios.

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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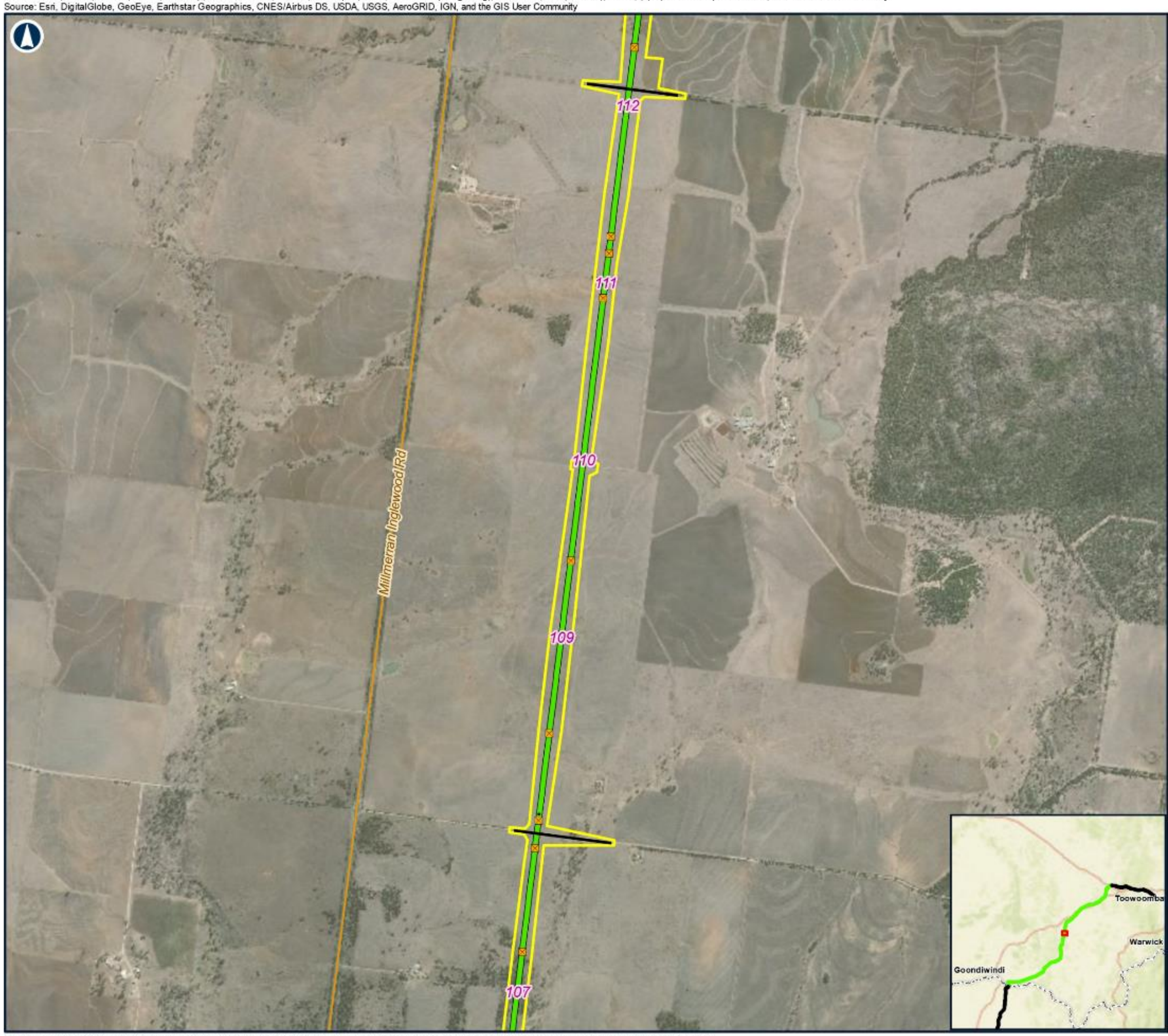

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BORDER TO GOWRIE
Figure 12.22a:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Project footprint
- Local drainage culvert

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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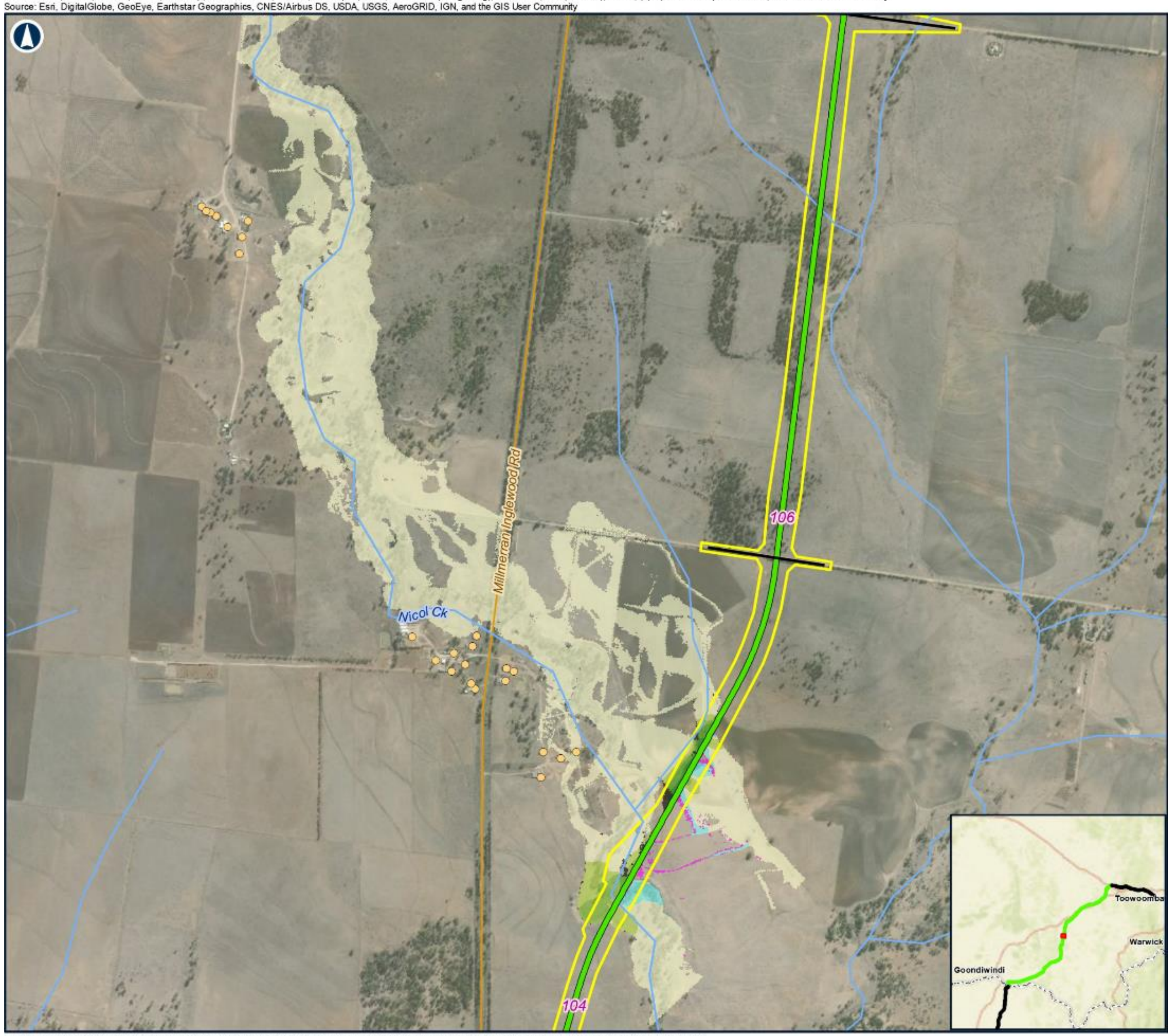

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BORDER TO GOWRIE
Figure 12.22b:
Developed Case
1% AEP Change in peak water levels
Nicol Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.5 1 km

Coordinate System: GDA 1994 MGA Zone 56

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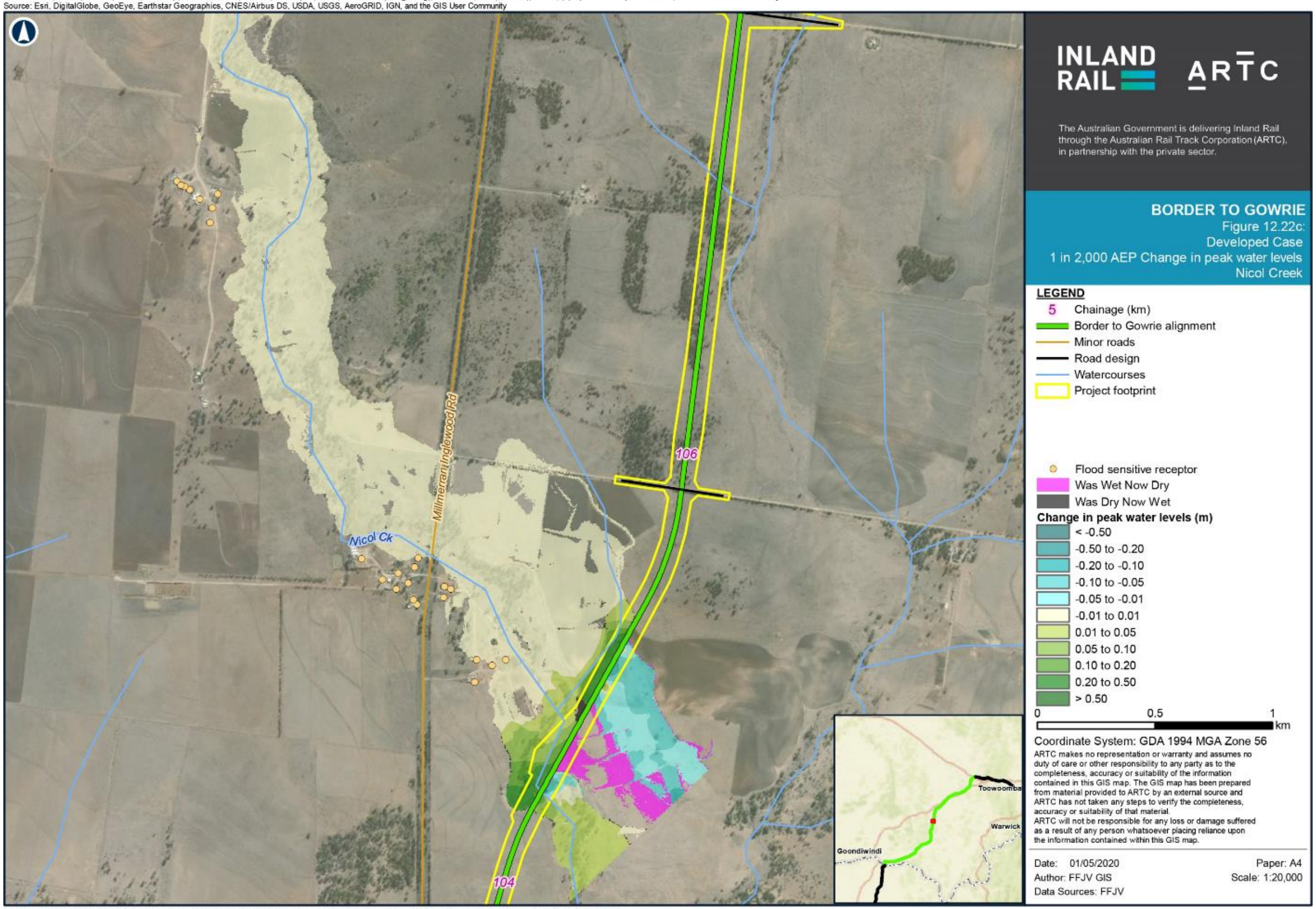

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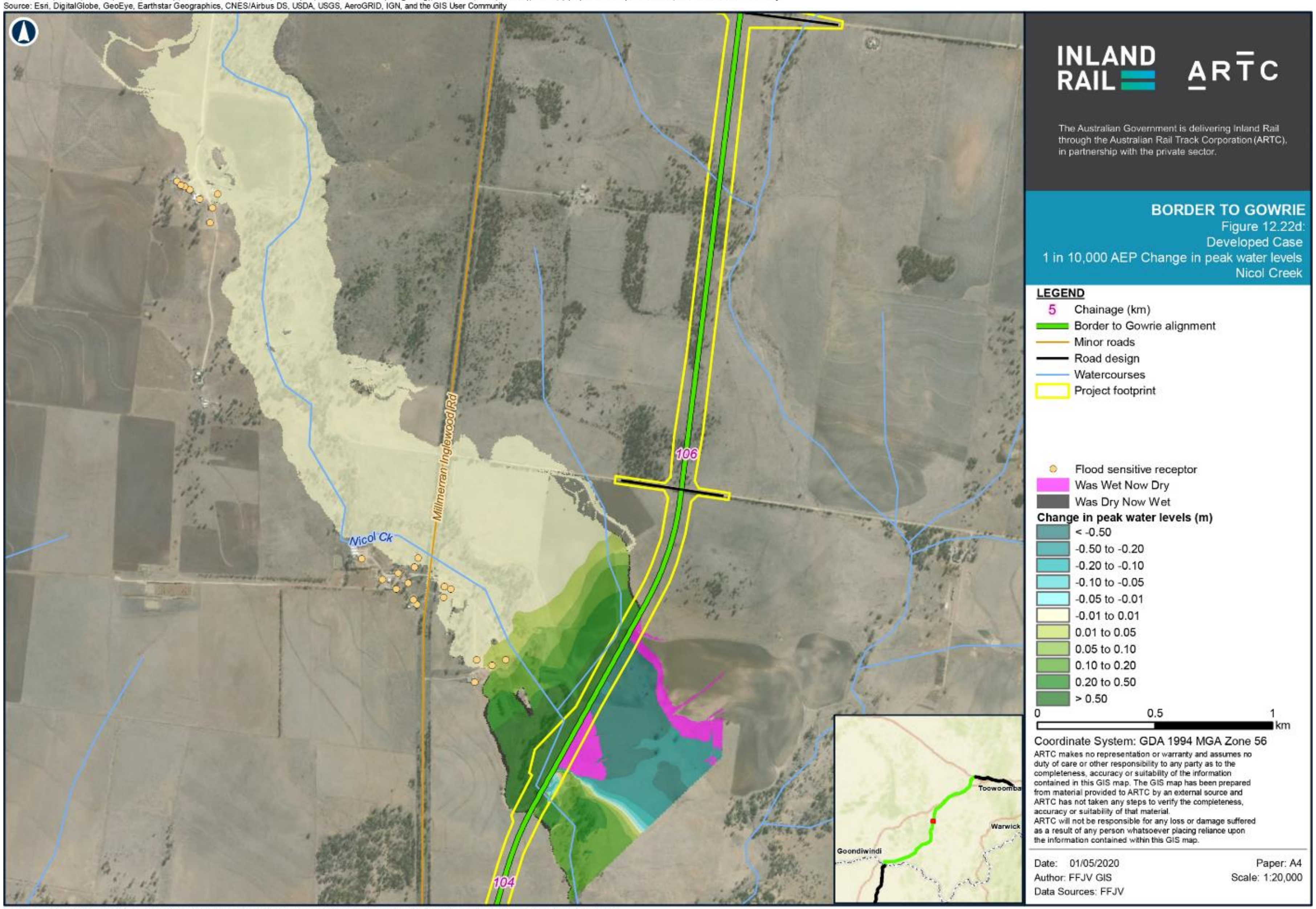

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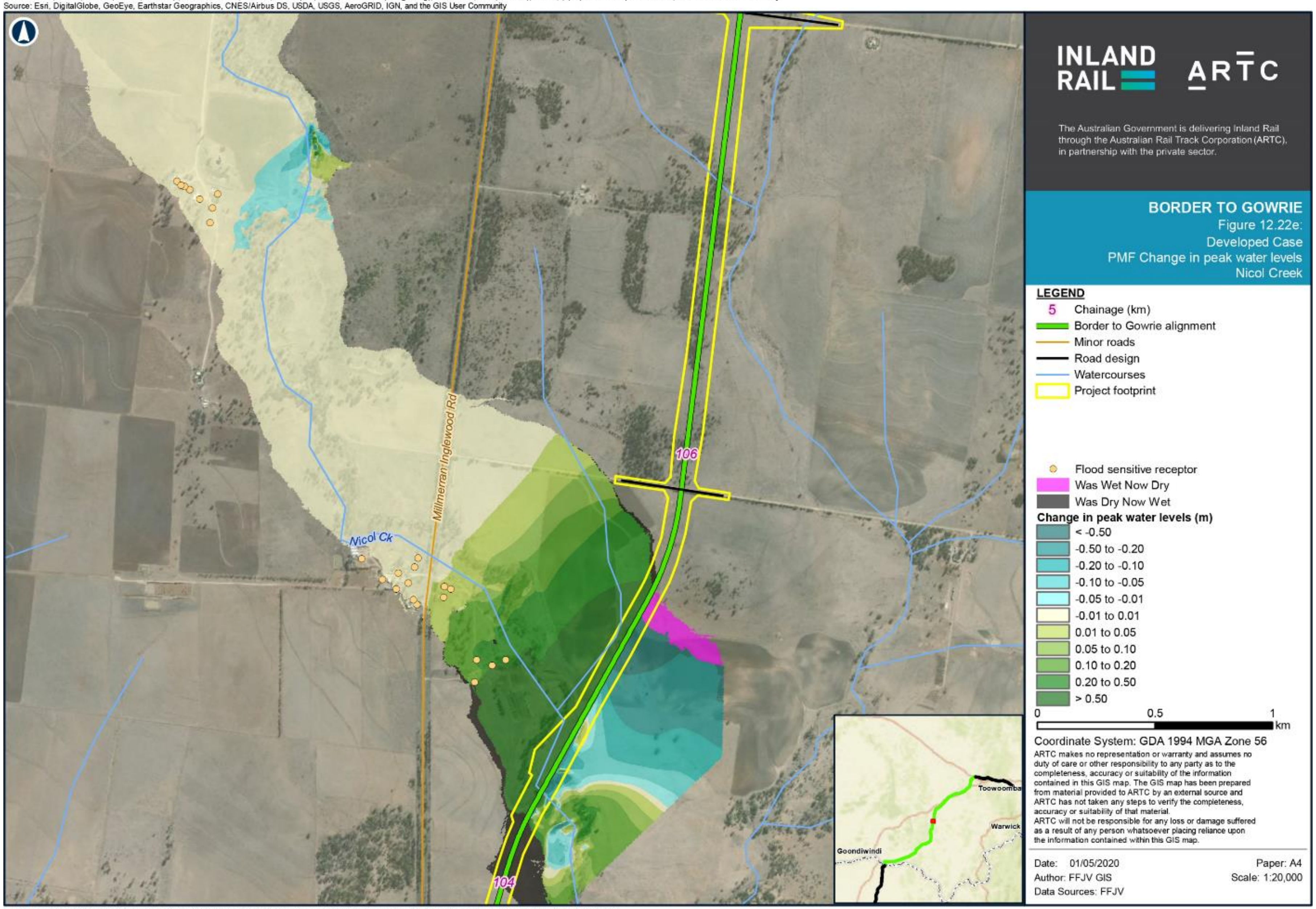

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BORDER TO GOWRIE
Figure 12.22f:
Developed Case
1% AEP Change in peak velocities
Nicol Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.5 1 km

Coordinate System: GDA 1994 MGA Zone 56

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12.10.2.6 Bringalily Creek

In the Bringalily Creek floodplain, the Project design includes:

- Two bridges
- Eight RCP locations (a total of 55 cells)
- Three RCBC locations (a total of 28 cells).

Details of the floodplain structures required to convey Bringalily Creek flood flows are presented in Table 12.94 and Table 12.95 with structure locations presented in Table 12.23a also presents the location of catchment drainage structures.

TABLE 12.94 BRINGALILY CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
97.58	310-BR08	Bridge	332.1	299
100.39	310-BR10	Bridge	333.2	621

TABLE 12.95 BRINGALILY CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
100.00	C100.00	RCP	8	1.50
99.84	C99.84	RCP	14	0.90
99.38	C99.38	RCP	17	0.90
97.29	C97.29	RCP	2	0.90
98.87	C98.87	RCP	1	1.50
99.77	C99.77	RCP	1	1.50
98.36	C98.36	RCP	10	0.90
97.38	C97.38	RCP	2	0.90
96.20	C96.20	RCBC	8	2.40 x 1.20
94.91	C94.91	RCBC	5	2.41 x 0.90
95.07	C95.07	RCBC	15	2.40 x 1.50

Table notes:
1. For RCP height equals diameter

Change in peak water levels

Figure 12.23b presents the change in peak water levels under the 1% AEP event and Table 12.96 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the change in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.96 BRINGALILY CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside Project footprint[1]	97.80 to 98.70	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+372	25.6 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm
Private land outside Project footprint	97.90 to 98.40	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+255	34.1 ha in total affected by afflux > 10 mm < 0.1 ha affected by afflux > 200 mm

Table note:
1. Project footprint is indicated in Figure 12.23b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with noticeable floodplain inundation starting under the 20% AEP event.

For events exceeding the 10% AEP event, minor changes in peak water levels occur to the east of the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Bringalily Creek floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

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.

Velocities

Figure 12.18f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Bringalily Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.23c to Figure 12.23e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.97 outlines the changes in peak water levels 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 occur generally when there are already high flood depths, as would be expected under such a rare event.

TABLE 12.97 BRINGALILY 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)
BRI_ID_1	-29	0.55	+47	1.21	+193	3.54
BRI_ID_2	+4	0.68	+63	1.36	+217	3.66
BRI_ID_3	-17	0.63	+68	1.25	+176	3.64
BRI_ID_4	-33	0.59	+50	1.24	+187	3.60
BRI_ID_5	-	-	-	-	+26	2.48
BRI_ID_6	-	-	-	-	+27	2.01
BRI_ID_7	-	-	-	-	+28	1.39
BRI_ID_8	-	-	-	-	+28	1.70
BRI_ID_9	-	0.05	+2	0.18	+52	2.33
BRI_ID_10	-	-	-	0.18	+64	2.22
BRI_ID_11	-	-	-	0.11	+106	1.89
BRI_ID_12	-	-	-	-	+215	1.61
BRI_ID_13	-	-	-	-	+75	2.21
BRI_ID_14	-	-	-	-	+101	1.72
BRI_ID_15	-	-	-	-	+451	1.85
BRI_ID_16	-	-	-	-	+480	1.66
BRI_ID_17	-	-	-	0.41	+173	2.39
BRI_ID_18	+16	0.79	+8	1.87	+42	4.62
BRI_ID_19	-	0.00	+54	0.31	+141	3.05
BRI_ID_21	-17	0.45	-29	1.35	+12	3.90
Forestry Road	+8	0.36	+165	0.82	+17	3.38
Heckels Road	+56	1.20	+106	2.28	+328	4.85
Millmerran–Inglewood Road	+667	3.06	+1,215	4.34	+790	7.06

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 12.98 outlines the overtopping locations and depths.

TABLE 12.98 BRINGALILY CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
95.70	-	-	2.6
95.80	<0.1	0.2	2.5
95.90	-	<0.1	2.5
96.00	-	-	2.4
96.10	<0.1	0.6	3.2
96.20	-	-	2.4
96.30	-	<0.1	2.3
96.40	-	-	2.3
96.50	-	0.1	2.3
96.60 to 96.80	-	-	1.9
96.90 to 97.00	-	-	0.6
97.50 to 97.70	2.8	3.6	6.0
99.00 to 99.20	-	-	0.4
99.30 to 100.00	-	-	1.5
100.10 to 100.60	5.0	6.3	9.0
100.70 to 101.20	-	-	1.9
101.30 to 101.70	-	-	0.7
96.60 to 96.80	-	-	2.6

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23.9 per cent across the Bringalily Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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 0.5 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 12.99 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.99 BRINGALILY CREEK—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood-sensitive receptor ID	Change in peak water level (mm)	Existing case flood depth[2] (m)
BRI_ID_18	+19	0.54
Heckels Road[1]	+32	0.94
Millmerran–Inglewood Road[1]	+533	2.74

Table notes:

1. These roads are affected by climate change, regardless of the Project, and so the amenity of the roads is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

Under the 50 per cent blockage scenario, the peak 1% AEP afflux caused by the Project within the Bringalily Creek floodplain increases from 372 mm to 518 mm; however, the total area affected by 1% AEP afflux (> 10 mm) only increases from 101.2 ha to 102.3 ha.

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

Table 12.102 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.100 BRINGALILY CREEK—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood-sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
BRI_ID_18	0.54	+17
Heckels Road	0.94	+17
Millmerran–Inglewood Road	2.74	+342

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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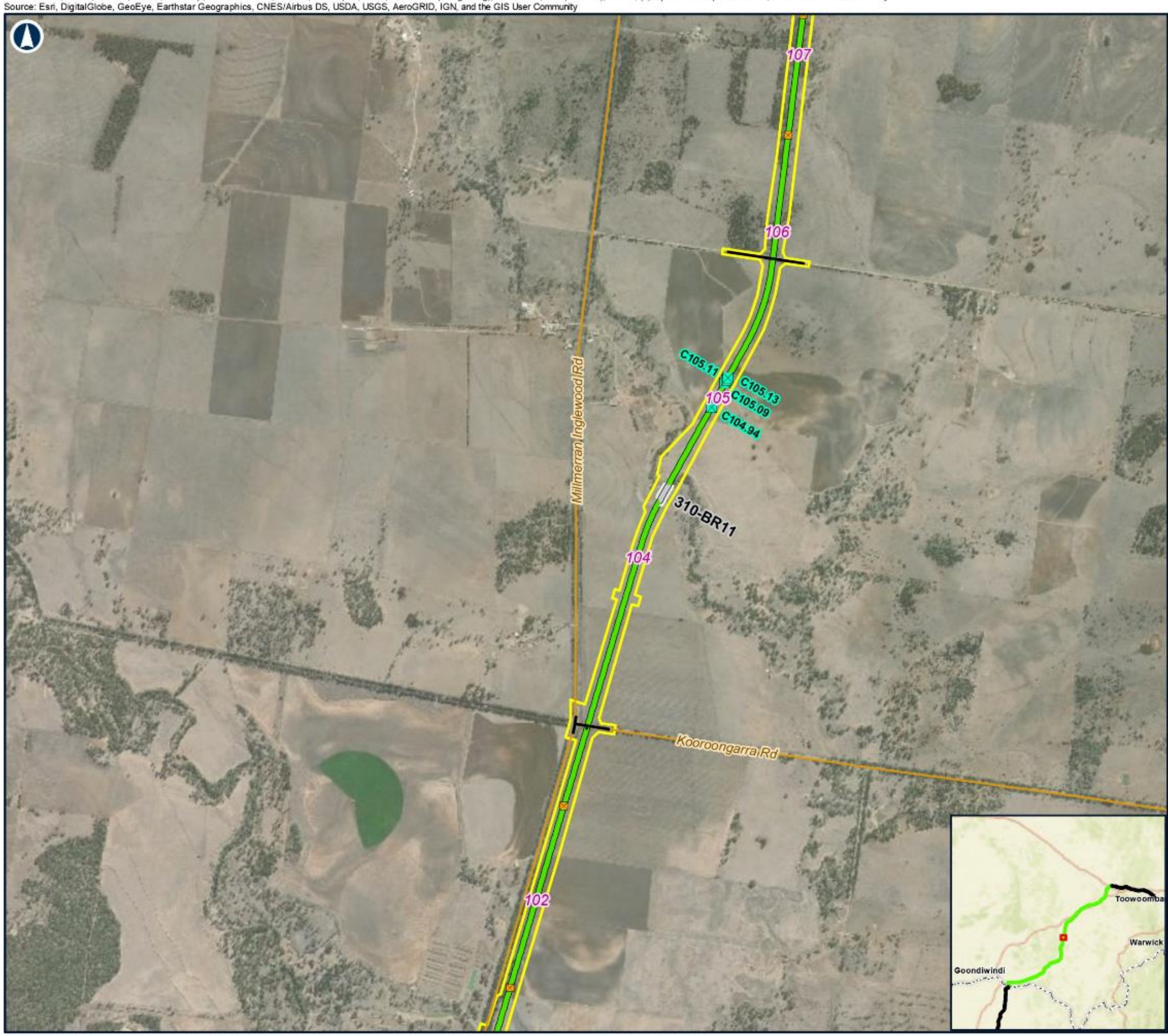

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BORDER TO GOWRIE
Figure 12.23a.1
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

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BORDER TO GOWRIE

Figure 12.23a.2:
Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

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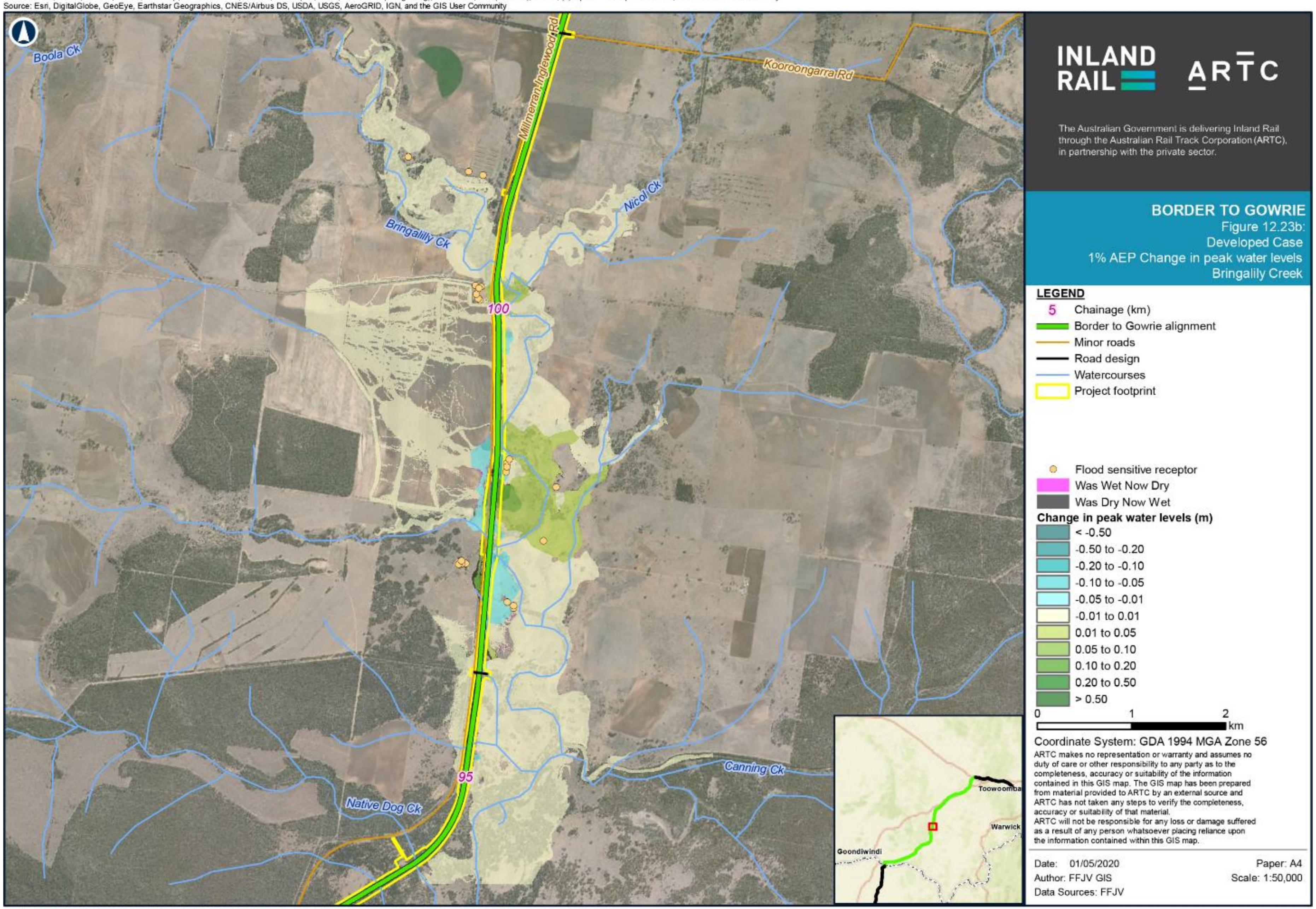

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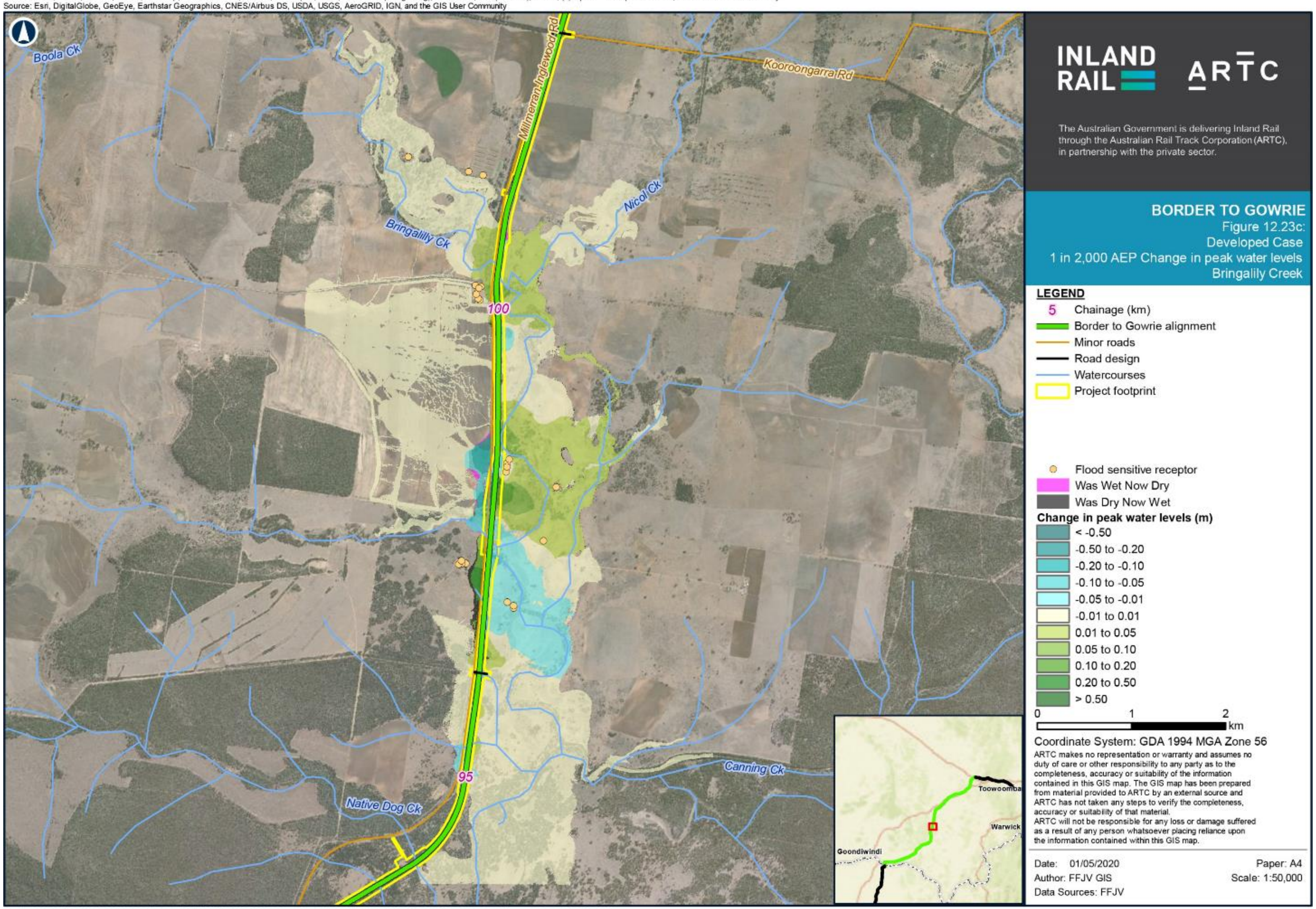

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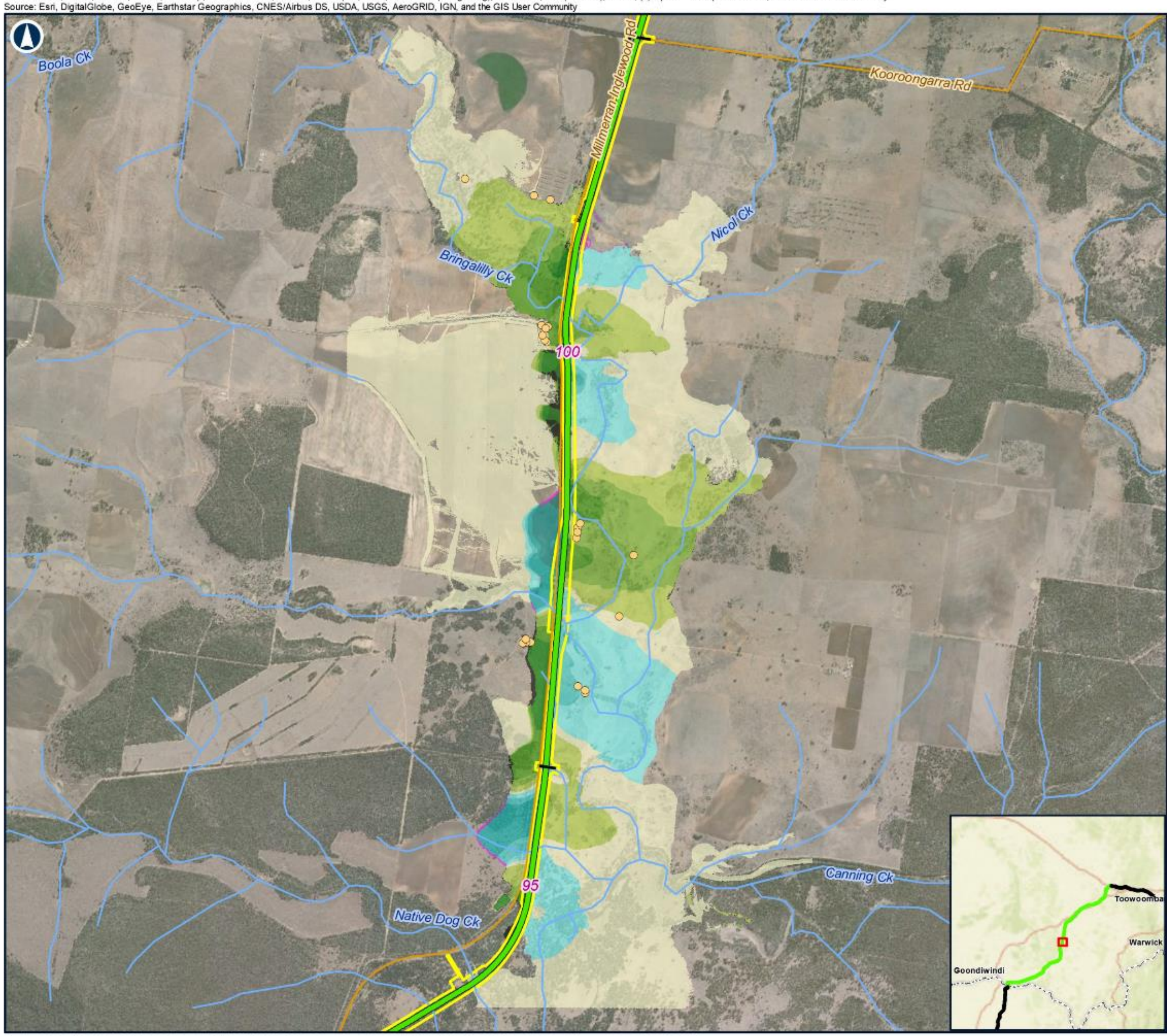

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BORDER TO GOWRIE
Figure 12.23d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Bringalily Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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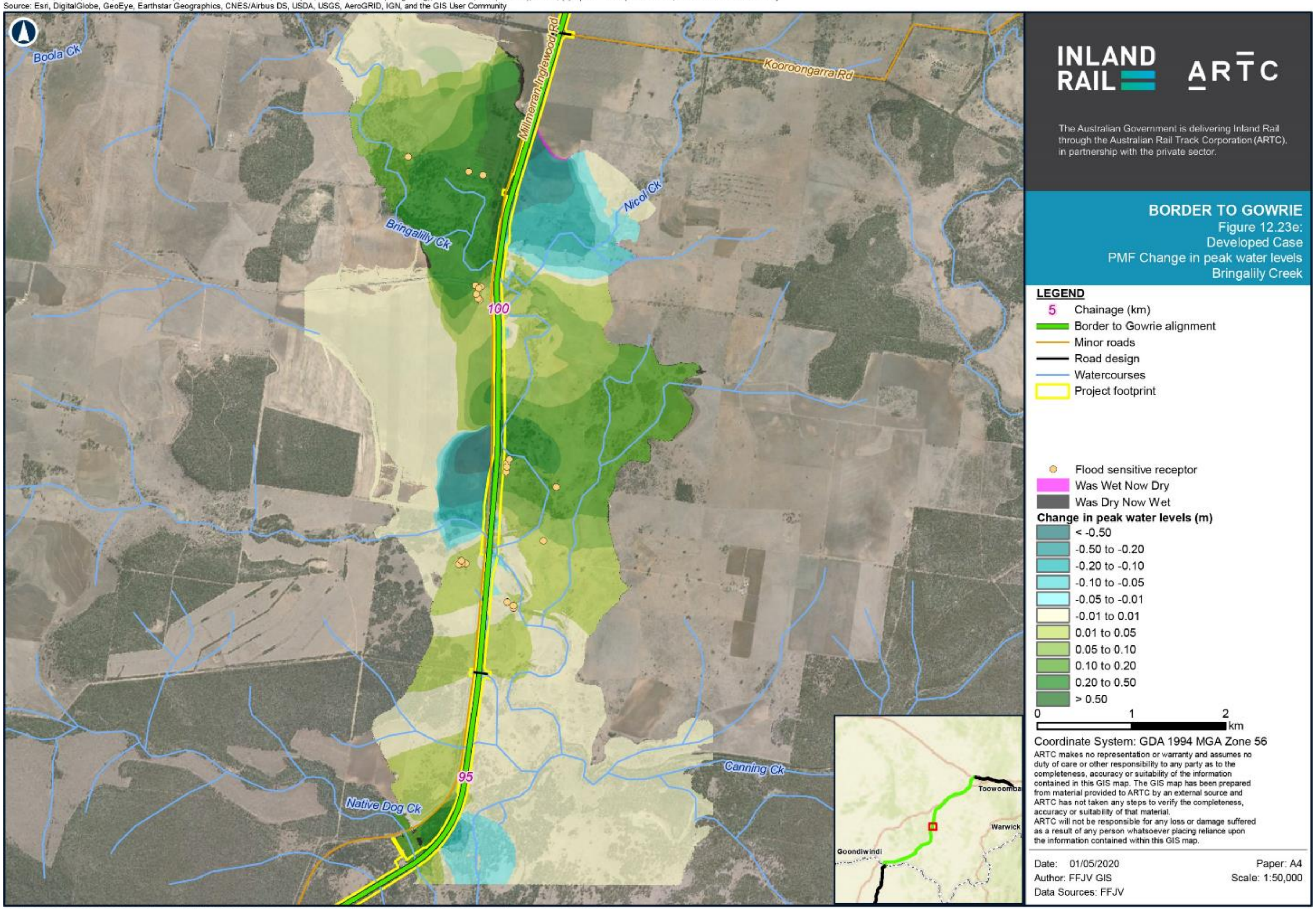

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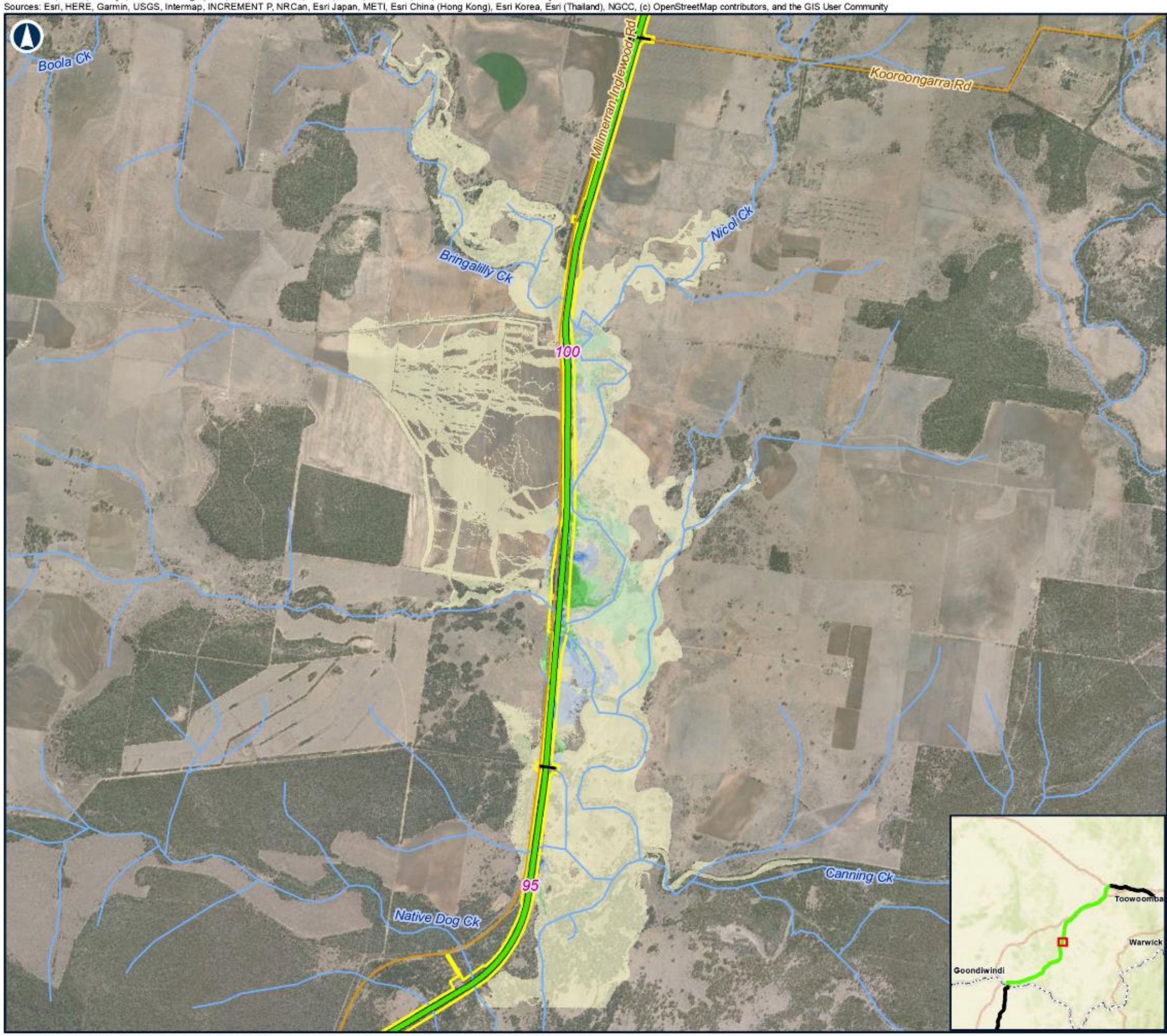

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BORDER TO GOWRIE
Figure 12.23f:
Developed Case
1% AEP Change in peak velocities
Bringalily Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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12.10.2.7 Native Dog Creek

In the Native Dog Creek floodplain, the Project design includes one bridge.

Details of the floodplain structure required to convey Native Dog Creek flood flows are presented in Table 12.101, with the structure location presented in Figure 12.24a. Figure 12.24a also presents the location of local catchment drainage structures.

TABLE 12.101 NATIVE DOG CREEK—FLOODPLAIN STRUCTURE LOCATION AND DETAIL

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
93.90	310-BR07	Bridge	327.2	184

Change in peak water levels

Figure 12.24b presents the change in peak water levels under the 1% AEP event. No changes in peak water levels, outside exceeding the flood-impact objectives, are predicted (refer Section 12.6.3.2).

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with some floodplain inundation starting under the 20% AEP event. There is little difference between the 20% and 1% AEP event floodplain inundation extents.

No noticeable changes in peak water levels for all events up to the 1% AEP event occur but some impacts adjacent to the Project alignment are evident for events exceeding the 1 in 2,000-year AEP event.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Native Dog Creek floodplain are negligible, as demonstrated in the 'change in time of inundation map' in Appendix Q2: Hydrology and Flooding Technical Report.

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.

Velocities

Figure 12.24f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Native Dog Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.24c to Figure 12.24e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.102 outlines the changes in peak water levels 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.

TABLE 12.102 NATIVE DOG 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)
Millmerran–Inglewood Road	-	2.25	+3	3.35	+1,230	5.49

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 12.103 outlines the overtopping locations and depths.

TABLE 12.103 NATIVE DOG CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
93.85 to 94.05	1.7	2.3	4.1
94.25 to 94.55	-	-	0.4
94.55 to 94.65	-	0.1	0.2
94.65 to 94.75	-	-	0.4
94.75 to 95.15	-	0.5	0.6
95.15 to 95.25	0.1	0.4	0.2
95.25 to 95.55	-	0.2	2.9
95.55 to 95.65	-	-	2.6

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project with an associated increase in rainfall intensity of 23.9 per cent across the Native Dog Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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.

No flood-sensitive receptors are detrimentally affected by the climate change scenario.

The downstream extents of these impacts are similar to those under the 1% AEP event.

Blockage

As previously stated, ARR 2016 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 2016 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.

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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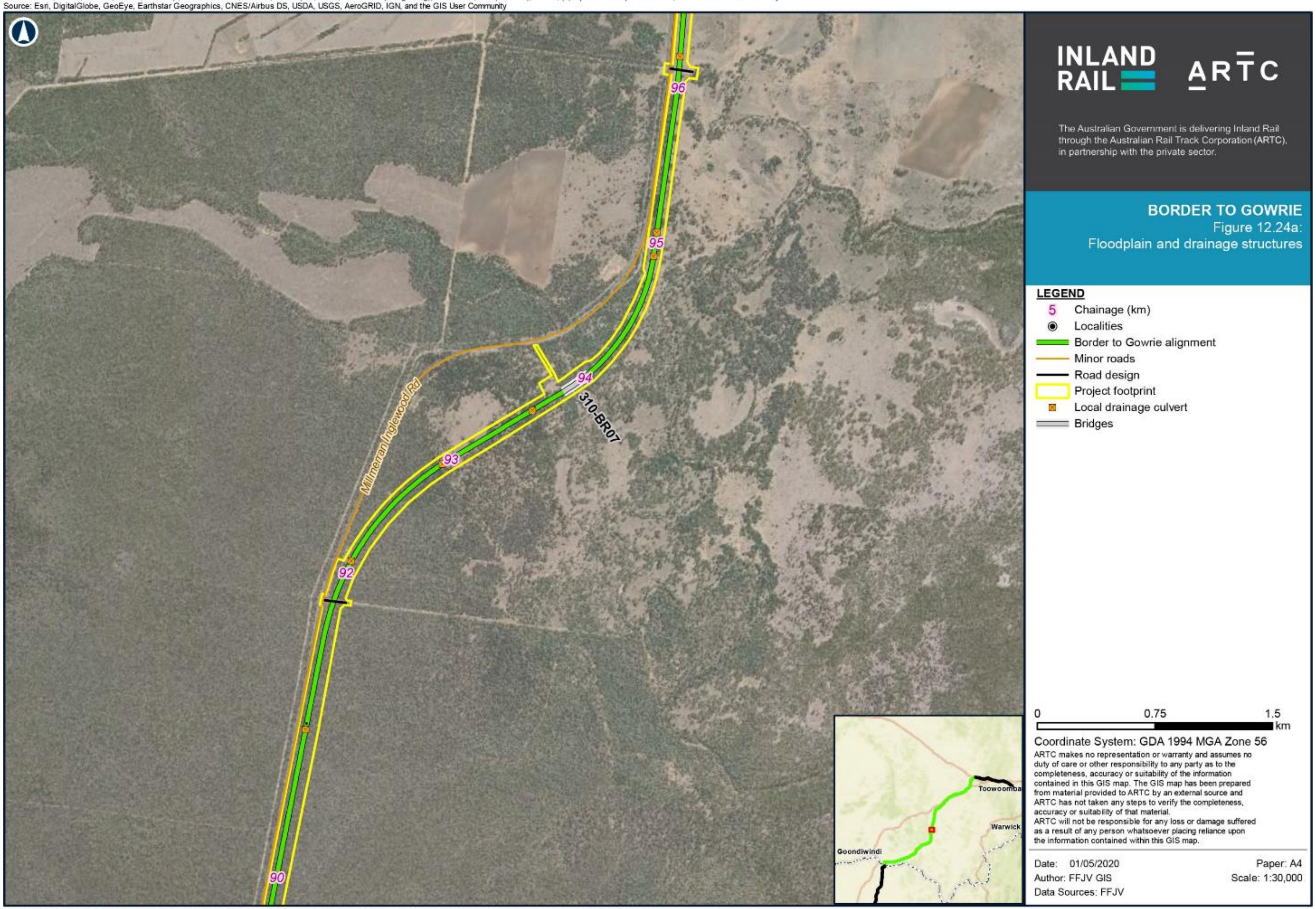

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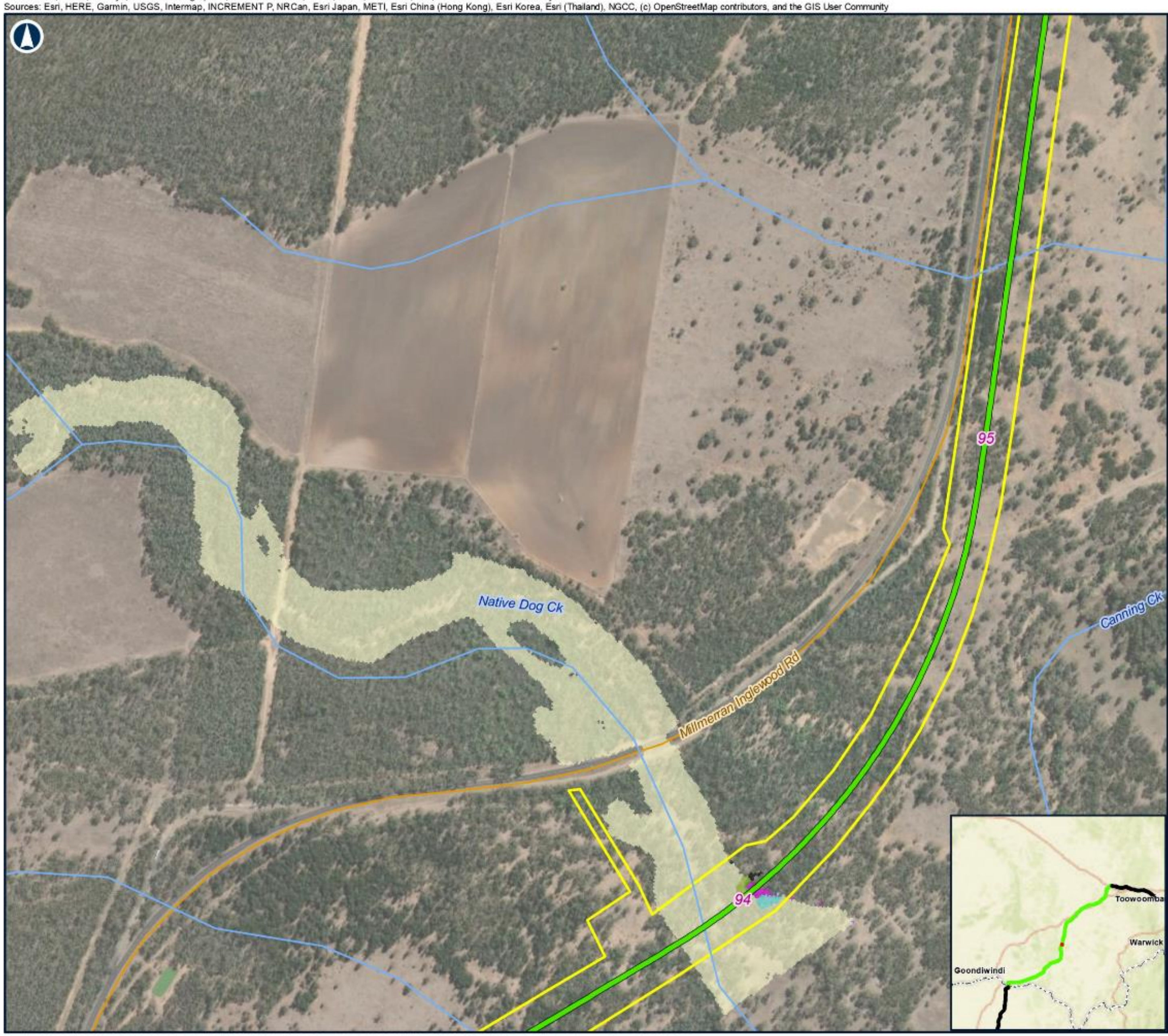

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BORDER TO GOWRIE

Figure 12.24b: Developed Case 1% AEP Change in peak water levels Native Dog Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 56

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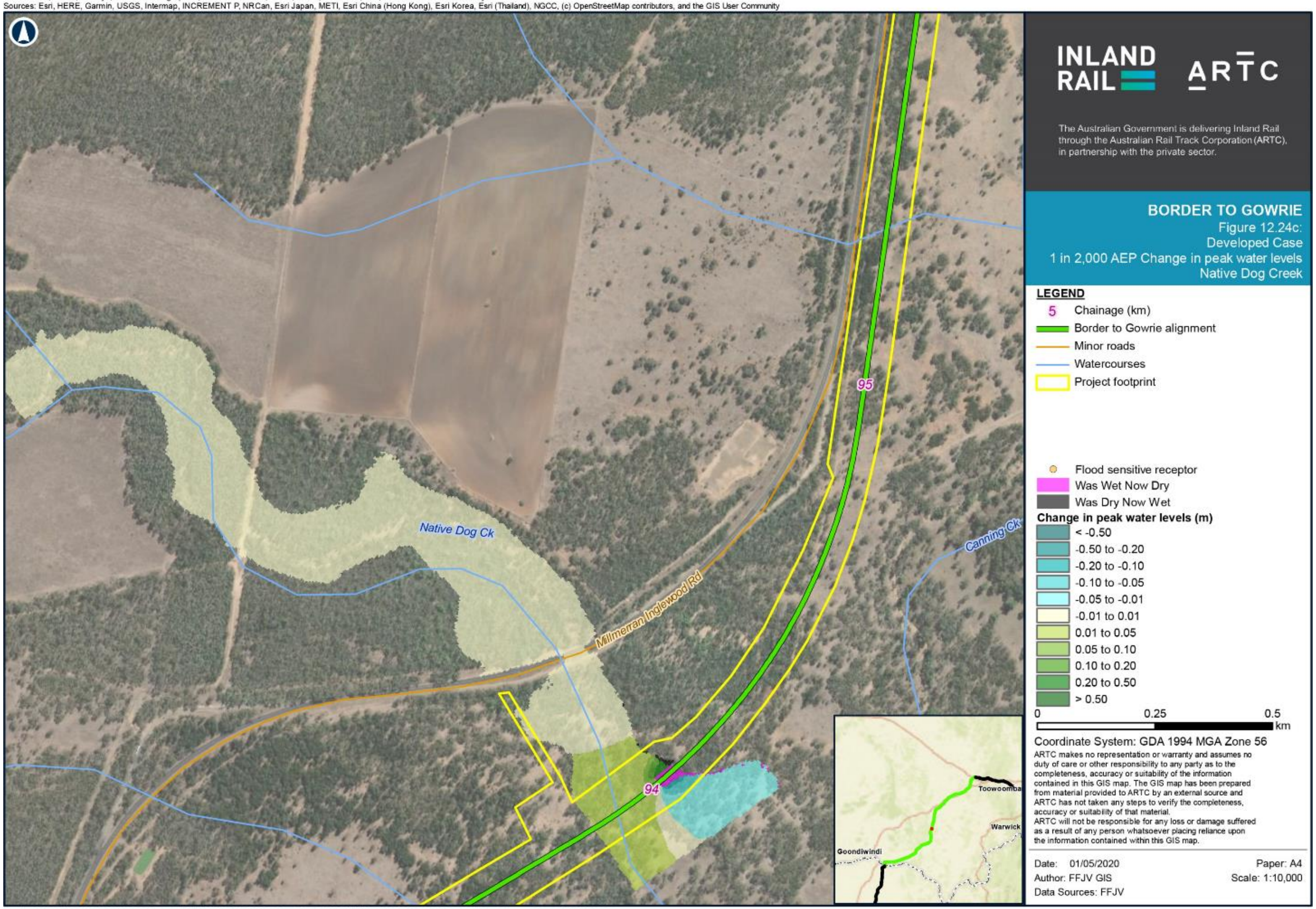

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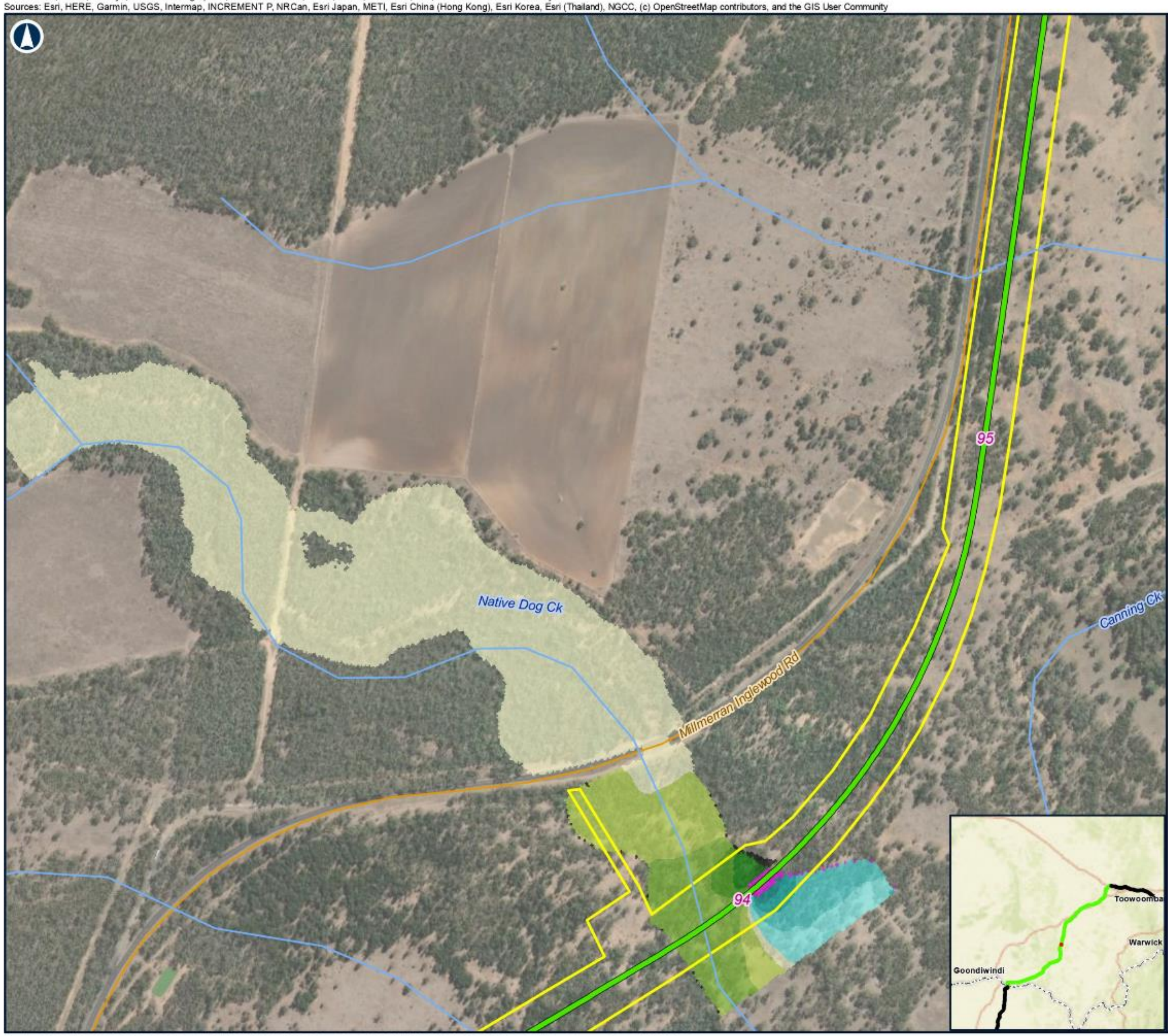

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BORDER TO GOWRIE
Figure 12.24d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Native Dog Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.25 0.5 km

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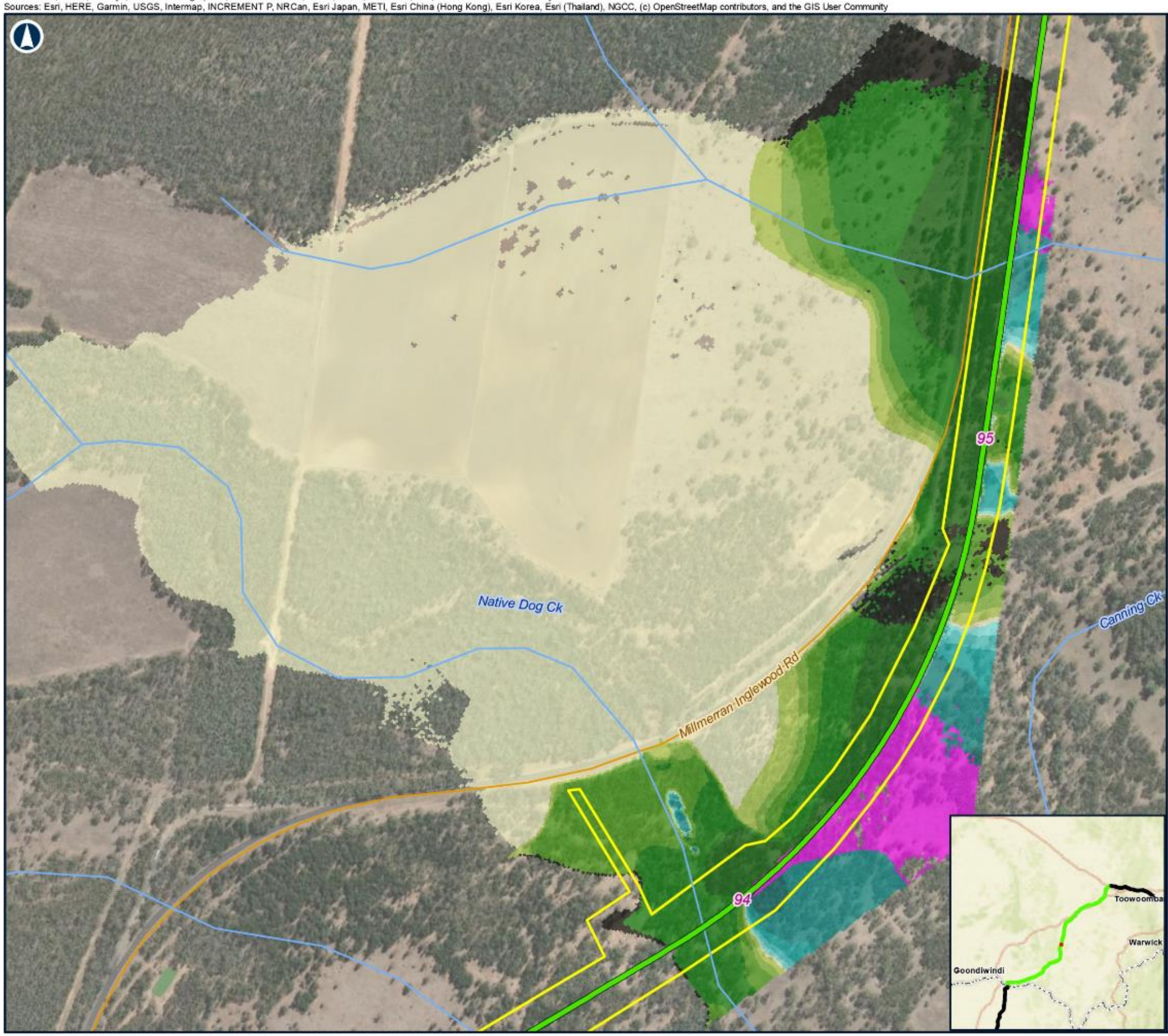

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BORDER TO GOWRIE
Figure 12.24e:
Developed Case
PMF Change in peak water levels
Native Dog Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.25 0.5 km

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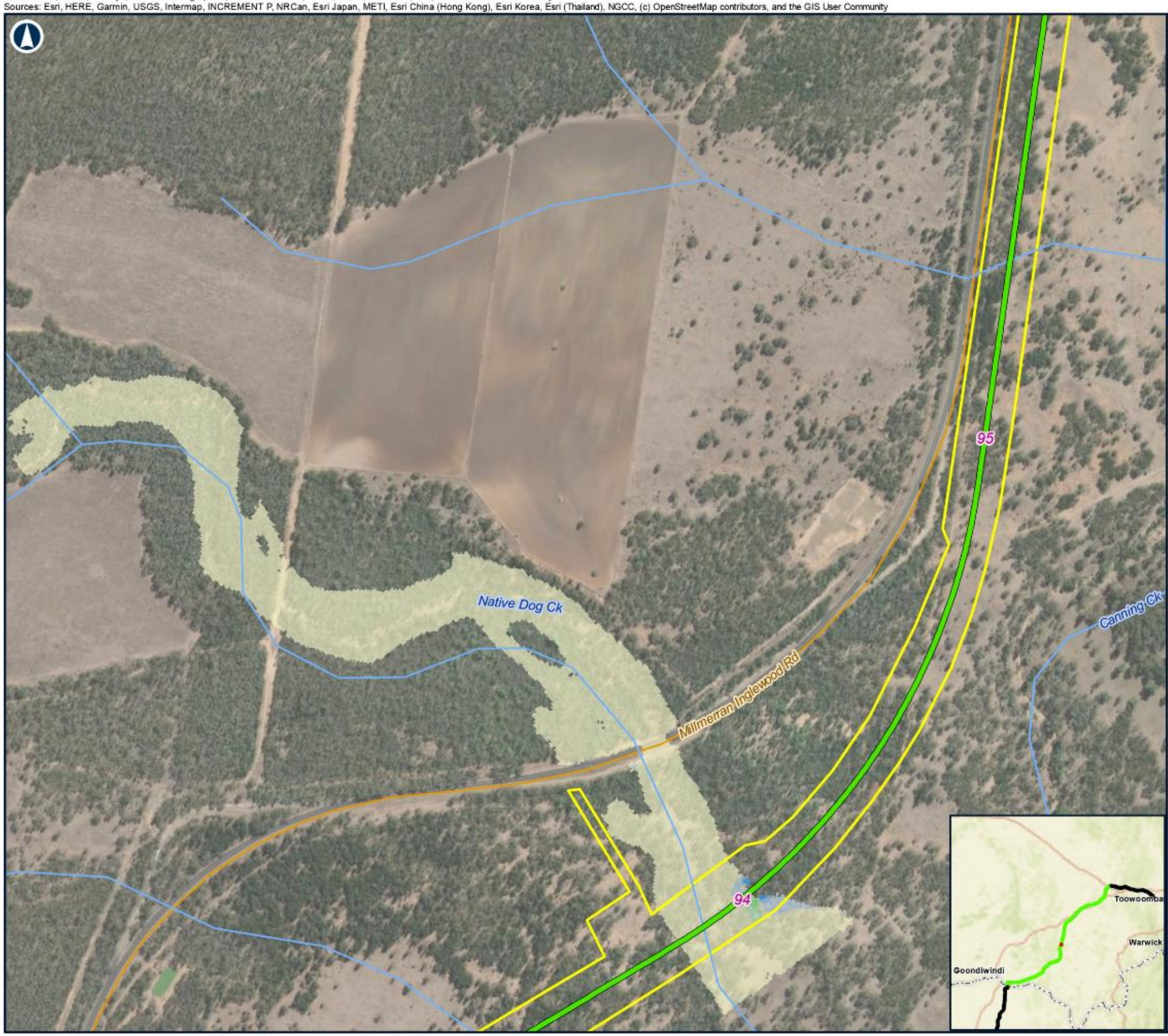

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BORDER TO GOWRIE
Figure 12.24f:
Developed Case
1% AEP Change in peak velocities
Native Dog Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.25 0.5 km

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12.10.2.8 Cattle Creek

In the Cattle Creek floodplain, the Project design includes:

- One bridge
- One RCP location (a total of six cells)
- One RCBC location (a total of 15 cells).

Details of the floodplain structures required to convey Cattle Creek flood flows are presented in Table 12.104 and Table 12.105, with structure locations presented in Figure 12.25a. Figure 12.25a also presents the location of local catchment drainage structures.

TABLE 12.104 CATTLE CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
88.28	310-BR06	Bridge	329.0	138

TABLE 12.105 CATTLE CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
87.37	C87.37	RCP	6	2.10
87.19	C87.19	RCBC	15	2.40 x 1.50

Table notes:

1. For RCP height equals diameter

Change in peak water levels

Figure 12.25b presents the change in peak water levels under the 1% AEP event. Changes in peak water levels are consistent with the intent of the flood-impact objectives (refer Section 12.6.3.2).

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with some floodplain inundation starting under the 20% AEP event. There is not much difference between the 20% and 1% AEP event floodplain inundation extents.

No noticeable changes in peak water levels for all events up to the 1% AEP event occur but some impacts to land adjacent to the Project alignment are evident for events exceeding the 1 in 10,000-year AEP event.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Cattle Creek floodplain are negligible, as demonstrated in the change in time of inundation map in Appendix Q2: Hydrology and Flooding Technical Report.

Flood flow distribution

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

Velocities

Figure 12.25f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Cattle Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.25c to Figure 12.25e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.106 outlines the changes in peak water levels 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 occur generally when there are already high flood depths, as would be expected under such a rare event.

TABLE 12.106 CATTLE CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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)
Millmerran–Inglewood Road	-	3.17	+2,180	4.10	+4,953	6.17

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. Table 12.107 outlines the overtopping locations and depths.

TABLE 12.107 CATTLE CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
86.55 to 87.25	-	-	2.1
87.25 to 87.65	-	-	0.7
88.25 to 88.35	1.8	2.7	6.0

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23.9 per cent across the Cattle Creek catchment area.

Appendix Q1/Q2: Hydrology and Flooding Technical Report 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.

No flood-sensitive flood receptors are detrimentally affected by the climate change scenario.

The downstream extents of these impacts are similar to those under the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

During detail design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in a varied and/or lower blockage factors being applied along the Project alignment. There are no changes to impacts on flood-sensitive receptors under the blockage scenarios.

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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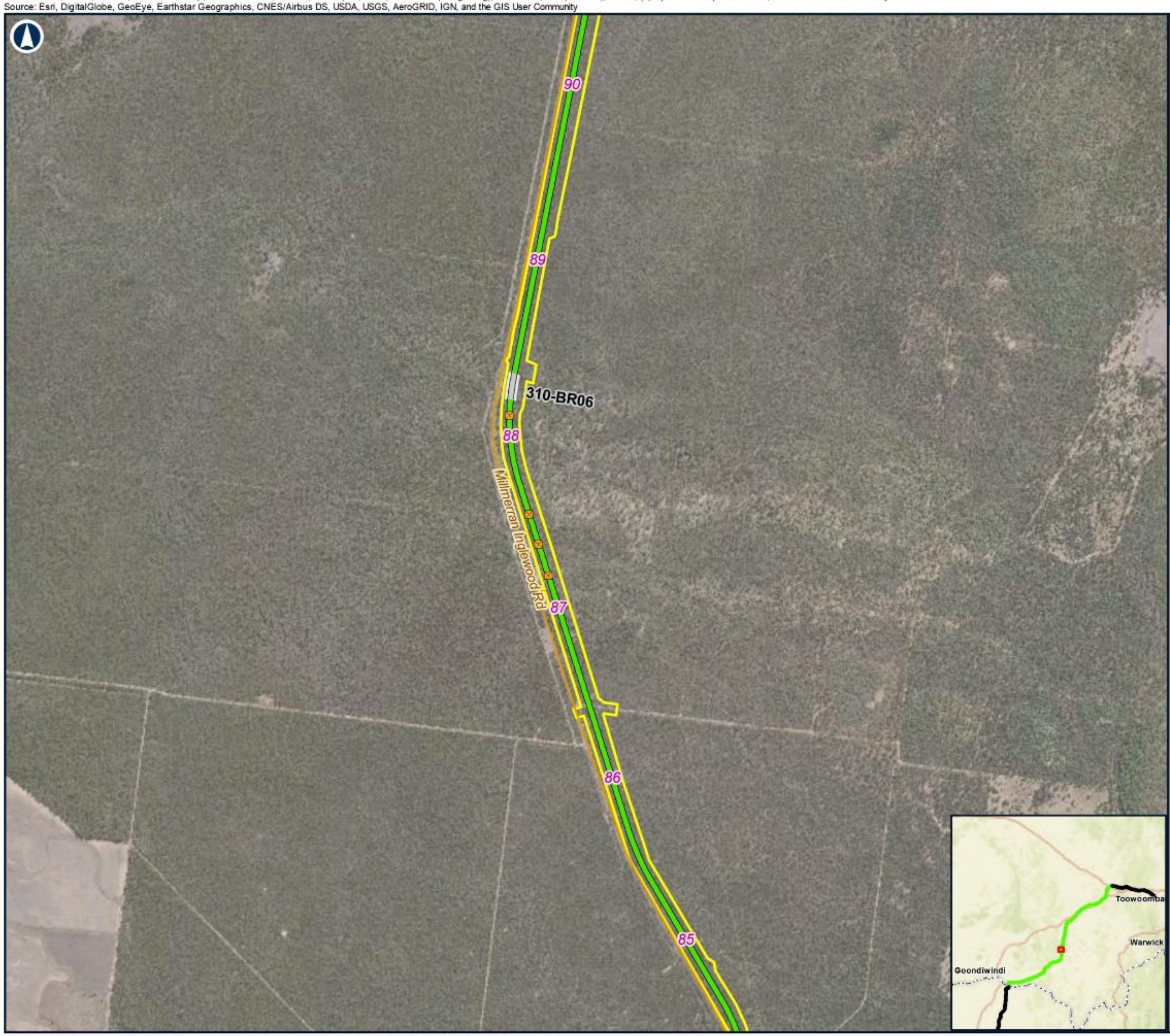

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BORDER TO GOWRIE
Figure 12.25a:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Minor roads
- Road design
- Project footprint
- Local drainage culvert
- Bridges

0 0.75 1.5 km

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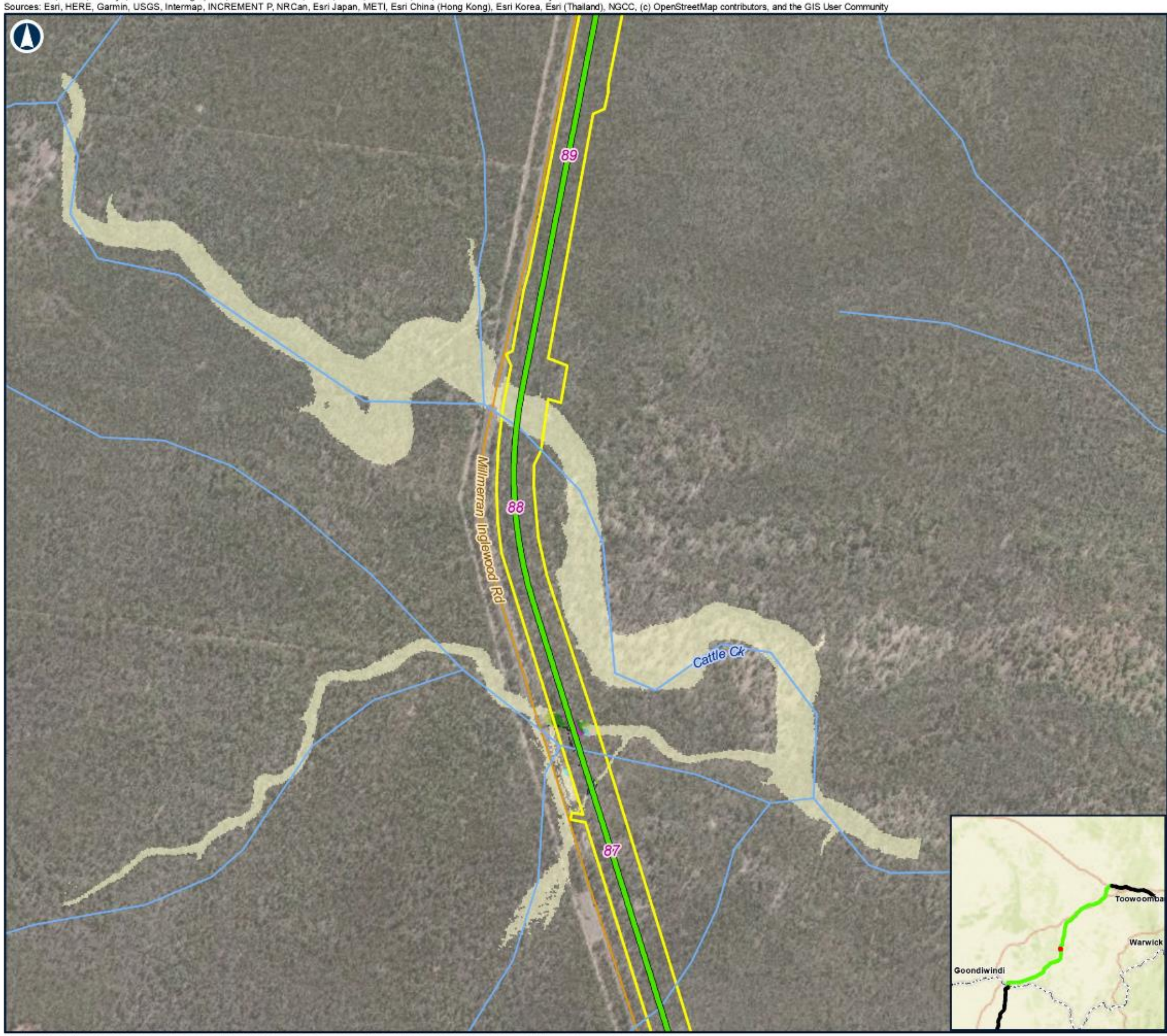

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BORDER TO GOWRIE
Figure 12.25b:
Developed Case
1% AEP Change in peak water levels
Cattle Creek

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.35 0.7 km

Coordinate System: GDA 1994 MGA Zone 56

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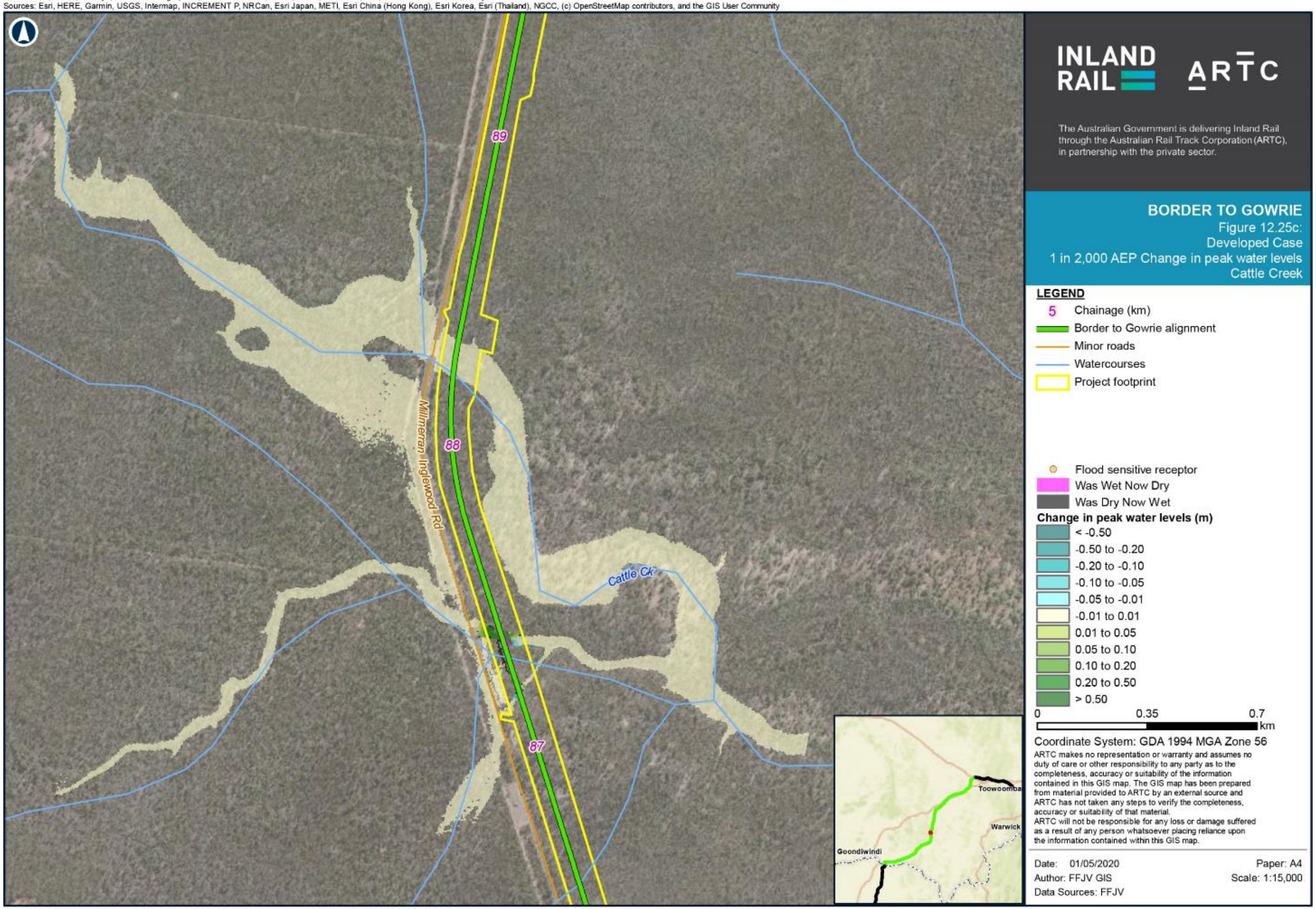

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BORDER TO GOWRIE

Figure 12.25d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Cattle Creek

LEGEND

5 Chainage (km)
Border to Gowrie alignment
Minor roads
Watercourses
Project footprint

Flood sensitive receptor
Was Wet Now Dry
Was Dry Now Wet

Change in peak water levels (m)

< -0.50
-0.50 to -0.20
-0.20 to -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 to 0.20
0.20 to 0.50
> 0.50

0 0.35 0.7 km

Coordinate System: GDA 1994 MGA Zone 56

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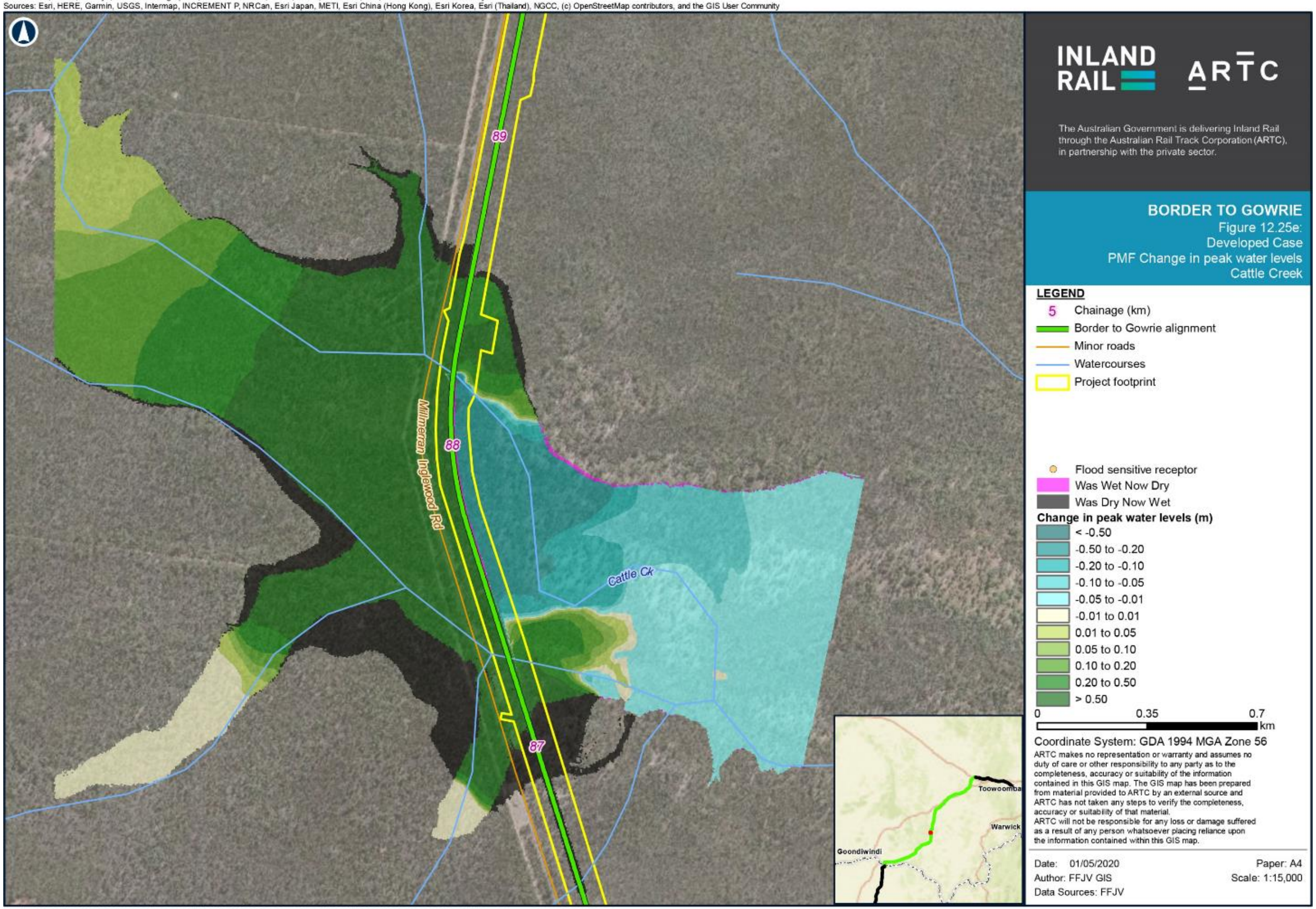

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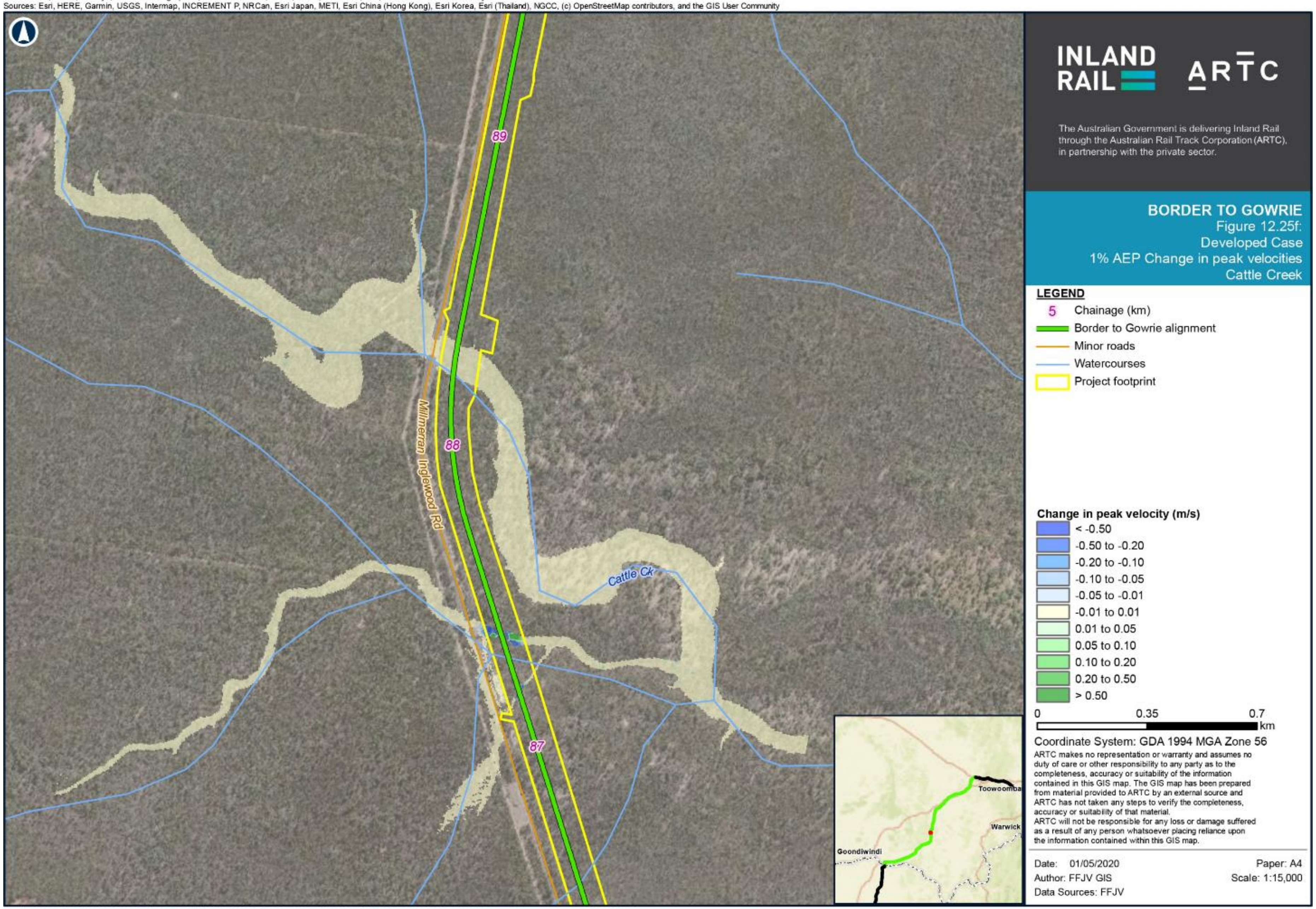

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12.10.2.9 Pariagara Creek

In the Pariagara Creek floodplain, the Project design includes:

- One bridge
- 17 RCP locations (a total of 136 cells)
- Two RCBC locations (a total of 48 cells).

Details of the floodplain structures required to convey Pariagara Creek flood flows are presented in Table 12.108 and Table 12.109, with structure locations presented in Figure 12.26a. Figure 12.26a also presents the location of local catchment drainage structures.

TABLE 12.108 PARIAGARA CREEK—FLOODPLAIN STRUCTURE LOCATION AND DETAIL (BRIDGE)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
67.35	310-BR05	Bridge	285.7	345

TABLE 12.109 PARIAGARA CREEK—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No of cells	Diameter/width x height (m)[1]
68.75	C68.75	RCBC	40	2.1 x 2.1
66.23	C66.23	RCBC	8	2.4 x 1.5
69.80	C69.80	RCP	5	1.8
69.67	C69.67	RCP	5	1.8
69.54	C69.54	RCP	5	1.8
69.41	C69.41	RCP	5	1.8
69.28	C69.28	RCP	2	1.8
69.21	C69.21	RCP	2	1.8
69.14	C69.14	RCP	2	1.5
69.10	C69.10	RCP	2	1.2
69.02	C69.02	RCP	2	1.2
68.89	C68.89	RCP	2	1.2
67.57	C67.57	RCP	8	1.2
67.64	C67.64	RCP	8	1.2
67.70	C67.70	RCP	8	1.2
67.83	C67.83	RCP	20	1.2
67.96	C67.96	RCP	20	1.2
68.09	C68.09	RCP	20	1.2
68.41	C68.41	RCP	20	1.2

Table notes:

1. For RCP height equals diameter

Change in peak water levels

Figure 12.26b presents the change in peak water levels under the 1% AEP event and Table 12.110 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.110 PARIAGARA CREEK—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate chainage (km)	Existing land use	Flood impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside of Project footprint[1]	66.20	Agricultural (grazing/ forestry)	≤200 mm (up to 400 mm)	+580[1]	0.3 ha in total affected by afflux > 10 mm
Private land outside of Project footprint	67.30 to 68.70	Agricultural (grazing/ forestry)	≤200 mm (up to 400 mm)	+214	47.2 ha in total affected by afflux > 10 mm <0.1 ha affected by afflux > 200 mm

Table notes:
1. All impacts at this location are contained to an area within an existing creek channel
2. Project footprint is indicated in Figure 12.26b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur to the east of Thornton Road adjacent to the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Pariagara Creek floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

Flood flow distribution

To understand the magnitude of these flowpaths, flows were extracted from the hydraulic model at key locations. The difference between the Existing Case and Developed Case was considered and is reported in Table 12.111. Figure 12.26g presents the selected flowpath comparison locations. The flow is calculated across the length of the line; therefore, the lines presented are either calculating the flow across the width of the floodplain (for the longer flow lines) or the main flowpath of the waterways (generally for smaller flow lines).

TABLE 12.111 PARIAGARA CREEK—FLOW COMPARISON

	10% AEP			1% AEP		
Location ID	Existing Case peak flow (m^3/s)	Developed Case peak flow (m^3/s)	% Change	Existing Case peak flow (m^3/s)	Developed Case peak flow (m^3/s)	% Change
A	249.8	246.0	-1.5%	398	404	+1.5%
B	34.2	28.6	-16.5%	106	92	-13.6%
C	294.1	296.0	+0.7%	527	537	+1.9%
D	294.1	295.9	+0.6%	525	535	+1.8%
E	301.7	307.7	+2.0%	565	570	+0.8%
F	300.9	304.7	+1.3%	613	606	-1.2%

Velocities

Figure 12.26f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Pariagara Creek main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.26c–e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.112 outlines the changes in peak water levels 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.

TABLE 12.112 PARIAGARA CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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)
PAR_ID_18	-	-	-	-	+13	1.37
PAR_ID_19	-	-	-	-	+10	1.82
PAR_ID_20	-	-	-	-	+12	1.42
PAR_ID_21	-	-	+9	0.34	+10	2.04
Thornton Road	+223	4.38	+661	4.98	+657	6.57
Unnamed Road	+155	2.26	+602	3.02	+605	4.64
Lovells Crossing Road	-	0.83	+553	1.64	+777	3.25

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 12.113 outlines the overtopping locations and depths.

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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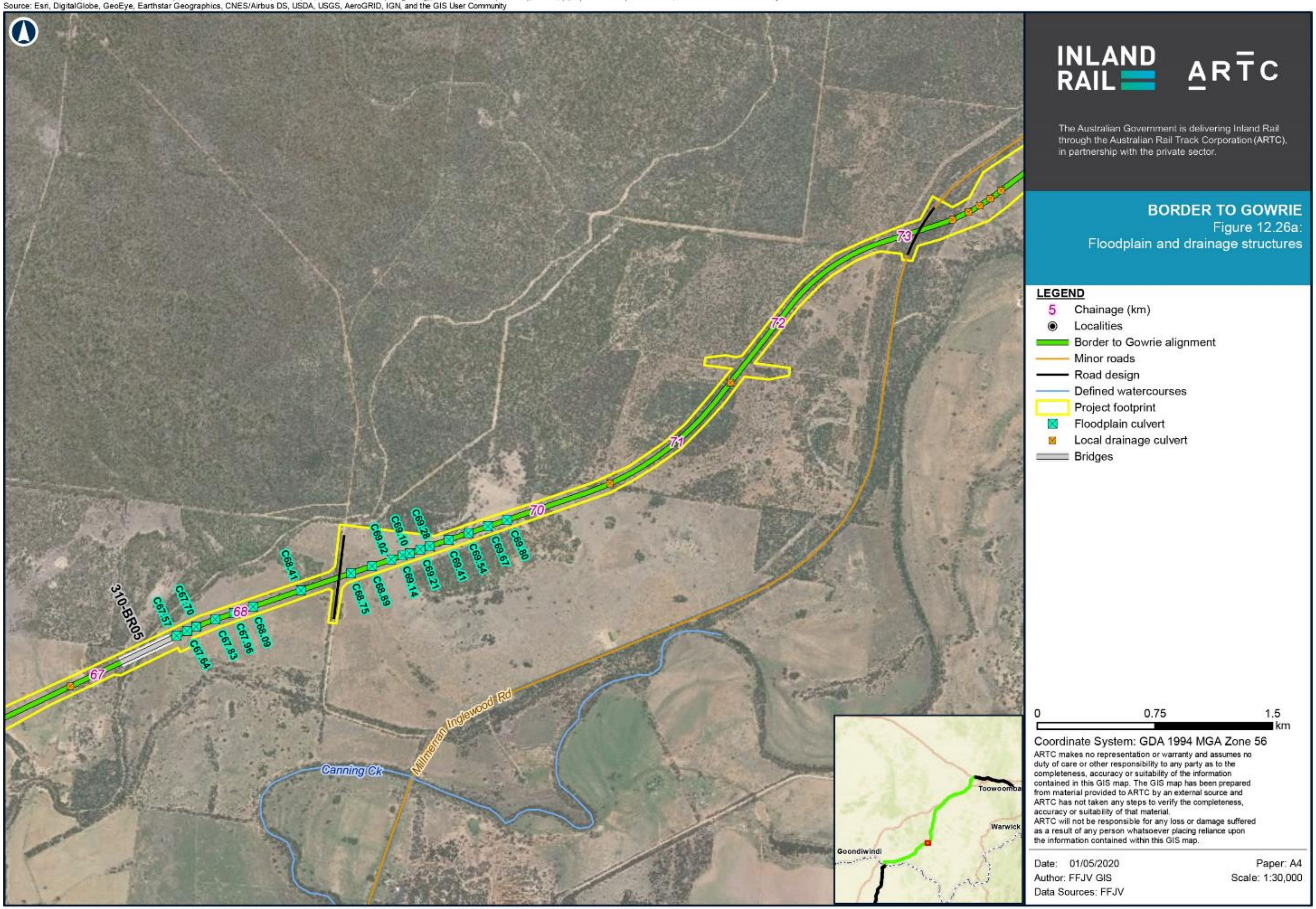

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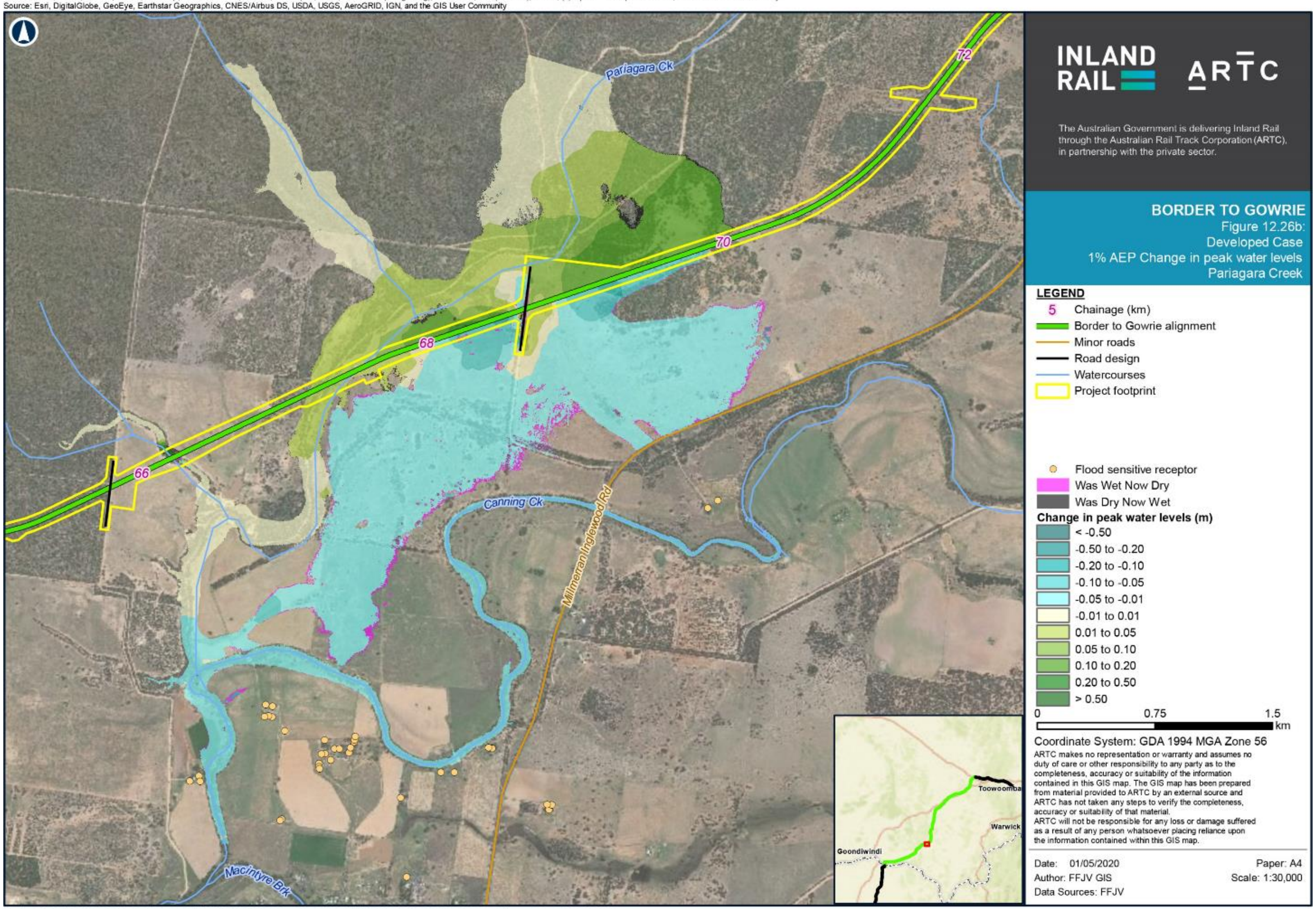

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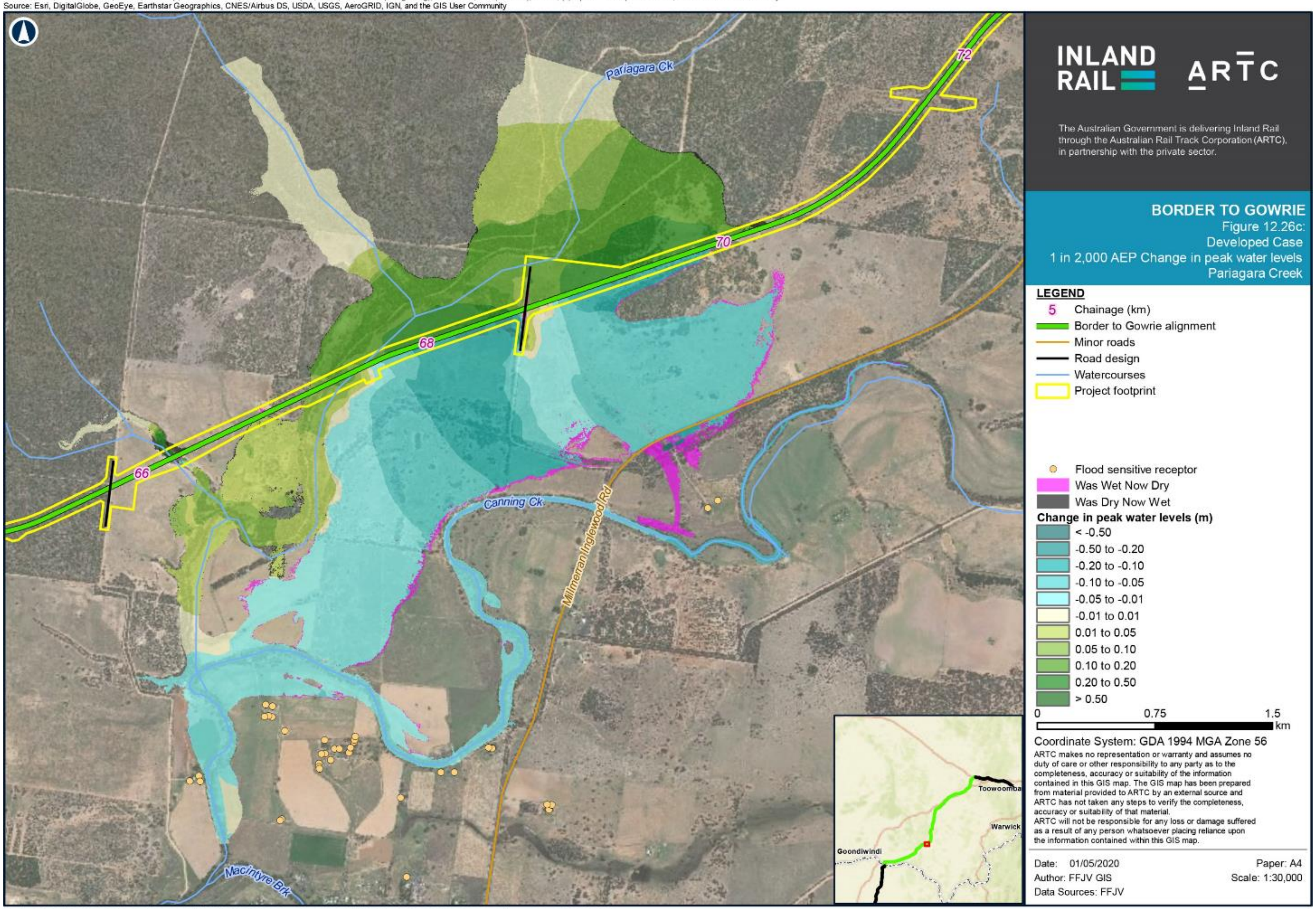

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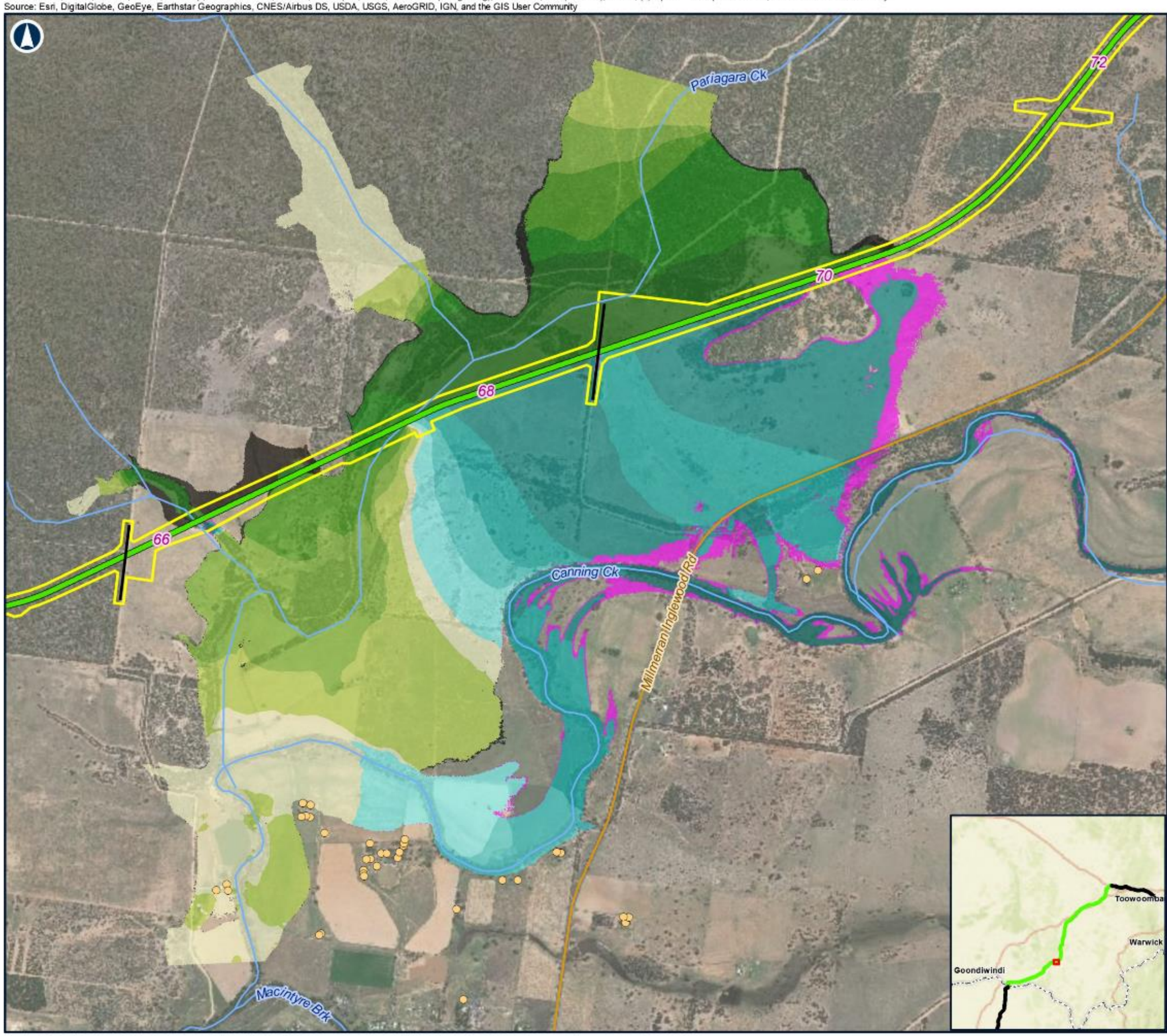

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BORDER TO GOWRIE
Figure 12.26d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Pariagara Creek

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 0.75 1.5 km

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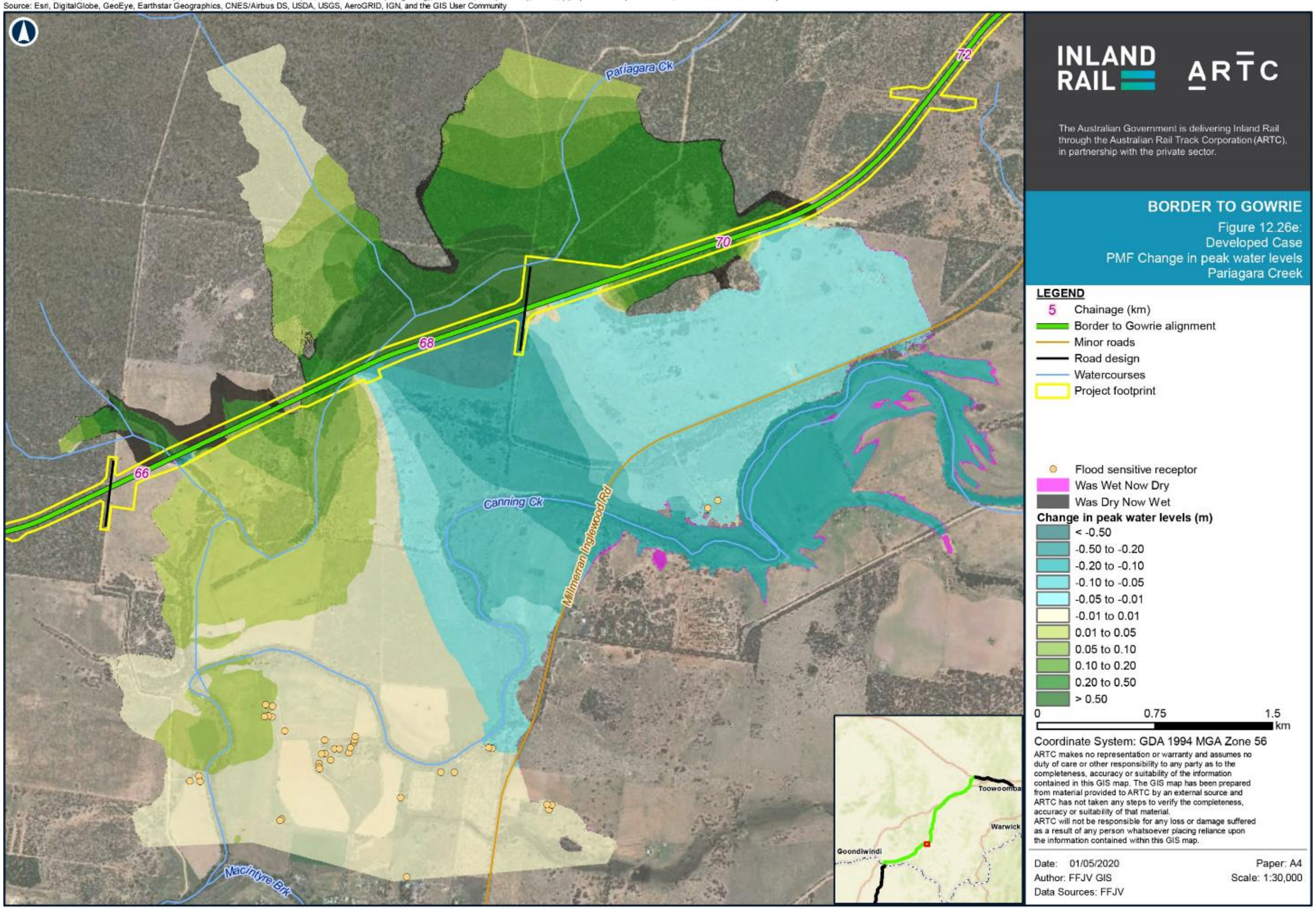

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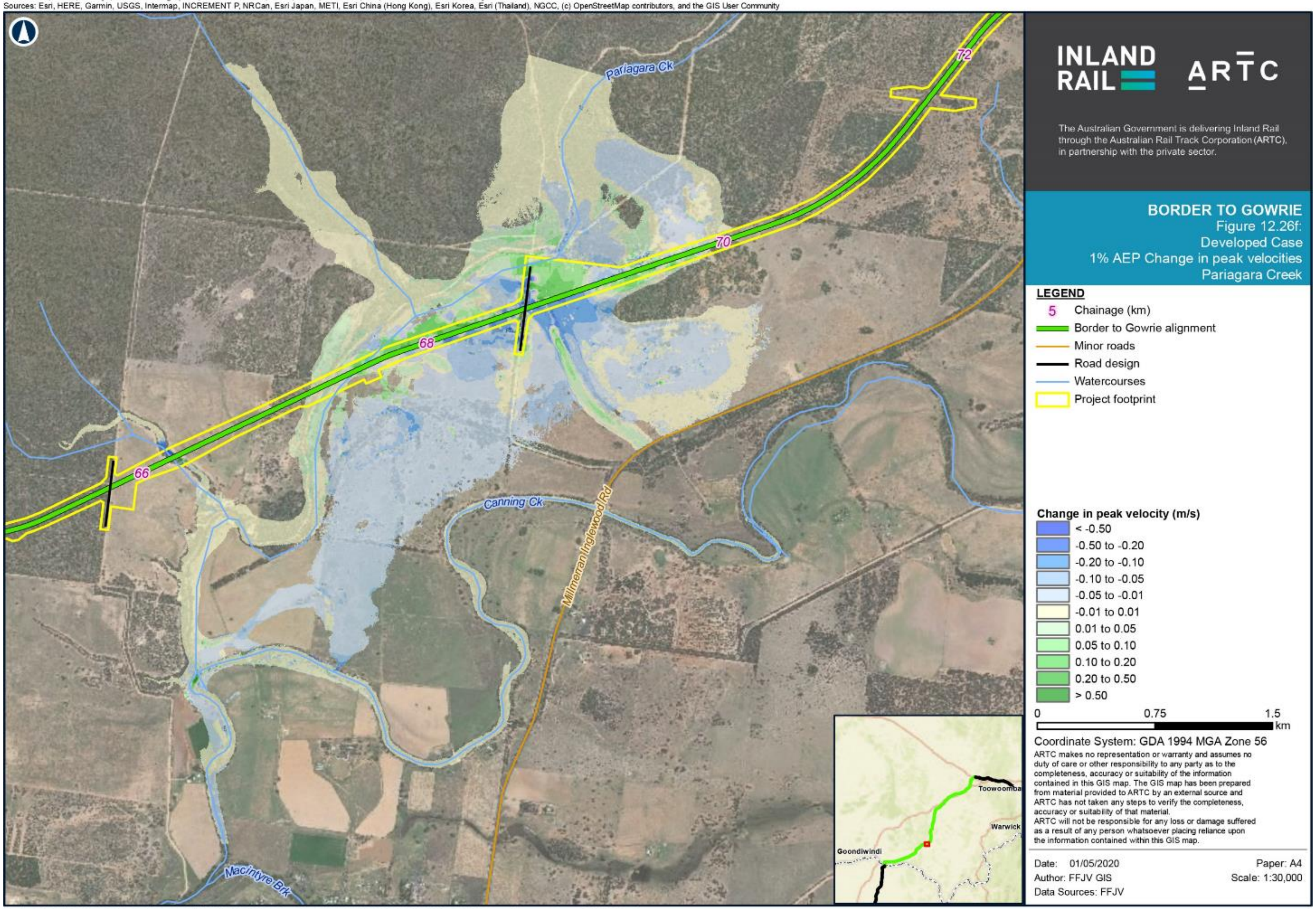

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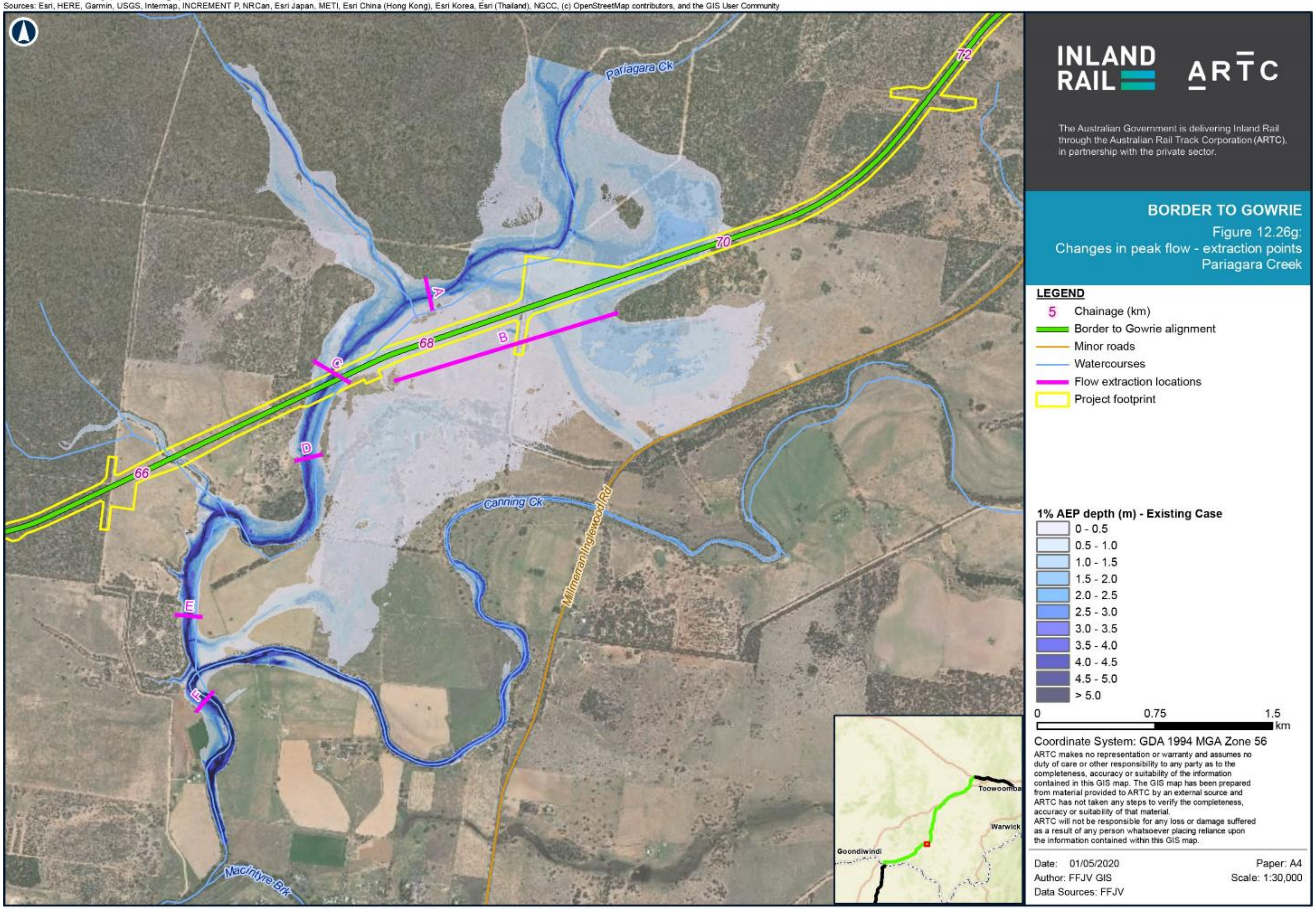

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TABLE 12.113 PARIAGARA CREEK—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
66.25	-	-	0.5
66.65	-	-	0.3
66.85	-	0.4	0.8
67.05	-	-	0.1
67.15	4.1	4.8	6.2
68.45	-	-	0.9
68.95	-	-	1.2
70.05	-	-	<0.1

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23.9 per cent across the Pariagara Creek catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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.

The only affected flood-sensitive receptor is Thornton Road, with the change in peak water levels still less than 100 mm. Thornton Road is affected by climate change regardless of the Project and so the amenity of this road is not compromised by the Project.

Table 12.114 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.114 PARIAGARA CREEK—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood sensitive receptor ID	Change in peak water level (mm)	Existing case flood depth[2] (m)
Thornton Road[1]	+222	4.25
Unnamed Road[1]	+216	2.11
Lovells Crossing Road[1]	+87	0.72
Millmerran–Inglewood Road[1]	+107	0.07

Table notes:
1. These roads are affected by climate change regardless of the Project and so the amenity of the roads is not compromised by the Project
2. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

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

Table 12.115 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.115 PARIAGARA CREEK—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
Thornton Road	4.25	+152
Unnamed Road	2.11	+67

12.10.2.10 Macintyre Brook (Yelarbon to Inglewood)

The Project includes a section of the corridor running through Yelarbon. The design standard for the proposed rail 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 (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 peak flow estimates in the 1% AEP event for the three catchments are as follows:

- 146 m^3/s for Macintyre Brook (flows that break out from the Macintyre Brook and head north through Yelarbon only)
- 114 m^3/s for Kippenbung Creek
- 340 m^3/s for Brigalow Creek.

It is noted that the timing of these peaks would vary significantly. 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 design at Yelarbon are listed below:

- 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 'Glass Wall Raise' (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 Q2: Hydrology and Flooding Technical Report.

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 design includes:

- Two bridges across minor tributaries of the Macintyre Brook (at Bybera Road and Cremascos Road)
- 21 RCP locations (a total of 509 cells)
- 13 RCBC locations (a total of 181 cells).

Details of the floodplain structures required to convey Macintyre Brook flood flows are presented in Table 12.116 and Table 12.118, with structure locations presented in Figure 12.27a. Figure 12.27a also presents the location of local catchment drainage structures.

TABLE 12.116 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)[1]

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
55.55	310-BR04	Bridge at Bybera Road	283.9	207
52.58	310-BR03	Bridge at Cremascos Road	279.7	184

Table note:
1. Separate localised flood models were developed to determine required bridge sizes at Bybera Road and Cremascos Road.

TABLE 12.117 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—FLOODPLAIN STRUCTURE DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No. of cells	Diameter/width x height (m)[1]
25.15	C25.15	RCBC	1	3.00 x 0.60
25.19	C25.19	RCBC	1	3.00 x 0.60
25.46	C25.46	RCP	21	0.90
25.50	C25.50	RCP	21	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
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
27.53	C27.53	RCBC	20	1.50 x 1.20
42.87	C42.88	RCP	15	0.90
43.02	C43.02	RCP	15	1.20
43.08	C43.08	RCP	30	1.20
43.16	C43.16	RCBC	9	3.00 x 1.50
43.34	C43.34	RCP	45	1.20

Approximate chainage (km)	Structure ID	Structure type	No. of cells	Diameter/width x height (m)[1]
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
44.88	C44.88	RCP	30	0.90
44.99	C44.99	RCP	35	0.90
45.24	C45.24	RCP	35	0.90
45.30	C45.30	RCP	35	0.90
45.39	C45.39	RCP	40	0.90
45.46	C45.46	RCP	40	0.90
45.53	C45.53	RCP	40	0.900
45.67	C45.67	RCP	7	0.90

Table note:
1. For RCP, height equals diameter

Change in peak water levels

Figure 12.27b presents the change in peak water levels under the 1% AEP event and Table 12.118 presents details of where the change in peak water levels lie outside the flood-impact objectives.

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.118 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Flood-sensitive receptor ID	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
House	MCB_ID_243	26.30	Dwelling	< 10 mm	+50	Existing 1% AEP flood depth: 130 mm
House	MCB_ID_242	26.30	Dwelling	< 10 mm	+40	Existing 1% AEP flood depth: 50 mm
House	MCB_ID_241	26.30	Dwelling	< 10 mm	+20	Existing 1% AEP flood depth: 120 mm
House	MCB_ID_244	26.30	Dwelling	< 10 mm	+20	Existing 1% AEP flood depth: 120 mm
State-controlled road	-	26.80 to 27.60	Roadway	≤ 100 mm	+190	Cunningham Highway (Inglewood to Goondiwindi) Existing 1% AEP flood depth: 0.53 m Minor change in AAToS of +0.2 hrs (existing AAToS: 1.8 hrs/yr)

Location	Flood-sensitive receptor ID	Approximate chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Existing QR South Western Line	-	45.00	Rail Line	≤ 100 mm	+150	Existing 1% AEP flood depth: 650 mm Affected area is immediately east of the Project and afflux dissipates to less than 100 mm within 200 m along the existing QR South Western Line
Private land outside of Project footprint[1]	-	68.70	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+320[1]	89 ha in total affected by afflux > 10 mm 0.7 ha affected by afflux > 200 mm
Private land outside of Project footprint	-	45.60 to 45.90	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+288	11.6 ha in total affected by afflux > 10 mm 0.9 ha affected by afflux > 200 mm

Table notes:

1. Change in peak water levels at this location is contained to a localised area directly adjacent to Thornton Road
2. Project footprint is indicated in Figure 12.27b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur to the west of Yelarbon and to the northeast if Whetstone (north of the Cunningham Highway) adjacent to the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Macintyre Brook floodplain are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

The Cunningham Highway outside the levee-protected Yelarbon (south of levee) currently floods to a depth of up to 180 mm in a 5% AEP event and up to 530 mm in a 1% AEP event. The road does not currently flood in a 10% AEP event. The total length of road inundated at this location during a 5% AEP event is 390 m and in a 1% AEP a 4.6-km long section of road is affected by flooding. The maximum ToS in a 5% AEP event is 15.4 hrs and in a 1% AEP event the maximum ToS is 35 hrs. The Project is expected to increase peak water levels on the Cunningham Highway at this location by up to 170 mm in a 5% AEP and by up to 190 mm in a 1% AEP event. ToS is not expected to increase in a 5% AEP event, but it is expected to increase by up to 5 hrs in a 1% AEP event. The change in AAToS on the Cunningham Highway south of the levee is expected to be up to +0.2 hours per year.

Further details regarding flood impacts on other roads within the Macintyre Brook floodplain are presented in Appendix Q2: Hydrology and Flooding Technical Report.

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. In addition, the Project alignment does not cross the Macintyre Brook but runs to the north of the floodplain.

Velocities

Figure 12.27f presents the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Macintyre Brook main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.27c to Figure 12.27e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.119 outlines the changes in peak water levels 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.

TABLE 12.119 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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_10	+4	1.37	+16	1.81	+14	3.29
MCB_ID_11	+5	1.36	+15	1.80	+14	3.29
MCB_ID_12	+4	1.28	+14	1.72	+13	3.21
MCB_ID_13	0	1.28	+13	1.79	+12	3.29
MCB_ID_14	0	1.44	+12	1.96	+11	3.49
MCB_ID_15	0	1.41	+12	1.94	+11	3.48
MCB_ID_16	0	1.38	+5	1.77	+8	3.17
MCB_ID_230	-22	0.95	+17	1.32	+45	2.61
MCB_ID_233	+103	1.02	+63	1.39	+44	2.67
MCB_ID_241	+45	0.56	+69	0.91	+23	2.19
MCB_ID_242	+35	0.51	+66	0.85	+21	2.09
MCB_ID_243	+36	0.69	+67	1.03	+18	2.24
MCB_ID_244	+48	0.42	+72	0.77	+25	2.06
MCB_ID_246	+91	1.30	+69	1.67	+39	2.96
MCB_ID_75	+42	1.74	+33	2.44	+11	5.08
MCB_ID_76	+42	1.03	+33	1.73	+11	4.35
MCB_ID_78	-	-	-	-	+10	2.15
MCB_ID_79	-	-	-	-	+11	2.08
MCB_ID_80	-	-	-	-	+11	1.92
MCB_ID_82	+96	1.94	+85	2.63	+23	5.30
MCB_ID_83	+66	1.79	+62	2.47	+20	5.12

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)
MCB_ID_86	+30	2.38	+32	3.06	+13	5.75
MCB_ID_87	+29	0.43	+32	1.12	+13	3.82
Cunningham Highway North	+110	1.52	+85	1.87	+63	3.10
Cunningham Highway	+159	1.53	+126	1.91	+26	3.15
Existing QR South Western Line	+166	2.03	+86	2.80	+21	5.59
Access Road	+170	2.16	+142	2.86	+30	5.55

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 12.120 outlines the overtopping locations and depths.

TABLE 12.120 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP overtopping depth (m)	1 in 10,000 AEP overtopping depth (m)	PMF overtopping depth (m)
14.75 to 19.05	0.2	0.4	1.0
21.15 to 32.30	0.4	0.6	2.0
35.05 to 35.50	-	-	0.8
42.00 to 46.15	0.2	0.9	3.7

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.

Climate change

The climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23 per cent across the Macintyre Brook catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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 0.6 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 12.121 outlines the changes in peak water levels at flood-sensitive receptors for the climate change scenario where the increase exceeds 10 mm.

TABLE 12.121 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1% AEP climate change event	
Flood-sensitive receptor ID	**Change in peak water level (mm)**	**Existing case flood depth[3] (m)**
MCB_ID_241	+10	0.33
MCB_ID_243	+11	0.33
MCB_ID_75	+14	0.69
MCB_ID_76	+15	-[2]
MCB_ID_82	+39	0.96
MCB_ID_83	+20	0.83
Cunningham Highway North[1]	+91	1.20
Cunningham Highway[1]	+226	1.20
Existing QR South Western Line[1]	+135	1.38
Access Road[1]	+87	1.51

Table notes:
1. These roads are affected by climate change regardless of the Project and so the amenity of the roads is not compromised by the Project
2. Not currently flooded
3. Existing case flood depth excluding 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 in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 Q1/Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

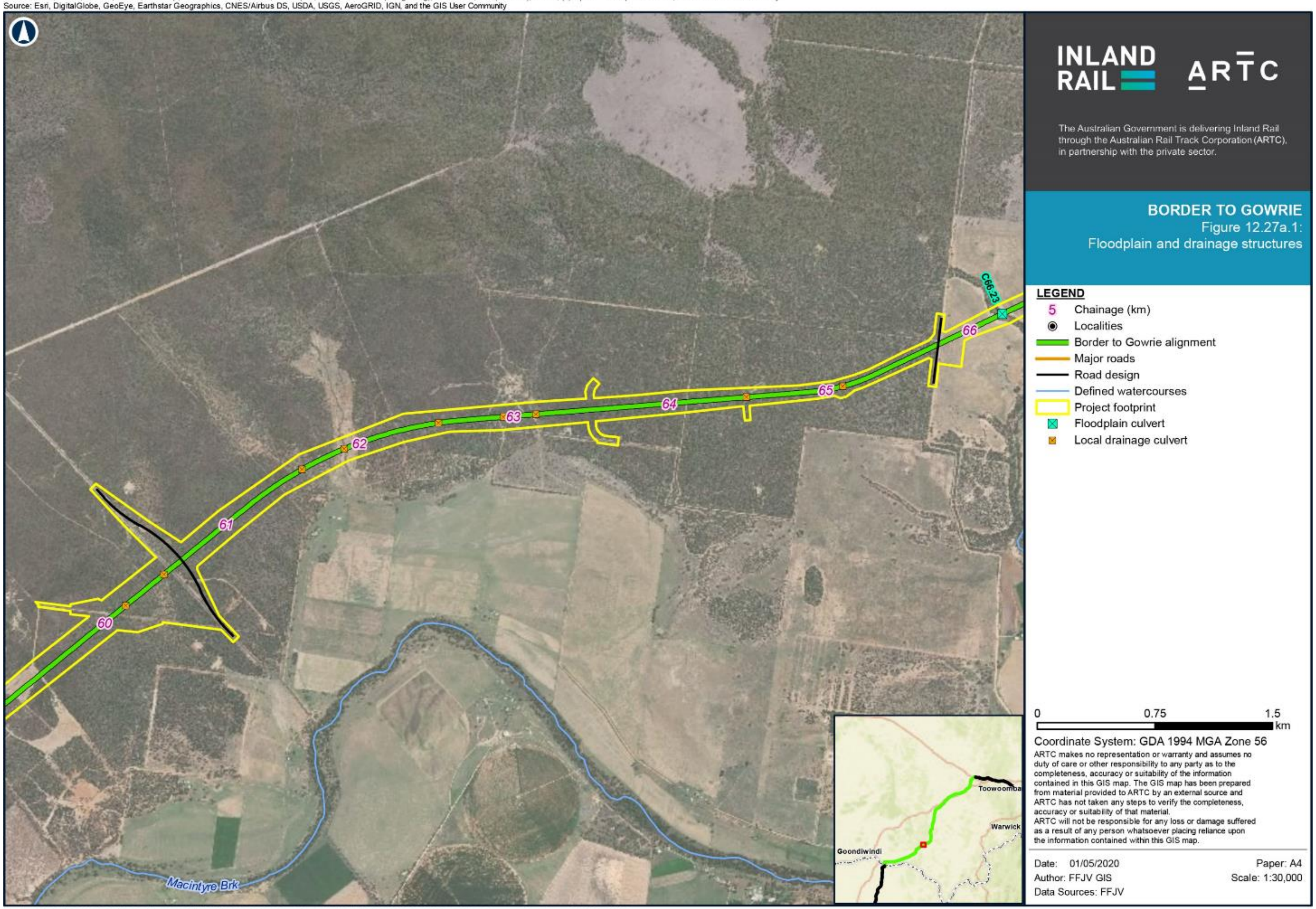
During detail design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in a varied and/or lower blockage factors being applied along the Project alignment.

Table 12.122 outlines the changes in peak water levels at flood-sensitive receptors for the 50 per cent blockage scenario (1% AEP) where the increase exceeds 10 mm.

TABLE 12.122 MACINTYRE BROOK (YELARBON TO INGLEWOOD)—SUMMARY OF 50 PER CENT BLOCKAGE IMPACTS AT FLOOD-SENSITIVE RECEPTORS (1% AEP)

Flood-sensitive receptor ID	Existing case flood depth (m)	Change in peak water level (mm)
MCB_ID_241	0.33	+40
MCB_ID_242	0.33	+42
MCB_ID_243	0.33	+60
MCB_ID_82	0.96	+21
Cunningham Highway North	1.20	+105
Cunningham Highway	1.20	+269
Existing QR South Western Line	1.38	+137
Access Road	1.51	+63

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, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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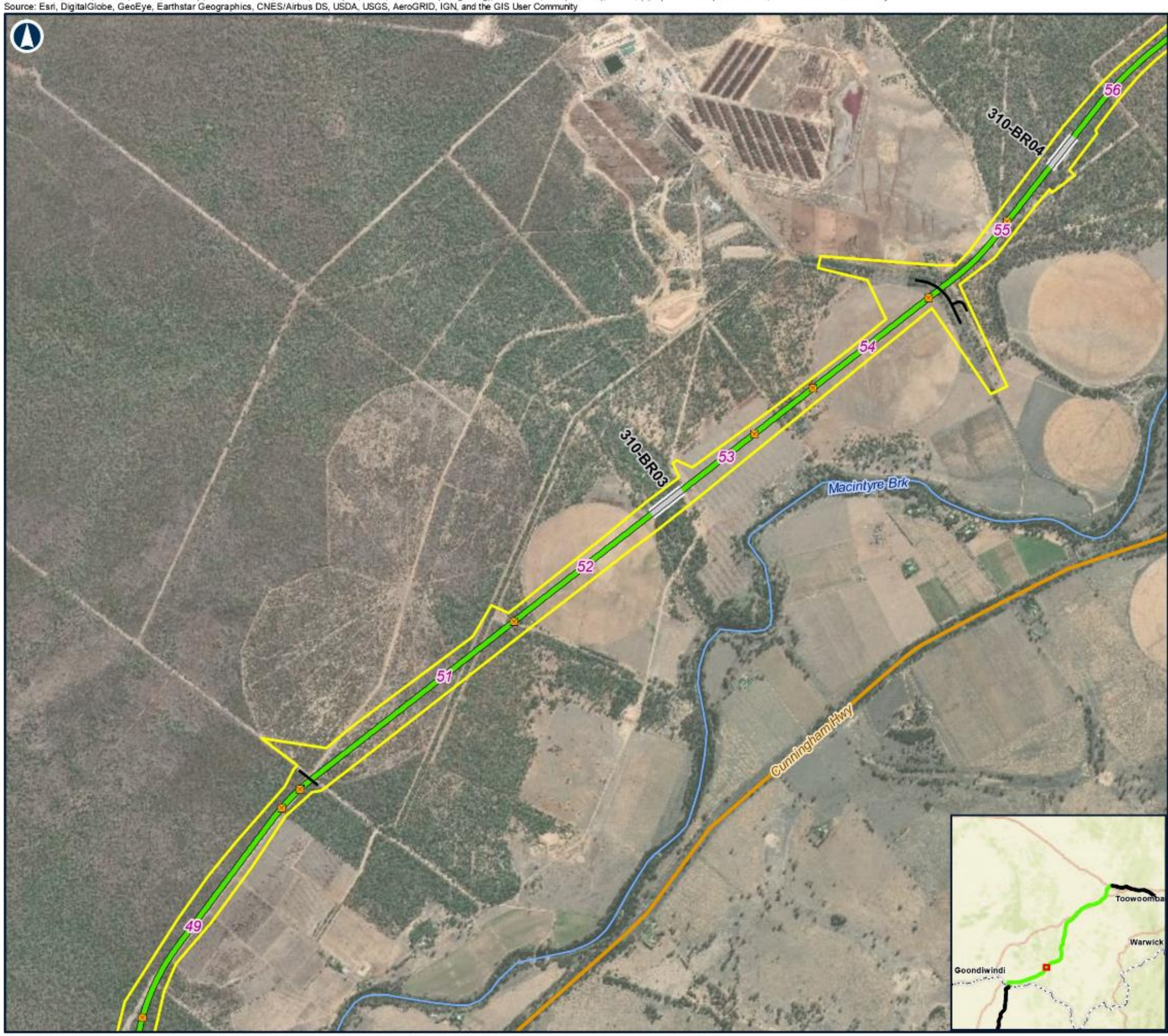

INLAND RAIL ARTC

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BORDER TO GOWRIE
Figure 12.27a.2:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Major roads
- Road design
- Defined watercourses
- Project footprint
- Local drainage culvert
- Bridges

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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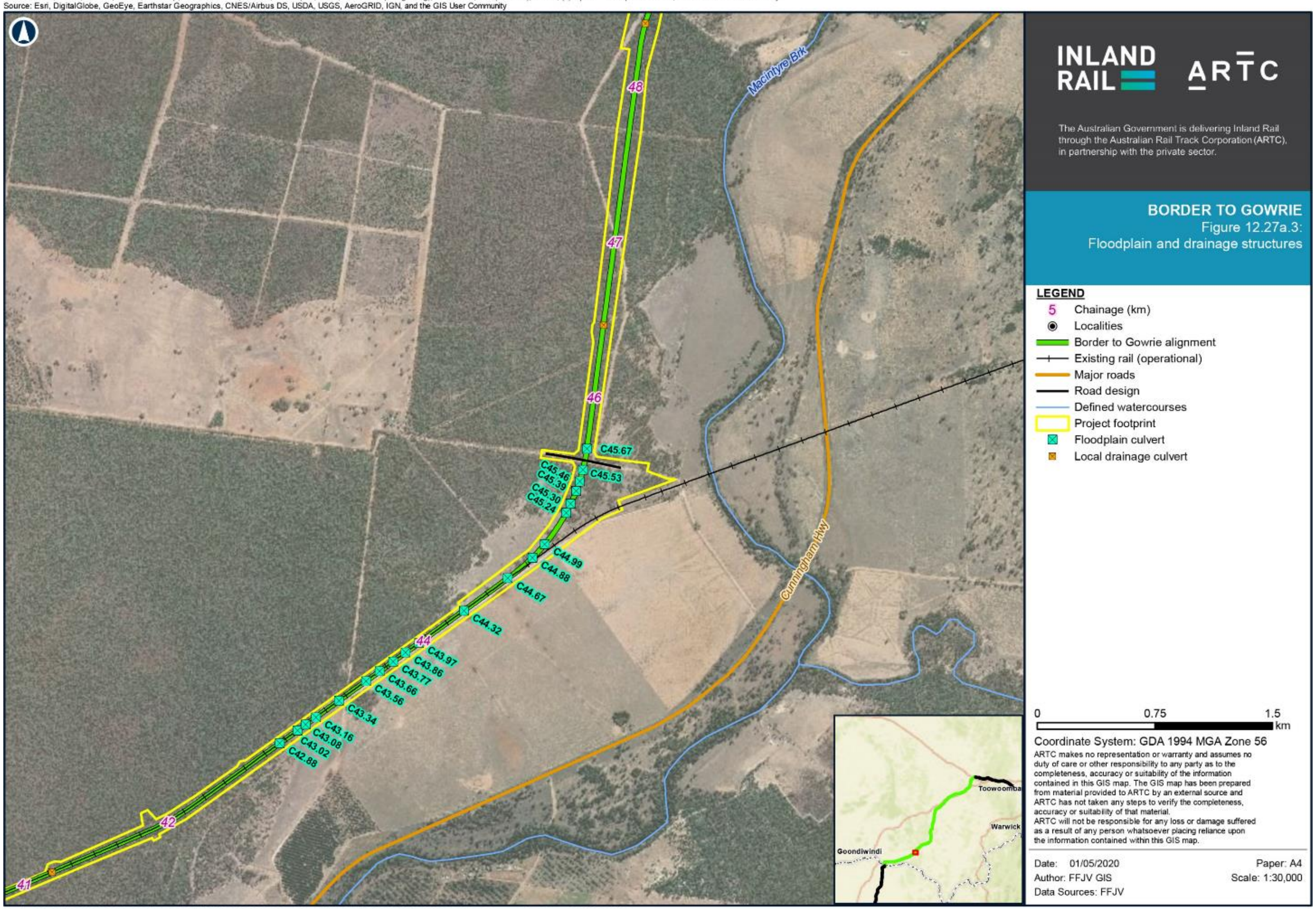

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INLAND RAIL

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BORDER TO GOWRIE

Figure 12.27a.4:
Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Defined watercourses
- Project footprint
- Local drainage culvert

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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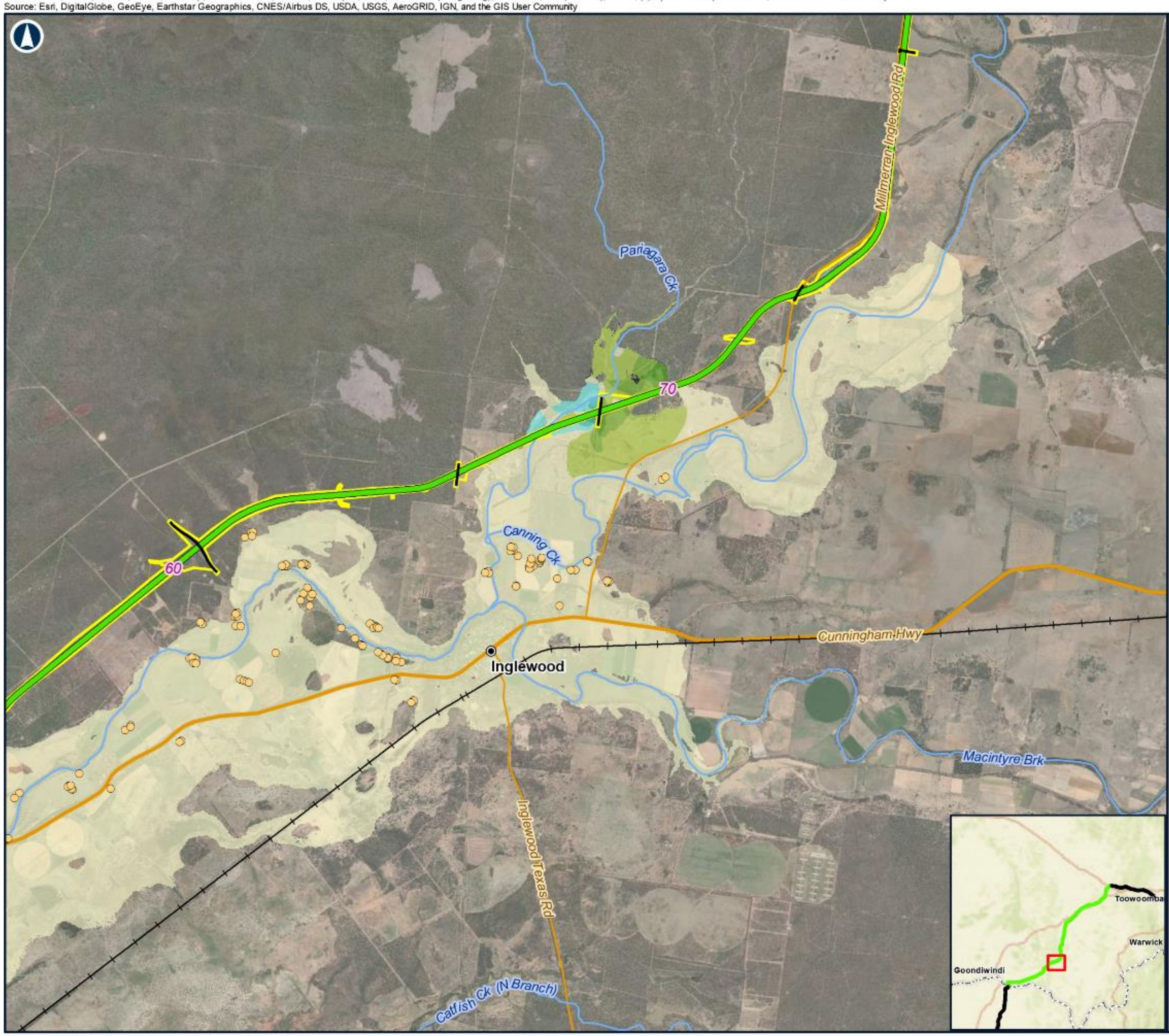

INLAND RAIL ARTC

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BORDER TO GOWRIE
Figure 12.27b.1:
Developed Case
1% AEP Change in peak water levels
Macintyre Brook

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 01/05/2020 Paper: A4
Author: FFJV GIS Scale: 1:100,000
Data Sources: FFJV

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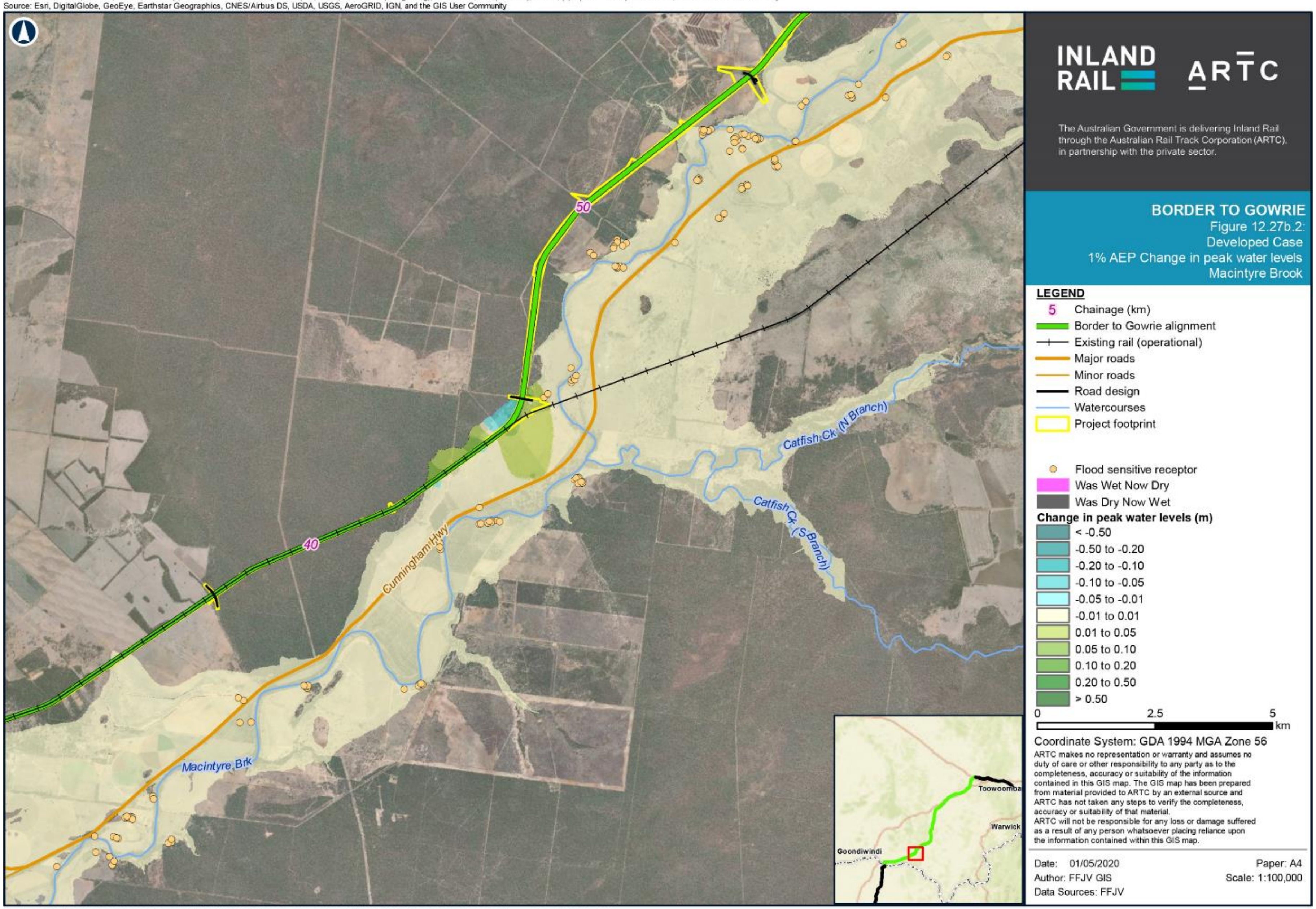

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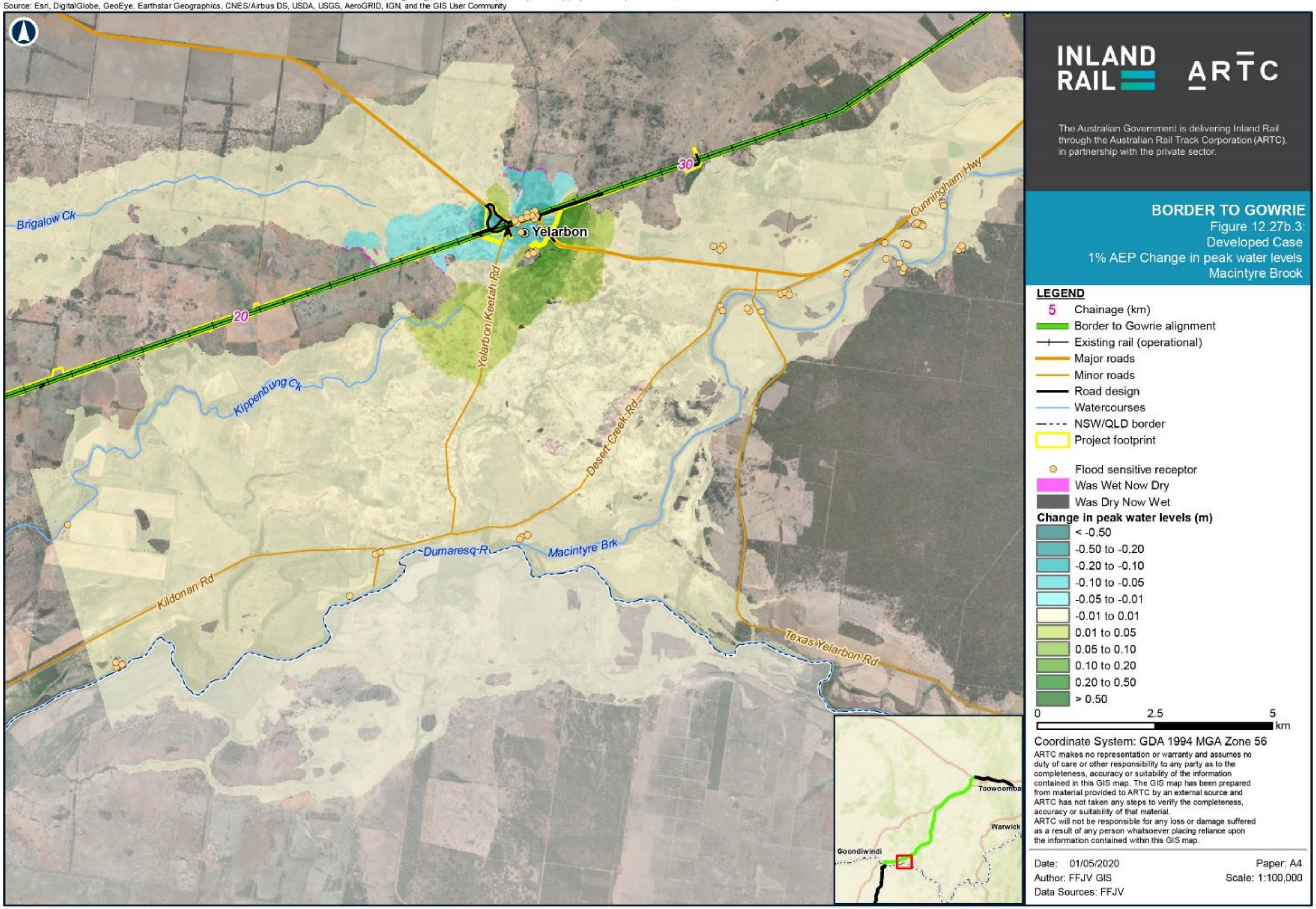

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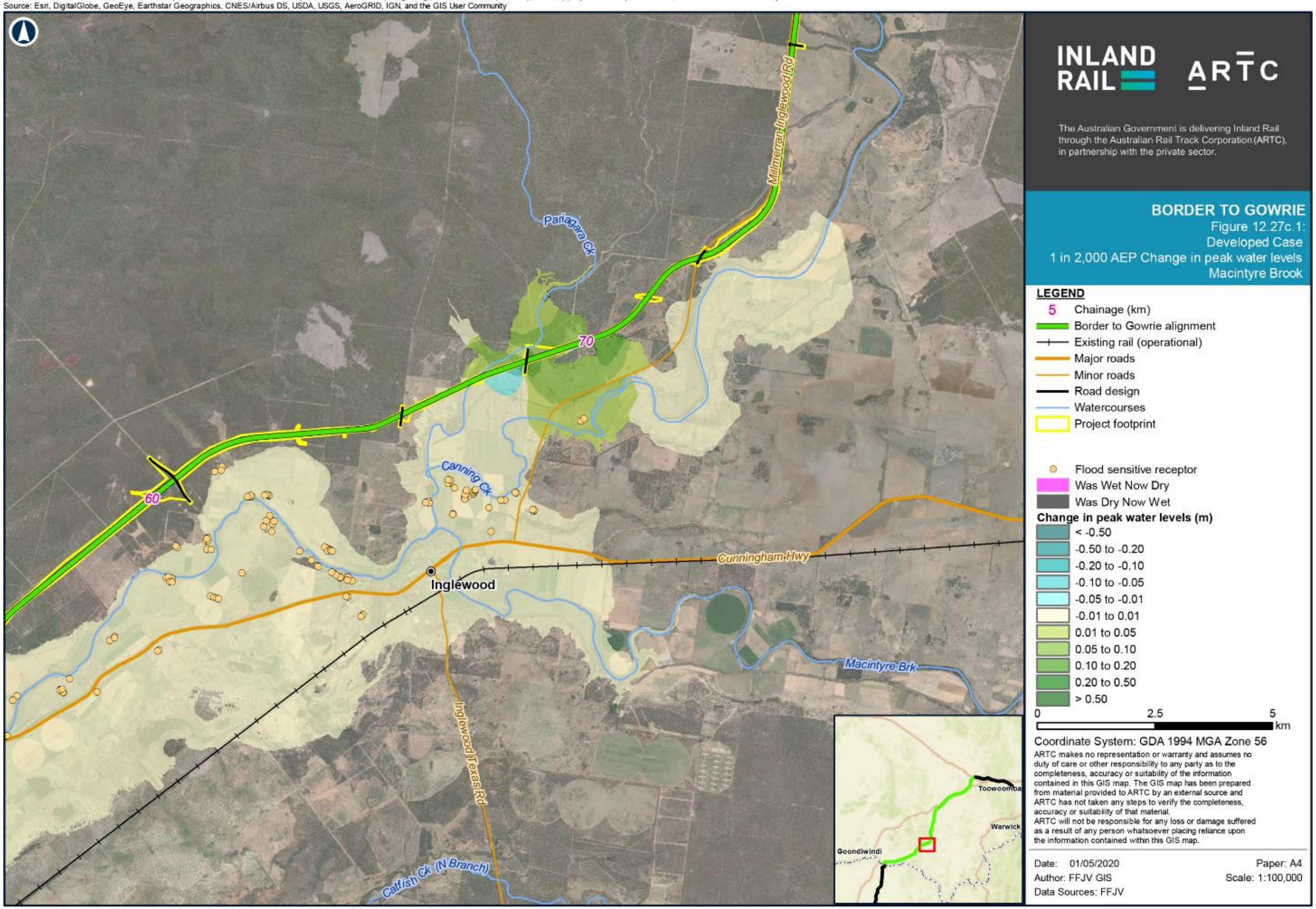

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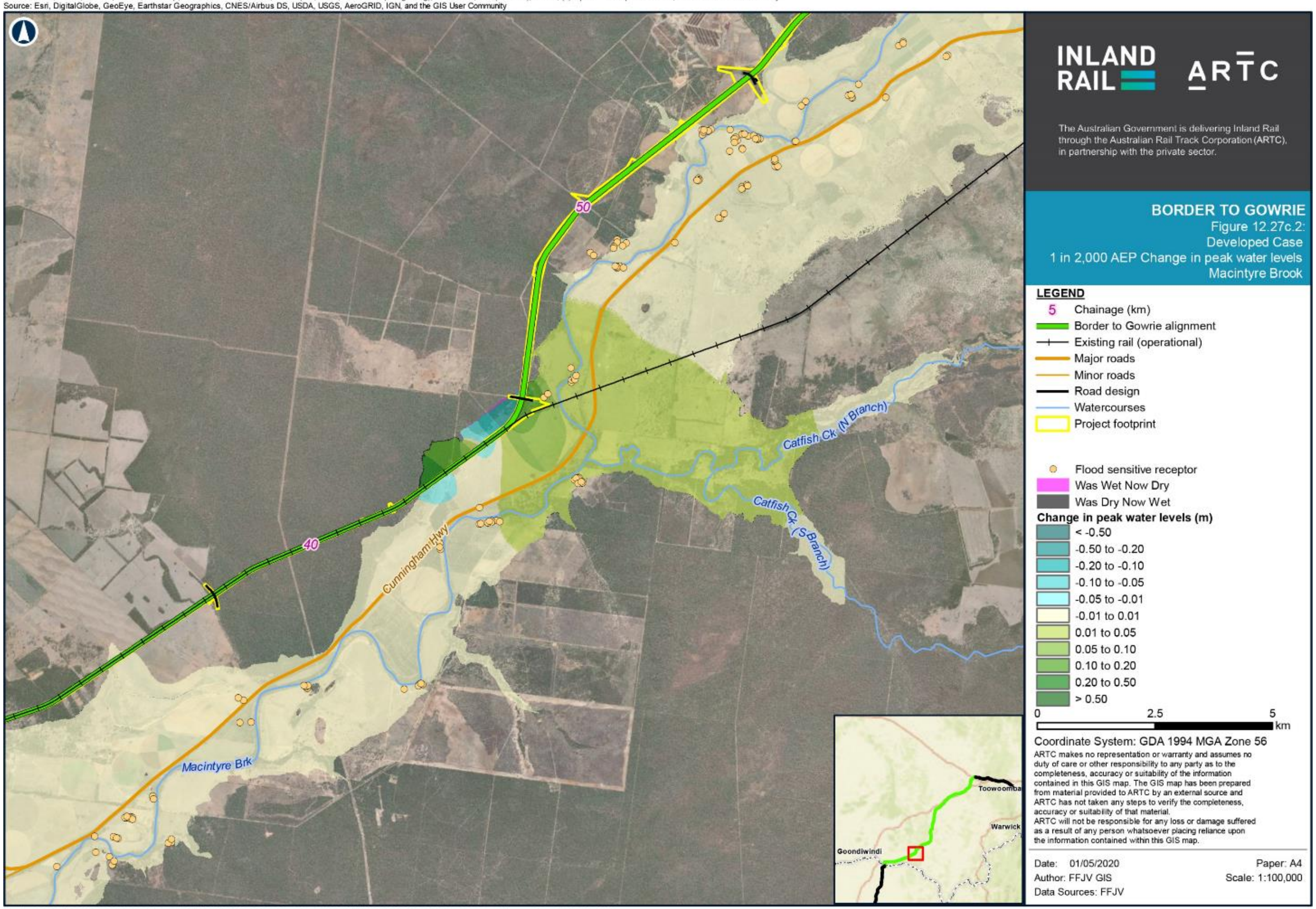

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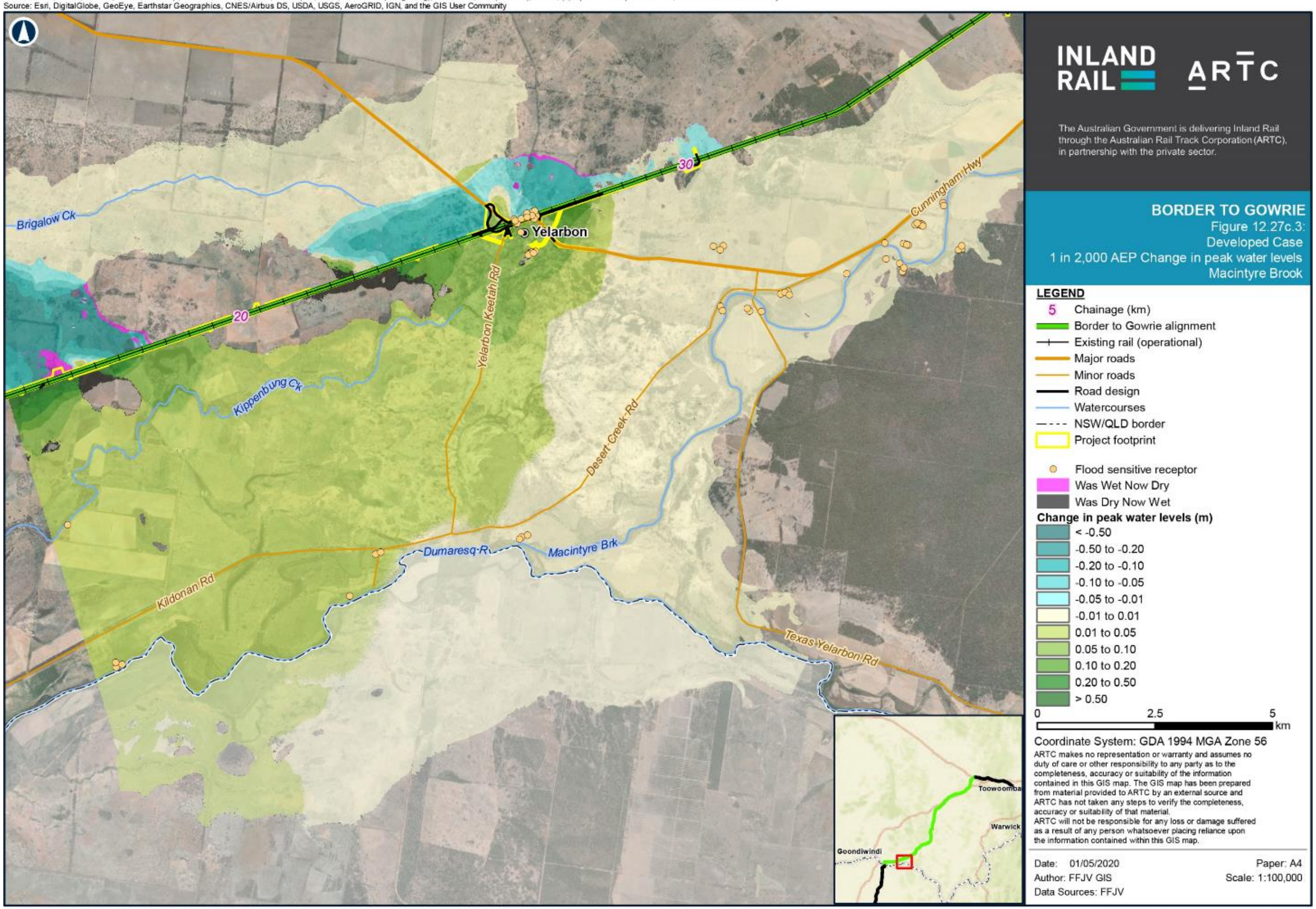

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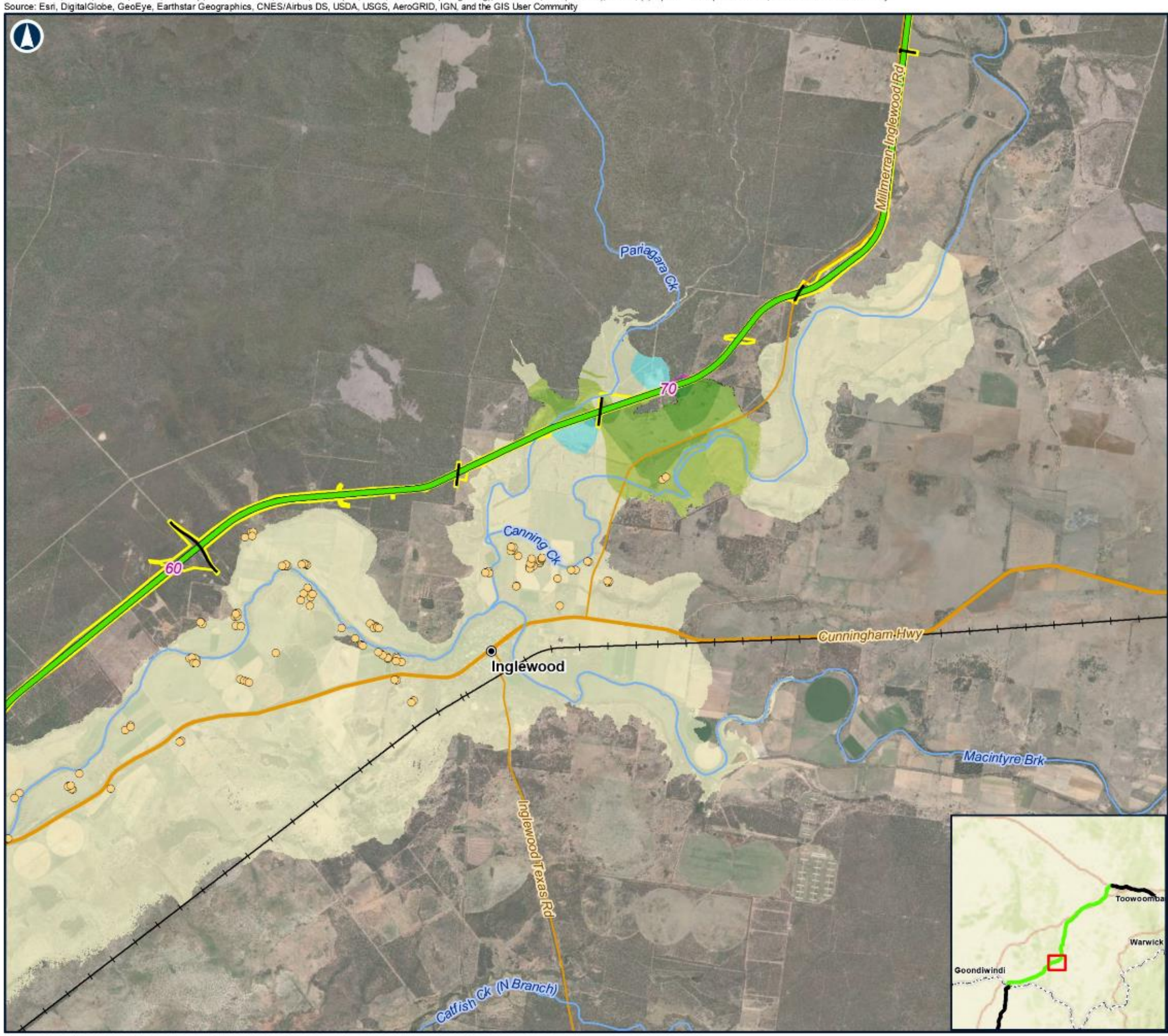

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BORDER TO GOWRIE
Figure 12.27d.1:
Developed Case
1 in 10,000 AEP Change in peak water levels
Macintyre Brook

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 01/05/2020 Paper: A4
Author: FFJV GIS Scale: 1:100,000
Data Sources: FFJV

Map by: MF/DTH Z:\GIS\GIS_310_B2G\Tasks\310-IHY-202005121229_SurfaceWaterEIS\310-IHY-202005121229_ARTC_Fig12-Xbode_Afflux.mxd Date: 8/06/2020 18:33

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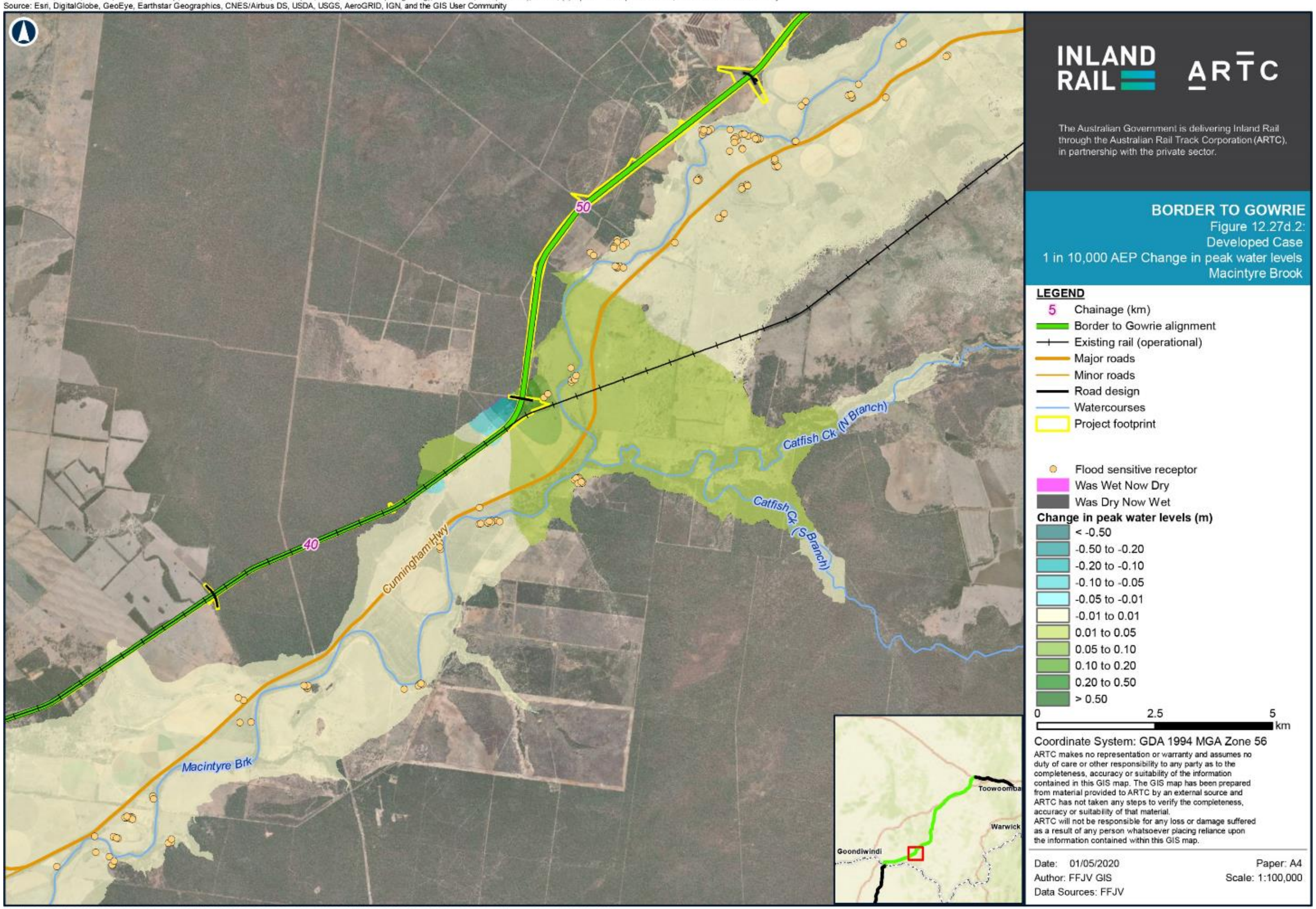

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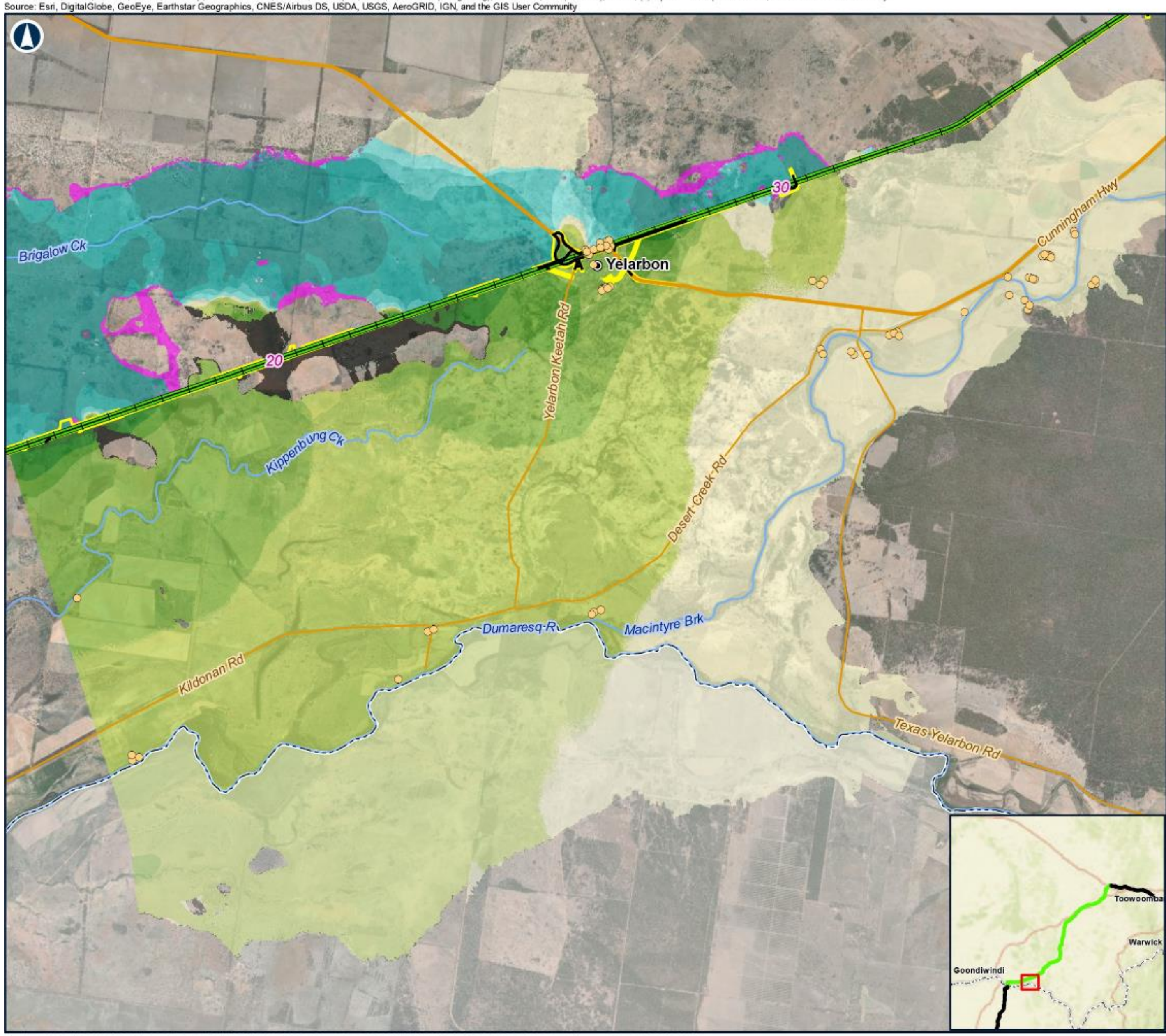

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BORDER TO GOWRIE
Figure 12.27d.3:
Developed Case
1 in 10,000 AEP Change in peak water levels
Macintyre Brook

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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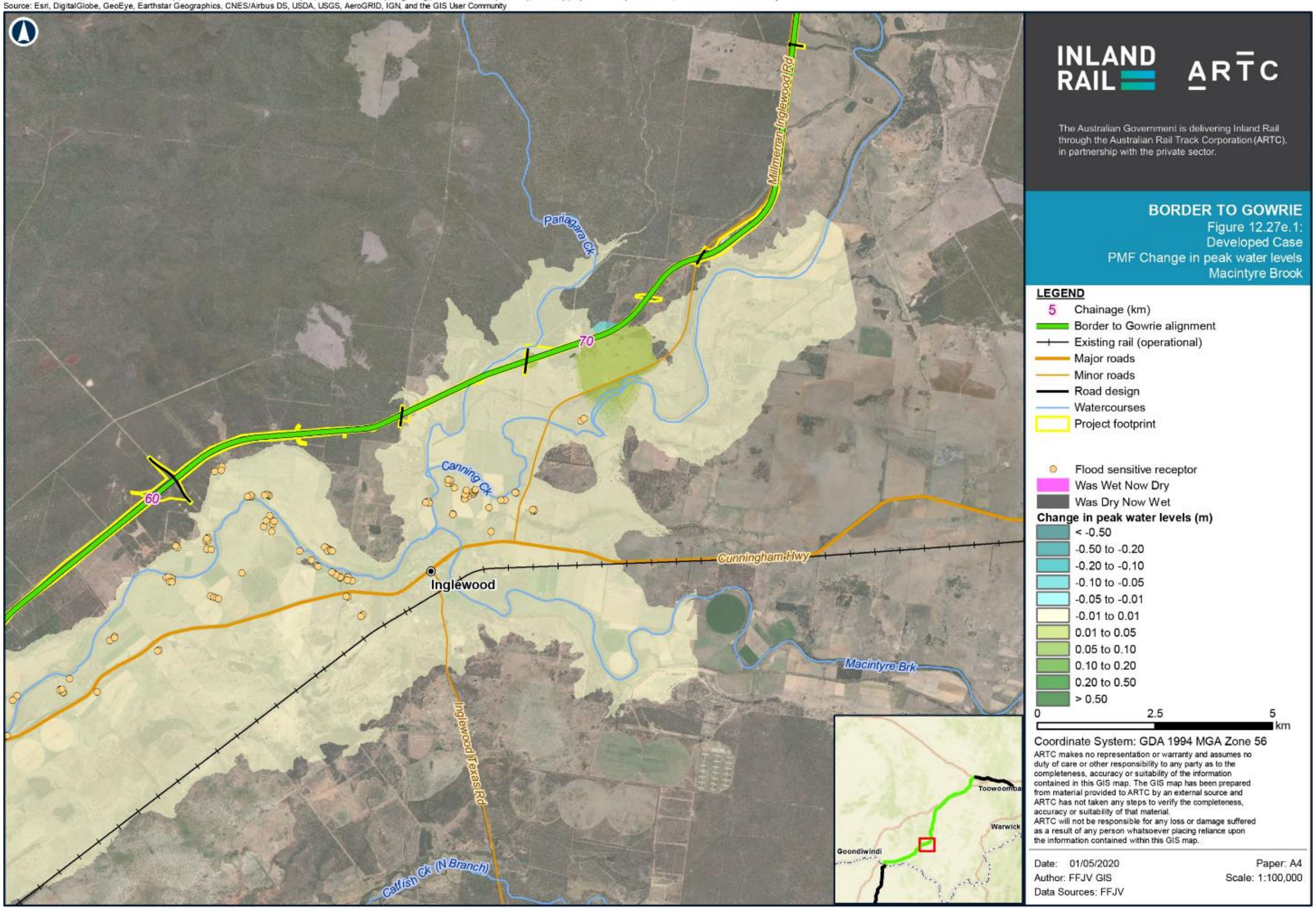

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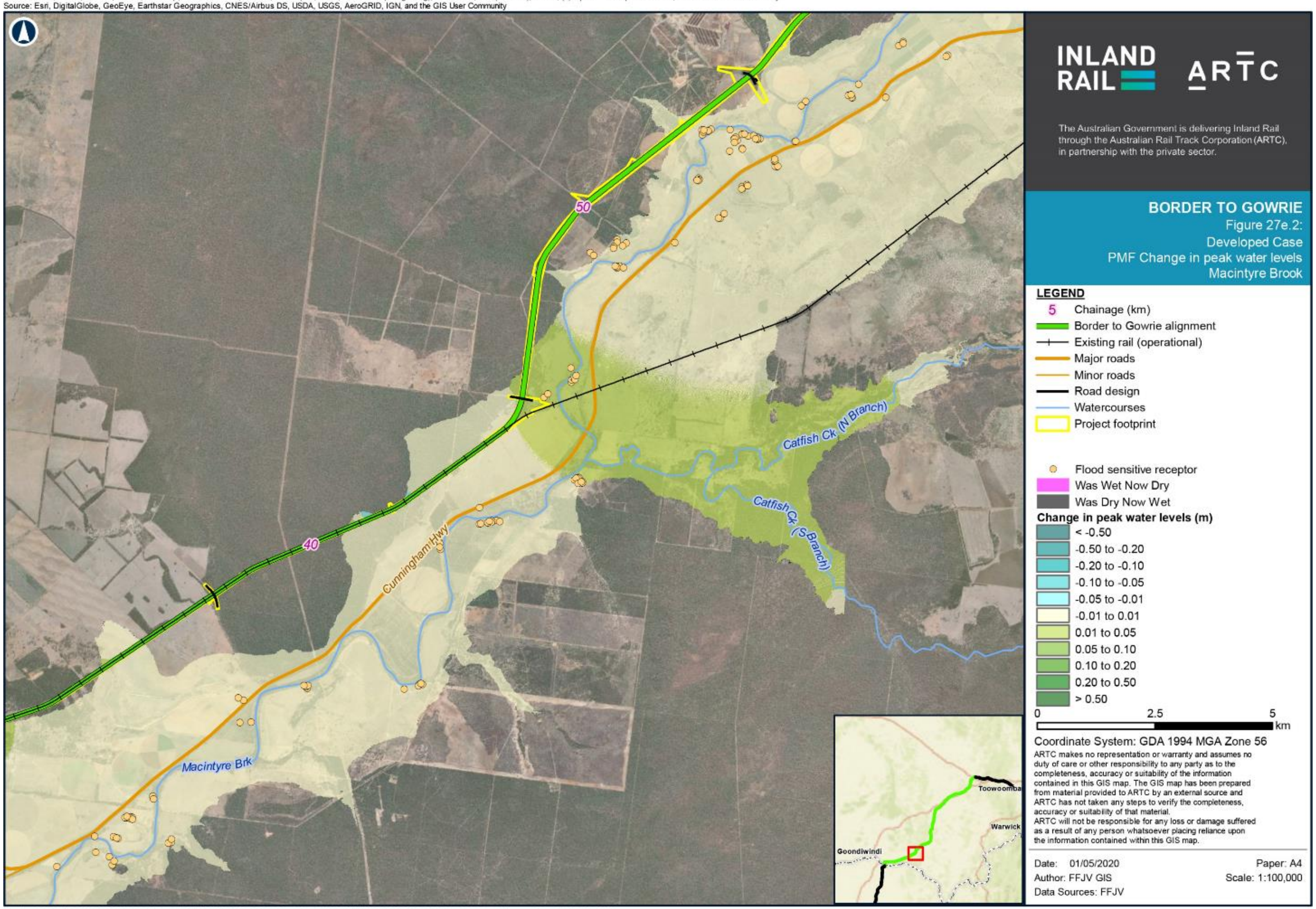

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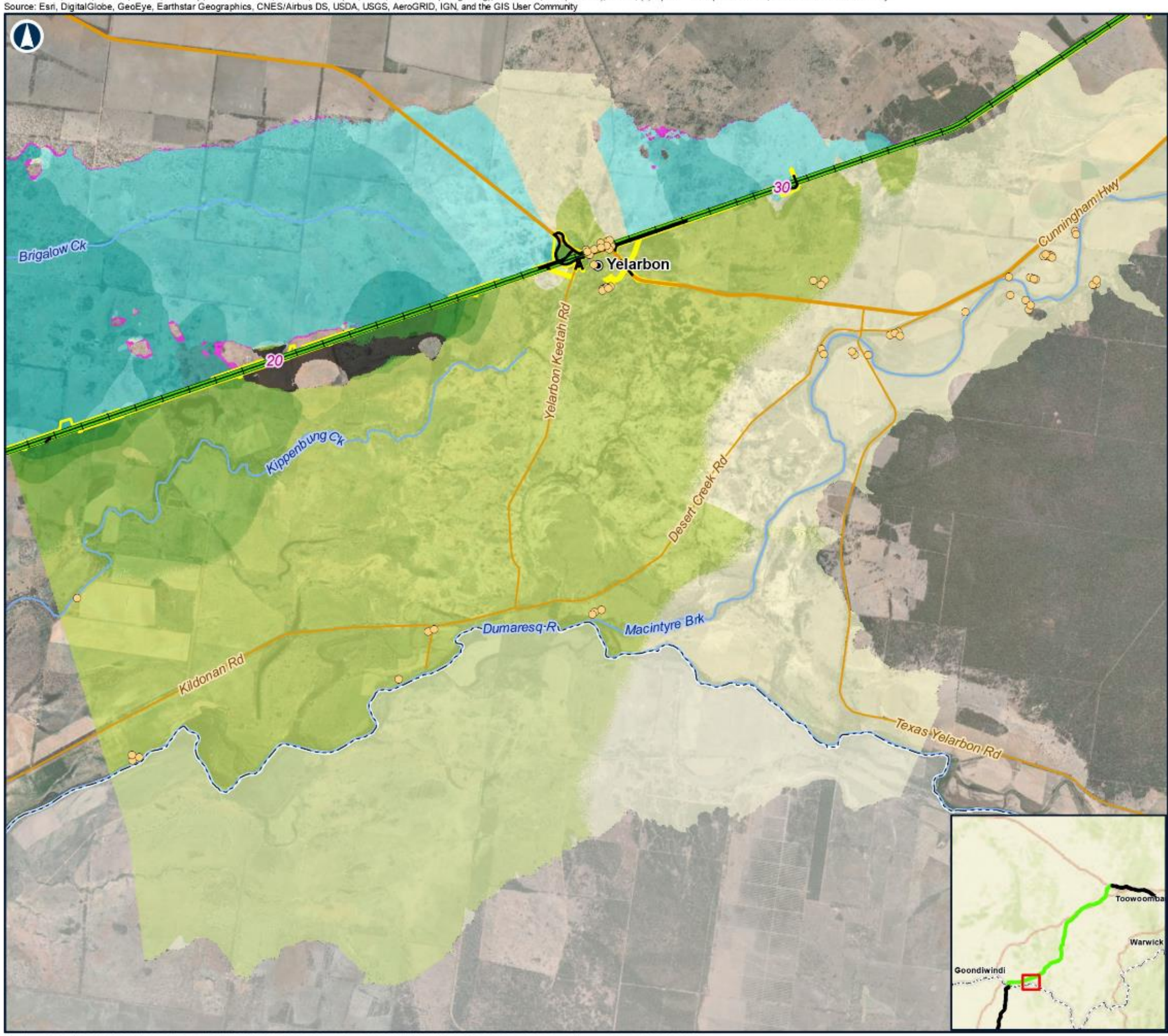

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BORDER TO GOWRIE
Figure 12.27e.3:
Developed Case
PMF Change in peak water levels
Macintyre Brook

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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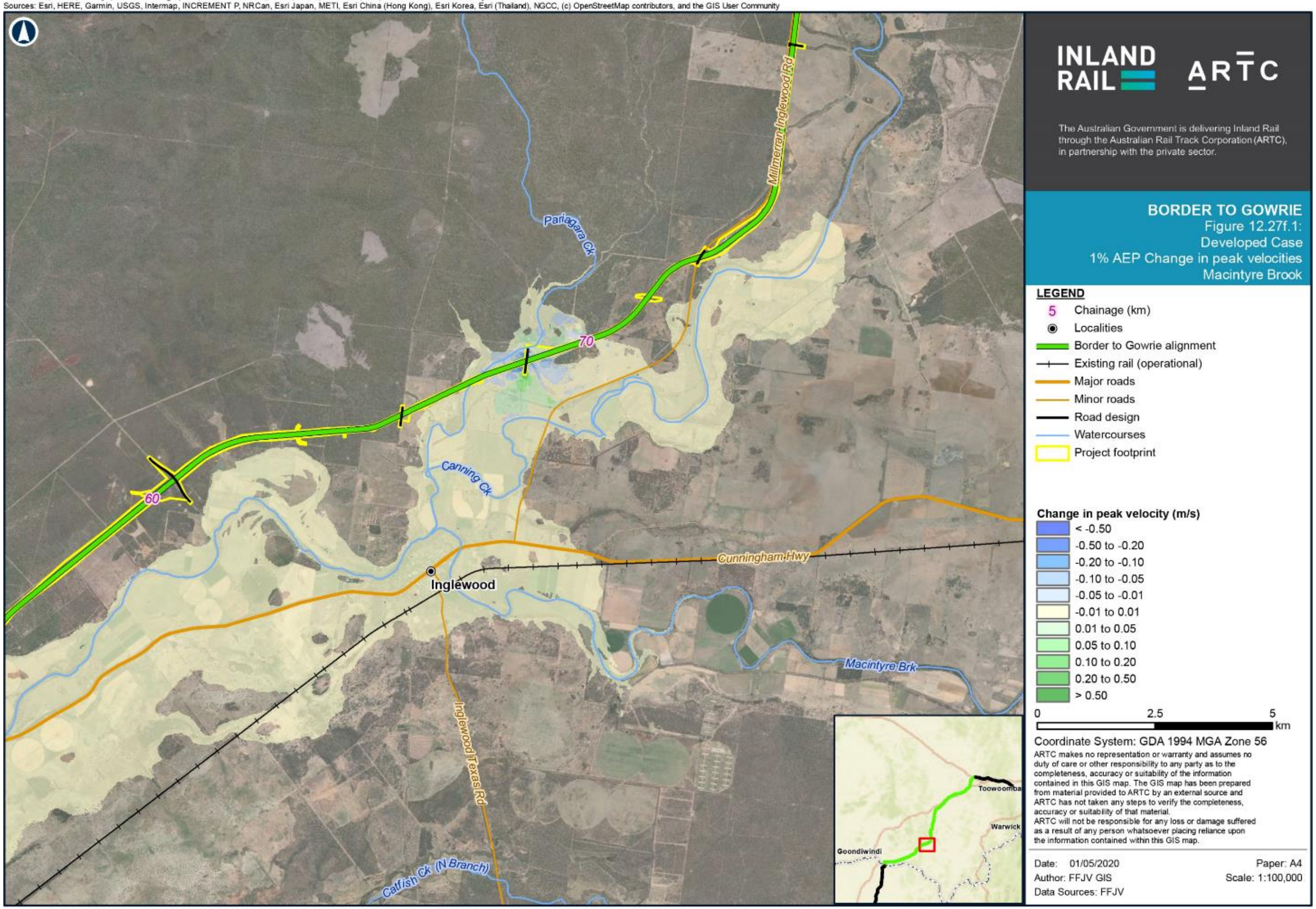

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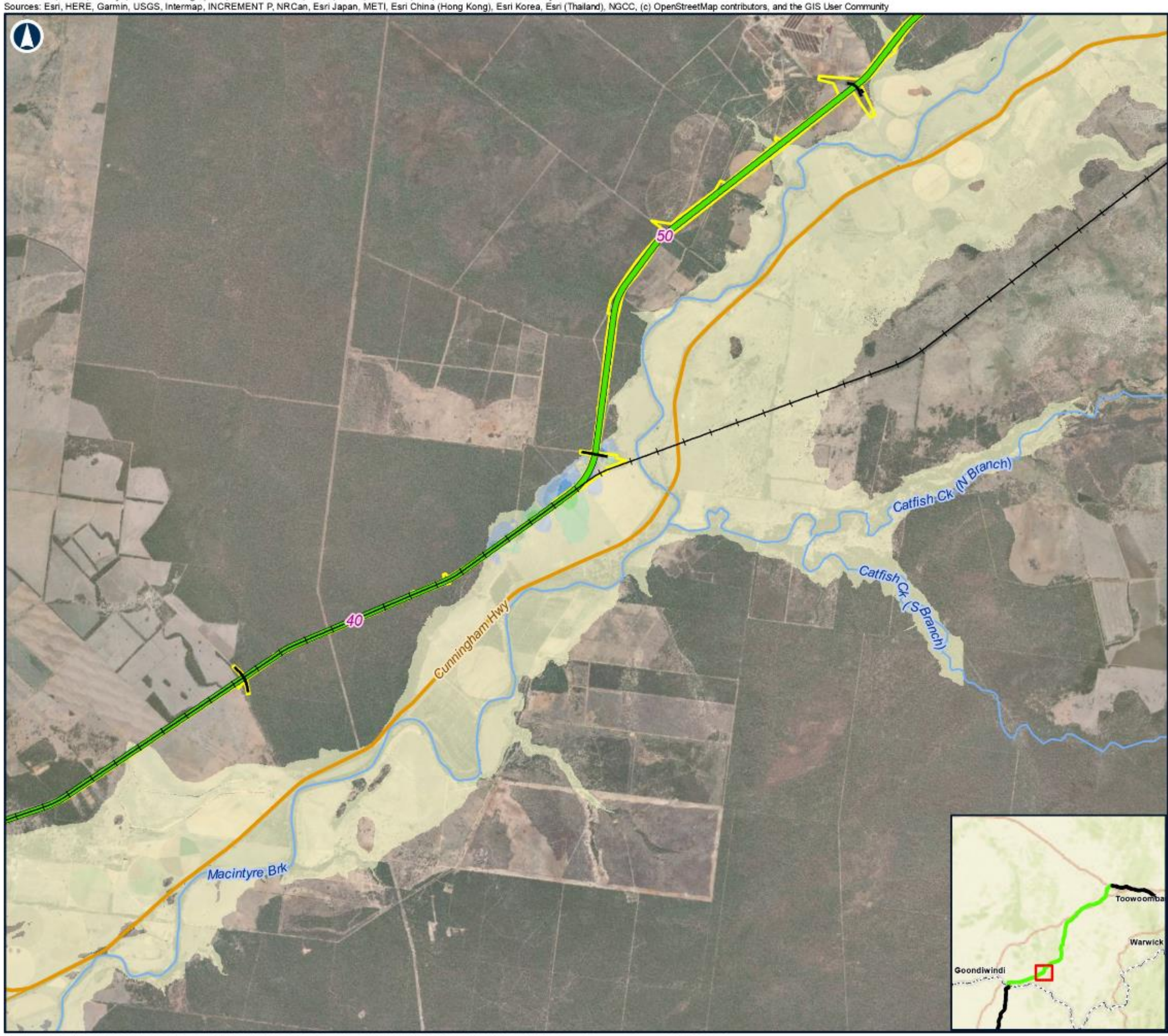

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BORDER TO GOWRIE
Figure 12.27f.2:
Developed Case
1% AEP Change in peak velocities
Macintyre Brook

LEGEND
- 5 Chainage (km)
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Watercourses
- Project footprint

Change in peak velocity (m/s)
- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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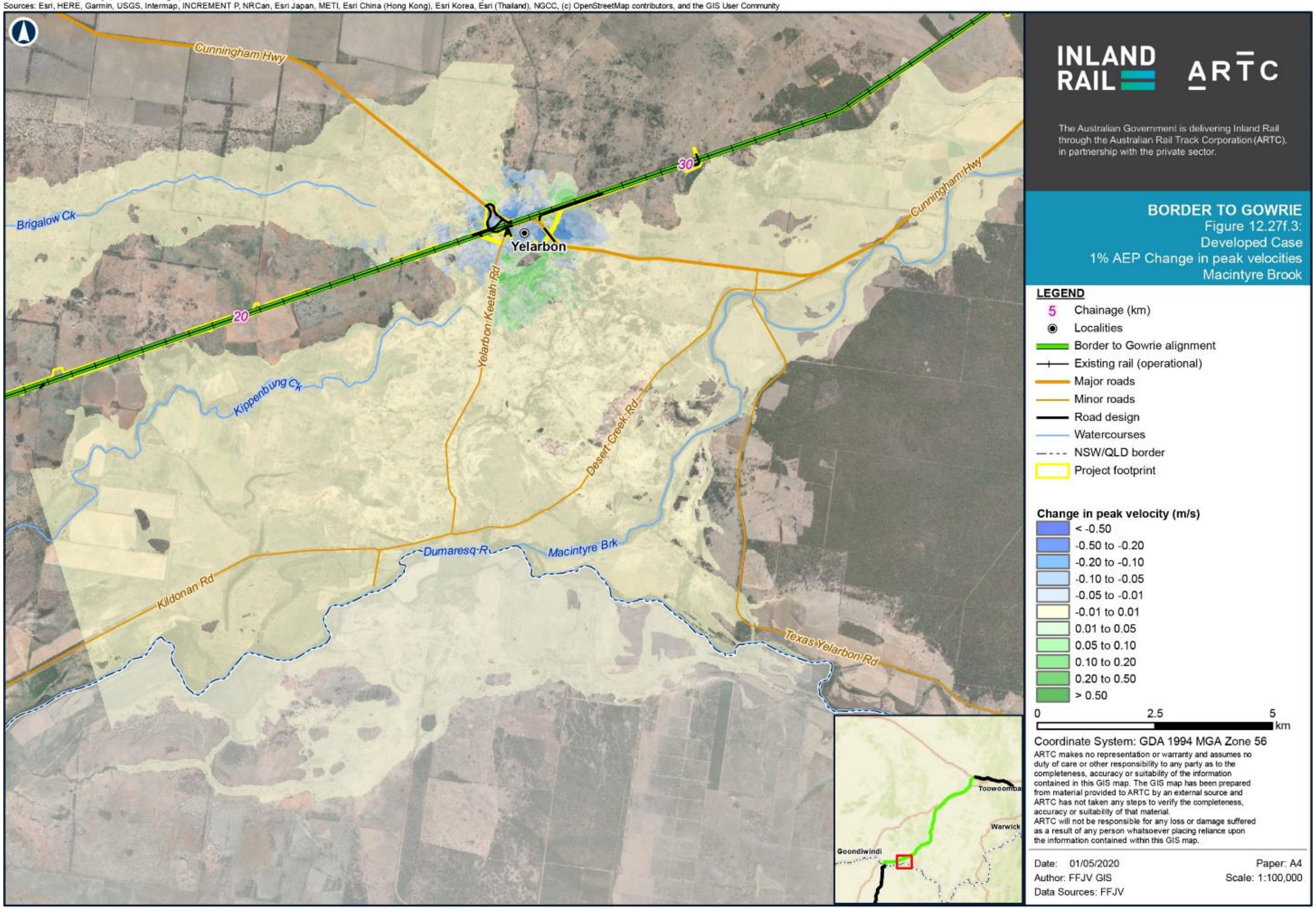

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12.10.2.11 Macintyre River

Major floodplain structures for the Inland Rail within the Macintyre River floodplain are located within NSW, in the adjoining North Star to NSW/Queensland Border project.

In the Macintyre River floodplain north of the NSW/QLD border, the Project design includes:

- Three bridges
- Four RCP locations (a total of 50 cells).

Details of the floodplain structures required to convey Macintyre River flood flows are presented in Table 12.123 and Table 12.124, with structure locations presented in Figure 12.28a. Figure 12.28a also presents the location of local catchment drainage structures.

TABLE 12.123 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER)—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (BRIDGES)

Approximate chainage (km)	Bridge design ID	Structure type	Soffit level (m AHD)	Bridge length (m)
30.63 (NS2B)	270-BR11	Bridge	230.0	1,748
31.52 (NS2B)	270-BR12	Bridge	227.5	144
32.56 (NS2B)	270-BR13	Bridge	225.7	521

TABLE 12.124 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER)—FLOODPLAIN STRUCTURE LOCATIONS AND DETAILS (CULVERTS)

Approximate chainage (km)	Structure ID	Structure type	No. of 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
31.97 (NS2B)	C31.97	RCP	15	0.90

Table notes:
1. For RCP height equals diameter

Change in peak water levels

Figure 12.25b presents the change in peak water levels under the 1% AEP event and Table 12.125 presents details of where the change in peak water levels north of the NSW/QLD border lie outside the flood-impact objectives (north of the NSW/QLD border).

Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood-impact objectives (refer Section 12.6.3.2).

TABLE 12.125 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER)—1% AEP EVENT—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD-IMPACT OBJECTIVES

Location	Approximate NS2B chainage (km)	Existing land use	Flood-impact objectives for 1% AEP event	Maximum increase in peak water level (mm)	Comment
Private land outside of Project footprint[1]	31.00 to 31.40	Agricultural (grazing)	≤ 200 mm (up to 400 mm)	+222	7.4 ha in total affected by afflux > 10 mm

Table note:
1. Project footprint is indicated in Figure 12.27b

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are presented in Appendix Q2: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting under the 20% AEP event.

For events exceeding the 10% AEP event, minor changes in peak water levels occur between the NSW/QLD border and Kildonan Road adjacent to the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases.

Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed Cases. Changes to the duration of the design flood event within the Macintyre River floodplain north of the QLD/NW border are negligible, as demonstrated in the 'change in time of inundation' map in Appendix Q2: Hydrology and Flooding Technical Report.

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.

Velocities

Figure 12.28f presents the change in peak velocities under the 1% AEP event associated with the Project alignment; in general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Macintyre River main channels are negligible.

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 the *Guide to Road Design Part 5B: Drainage* (Austroads, 2013b). 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.

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.

Figure 12.28c to Figure 12.28e present the change in peak water levels for the 1 in 2,000 AEP, 10,000 AEP and PMF events, respectively.

Table 12.126 outlines the changes in peak water levels 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.

TABLE 12.126 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER)—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood-sensitive receptor ID	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_41	+212	1.12	+235	1.46	+336	2.60
MCR_ID_36	+4	2.63	+22	2.88	+51	3.84
MCR_ID_93	-	-	-	-	+34	0.42
MCR_ID_95	+5	0.04	+21	0.08	+34	0.46
MCR_ID_98	-	-	-	-	+94	0.20
MCR_ID_104	+5	1.31	+22	1.49	+44	2.25
MCR_ID_105	+6	1.28	+23	1.48	+44	2.22
MCR_ID_106	+6	1.92	+23	2.12	+42	2.86
MCR_ID_108	+6	0.07	+24	0.15	+53	1.05
MCR_ID_111	+75	0.84	+233	1.18	+215	2.32
MCR_ID_115	+5	0.47	+25	0.68	+53	1.58
MCR_ID_118	+8	1.41	+29	1.66	+57	2.61
MCR_ID_120	+50	1.38	+154	1.79	+117	3.06

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)
MCR_ID_123	-	-	+89	0.08	+68	1.62
MCR_ID_126	+1	2.12	+7	2.55	+29	4.21
MCR_ID_128	0	1.09	+2	1.43	+19	3.11
MCR_ID_129	0	0.85	+2	1.19	+19	2.87
MCR_ID_130	0	0.69	+3	1.04	+19	2.73
MCR_ID_131	0	0.72	+3	1.06	+19	2.75
Kildonan Road—Downstream of the Project alignment	+6	2.39	+28	2.67	+53	3.75
Kildonan Road—Upstream of the Project alignment	+17	2.98	+56	3.44	+61	4.74

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 PMF event. Table 12.127 outlines the overtopping locations and depths.

TABLE 12.127 MACINTYRE RIVER (NORTH OF NSW/QLD BORDER)—PROJECT ALIGNMENT—EXTREME EVENT RAIL OVERTOPPING DETAILS

Approximate chainage (km)[1]	1 in 2,000 AEP formation overtopping depth (m)	1 in 10,000 AEP formation overtopping depth (m)	PMF formation overtopping depth (m)
28.50–31.00 (NS2B)	-	-	0.6
31.00–34.00 (NS2B)	-	-	0.5
34.00–39.50 (NS2B)	-	-	1.3
0.00–10.00	-	-	0.7
10.00–15.00	-	0.2	0.5

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 31.00 km and Ch 36 km the alignment experiences the increase in peak water levels upstream of the proposal alignment in the PMF. During detail design, mitigation measures to refine the design and to address the risks to the embankment and rail infrastructure as well as downstream properties 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 climate change guidelines set out in ARR 2016 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 RCP8.5 (2090 horizon) climate change scenario has been adopted for the Project, with an associated increase in rainfall intensity of 23 per cent across the Macintyre River catchment area.

Appendix Q2: Hydrology and Flooding Technical Report 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.

One flood-sensitive receptor (a shed) is impacted by the climate change. Flood-sensitive receptor MCR_ID_41 has a predicted impact of +120 mm in the 1% AEP flood event with climate change, with an existing 1% AEP (with no climate change) predicted flood depth of 453 mm.

The downstream extents of these impacts are similar to those under the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. ARR 2016 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 2016 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 no blockage factor 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 under the 50 per cent blockage scenario, tested with both 0 per cent and 50 per cent blockage of all culverts. Appendix Q2: Hydrology and Flooding Technical Report presents the change in peak water levels associated with the Project alignment for the blockage scenarios.

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

There is negligible change to the 1% AEP afflux caused by the Project within the Macintyre River floodplain under the blockage scenarios, given the significant bridge spans allowed for in the design. There are no changes to impacts on flood-sensitive receptors.

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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BORDER TO GOWRIE

Figure 12.28a.1:
Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Road design
- Project footprint
- Floodplain culvert
- Local drainage culvert
- Bridges

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE
Figure 12.28a.2:
Floodplain and drainage structures

LEGEND
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Road design
- Project footprint
- Local drainage culvert

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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BORDER TO GOWRIE

Figure 12.28a.3: Floodplain and drainage structures

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Road design
- Project footprint
- Local drainage culvert

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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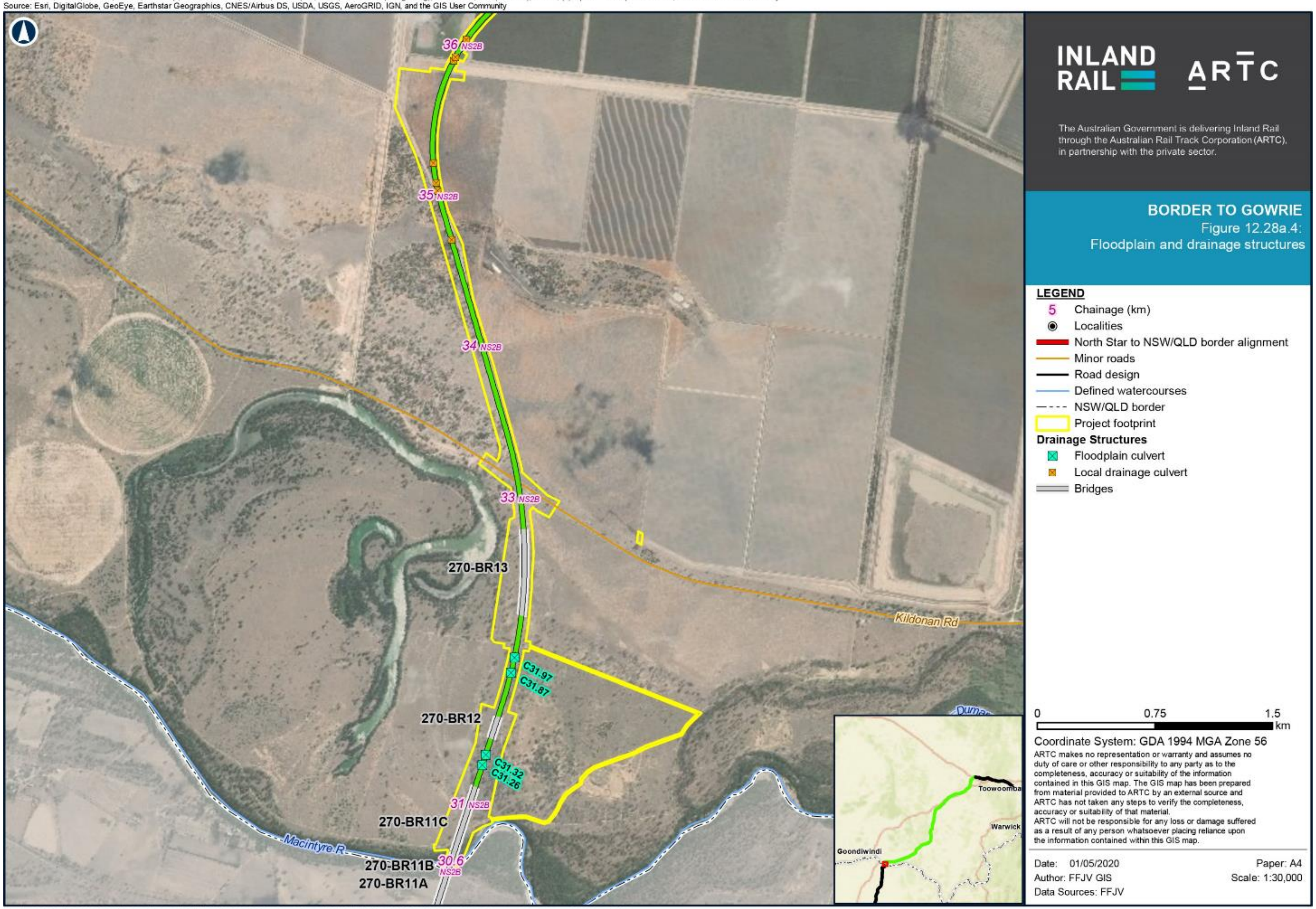

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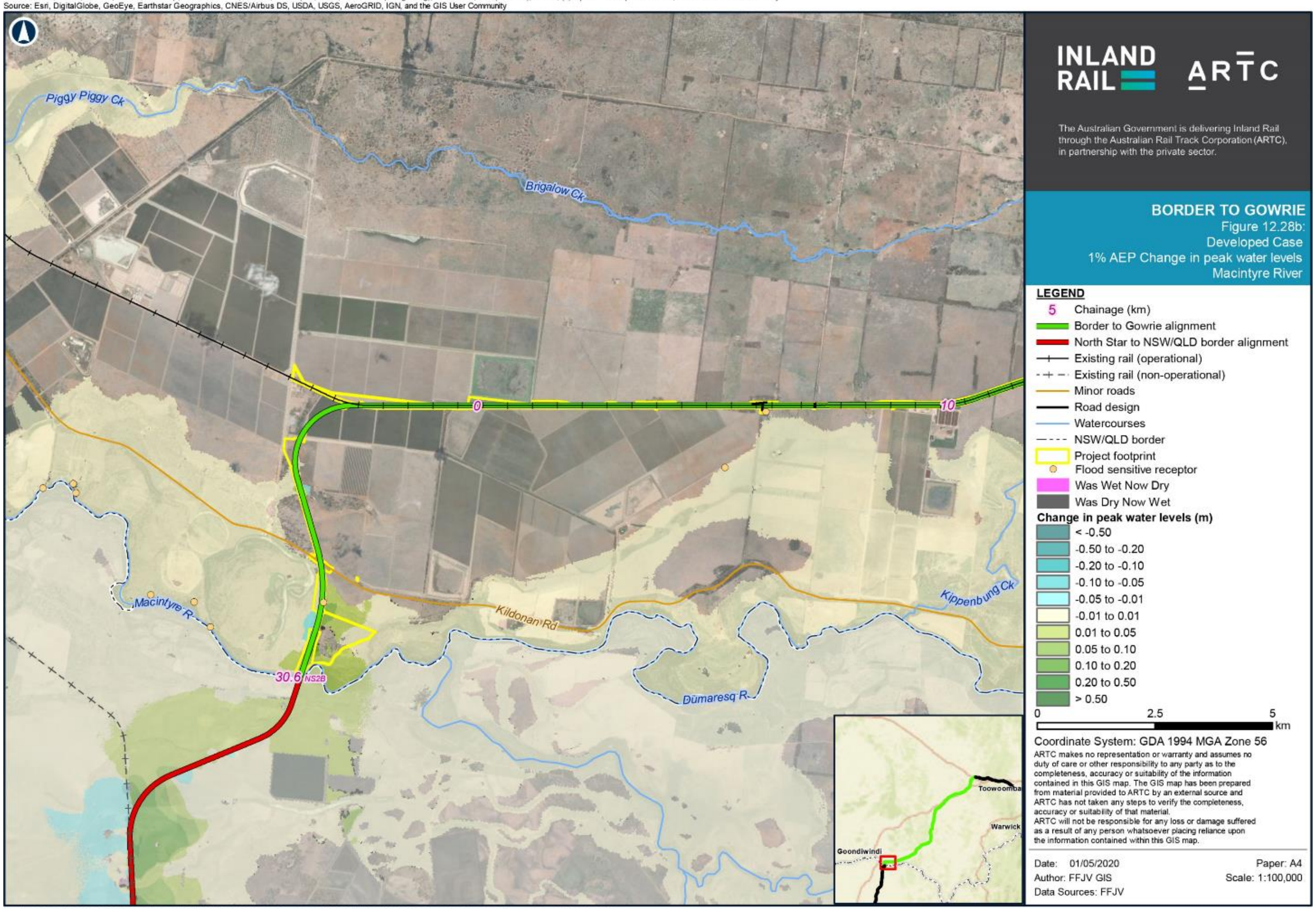

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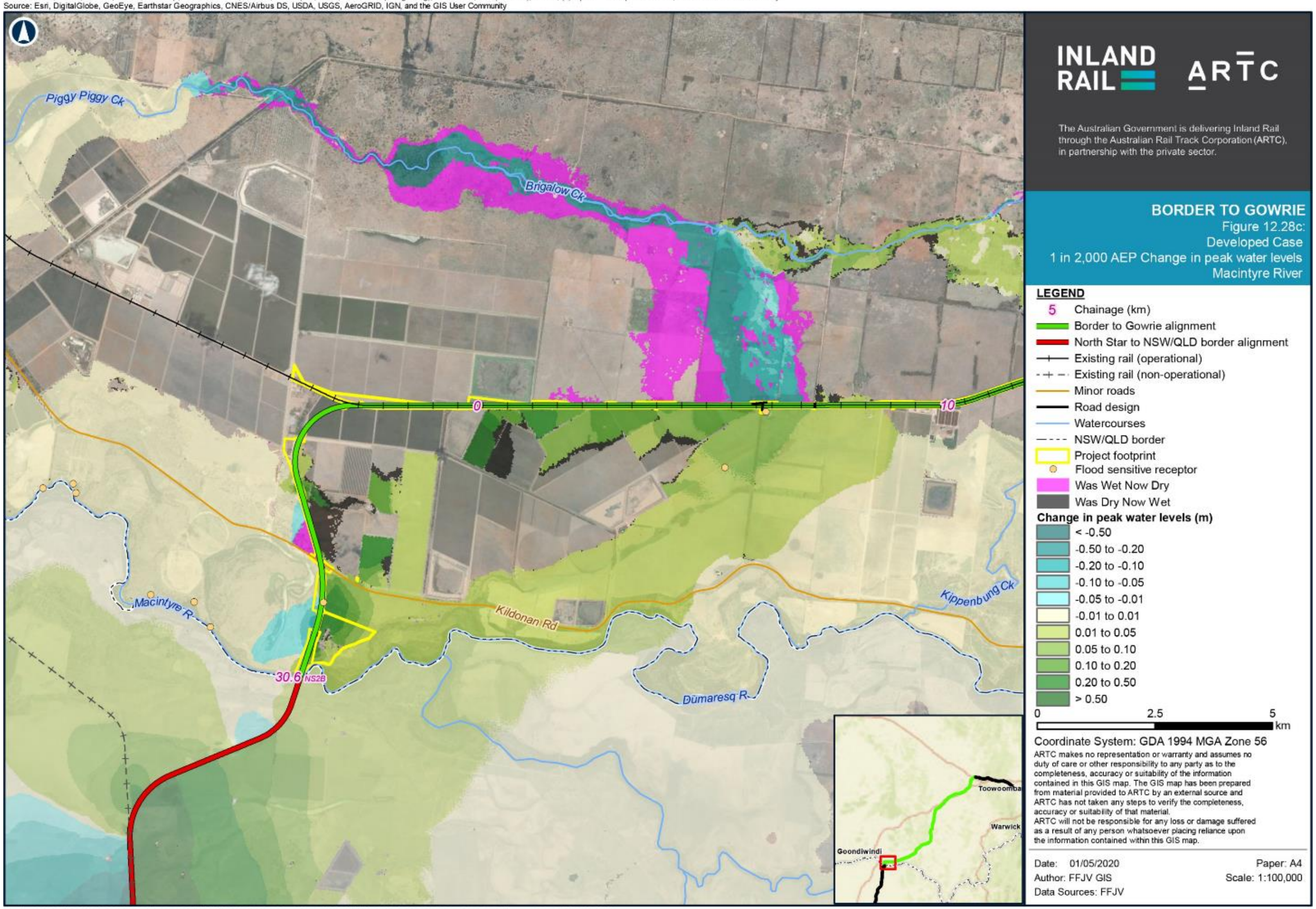

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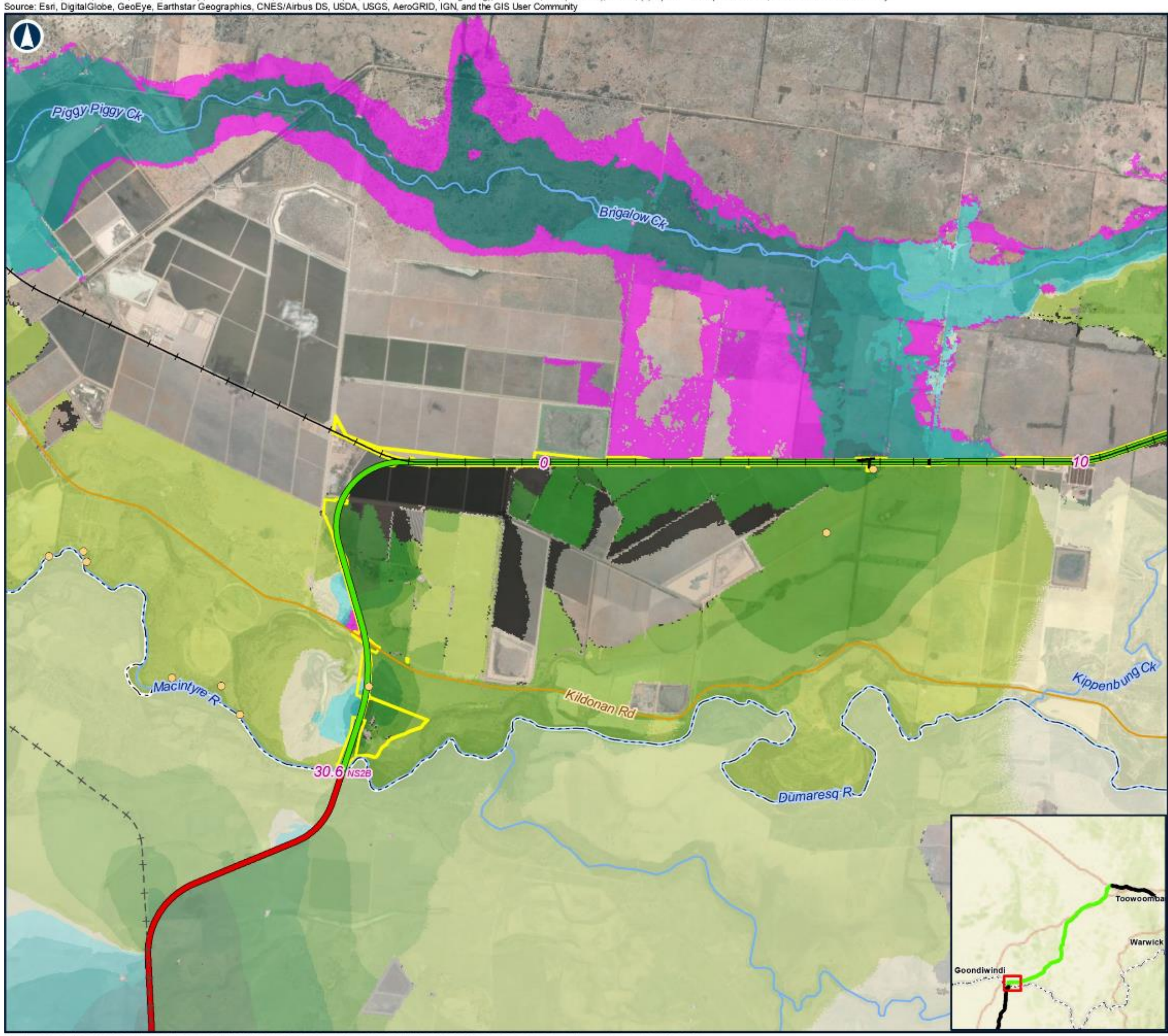

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BORDER TO GOWRIE
Figure 12.28d:
Developed Case
1 in 10,000 AEP Change in peak water levels
Macintyre River

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint
- Flood sensitive receptor
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:100,000
Data Sources: FFJV

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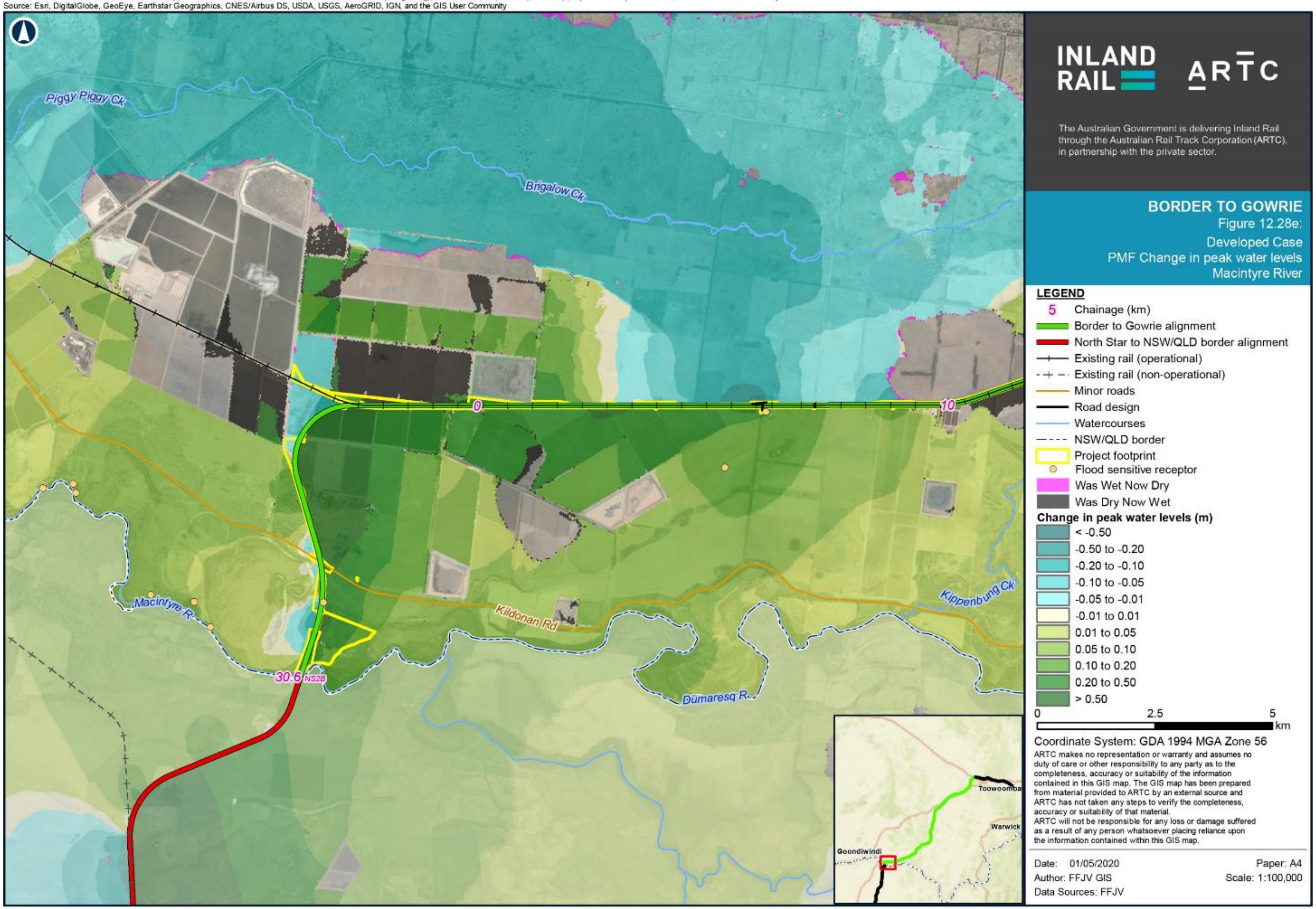

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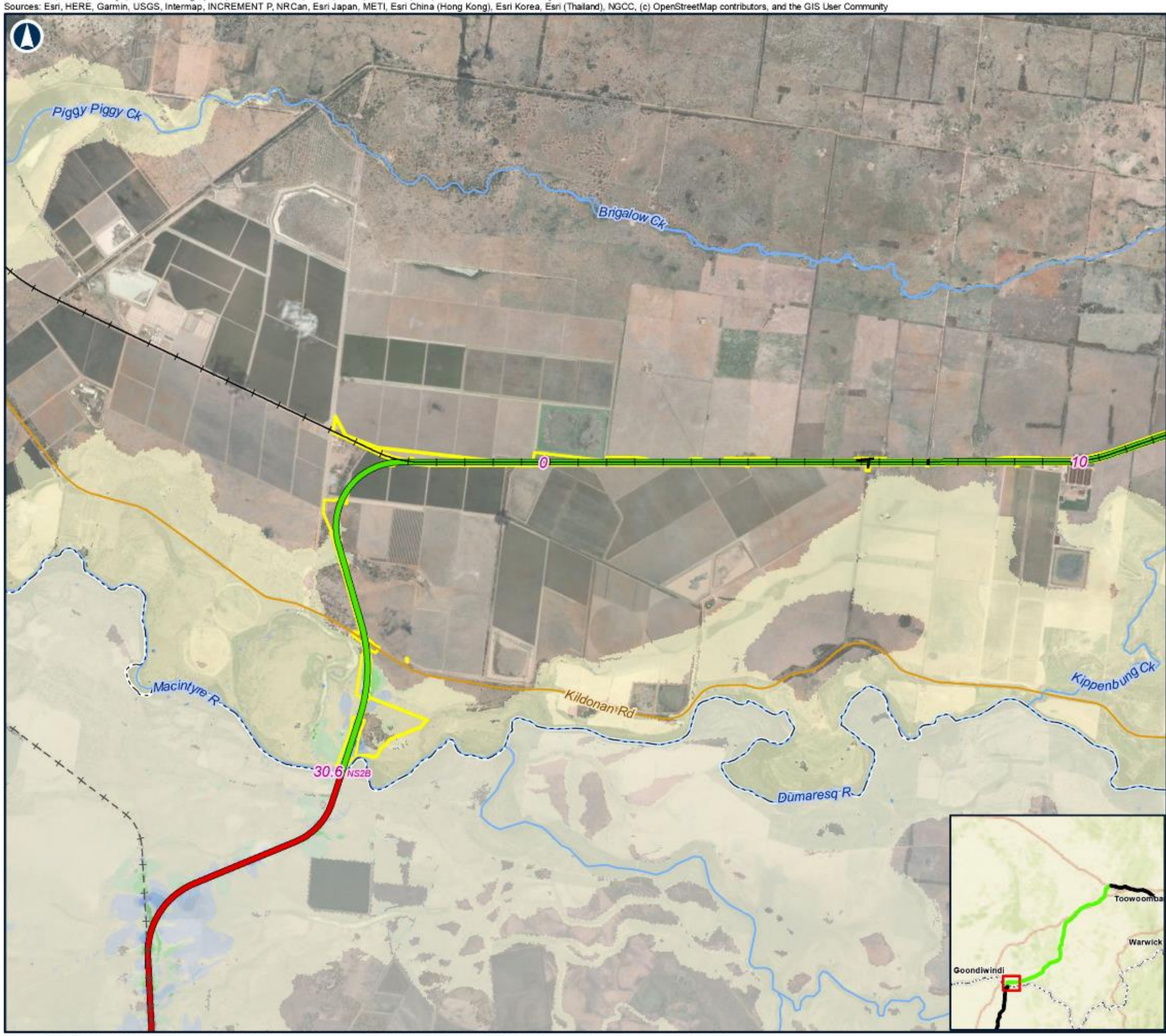

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BORDER TO GOWRIE
Figure 12.28f:
Developed Case
1% AEP Change in peak velocities
Macintyre River

LEGEND

- 5 Chainage (km)
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Minor roads
- Road design
- Watercourses
- NSW/QLD border
- Project footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -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 to 0.20
- 0.20 to 0.50
- > 0.50

0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56

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12.11 Cumulative impacts

12.11.1 Surface water cumulative impact assessment

It is a requirement of the ToR for this Project that the potential for cumulative impacts be considered. This section provides a discussion on the potential for cumulative impacts in relation to surface water. Further details on the potential for cumulative impacts to arise as a result of the Project, in combination with others, is presented in Chapter 21: Cumulative Impacts. Details on the assessment methodology for cumulative impacts is presented in Chapter 4: Assessment Methodology.

Projects with spatial and/or temporal overlap can result in cumulative impacts. Cumulative impacts may:

- Differ from those of an individual project when considered in isolation
- Be positive or negative
- Differ in severity and duration depending on the spatial and temporal overlap of projects occurring in an area.

Twenty-three projects were initially identified as having potential to contribute to cumulative impacts in combination with the Project. These projects are either currently operational, expected to undergo future expansion or are currently going through an approval process. A full list of the 23 projects, with a description of each, is presented in Chapter 21: Cumulative Impacts. All of these projects may result in the following, to some extent:

- Riparian vegetation loss, reducing ecosystem services to water quality
- Impacts to aquatic fauna species through water quality and barrier works
- Reduction in waterway connectivity
- Increase in erosion and sedimentation of waterways
- Increase in contamination of waterways
- Saline discharge into proximal waterway (intra-catchment)
- Increase in surface expression within alluvial waterways.

For the purposes of surface water, projects that will have temporal overlap in construction or expansion activities and may cause impacts to existing EVs additional to impacts from the Project are considered to have potential to result in cumulative impacts. Only seven of the initial projects identified meet these criteria. These projects are listed in Table 12.128.

TABLE 12.128 PROJECTS CONSIDERED WITHIN THE CUMULATIVE ASSESSMENT

Projects	Location	Description	Construction dates
New Acland Coal Mine Stage 3	35 km northwest of Toowoomba 18 km north of the Project footprint	Expansion of the existing New Acland open-cut coal mine to up to 7.5 million tonnes/annum.	2019–TBC
InterLinkSQ	13 km west of Toowoomba The northern limit of the Project is situated adjacent to the InterLinkSQ site	200 ha of new transport, logistics and business hub. Located on the narrow-gauge regional rail network and interstate network. Located at the junction of the Gore, Warrego and New England Highways.	2018–TBC
Asterion Medicinal Cannabis Facility	Wellcamp, Queensland Adjoins the Project footprint 1 km south of Toowoomba–Cecil Plains Road	A high-tech medicinal cannabis cultivation, research and manufacturing facility. The project involves construction of a 40-ha glasshouse to produce 20,000 plants per day, at full capacity. Medicinal-grade cannabis grown at the facility will be manufactured into a range of medicinal products, including single patient packs, cannabis oils, gels, salts and related products, destined solely for the medicinal market. This facility is anticipated to be the largest facility of its kind in the world.	2020–2021

Projects	Location	Description	Construction dates
Commodore Mine and Millmerran Power Station	Domville, Queensland The Project is aligned adjacent to potential future coal reserves for the mine	The Commodore Mine is an open-cut coal mine, which provides coal for the 850 MW Millmerran Power Station (Mininglink, n.d.). The Millmerran Power Station is a coal-fired power station that supplies enough electricity to power approximately 1.1 million homes (Power Technology, 2018).	Operational, but subject to possible future expansion of footprint
Goondiwindi Abattoir	Goondiwindi, Queensland 13 km north of the Project footprint	A new beef abattoir located on the outskirts of Goondiwindi, with beef processing of up to 72,000 tonnes per year.	TBA
North Star to Border (Inland Rail)—ARTC	Rail alignment from North Star, NSW to the NSW/QLD border Adjoins the Project at its southern limit	37 km single-track dual-gauge freight rail line as part of the ARTC Inland Rail Program.	2021—2024
Gowrie to Helidon (Inland Rail)—ARTC	Rail alignment from Gowrie to Helidon, Queensland Adjoins the Project at its northern limit	26 km single-track dual-gauge freight railway as part of the ARTC Inland Rail Program.	2021–2025

Commentary on the potential for cumulative impacts to occur is presented in Table 12.129. An assessment of cumulative impacts that may arise from these projects in combination with the Project is presented in Table 12.130.

The cumulative impacts of multiple projects occurring in the vicinity of the impact assessment area may contribute to impacts to water quality if not managed appropriately. This risk is considered inherently low due to the highly ephemeral nature of the majority of waterways in the impact assessment area.

Following consideration of the probability of impact, duration of impact, magnitude of impact and sensitivity of the receiving environment, the significance of potential cumulative impacts is considered to be low for all potential impacts, apart from riparian vegetation loss from vegetation clearing and/or removal.

The implementation of the mitigation measures and controls specified in Table 12.57 and Table 12.130 are considered appropriate for managing the potential for cumulative impacts to water quality.

All of these projects are subject to environmental controls, either through EIS assessment processes or operational licences, such as an EA under the EP Act or through the implementation of detailed environmental management plans (EMPs). Noting that projects within the cumulative area of influence have been assessed as operating/constructing as 'business-as-usual' (i.e. likelihood of occurrence of impact with standard operating procedures), the cumulative impact assessment has disregarded cumulative impacts that may result from critical failures within other projects.

TABLE 12.129 POTENTIAL FOR CUMULATIVE IMPACTS TO SURFACE WATER

Potential cumulative impact	Potential for cumulative impact to occur
Riparian vegetation loss from vegetation clearing/removal—loss of ecosystem service to water quality	A potential exists for a cumulative impact from the loss of sensitive receptors (riparian vegetation communities) with works involving waterways and associated crossings across the projects. Impacts may be compounded with interface between the Project and other listed projects in regard to decreased resilience to biotic and abiotic factors. Potential consequences include loss of bank stability, loss of diversity and reduction in water-quality values, due to decreased performance of ecosystem services to water quality. The proximity of other projects to watercourses and inadequate rehabilitation on those projects and the NSW/Queensland Border to Gowrie Project would result in the highest risk of significant cumulative impact. Interaction of impacts leading to a loss of ecosystem services or water quality are considered possible between the Project and the New Acland Coal Mine Stage 3 expansion, Asterion Medicinal Cannabis Facility, InterLinkSQ, Commodore Mine and Millmerran Power Station operations, and construction of the North Star to NSW/QLD Border and Gowrie to Helidon sections of Inland Rail.
Potential impacts to aquatic fauna species both through impacts to water quality and barrier works	There is potential for cumulative downstream impacts from water-quality issues associated with overland works and waterway barrier works. Cumulative impacts would be expected to occur in relatively short spatial distances (as cumulative point-source impacts) and would be expected to 'dilute' with increasing distance downstream from point-source impact. It is expected that cumulative impacts would be expected to occur between projects linked spatially and temporally during construction. As such, the current Project and North Star to NSW/QLD Border and Gowrie to Helidon sections of Inland Rail are expected to generate cumulative impacts, as well as Asterion Medicinal Cannabis Facility and InterLinkSQ.
Reduction in the connectivity of waterways	There is potential for impact due to multiple crossings of, or disturbances to, waterways, with progressive accumulation of impact between each project. Whole catchments may be impacted from separate projects on separate waterways; however, the greatest cumulative impacts would be expected where there is spatial interface between separate projects. Water-quality degradation may arise from reduced waterway connectivity and the associated decrease in ecosystem resilience. Cumulative impacts are most likely to arise due to projects in proximity to waterways that are crossed by the NSW/Queensland Border to Gowrie Project—the New Acland Coal Mine Stage 3 expansion, Asterion Medicinal Cannabis Facility, InterLinkSQ, Commodore Mine and Millmerran Power Station operations and construction of the North Star to NSW/QLD Border and Gowrie to Helidon sections of Inland Rail. Note that the Goondiwindi Abattoir is removed from this potential cumulative impact due to sub-catchment separation from the Project.
Increase in erosion and sedimentation in the waterways	Cumulative impacts may arise due to increase in waterway sedimentation from simultaneous activities within catchments. Cumulative impacts in regard to erosion may arise from impaction of waterway structure/hydrological regimes and may be further impacted by cumulative impacts on riparian vegetation loss. Due to this specific cumulative impact, it is expected that the greatest cumulative impact would be generated from close-proximity projects including InterLinkSQ, Asterion Medicinal Cannabis Facility, the Commodore Mine and Millmerran Power Station operations and construction of the North Star to NSW/QLD Border and Gowrie to Helidon sections of Inland Rail.

Potential cumulative impact	Potential for cumulative impact to occur
Increase in contamination of waterways (water column and sediment)	There is potential for cumulative impacts to arise from contamination of waterways from in-blow or direct deposition of contaminants into waterways. This is most likely to occur where projects are located in the same hydrological catchment (e.g. sub-catchments within a greater catchment). The likelihood of occurrence decreases with greater distance between projects. Based on this, it would be expected that the New Acland Coal Mine Stage 3 expansion, Asterion Medicinal Cannabis Facility, InterLinkSQ, Commodore Mine and Millmerran Power Station operations, Goondiwindi Abattoir and construction of the North Star to NSW/QLD Border and Gowrie to Helidon sections of Inland Rail may contribute to potential cumulative impacts.
Saline discharge into proximal waterways	There is a potential for cumulative impacts to arise from overlapping construction activities within high salinity risk rating areas across the Project footprint, resulting in increased potential of sodosol erosion and dispersive soil discharge. Due to this, construction activities would need to occur within the same sub-catchment and in moderate-to-high salinity hazard areas, in order for cumulative impacts to arise. As such, it would be expected that potential cumulative impacts may be expected with all projects, excluding the Goondiwindi Abattoir.
Increase in surface salinity around alluvial waterways	Salinity expression may arise due to overlapping construction activities requiring the clearing of riparian vegetation within alluvial-based waterways. This is most likely to occur where there is a direct spatial interface between projects and a temporal overlap in construction. Due to the regional geology across the catchment, the potential for this cumulative impact is limited to the region (and projects within) of clay alluvia and lacustrine deposits between Millmerran and Pittsworth (associated with the Condamine River alluvial aquifer). While other waterways may demonstrate highly localised alluvia, it is expected that the highest risk of this cumulative impact occurring would be restricted to this region of alluvia (as surface salinity from drainage line expressions). As such, it is expected that the potential for cumulative impact would be restricted to the potential expansion of the Commodore Mine and Millmerran Power Station.

TABLE 12.130 SUMMARY OF THE CUMULATIVE IMPACT ASSESSMENT FOR SURFACE WATER

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
New Acland Coal Mine Stage 3	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: ▶ Rehabilitation and Landscaping Management Sub-plan ▶ Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring ▶ Soil Management Sub-plan, including erosion and sediment control measures ▶ Hazardous Materials Management Sub-plan. The potential for cumulative impacts during construction will also be managed through adherence to the following, through detail design and construction: ▶ Riverine protection permit exemption requirements (WSS/2013/726) ▶ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (Department of Agriculture and Fisheries (DAF), 2018e) ▶ Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works.	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Reduction in waterway connectivity	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
New Acland Coal Mine Stage 3 (continued)	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
Asterion Medicinal Cannabis Facility	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: ▸ Rehabilitation and Landscaping Management Sub-plan ▸ Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring ▸ Soil Management Sub-plan, including erosion and sediment control measures ▸ Hazardous Materials Management Sub-plan. The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction: ▸ Riverine protection permit exemption requirements (WSS/2013/726) ▸ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e) ▸ Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works.	Probability of the impact	Medium (2)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Reduction in waterway connectivity	Probability of the impact	Low (1)	4	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Low (1)	4	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
Asterion Medicinal Cannabis Facility (continued)	Increase in waterway contamination	Probability of the impact	Low (1)	4	Low	The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
InterLinkSQ	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: - Rehabilitation and Landscaping Management Sub-plan - Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring - Soil Management Sub-plan, including erosion and sediment control measures - Hazardous Materials Management Sub-plan. The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction: - Riverine protection permit exemption requirements (WSS/2013/726) - *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e) - Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply. The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works.	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Reduction in waterway connectivity	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
InterLinkSQ (continued)	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
Commodore Mine and Millmerran Power Station	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: ▸ Rehabilitation and Landscaping Management Sub-plan ▸ Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring ▸ Soil Management Sub-plan, including erosion and sediment control measures ▸ Hazardous Materials Management Sub-plan. ▸ The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction: ▸ Riverine protection permit exemption requirements (WSS/2013/726) ▸ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works.	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Reduction in waterway connectivity	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
Commodore Mine and Millmerran Power Station (continued)	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	- Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply - The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
Goondiwindi Abattoir	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Low (1)	6	Low	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: - Rehabilitation and Landscaping Management Sub-plan - Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring - Soil Management Sub-plan, including erosion and sediment control measures - Hazardous Materials Management Sub-plan. - The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction:
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Reduction in waterway connectivity	Probability of the impact	Low (1)	4	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
Goondiwindi Abattoir (continued)	Increase in erosion and sedimentation of waterways	Probability of the impact	Low (1)	5	Low	▸ Riverine protection permit exemption requirements (WSS/2013/726) ▸ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e) ▸ Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply. ▸ The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
North Star to Border (Inland Rail)	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: ▸ Rehabilitation and Landscaping Management Sub-plan ▸ Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures

North Star to Border (Inland Rail) (continued)	Reduction in waterway connectivity	Probability of the impact	Medium (2)	6	Low	• Soil Management Sub-plan, including erosion and sediment control measures
						• Hazardous Materials Management Sub-plan.
						• The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction:
						  ◦ Riverine protection permit exemption requirements (WSS/2013/726)
						  ◦ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e)
						  ◦ Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply.
						The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.

		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
Gowrie to Helidon (Inland Rail)	Riparian vegetation loss from vegetation clearing and /or removal	Probability of the impact	Medium (2)	7	Medium	The potential for cumulative impacts during construction will be managed through development and implementation of the following, as part of the CEMP: ▸ Rehabilitation and Landscaping Management Sub-plan ▸ Surface Water Management Sub-plan, including the establishment of baseline conditions and construction phase monitoring ▸ Soil Management Sub-plan, including erosion and sediment control measures ▸ Hazardous Materials Management Sub-plan. The potential for cumulative impacts during construction will also be managed through adherence to the following through detail design and construction: ▸ Riverine protection permit exemption requirements (WSS/2013/726) ▸ *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF, 2018e) ▸ Permit/approval conditions if either of the previous two listed requirements cannot be adhered to or do not apply. The success of riparian rehabilitation for the Project will be monitored to ensure that its contribution to riparian vegetation loss is appropriately rectified.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Medium (2)			
	Potential impacts to aquatic fauna species both through impacts to water quality and barrier works.	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Reduction in waterway connectivity	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in erosion and sedimentation of waterways	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in waterway contamination	Probability of the impact	Medium (2)	6	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors[a]	Impact significance[b]	Comments and management measures
Gowrie to Helidon (Inland Rail) (continued)	Saline discharge into proximal waterways (intra-catchment scope)	Probability of the impact	Medium (2)	6	Low	▸
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			
	Increase in surface salinity around alluvial waterways	Probability of the impact	Low (1)	5	Low	
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Medium (2)			

Table notes:

a Relevance factors between 1 and 3 were determined using professional judgement to select most appropriate relevance factor for each aspect and summing the relevance factors.

Sum of relevant factors definition:

- Low (1–6): Negative impacts need to be managed by standard environmental management practices. Monitoring to be part of general Project monitoring program.
- Medium (7–9): Mitigation measures likely to be necessary and specific management practices to be applied. Targeted monitoring program required, where appropriate.
- High (10–12): Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Targeted monitoring program necessary, where appropriate.

b Impact significance is considered the residual impact after implementation of avoidance strategies and mitigation measures outlined in the comments and management measures.

12.11.2 Hydrology and flooding cumulative impact assessment

The hydrologic and hydraulic investigation has included all existing infrastructure in the Existing Case. The Existing Case has been used as the basis to compare the Developed Case against to determine potential impacts and then derive appropriate mitigation measures. This process is followed for all infrastructure projects that have the potential to impact on this investigation, with projects required to mitigate and minimise impacts to acceptable levels; therefore, cumulative impacts have been included in the assessment of Existing Case vs Developed Case.

The exception is the North Star to NSW/Queensland Border and the Gowrie to Helidon Inland Rail projects that are being concurrently developed. The North Star to NSW/Queensland Border and the Gowrie to Helidon Inland Rail projects have been included in the Developed Case for this Project to enable cumulative impacts to be considered and addressed. As a result, cumulative hydrological impacts with these projects has been documented in Section 12.10.2.

12.12 Conclusions

12.12.1 Water quality

The Project alignment traverses the Border Rivers and Condamine River basins. Existing surface water conditions within the impact assessment area have been established based on a review of published data and data that was collected for the Project through surface water monitoring and sampling. This sampling occurred over four separate sampling events between June 2018 and May 2019.

Review of historic and field assessed water-quality data identified that surface waters within the impact assessment area do not currently achieve all WQOs for the protection of aquatic ecosystems within each basin.

All waterways within the impact assessment area have been identified as sensitive receptors within the receiving environment. Of these, a number of high sensitivity water-quality receptors with associated EVs were identified within the impact assessment area. Associated EVs included MNES species and MSES wetlands. High sensitivity water-quality receptors include the Macintyre River, Macintyre Brook, Canning Creek and the Condamine River.

It has been identified that the construction and operation of the Project has the potential to impact on surface water quality through:

- Increased debris
- Change to water quality and hydrology
- Increase in salinity
- Increase in contaminants
- Increases in erosion and sedimentation
- Exacerbation of listed impacts above, from inadequate rehabilitation processes.

Additionally, the Project has potential to result in impacts to waterway morphology and the availability of surface waters for existing users.

A significance assessment was undertaken and assessed the residual impact of identified potential impacts after assessment of design considerations and additional mitigation measures. The assessment identified:

- During the construction phase, the combination of design considerations and mitigation measures relevant to surface water quality would be sufficient to mitigate most potential impacts, such that the residual significance would be low
- For the operation phase, the combination of design considerations and mitigation measures relevant to surface water quality would be sufficient to mitigate most potential impacts, such that the residual significance would be low.

The significance impact assessment has identified that with design considerations and mitigation measures in place, the risk of significance of impact from construction phase (including pre-construction) and operation phase activities is low. It is not expected that significant residual impact on surface water quality will be a result of Project activities.

A cumulative impact assessment considering the impact of five other Projects was carried out. The cumulative impacts of several projects within the impact assessment area included:

- Riparian vegetation loss from vegetation clearing/removal
- Potential impacts to aquatic fauna species both through impacts to water quality and barrier works
- Displacement of flora and fauna species from invasion of weed and pest species
- Reduction in the connectivity of waterways
- An increase in erosion and sedimentation in the waterways
- An increase in litter (waste)
- Saline discharge into proximal waterways
- An increase in surface salinity around alluvial waterways.

These potential impacts were all considered to have carry on impacts to surface water quality within the cumulative impact assessment area.

The cumulative impact assessment identified a medium risk of potential impact occurring during construction activities due to riparian vegetation loss from vegetation clearing/removal. It is considered that the potential for these impacts will be appropriately managed through application of the suite of mitigation measures proposed for the Project in its own right.

12.12.2 Hydrology and flooding

The Project alignment crosses several major waterways, with the key waterways being the Macintyre River, Macintyre Brook, Condamine River and Gowrie Creek. Other major creek crossings include Pariagara Creek, Cattle Creek, Native Dog Creek, Bringalily Creek, Nicol Creek, Back Creek, Westbrook Creek and Dry Creek. Detailed hydrologic and hydraulic assessments have been undertaken due to the catchment sizes and substantial floodplain flows associated with each of these watercourses.

Hydrologic and hydraulic modelling was undertaken for each of these catchments, with the models calibrated, where possible, to multiple historical events using stream gauges records, community feedback and available anecdotal data. Based on this performance, the hydrologic and hydraulic models were considered suitable to assess the potential impacts associated with the Project.

Design event hydrology was developed using the calibrated hydrologic models using ARR 2016 flood flow estimation techniques. The hydraulic models were run for a suite of design events from the 20% AEP event to the 1 in 10,000 AEP and PMF events.

Modelling of the current state of development (Existing Case) was undertaken and details of the existing flood regime were determined for the modelled design events. The proposed works associated with the Project were incorporated into the hydraulic models (Developed Case) and assessment of the potential impacts on the existing flood regime was undertaken. Changes in peak water levels, velocities, flow patterns and flood inundation extents and durations have been identified, mapped or tabulated.

Consultation with stakeholders (i.e. landowners) was undertaken at key stages, including validation of the performance of the modelling in replicating experienced historical flood events and presentation of the design outcomes and impacts on properties and infrastructure.

Flood-impact objectives were provided by ARTC and used to guide mitigation of impacts through refinement of the hydraulic design, including adjustment of the numbers, dimensions and locations of major drainage structures.

Flood-impact objectives, as presented in Table 12.8, have been established and used to guide the Project design, including mitigation of impacts through refinement of the hydraulic design, including adjustment of the numbers, dimensions and location of major drainage structures. Table 12.131 summarises how the Project design performs against each of the flood-impact objectives.

TABLE 12.131 FLOOD IMPACT OBJECTIVES AND OUTCOMES

<table>
<tr><th>Parameter</th><th colspan="6">Objectives and outcomes</th></tr>
<tr><td rowspan="3">Change in peak water levels</td><td>Existing habitable and/or commercial and industrial buildings/ premises (e.g. dwellings, schools, hospitals, shops)</td><td>Residential or commercial/industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)</td><td>Existing non-habitable structures (e.g. agricultural sheds, pump-houses)</td><td>Roadways
Rail lines</td><td>Agricultural (cropping) land</td><td>Agricultural (grazing) land/forest areas and other non-agricultural land</td></tr>
<tr><td>≤ 10 mm</td><td>≤ 50 mm</td><td>≤ 100 mm</td><td>≤ 100 mm</td><td>≤ 100 mm with localised areas up to 400 mm</td><td>≤ 200 mm with localised areas up to 400 mm</td></tr>
<tr><td colspan="6">Objective: Changes in peak water levels are to be assessed against the above proposed limits.
Outcome: Generally, the Project design meets the above limits with the exception of a few localised areas along the Project alignment where these limits are exceeded. These areas are generally on agricultural land. Flood-sensitive receptors that are impacted by changes in peak water levels under the 1% AEP event that exceed the flood-impact objectives include:
‣ Nine dwellings (five between Pampas and Yandilla, and four at Yelarbon)
‣ One shed at Pampas
‣ Three commercial buildings (grain silos) at Yandilla
‣ One State-controlled road (Cunningham Highway at Yelarbon)
‣ One local public road (Leesons Road between Kingsthorpe and Gowrie Junction).</td></tr>
<tr><td>Change in duration of inundation</td><td colspan="6">Objective: Identify changes to duration of inundation through determination of ToS. For roads, determine AAToS (if applicable) and consider impacts on accessibility during flood events.
Outcome: There are localised increases in ToS at the same locations where peak water levels are increased. These changes in inundation duration do not affect flood-sensitive receptors except for one local public road—Draper Road—and one State-controlled road—the Cunningham Highway. The Cunningham Highway has a +0.8 hours per year increase in AAToS, which is a negligible change, with Draper Road experiencing an even lower impact.</td></tr>
<tr><td>Flood flow distribution</td><td colspan="6">Objective: Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas. Identify any changes and justify acceptability of changes through assessment of risk, with a focus on land use and flood-sensitive receptors.
Outcome: The Project has minimal impacts on flood flows and floodplain conveyance/storage, with significant floodplain structures included to maintain the existing flood regime.</td></tr>
<tr><td>Velocities</td><td colspan="6">Objective: Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures, taking into account existing soil conditions.
Outcome: In general, changes in velocities are minor, with most changes in velocities experienced immediately adjacent to the Project alignment and no flood-sensitive receptors impacted. Scour protection has been 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.</td></tr>
<tr><td>Extreme event risk management</td><td colspan="6">Objective: Consider the risks posed to neighbouring properties for events larger than the 1% AEP event, to ensure no unexpected or unacceptable impacts.
Outcome: A review of impacts under 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.</td></tr>
</table>

Parameter	Objectives and outcomes
Sensitivity testing	**Objective:** Consider risks posed by climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with Project alignment for both scenarios. **Outcomes:** Climate change—climate change has been assessed in accordance with ARR 2016 requirements, with the RCP8.5 (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. Blockage—blockage of drainage structures has been assessed in accordance with ARR 2016 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 on some flood-sensitive receptors. During detail design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in a varied and/or lower blockage factors being applied along the Project alignment.

The hydrologic and flooding assessment undertaken has demonstrated that the Project is predicted to result in impacts on the existing flooding regime that generally comply with the flood-impact objectives that have been adopted for the Project. A comprehensive consultation exercise has been undertaken to provide the community with detailed information and certainty around the flood modelling and the Project design. In future stages, ARTC will continue to work with:

- Landowners concerned with hydrology and flooding throughout the detail design, construction and operation phases of the Project
- Directly impacted landowners affected by the alignment throughout the detail design, construction and operation phases of the Project
- Local governments, State government agencies and local flood specialists throughout the detail design, construction and operation phases of the Project.