CHAPTER

08

Land Resources

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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8. Land Resources

8.1 Introduction

The purpose of this chapter is to identify existing land resources within the impact assessment area (refer Section 8.4.3), assess potential impacts of the Project on those land resources and to identify appropriate mitigation measures to address such impacts.

For the purpose of this assessment, land resources include the following:

- Topography
- Geology
- Soils
- Acid sulfate soil (ASS)/acid rock
- Naturally occurring asbestos
- Saline, dispersive and reactive soils
- Erosion risk
- Contaminated land
- Agricultural land
- Soil conservation plans
- Unexploded ordnance (UXO).

For each of these aspects, this assessment addresses the following:

- The relevant legislative context for land resources for the Project (refer Section 8.3)
- A description of land resources that are located within the impact assessment area (refer Section 8.4.5)
- The potential impacts of the Project on land resources (refer Section 8.6)
- Mitigation measures relevant to land resource issues (refer Section 8.7)
- An assessment of residual impact risk (refer Section 8.8)
- Consideration of the potential cumulative impacts to land resource (refer Section 8.9).
- This chapter should be read in conjunction with the following components of the draft EIS:
  - Appendix G: Geotechnical Investigation Data
  - Appendix H: EMR Certificates and Soil Laboratory Data
  - Appendix Y: Spoil Management Strategy
  - Volume 3: Design Drawings.

8.2 Terms of Reference requirements

This chapter has been prepared to address sections 11.88 to 11.93 and 11.150 to 11.154 of the ToR. A compliance check of this chapter against each of the relevant components of the ToR is presented in Table 8.1.

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

TABLE 8.1 COMPLIANCE AGAINST RELEVANT SECTIONS OF THE TERMS OF REFERENCE

Land resources Terms of Reference requirement		Draft EIS Section
Topography, geology and soils		
11.88	The assessment of impacts on topography, geology and soils will be in accordance with the Soil Science Guidelines of Australia, Queensland Branch (2015), in conjunction with the DES Information guideline for an environmental impact statement – Land and the CSIRO guidelines – Guidelines for surveying soil and land resources and Australian soil and land survey field handbook.	Section 8.3 Section 8.4.1 Section 8.4.2 Section 8.5.1 Section 8.5.3 The need for further investigations is discussed in Section 8.4.2 and Section 8.7.2
11.89	Discuss the projects impacts on Important Agricultural Areas as per the SPP – State interest guideline – Agriculture with reference to Agricultural Land Use Categories under the Queensland Agricultural Land Audit methodology.	Section 8.3 Section 8.5.4 Also addressed in Chapter 7: Land Use and Tenure
11.90	Identify and investigate areas of salinity, sodic, dispersive and cracking clay soils, and potential and actual areas of acid sulfate soils. Where potential areas are identified, further investigations (including field surveys) should be undertaken in accordance with accepted industry guidelines and the requirements of the SPP – State interest guideline emissions and hazardous activities.	Existing soil conditions discussed in Section 8.5.2 and Section 8.5.3 The need for further investigations is discussed in Section 8.4.2 and Section 8.7.2
11.91	Provide details, including maps, of the location of project works/infrastructure with respect to soil conservation works (contour banks, waterway discharge points, etc.) and existing erosion control works.	Section 8.5.5
11.92	Identify activities or operations likely to impact on existing erosion control works and any soil conservation plans, in particular, those approved as project plans or property plans approved under the provisions of the *Soil Conservation Act 1986*.	Section 8.5.5 and Section 8.6.4
11.93	Measures to avoid or mitigate potential impacts of the project on soil values, existing conservation works and erosion control works must be described.	Section 8.7
Land contamination		
11.150	Detail any known or potential sources of contaminated land within or adjoining the project area, including the location of any potential contamination identified by landowners. Provide results of searches of the Environmental Management Register (EMR) and/or the Contaminated Land Register (CLR) for the proposed alignment and disturbance areas.	Section 8.5.6
11.151	Provide a description of the nature and extent of contamination at identified sites.	Section 8.5.6 and Section 8.6.8
11.152	Describe the proposed management of any contaminated land either previously identified or encountered during construction activities and the potential for contamination from construction, commissioning, operation and decommissioning.	Section 8.7
11.153	Describe strategies and methods to be used to prevent, manage or remediate any land contamination resulting from the project, including but not limited to the management of any acid generation or management of chemicals and fuels to prevent spills or leaks.	Section 8.7.2
11.154	Describe how the presence of any known potential unexploded ordnance will be identified on maps of an appropriate size and scale and assessed within or adjoining the project area. Describe how any known or potential unexploded ordnance will be managed.	Section 8.5.6.2 and Section 8.7.2

8.3 Policies, standards and guidelines

The land resources assessment presented in this chapter has been undertaken in reference to the policies, standards and guidelines presented in Table 8.2.

Further information on legislation, policy, standard and guidelines relevant to the Project are provided in Chapter 3: Legislation and Project Approvals Process.

TABLE 8.2 POLICIES, STANDARDS AND GUIDELINES RELEVANT TO THIS ASSESSMENT

Policy, standard or guideline	Relevance to the Project
Commonwealth	
National Environment Protection (Assessment of Site Contamination) Measure 1999 (Cth) (ASC NEPM) (National Environment Protection Council, 2013)	The ASC NEPM is the national guidance document for the assessment of site contamination in Australia, which aims to establish a nationally consistent approach to assess site contamination to ensure sound environmental management practices are adopted. The desired outcome of ASC NEPM is to protect human health and the environment. Contaminated land in Queensland is expected to be assessed in accordance with the processes and guidance detailed in ASC NEPM.
Guidelines for Surveying Soil and Land Resources (McKenzie et al., 2008)	The Guidelines for Surveying Soil and Land Resources aims to promote the development and implementation of consistent methods for conducting soil and land resource surveys in Australia. The guideline provides information on how to best undertake field surveys to identify, describe, map and evaluate various soils or land resources.
Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain, 2009)	The *Australian Soil and Land Survey Field Handbook* provides specific methods and terminology for soil and land surveys. It is widely used throughout Australia to provide one reference set of definitions for the characterisation of landforms, vegetation, land surface, soil and substrate.
State	
Soil Conservation Guidelines for Queensland (Department of Science Information Technology and Innovation (DSITI), 2015)	These Queensland Government guidelines provide practical information and tools for application in soil conservation. The guidelines provide coverage of many land management aspects of relevance to the impact assessment area and the Project, including the management of land on floodplains.
State Planning Policy (SPP) *State Interest Guideline, Agriculture* (Department of Infrastructure, Local Government and Planning (DILGP), 2016a)	The SPP was established by the Queensland Government to define specific matters of State interest in land-use planning and development. Agriculture is identified as a State interest within the SPP. Specifically, the resources on which agriculture depends are protected to support the long-term viability and growth of the agricultural sectors. Audit information has been used to support the identification and mapping of important agricultural areas (IAAs), and Agricultural Land Classes A and B.
Environmental Impact Statement Information Guideline—Land (Department of Environment and Heritage Protection (DEHP), 2016a)	The Queensland EIS guideline for land describes information required to support applications for statutory approvals concerning land-related matters for resource projects. The guideline describes the information required for an EIS for land-related aspects of a resource project, such as topography, geology and geomorphology, and description of soil.
Environmental Impact Statement Information Guideline—Contaminated Land (DEHP, 2016b)	The Queensland EIS guideline for contaminated land describes the information required to support an EIS for resources projects, including: ‣ Existing contamination, potential impacts and management measures to be implemented during the project ‣ The extent to which Project activities would cause soil contamination, and how that would be managed ‣ The risks to human health and the environment posed by existing and potential soil contamination. The guideline also prescribes the information required should acid sulfate soils (ASS) be encountered for a resources project.

Policy, standard or guideline	Relevance to the Project
Salinity Management Handbook, 2nd edition (Department of Environment and Resource Management (DERM), 2011)	The *Salinity Management Handbook* provides a guide to salinity processes—investigating salinity risks within landscapes, and developing integrated management strategies should saline soils be encountered.
Other guidance documents	
Guidelines for Soil Survey along Linear Features (Soil Science Australia, 2015)	The guidelines prescribe soil survey techniques required for linear features, which are generally considered to be 10–100 m wide and include rail. The guidelines identify varying scales of soil mapping are required for different stages of a project. The guidelines recommend soil information for an EIS to require a scale of 1:250,000, while for the construction stage of a project, a scale of 1:5,000 is considered more appropriate. The mapping scale/intensity etc. defined in Tables 1, 2 and 3 of the Guidelines are for a project with a defined disturbance footprint and an alignment width of less than 100 m. The Project footprint for the Border to Gowrie Project is subject to confirmation through the detail design process but will be, in several locations, greater than 100 m in width; therefore, the mapping scale/intensity etc. defined in Tables 1, 2 and 3 of the Guidelines are not considered to be directly applicable the Border to Gowrie Project at the reference design (EIS) stage. ASRIS Atlas of Australian Soils (CSIRO, 2014a) Australian Soil Classification mapping is a national dataset published at a scale of 1:2,000,000 but is based on localised surveys and mapping completed at a scale of 1:250,000. Consequently, the mapping scale considered to be appropriate by the Guidelines for the purpose of an EIS can be achieved with reference to publicly available mapping, published by CSIRO. This data is provided in Figure 8.5 and reference has been made to this mapping in forming the discussions presented in Section 8.5.3. ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 8.7.2). The methodology for the detailed soil investigation will be developed in consultation with DNRME and will be in accordance with the *Guidelines for surveying soil and land resources* (McKenzie et al., 2008), the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features*. Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner. Weather permitting, these additional investigations will commence in the first quarter of 2021.
Central Darling Downs Land Management Manual (Harris et al., 1999)	This publication set describes the soils and land resources of the Central Darling Downs. It is part of a series, which details the recommended land management practices for the major cropping areas of Queensland. The survey area covers 2.6 million hectares in the shires of Millmerran, Pittsworth, Jondaryan, Toowoomba, Rosalie and Wambo. The field manual, resource book and soil chemical data book contain currently available land resource information, combined with local knowledge and experience, primarily concerning soils and their management. Land resource area mapping was produced at a scale of 1:250,000.
Land Management Manual Waggamba Shire (Thwaites, R.N. & Macnish, S.E., 1991)	This publication set describes the soils and land resources for the former Waggamba Shire in southern Queensland which, of relevance to this Project, includes the locality of Kurumbul and the town of Yelarbon. It is part of a series that details the recommended land management practices for the major cropping areas of Queensland. The field manual and resource book collate available soil and land information as well as current management recommendations. Fifteen distinct land resource areas were mapped at a scale of 1:250,000.
Land Management Manual: Shire of Inglewood (Cassidy, G.J, n.d)	This publication set describes the soils and land resources of the former Inglewood Shire in southern Queensland. It is part of a series that details the recommended land management practices for the major cropping areas of southern Queensland. In particular, the manual provides guidance on the conservation of soil and its fertility, as well as enhancement or maintenance of production by weed and pest control.

Policy, standard or guideline	Relevance to the Project
Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014 (Dear et al., 2014)	The management guidelines for ASS provide risk-based management measures, with a variety of 'preferred' or 'high risk' strategies that can be used to manage documented ASS. If ASS is disturbed directly or indirectly during Project activities, an ASS Management Plan is required to be prepared.
National Guidance for the Management of Acid Sulfate Soils in Inland Aquatic Ecosystems (Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council (EPHC & NRMMC), 2011).	This guidance document for the management of ASS in inland aquatic ecosystems is designed to guide the identification and management of inland ASS to reduce or eliminate the risks they pose to the environment and the economy. The document explains the complexities associated with managing ASS, and describes how to manage ASS in a range of aquatic environments in a drying climate.
Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland (Ahern C. R. et al., 1998)	These guidelines provide a State-wide standard, sampling and analysis regime, to enable accurate assessment of environmental impact prior to disturbance of acid sulphate soils (ASS)—the term includes potential acid sulfate soils (PASS). The guidelines are intended to enable objective decisions regarding the management of ASS to be made, in a manner consistent with the principles of ecologically sustainable development and best practice environmental management.
Best Practice Erosion & Sediment Control (International Erosion Control Association (IECA), 2008)	This publication set provides guidance on erosion and sediment control best practice within Australia. It contains the necessary strategies and techniques to assist erosion and sediment control practitioners to reduce the degradation of land and water from uncontrolled erosion and sedimentation. This publication set has been, and will continue to be, referenced in the planning, development and implementation of erosion and sediment control measures for the Project.

8.4 Methodology

This section provides an overview of the methodology adopted for the assessment of land resources, as documented in this chapter.

8.4.1 Data sources

This assessment has been prepared in reference to published datasets and literature, in addition to site-specific geotechnical and soils data collected during investigations undertaken to inform the development of the reference design and draft EIS for the Project. The policies, standards and guidelines that have been referenced for this assessment have been presented in Table 8.2.

Other publicly available sources of information that have been accessed and used in this assessment are as follows:

- Department of Natural Resource, Mines and Energy's (DNRME) Queensland geology series dataset
- Detailed solid and surface geology (Department of Natural Resources, Mines and Energy (DNRME), 2017a)
- *The Atlas of Australian Soils* (Northcote et al., 1960–68)
- The Australian Soil Resource Information System (ASRIS)
- The Agricultural Land Audit dataset (Department of Agriculture, Fisheries and Forestry (DAFF), 2013; updated in 2017)
- Topographical contour mapping (DNRME, 2017a)
- The Department of Defence UXO Mapping Application Information (Department of Defence, 2017)
- DNRME Soil Conservation Plans (under the *Soil Conservation Act 1986* (Qld))
- Department of Environment and Science (DES) Environmental Management Register (EMR) and Contaminated Land Register (CLR).

An assessment of land resources was undertaken to identify and assess the risks arising from the disturbance and excavation of land and the disposal of soil and spoil. The assessment was conducted in accordance with statutory requirements and guidelines identified for Queensland as shown in Table 8.2, which included the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia (SSA), 2015). The guideline recommends a 1:250,000 scale of soil mapping for characterisation of soil for an EIS.

8.4.2 Geotechnical and soil investigations

Between May 2018 and February 2019, geotechnical, soils and hydrogeological investigations were undertaken within the Project footprint with the objective of obtaining data to inform development of the reference design and the draft EIS.

The geotechnical and soils components of these investigations included the following:

- Seismic refraction surveys
- Boreholes
- Auger holes.

Seismic refraction surveys

Seismic refraction surveys were undertaken at 27 locations where bridge structures and deep cutting locations were proposed during development of the reference design. The purpose of the seismic refraction surveys was to assist in confirming or repositioning proposed intrusive investigation locations, to provide a more continuous record of subsurface conditions and to assess depth to bedrock.

The seismic survey was carried out in accordance with American Society for Testing and Materials (ASTM) Standard D5777: *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation* (ASTM, 2018).

Boreholes

Fifty-three geotechnical boreholes were commenced using a solid stem auger prior to being progressed by rotary drilling (water flush) techniques. If rock that was suited to rotary coring was encountered, then this drilling technique was used to complete the borehole. Boreholes not requiring future groundwater monitoring were backfilled with drilling waste with an 'Octoplug' installed into the borehole to assist in compacting the top metre of backfill.

Boreholes that were converted into groundwater monitoring bores are discussed in Chapter 13: Groundwater.

Auger holes

Forty auger holes were drilled, using a solid stem auger. Soils that rose on the auger were described, and the auger was lifted to the surface at intervals to allow nominally undisturbed (U50, U63, U75) tube sampling and standard penetration testing (SPT) to be undertaken. Bulk disturbed samples of soil were recovered using a 300 mm diameter auger within the top 1.5 m depth. Each auger hole was terminated at its proposed target depth or at a depth of auger practical refusal (maximum depth for these auger holes was 2.96 m below ground level (bgl)). Soil descriptions were made based on the drill cuttings and recovered samples. On completion, each auger hole was backfilled with drill cuttings.

Laboratory testing

Soil and rock samples collected from the above-mentioned drilling locations were analysed by a National Association of Testing Authorities (NATA) accredited laboratory.

Analysis of soil and rock samples for geotechnical purposes were carried out in accordance with current testing standards outlined in:

- AS1289—*Methods of testing soil for engineering purposes*
- AS4133.0—*Methods of testing rocks for engineering purposes*
- American Society for Testing and Materials (ASTM) test methods
- Roads and Maritime Services Test (RMST) methods.

Geotechnical analysis of Project soil samples included the following:

- Moisture content determination (AS1289 2.1.1): 120 tests performed
- Particle size distribution (AS1289 3.6.1): 84 tests performed
- Atterberg limits and linear shrinkage (AS1289 2.1.1, 3.1.2, 3.2.1, 3.3.1 and 3.4.1): 42 tests performed
- Shrink/swell properties (AS1289 7.1.1): 5 tests performed
- Emerson class number (AS1289 3.8.1): 47 tests performed
- Aggressivity testing suites, including pH, soluble sulfate and chloride content: 23 tests performed.

Bore logs and certificates of analysis for geotechnical testing are provided in Appendix G: Geotechnical Investigation Data.

In addition to geotechnical analysis, 44 soil samples from 24 auger holes were analysed for the following analytes:

- Sodium adsorption ratio—a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste
- Cation exchange capacity—the total capacity of a soil to hold exchangeable cations. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification
- Exchangeable sodium percentage—measure of sodium ions relative to other cations.

Soil analysis did not extend to potential contaminants. Details of results of these tests are provided in Section 8.5.3.1. Laboratory results for soil analysis is included in Appendix H: EMR Certificates and Soil Laboratory Certificates.

The soil physical and chemical analysis has been used to complement published soil data from previous soil assessments of relevance to the impact assessment area, and to verify published soil mapping (refer section 8.5.3). More geotechnical and soil sampling locations were targeted during the planning for these investigations; however, restrictions such as limited access to sections of operational rail corridor (one third of the Project alignment), meant that not all of the targeted locations could be investigated.

The development of a reference design is an interactive process and the Project footprint remains subject to confirmation through the detail design process. Consequently, it was considered to be of limited value to undertake soil sampling and analysis at a more intensive scale during the reference design stage for a Project of this nature. In acknowledging the preliminary nature of geotechnical and soil investigations undertaken to date, ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 8.7.2). Additional soil data will be incorporated into the final EIS and will enable identification of potential/actual problematic soils including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants.

The methodology for the detailed soil investigation will be developed in consultation with DNRME and will be in accordance with the *Guidelines for surveying soil and land resources* (McKenzie et al., 2008), the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015). Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner. Weather permitting, these additional investigations will commence in the first quarter of 2021.

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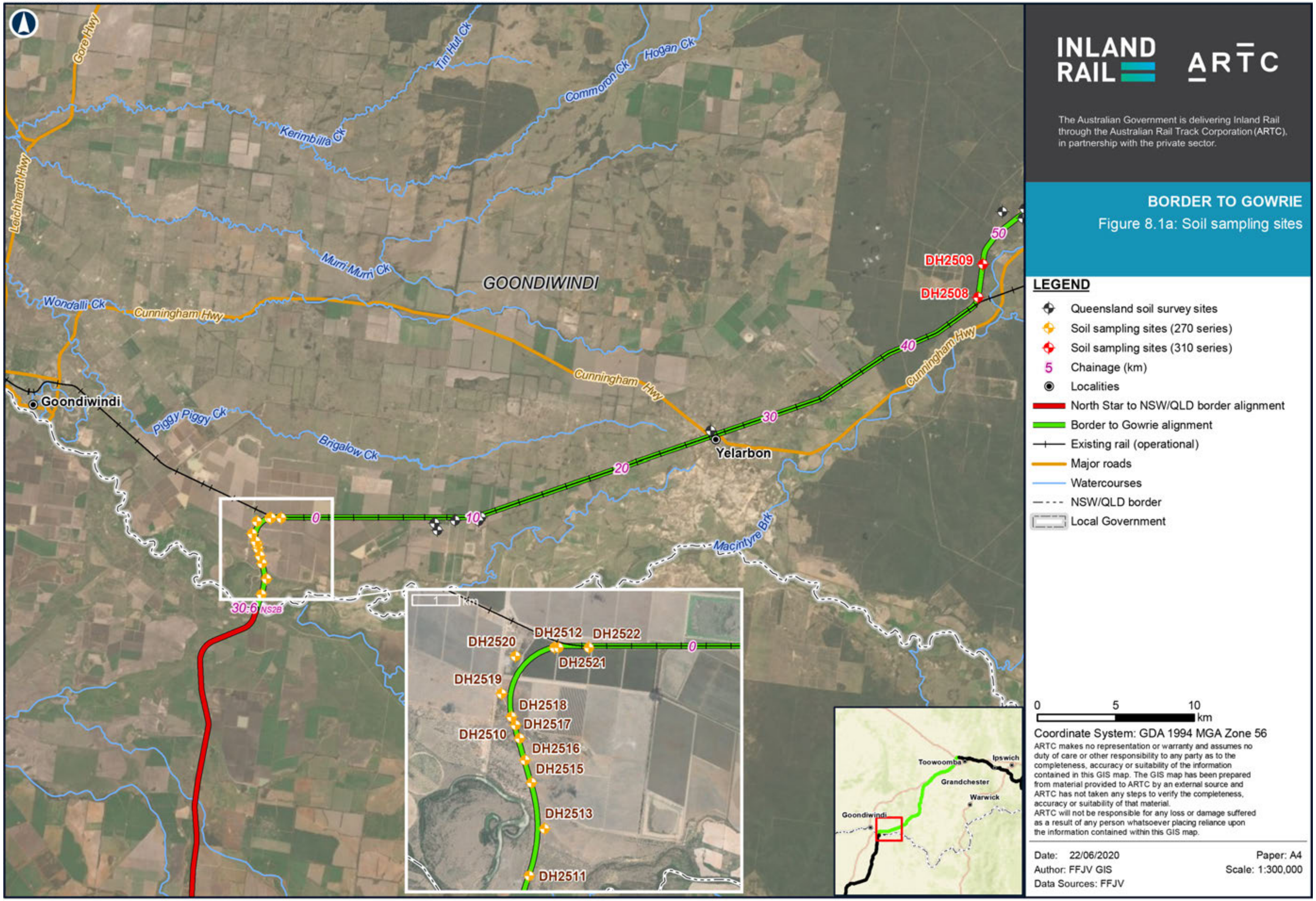

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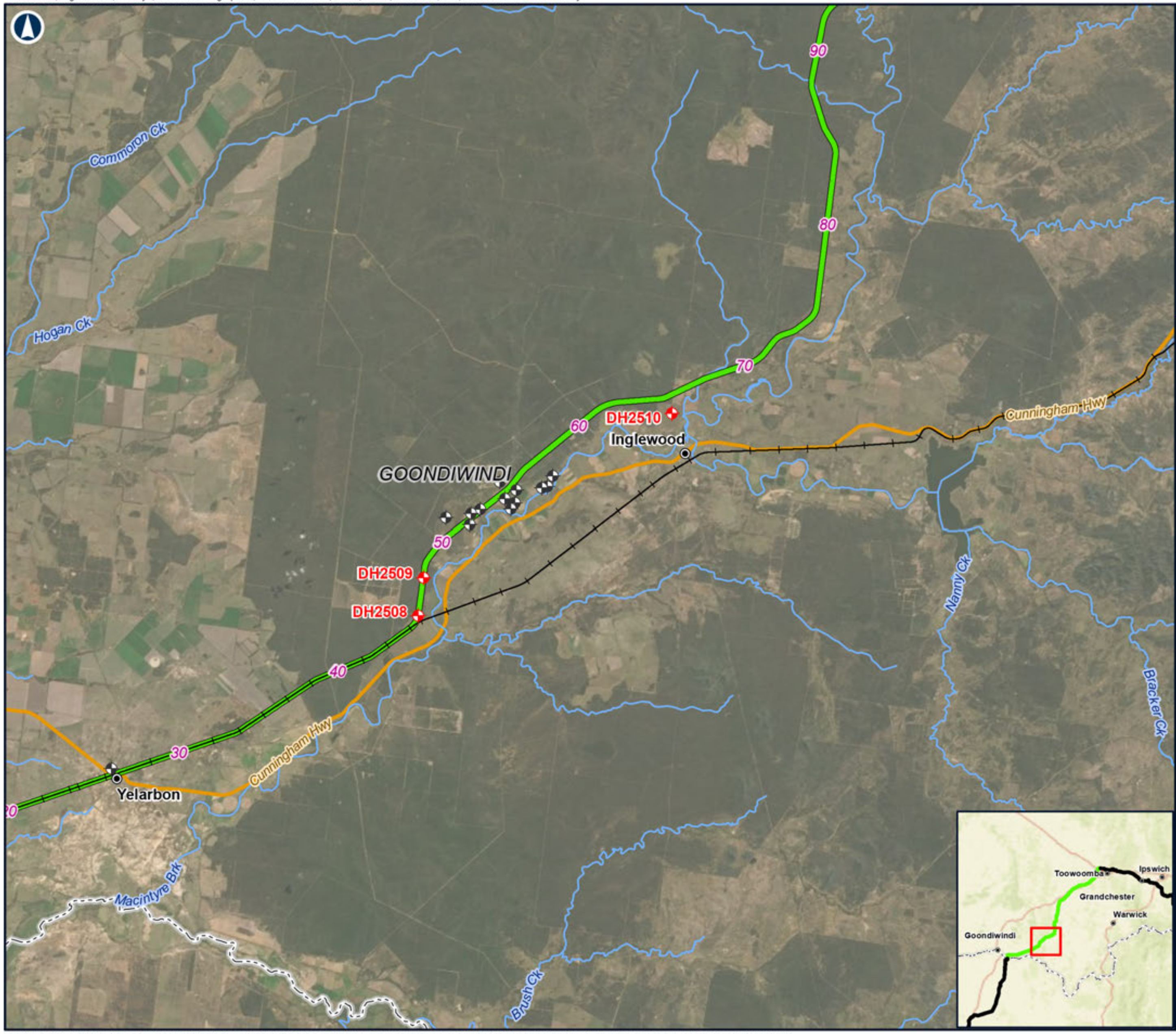

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BORDER TO GOWRIE

Figure 8.1b: Soil sampling sites

LEGEND

- Queensland soil survey sites
- Soil sampling site (310 series)
- Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Watercourses
- NSW/QLD border
- Local Government

0 5 10 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 26/06/2020 Paper: A4
Author: FFJV GIS Scale: 1:300,000
Data Sources: FFJV

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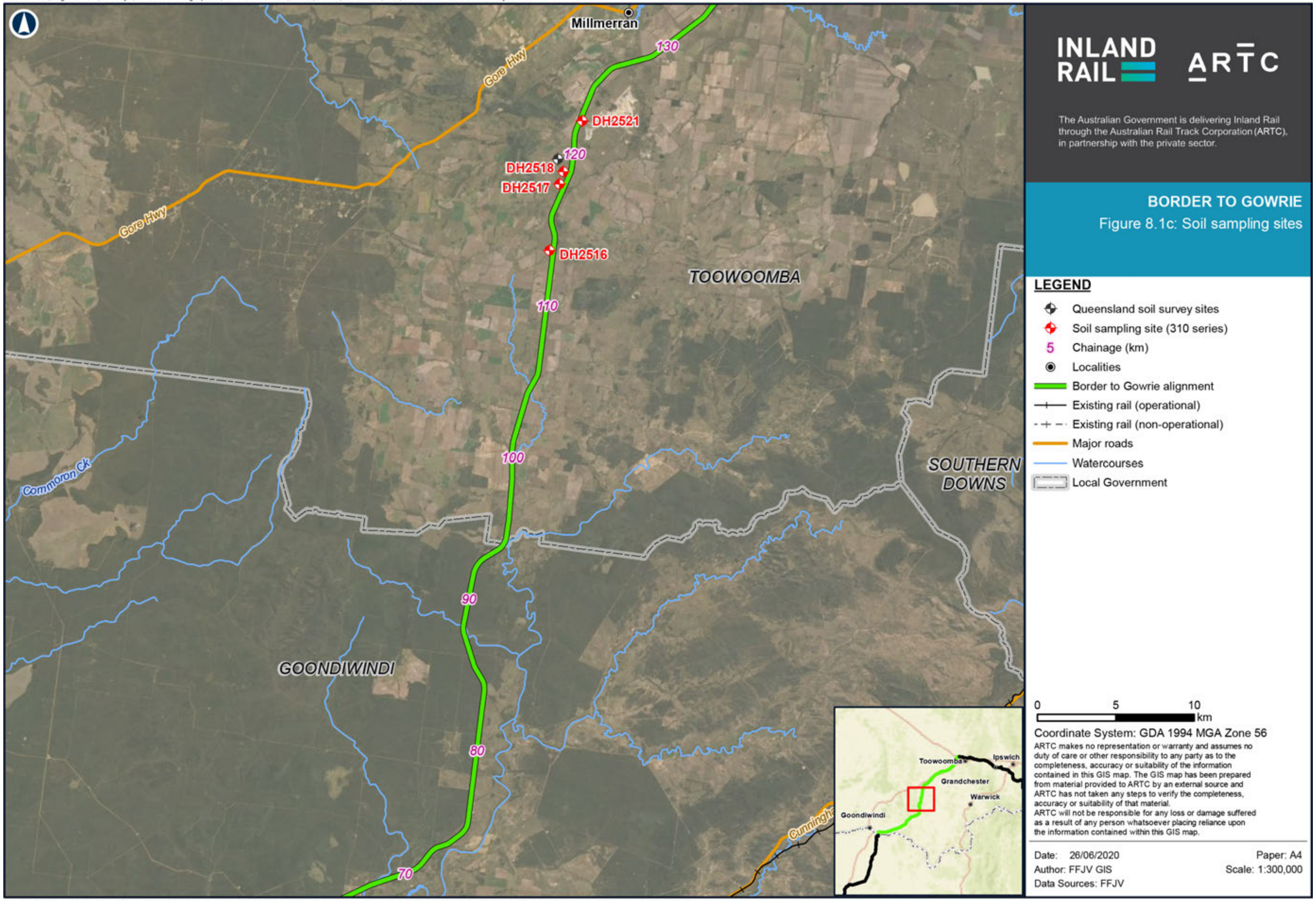

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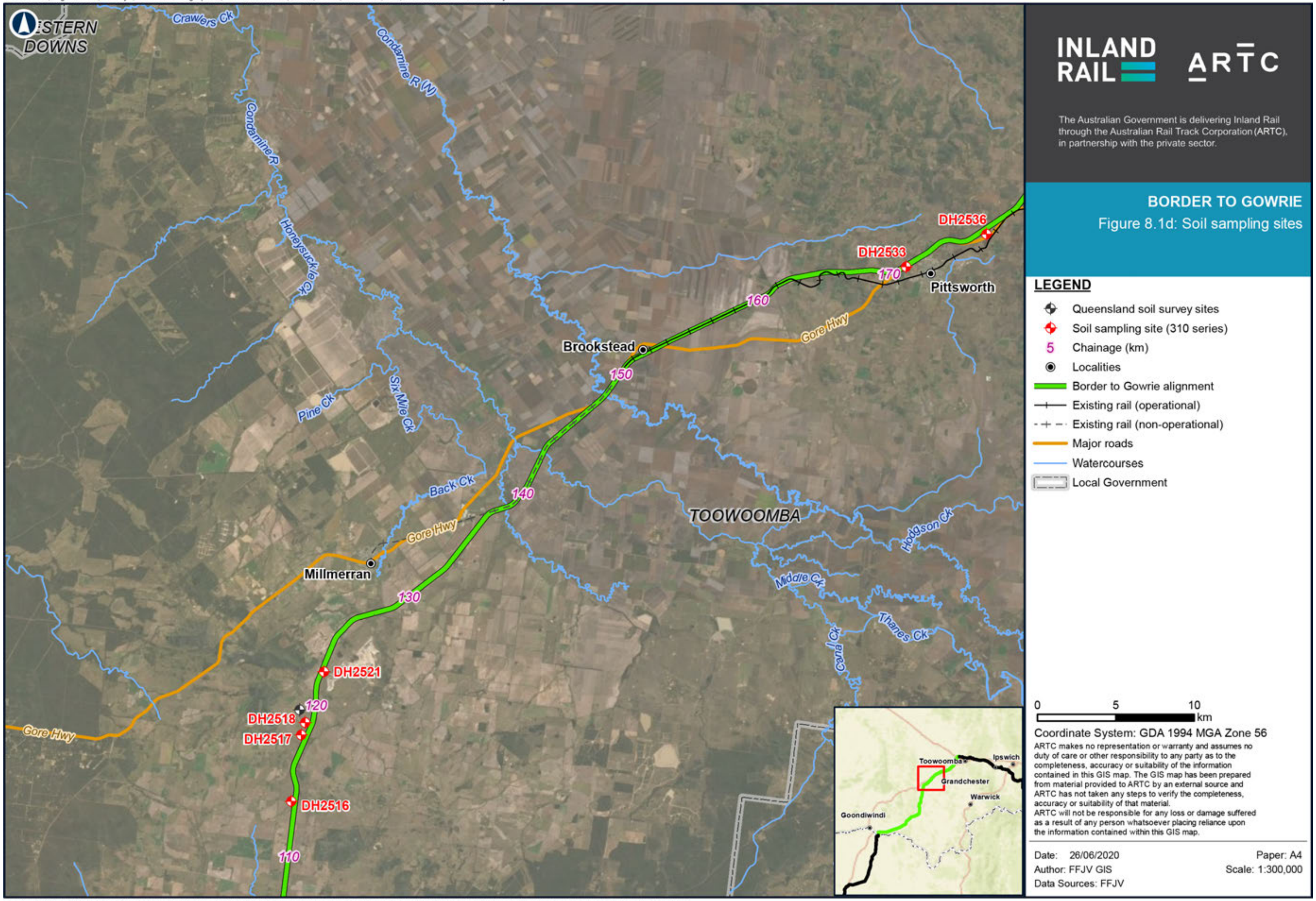

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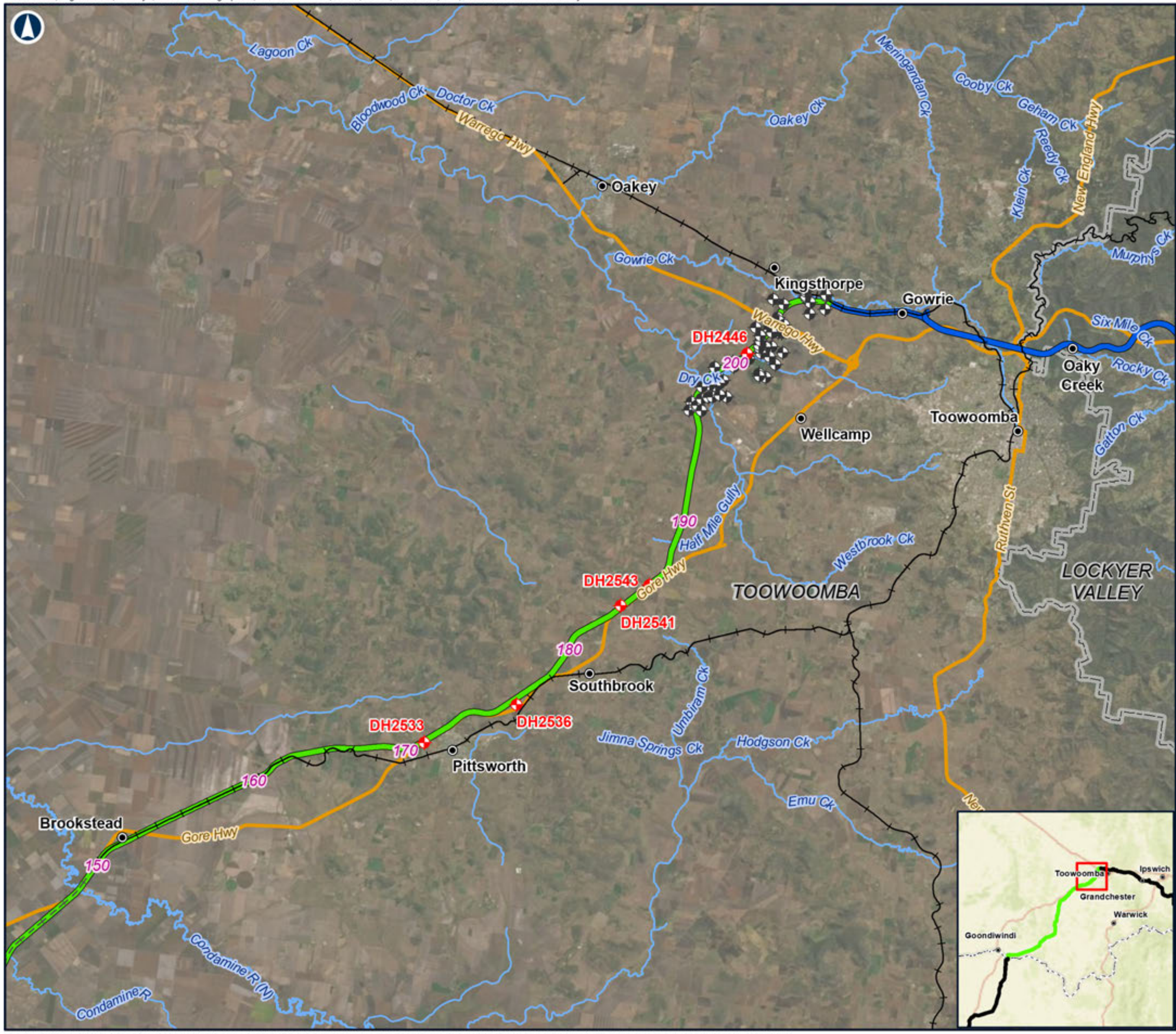

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BORDER TO GOWRIE

Figure 8.1e: Soil sampling sites

LEGEND

- Queensland soil survey sites
- Soil sampling site (310 series)
- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Watercourses
- Local Government

0 5 10 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:300,000
Data Sources: FFJV

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8.4.3 Contamination assessment

The land resources assessment included a Tier 1 Preliminary Site Investigation (contaminated land assessment), in accordance with ASC NEPM. A Tier 1 Preliminary Site Investigation was undertaken to identify the potential for contamination within the impact assessment area. This type of assessment is used to assess the potential for the land to pose a risk to ecological and human health receptors due to potentially contaminating activities. The assessment of contaminated lands was conducted by a suitably qualified person in accordance with the relevant Department of Environment and Science (DES) requirements.

8.4.4 Impact assessment methodology

The impact assessment for land resources was undertaken using both quantitative compliance risk assessment and qualitative risk assessment methodologies. Detailed descriptions of these methods are presented in Chapter 4: Assessment Methodology.

A quantitative compliance risk assessment was undertaken for:

- Soil properties, including:
  - Erosion and sedimentation
  - Problematic soils (i.e. saline, dispersive and reactive soils).

A qualitative risk assessment was undertaken for:

- Contaminated land, including:
  - Existing contaminated land
  - Construction risks (e.g. hydrocarbon spills)
  - Operational risks (e.g. hydrocarbon spills, use of pesticides/herbicides).
- Agricultural land, including soil conservation plans
- Geology, topography and geomorphology
- ASS/acid rock
- Naturally occurring asbestos
- UXO.

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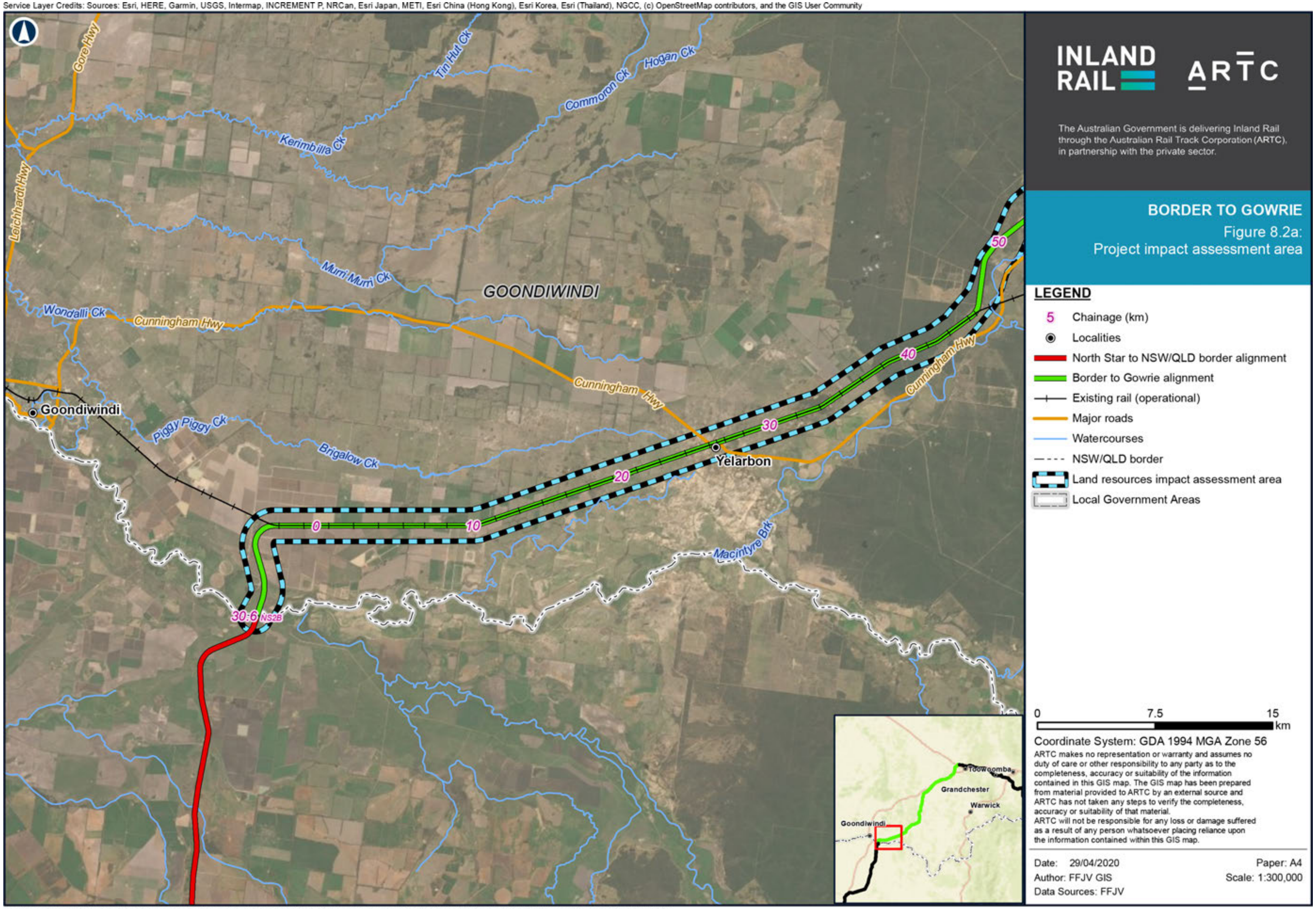

BORDER TO GOWRIE
Figure 8.2a:
Project impact assessment area

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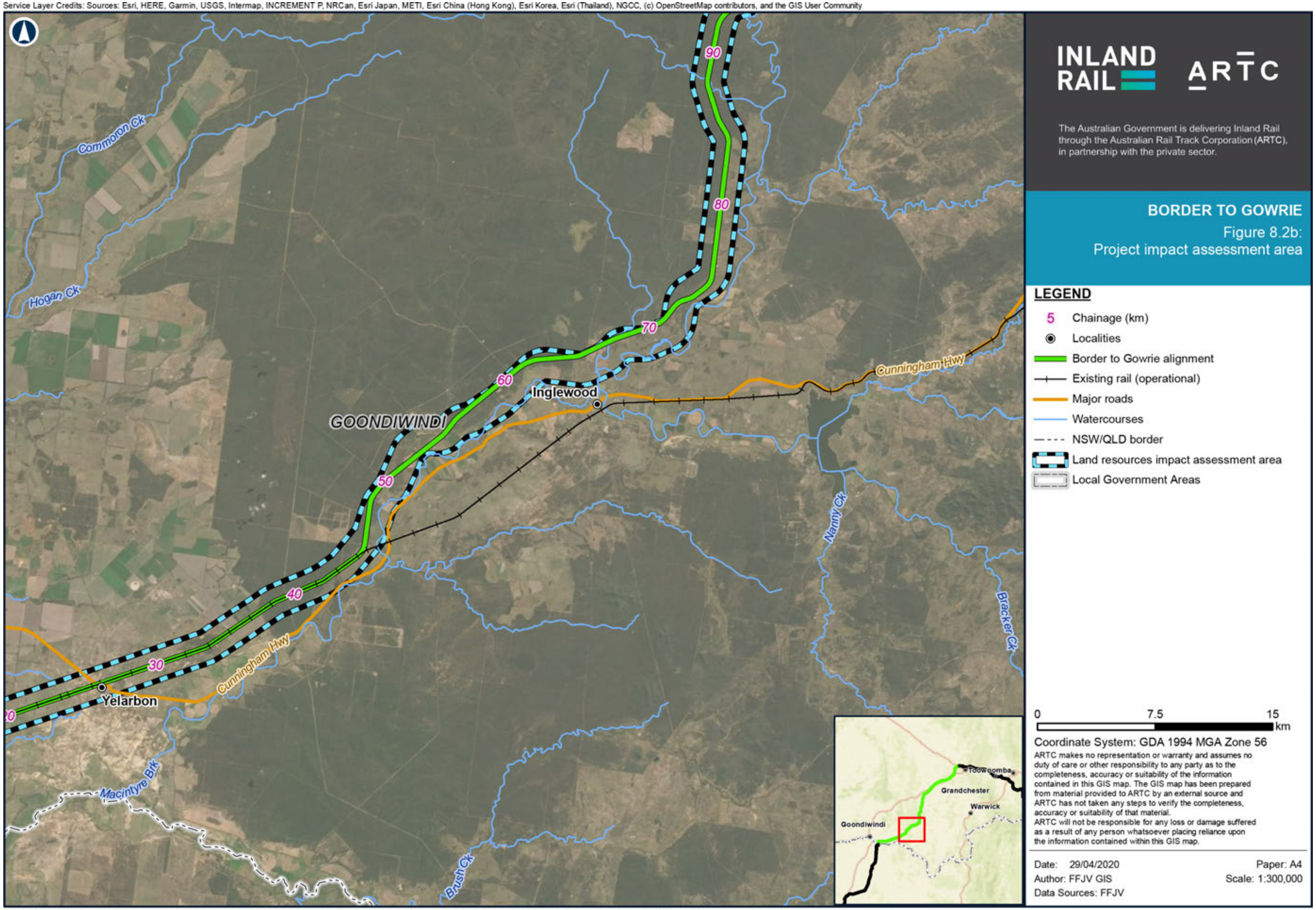

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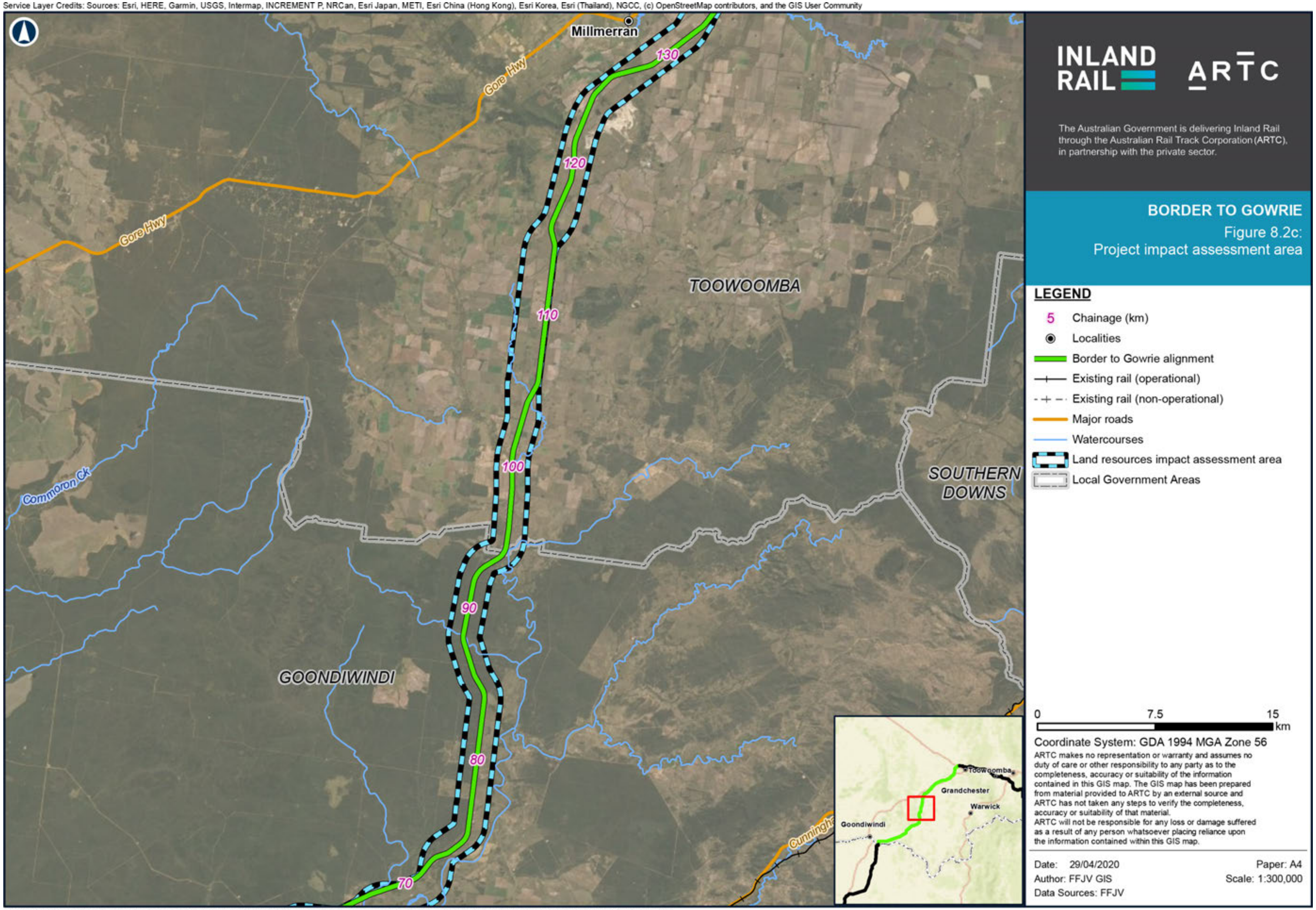

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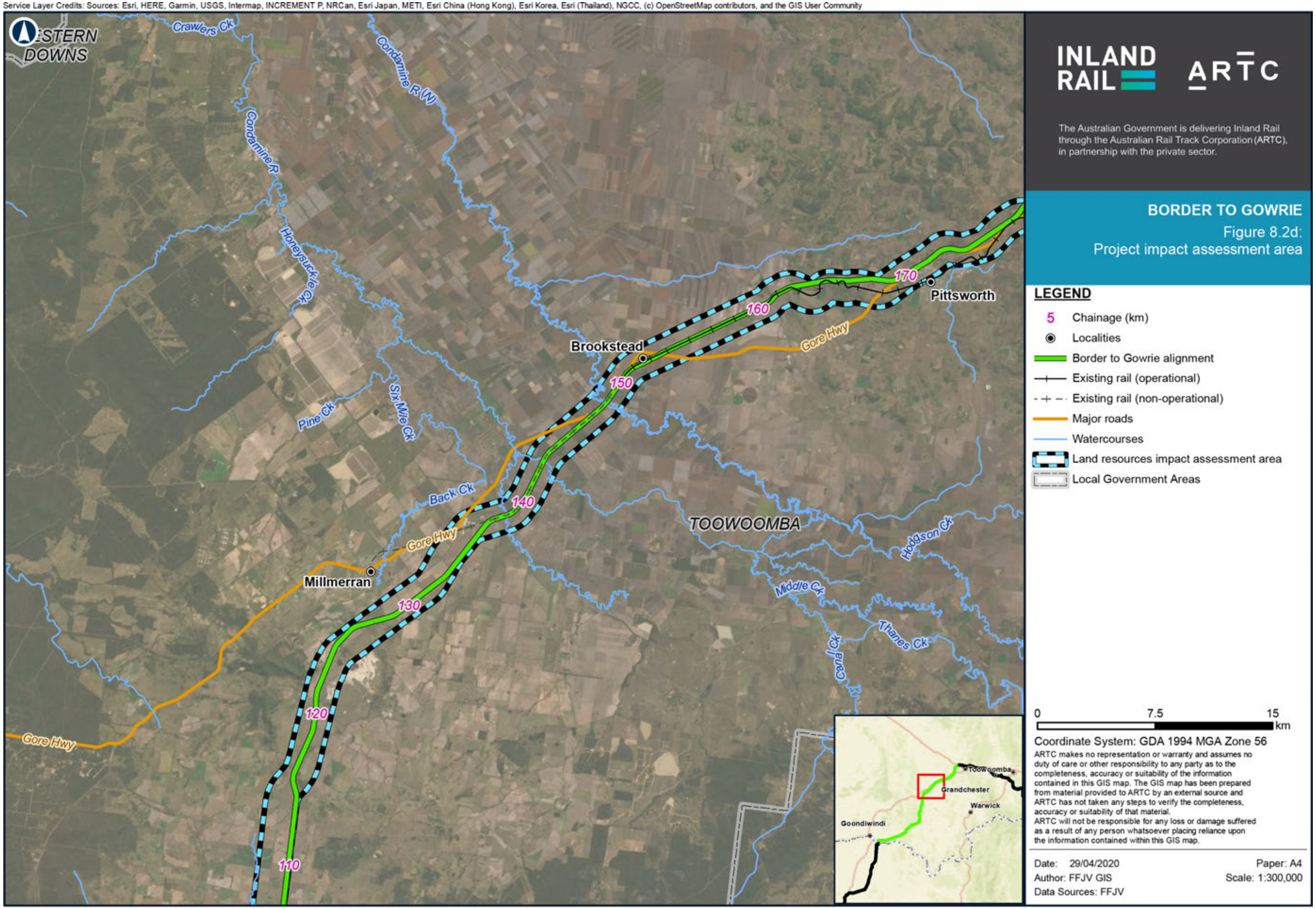

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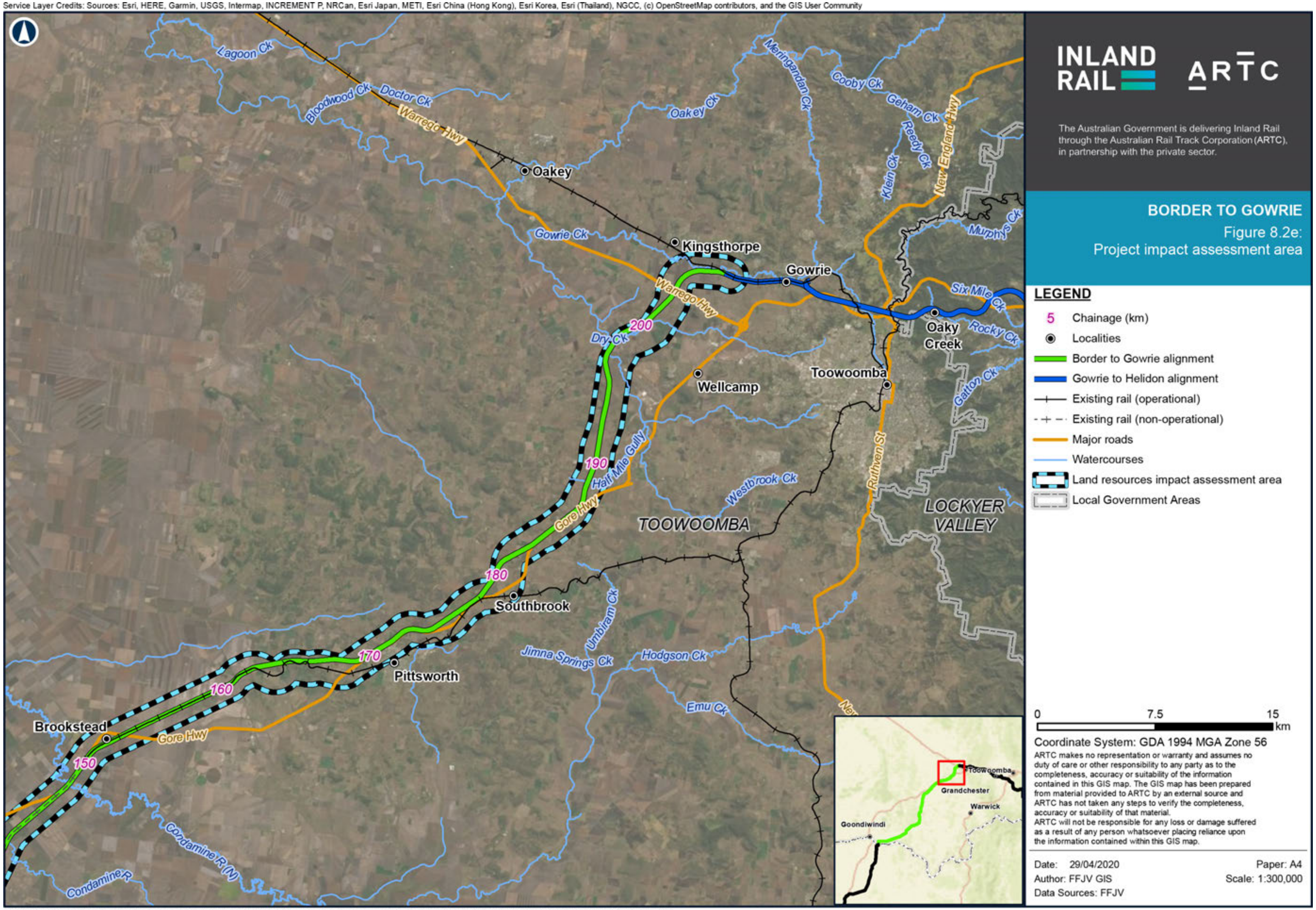

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8.4.5 Impact assessment area

The impact assessment area for land resources is a 2-km wide corridor (1 km either side of the alignment), which consists of the permanent and temporary footprints for the Project, including the location of all permanent Project infrastructure and the land temporarily required to enable construction.

The impact assessment area adopted a 2-km wide corridor after an initial assessment found a limited extent of relevant intensive industrial activities or potentially contaminating activities. A service station 300 m outside the 2 km corridor (refer Section 8.5.6.1) was assessed as a conservative measure, due to its proximity and land use.

The extent of the impact assessment area is shown in Figure 8.2.

8.5 Existing environment

8.5.1 Geological and topographical setting

8.5.1.1 Topographical setting

Elevation

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–Balonne catchments (Bureau of Meteorology (BOM), 2017a).

The Project has been aligned to avoid steep slopes, where possible, and therefore negate the risk of landslide. The Project's lowest point of elevation occurs at the southern end of the rail alignment at the Macintyre River with an approximate elevation of 227 m.

From this point, elevation along the Project alignment generally increases steadily at an average slope of 0.5 per cent in a northward direction towards Mount Domville and Commodore Peak, south of Millmerran. The Project alignment peaks at 482 m at Chainage (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 at an average slope of 1.6 per cent (maximum of 3.3 per cent) 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, at an average slope of 1.7 per cent (maximum of 5 per cent).

Topography of the impact assessment area is shown on Figure 8.3.

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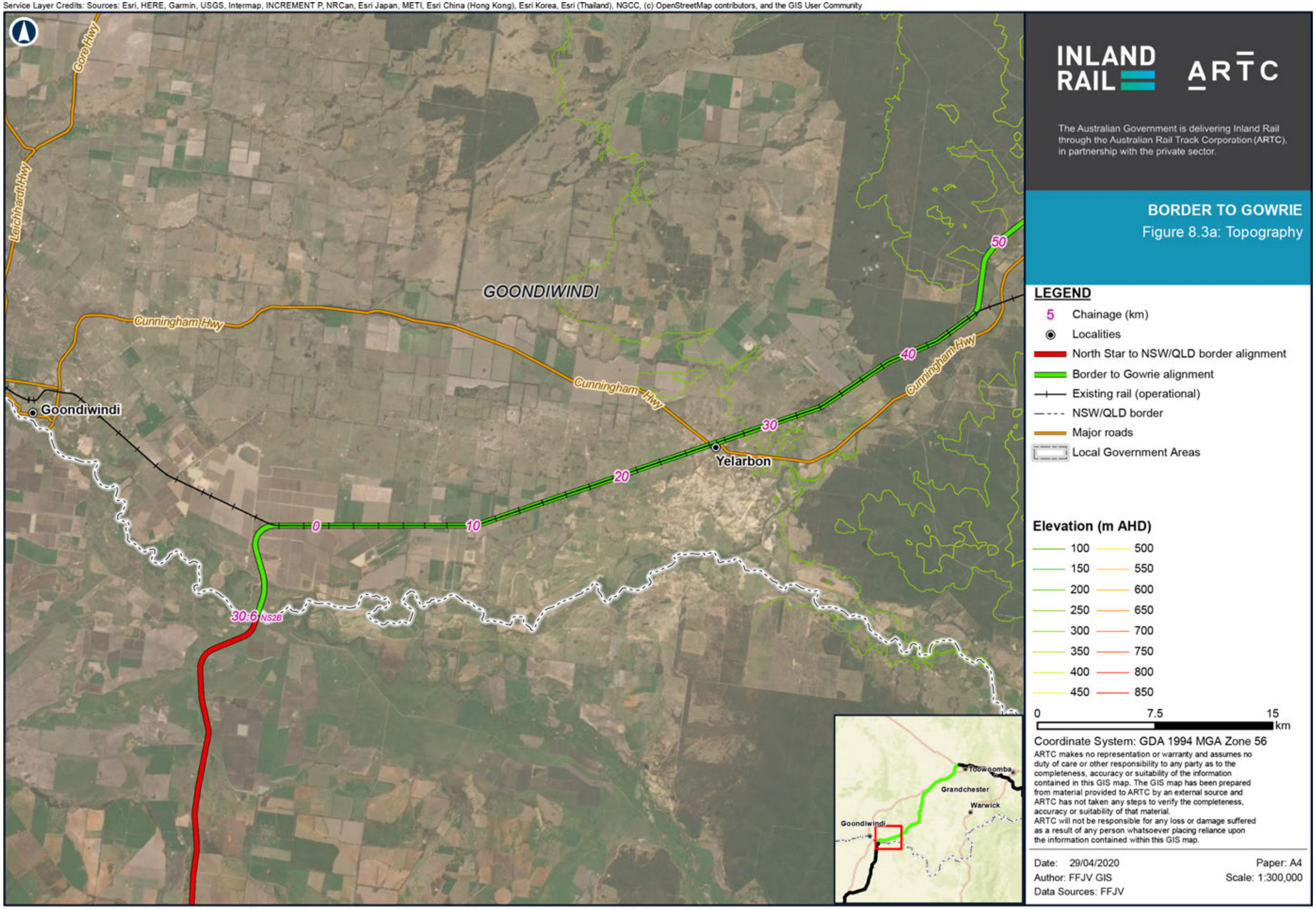

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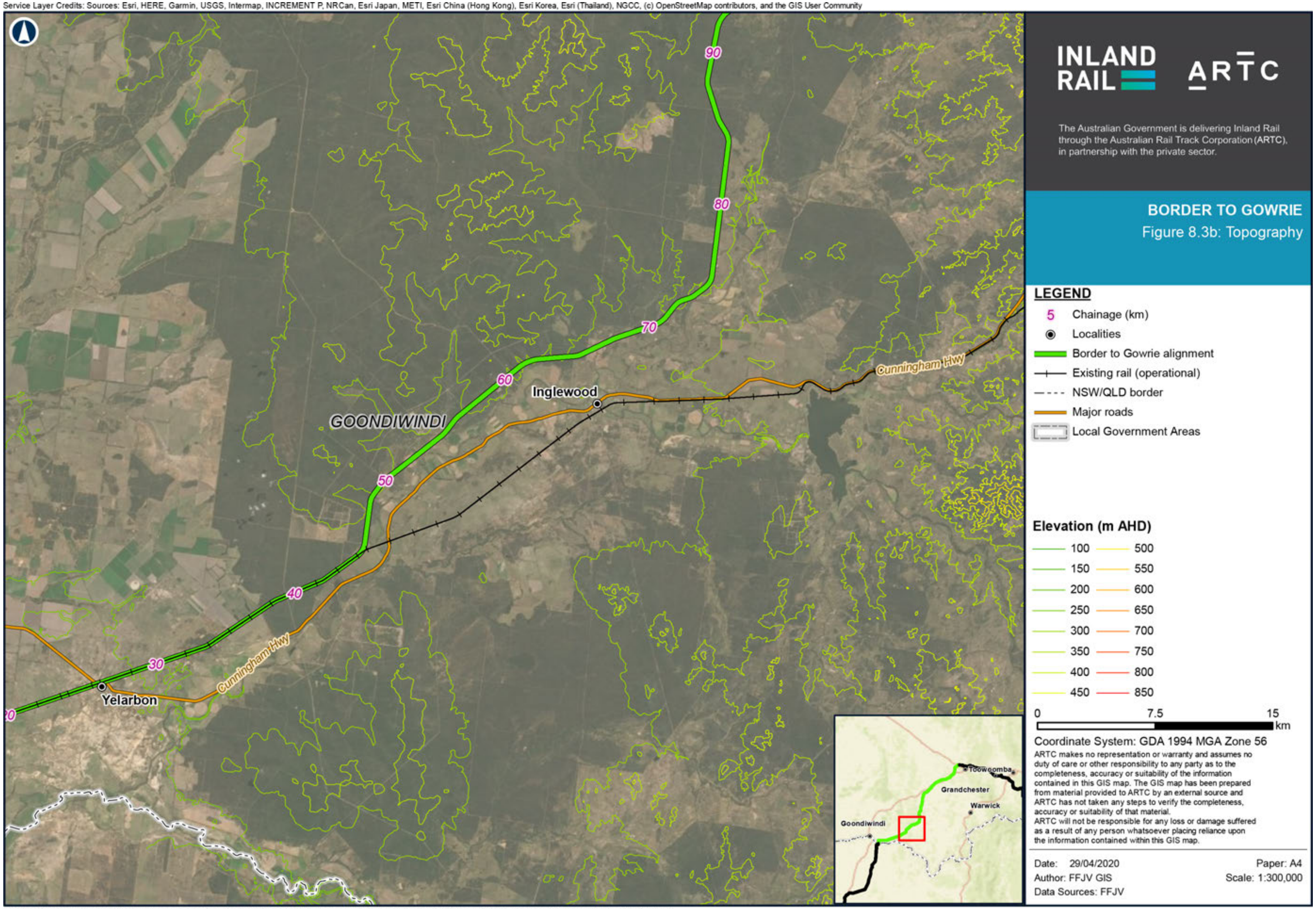

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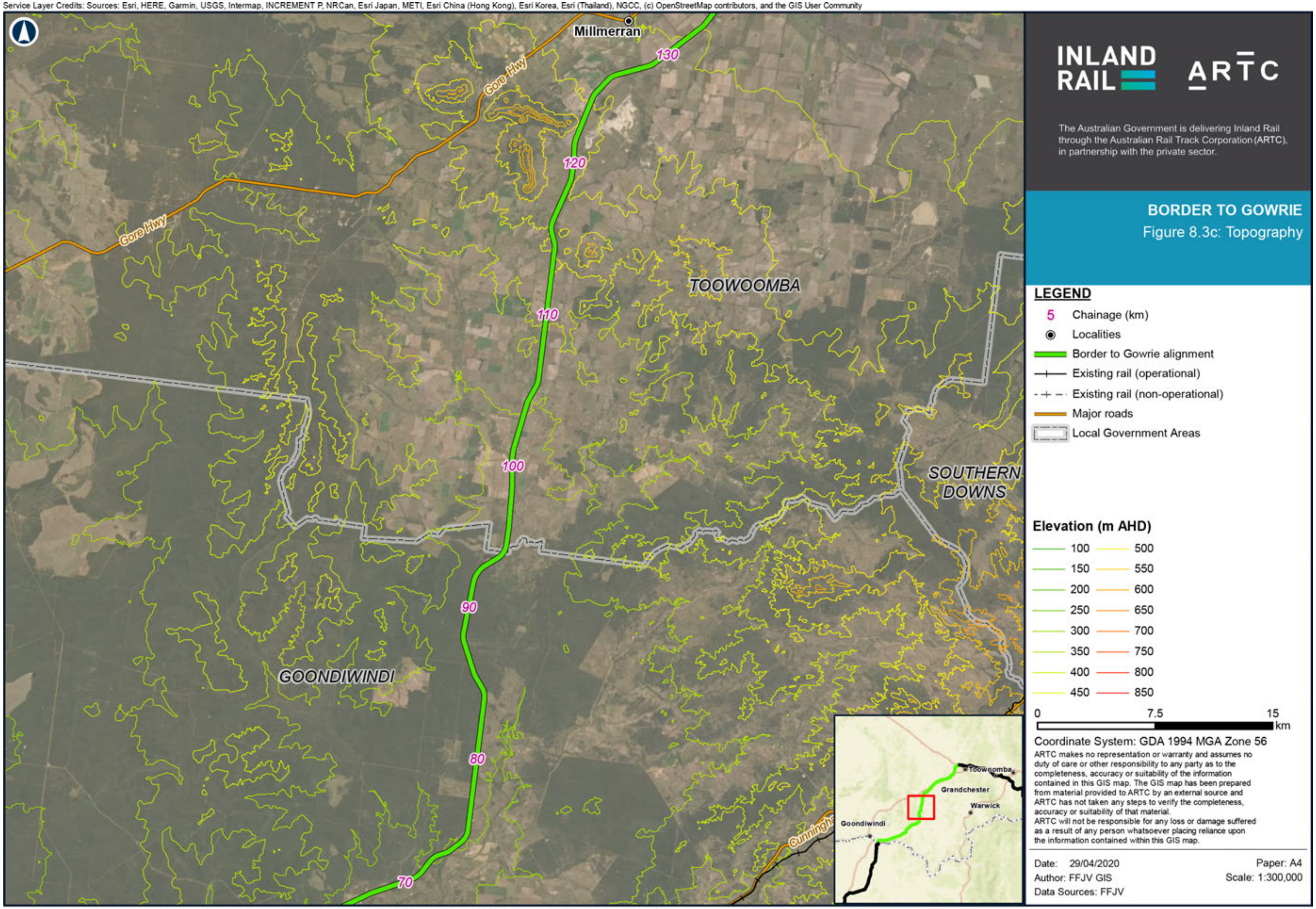

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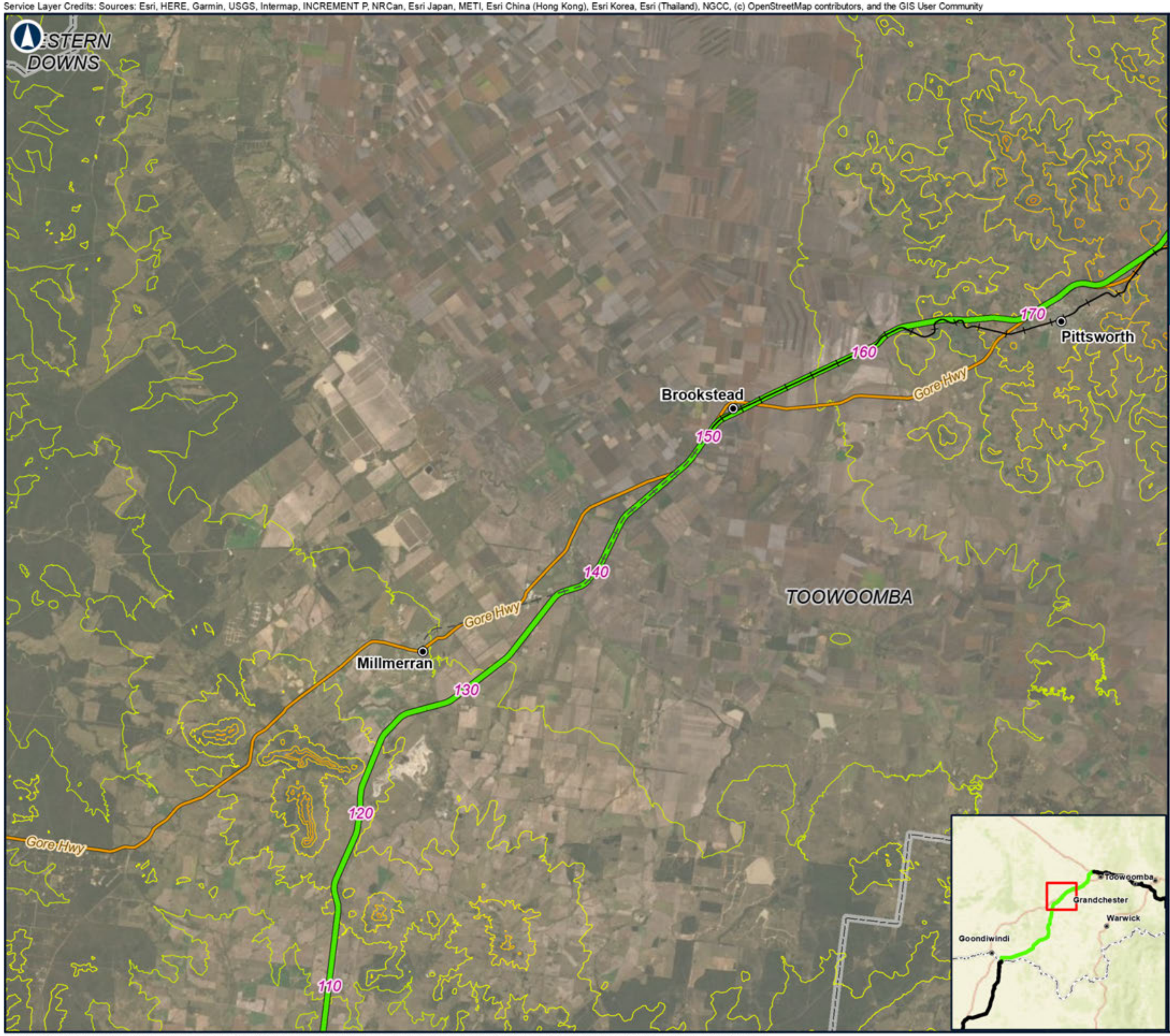

INLAND RAIL ARTC

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

BORDER TO GOWRIE

Figure 8.3d: Topography

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Local Government

Elevation (m AHD)

100	500
150	550
200	600
250	650
300	700
350	750
400	800
450	850

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 29/04/2020 Paper: A4
Author: FFJV GIS Scale: 1:300,000
Data Sources: FFJV

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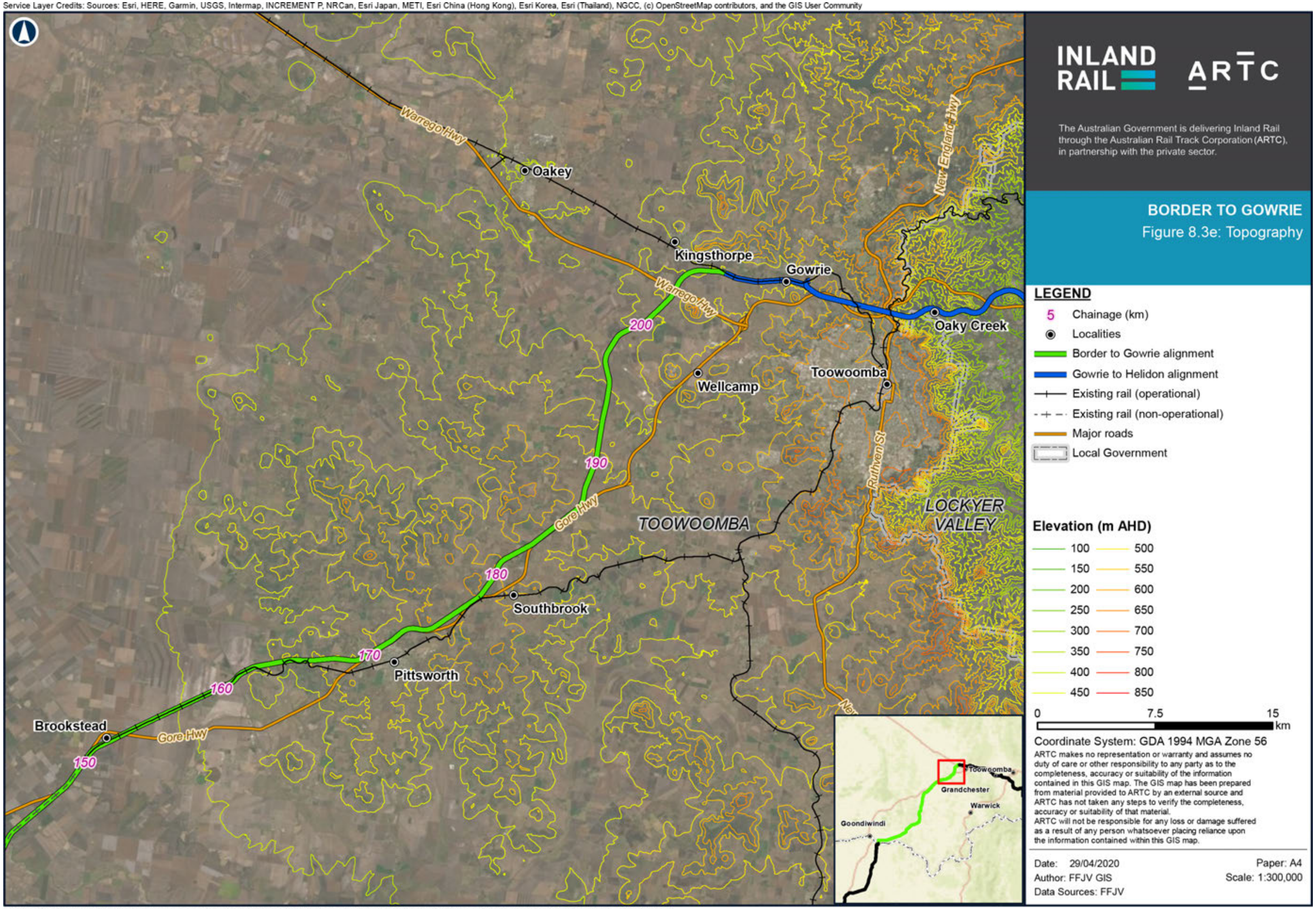

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Catchments

The Project is located across two surface water catchment areas, the Condamine River basin and the Border Rivers basin. The Project alignment extends through the Border 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.

The Border Rivers basin covers approximately 23,800 square kilometres (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, 2019c). This basin resides predominantly in Queensland with a portion extending into New South Wales.

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 New South Wales (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. Tributaries of the Condamine River include Emu Creek, Glengallan Creek, Hodgson Creek, Oakey Creek, Wilkie Creek and Charleys Creek.

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

The Project alignment passes through floodplains associated with the following waterways and their tributaries:

- Macintyre River
- Macintyre Brook
- Pariagara Creek
- Cattle Creek
- Native Dog Creek
- Bringalily Creek
- Nicol Creek
- Back Creek
- Condamine River
- Westbrook Creek and Dry Creek
- Gowrie Creek.

The details provided above are intended to give context to the discussion of geology and soils within the impact assessment area. Further details on the existing surface water and hydrological conditions within the impact assessment area are provided in Chapter 12: Surface Water and Hydrology.

8.5.1.1 Geological setting

Eighteen geological units underlie the impact assessment area, which have been identified in reference to the 1:100,000 scale detailed surface geology map of Queensland (DNRME, 2017a). This geological mapping is illustrated in Figure 8.4.

Details of each of the units that occur within the impact assessment area are summarised in Table 8.3.

TABLE 8.3 GEOLOGICAL UNITS

Geological unit	Location	Age	Description
Quaternary sediments (Qs–SQ)	▸ Northern edge of Rainbow Reserve to Kurumbul ▸ Yelarbon ▸ Canning Creek to Yandilla	Quaternary	Red sandy soil, silt and some gravel, floodout on sheet sand with alluvium deposit Miscellaneous unconsolidated sediments are the dominant rock type
Kumbarilla Beds	▸ Kurumbul	Late Jurassic to early Cretaceous	Sandstone, siltstone, mudstone and conglomerate with kaolinized deeply weathered sediments Arenite-mudrock is the dominant rock type
Springbok Sandstone	▸ West of Yelarbon ▸ South of the Whetstone State Forest	Late Jurassic	Deeply weathered labile sandstone, siltstone, mudstone and potential of some coal Arenite-mudrock is the dominant rock type
Walloon Coal Measures	▸ Northern extent of impact assessment area crossing Whetstone State Forest ▸ West of Domville	Middle Jurassic	Shale, siltstone, sandstone and coal seam dominated by arenite-mudrock
Quaternary alluvium (Qa–QLD)	▸ Macintyre River to northern edge of Rainbow Reserve ▸ Southern extent of project impact assessment area bordering Whetstone State Forest ▸ Canning Creek to Glenroy	Quaternary	Clay, silt, sand and gravel on a floodplain dominated by alluvium
Eurombah formation	▸ West of Avondale	Jurassic	Clayey sub-labile sandstone, some conglomerate, siltstone and mudstone dominated by sedimentary rock types
TS–SEQ	▸ South of Millwood	Tertiary	Quartzose to sub-labile sandstone, claystone, conglomerate with minor olivine basalt
TQr/b–SEQ	▸ South of Clontarf	Late Tertiary to Quaternary	Residual deposits and pediment slope wash consisting of clay, scree and soil developed from basalt Dominated by colluvium
Qa/b–QLD	▸ Pampas	Quaternary	Silt and mud (black soil) with basalt-derived alluvium Dominated by alluvium
Tqs–QLD	▸ Brookstead	Late Tertiary to Quaternary	Clayey sand, gravel, silt and mud passing into semi-consolidated clayey sandstone, conglomerate and claystone consisting of local ironstone nodules and siltstone Dominated by poor, consolidated sediments
Main Range Volcanics	▸ Yarranlea to Gowrie	Eocene to Miocene	Olive basalt dominated by basalt rock
TQR/B–SEQ>Main Range Volcanics	▸ Wellcamp	Late Tertiary to Quaternary	Residual deposits on weathered Crows Nest Granite, dominated by miscellaneous and unconsolidated sediments
Marburg Subgroup (Koukandowie Formation)	▸ South of Millmerran ▸ Southwest of Grays Gate	Early to Middle Jurassic	Lithofeldspatic labile to sublabile sandstone, siltstone, shale, minor coal, ferruginous marker bed dominated by arenite mudrock
Qal–SEQ	▸ Northeast of Inglewood ▸ Bringalily	Quaternary	Silt and clay lakes in alluvial plains with stratified units including volcanic and metamorphic rock

Geological unit	Location	Age	Description
Texas Beds	▸ Northeast of Inglewood	Early Carboniferous	Thin- to thick-bedded, volcaniclastic arenite, siltstone, mudstone and slate; local phyllite; sporadic lenses of jasper, chert, limestone and mafic volcanics; rare conglomerate
Qa/b–QLD	▸ Pampas	Quaternary	Silt, mud (black soil); basalt-derived alluvium
Td/q–QLD	▸ Southwest of Grays Gate	Tertiary	Silcrete and silicified quartz sandstone; duricrust
Tqs–QLD>Main Range Volcanics	▸ South of Pittsworth	Late tertiary to Quaternary	Clayey sand, gravel, silt and mud passing into semi-consolidated clayey sandstone, conglomerate and claystone; local ironstone nodules, siltstone

Source: 1:100,000 scale detailed surface geology map of Queensland (DNRME, 2017a)

The Surat Basin, on which the impact assessment area is located, formed above the Bowen Basin during a period of steady subsidence, which was halted after a compressional system caused fault reactivation and volcanic activity within the basin. As a result of climatic events, the geology of the area contains large layers of sandstone with smaller layers of volcanics (Sander, R. et al., 2014).

The most common rock types found within the impact assessment area include sandstone, siltstone, mudstone, shale, coal and conglomerate. The landscape in the low-lying areas is mostly composed of undulating siltstone lowlands while sandstone dominates the hills with alluvial sediment and highly weathered bedrock found along floodplains of the Condamine River (Sander, R. et al., 2014).

Alluvial and colluvial deposits are also evident within the landscape, as shown in Figure 8.4, and can be attributed to recent Tertiary and Quaternary weathering and erosion (Willey, 2003). The main form of alluvium deposit in the region was likely caused by the weathering of prairie soils, black earths and grey clays, which have developed on finer-grained sediment. Alluvium deposits in the region potentially lead to the deposition of sand, silt or silty clay at the base of hillslopes and along floodplains (Department of Science, Information Technology, Innovation and the Arts (DSITIA), 2012).

Arenites are another rock present within the geological layers of the region. Arenites are identified as texturally clean, matrix-free or matrix-poor sandstone that allow cement precipitates to form in what were originally empty intergranular pores (University of Puerto Rico—Mayaguez (UPRM) Geology Department, 2012).

A study of the soil distribution and physical properties of each soil unit indicates that parent material strongly influences soil development within the impact assessment area.

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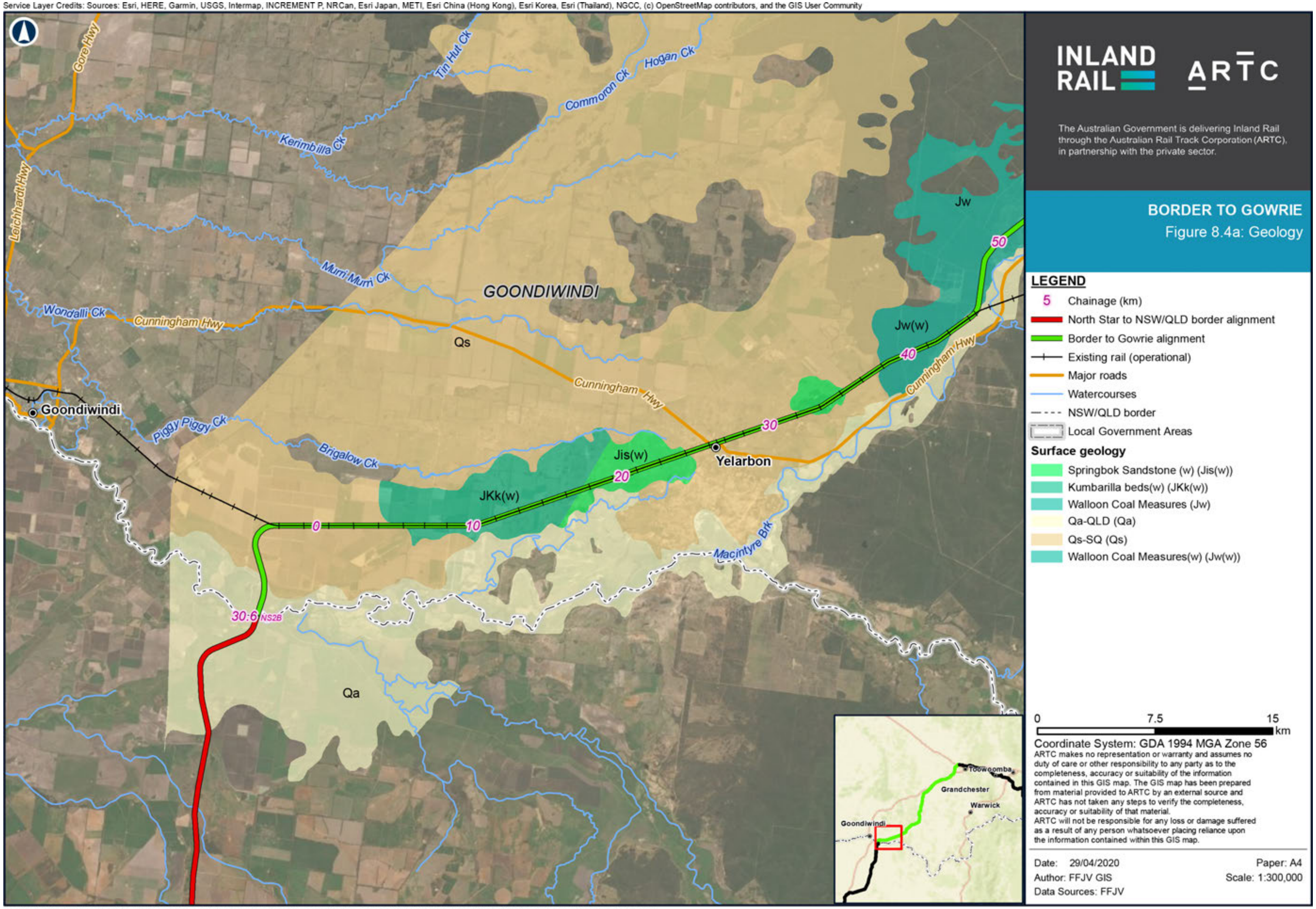

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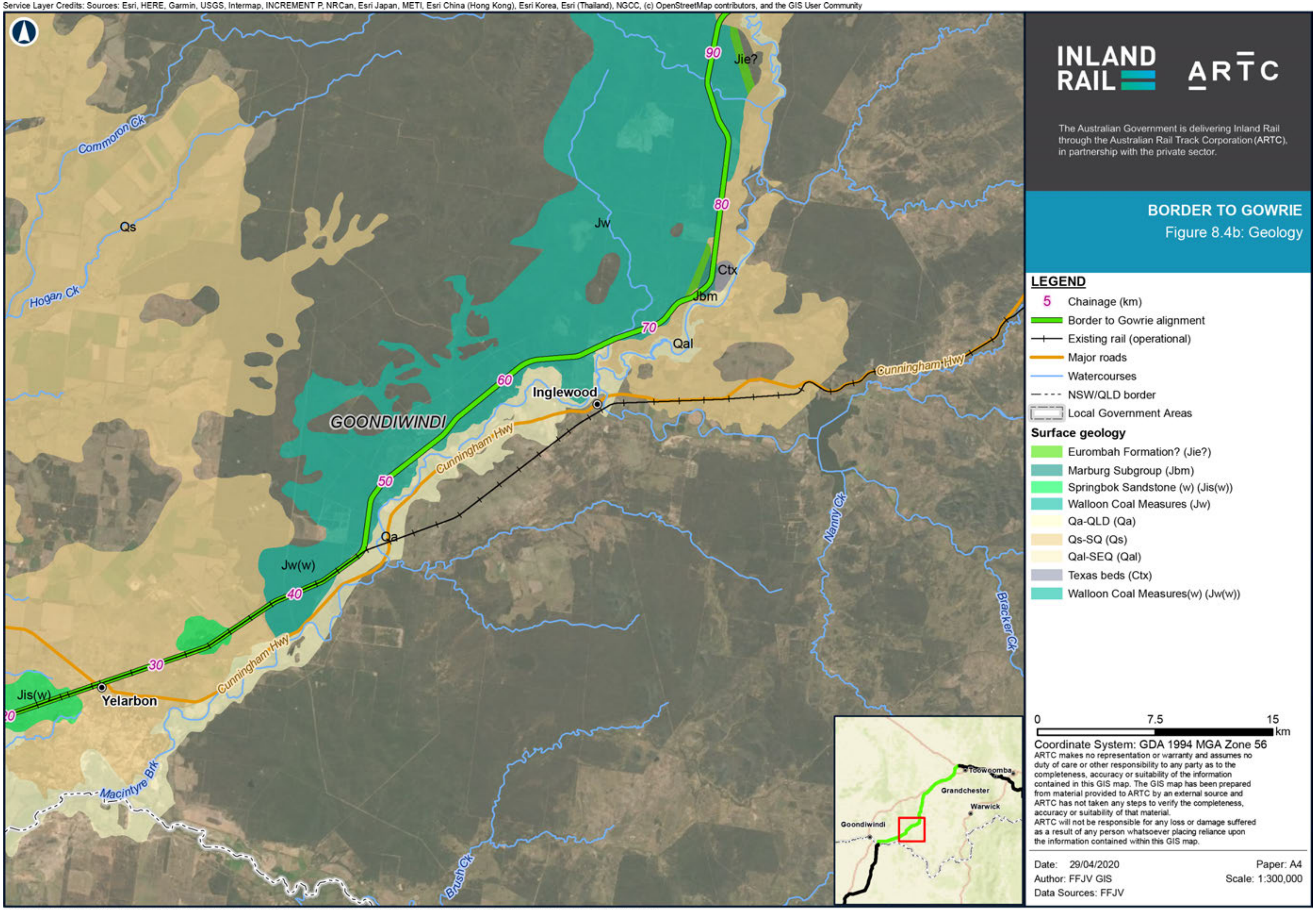

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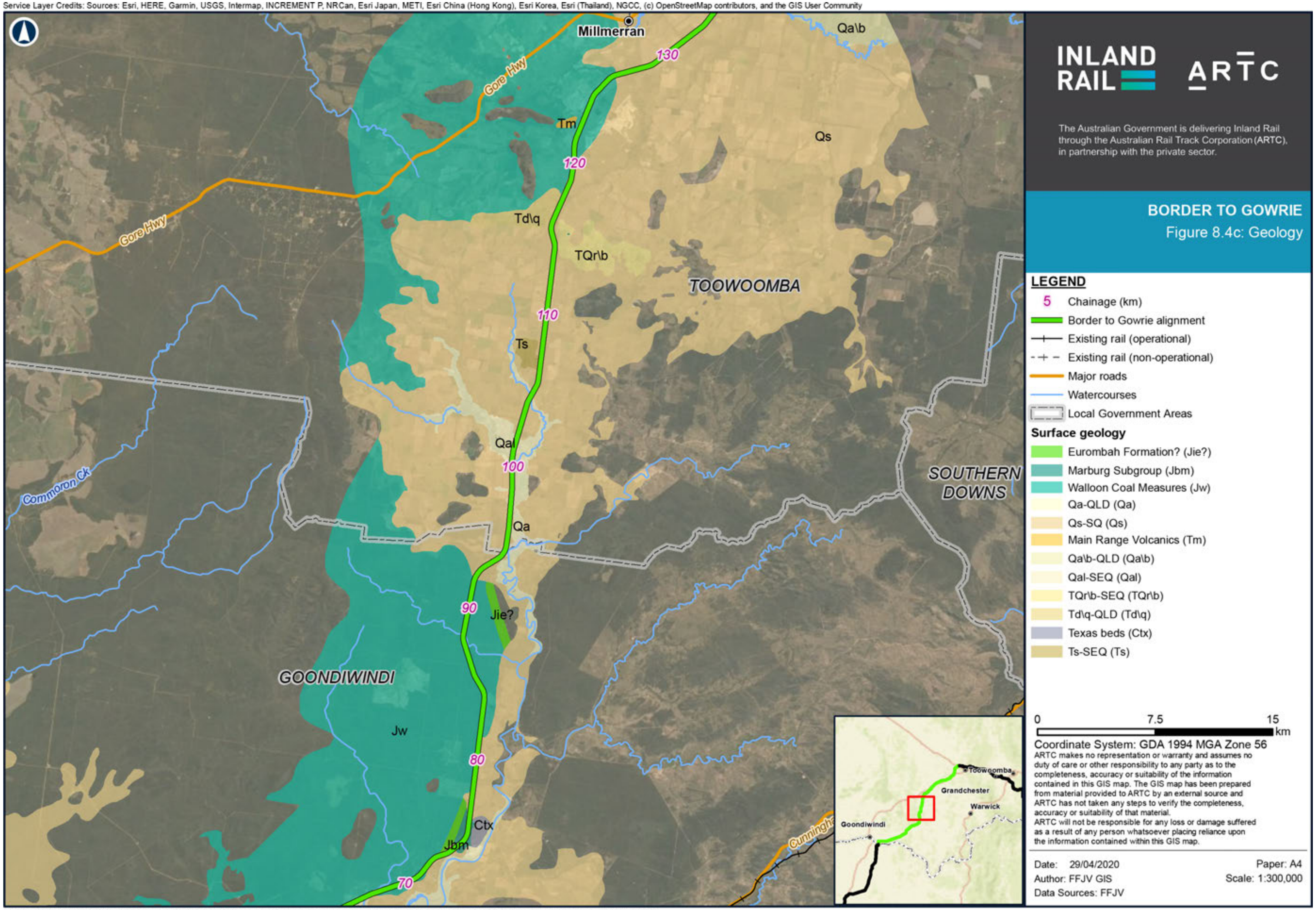

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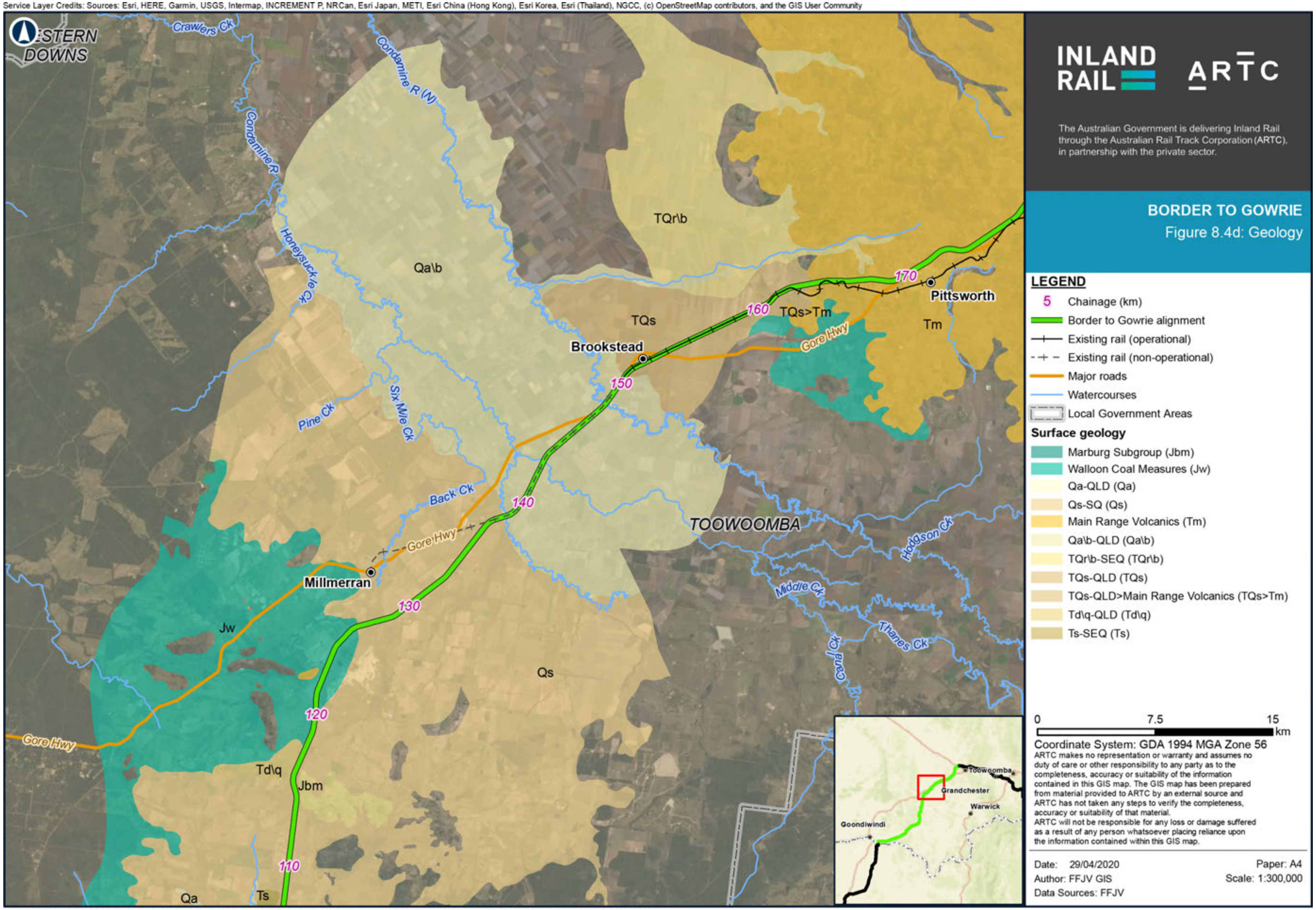

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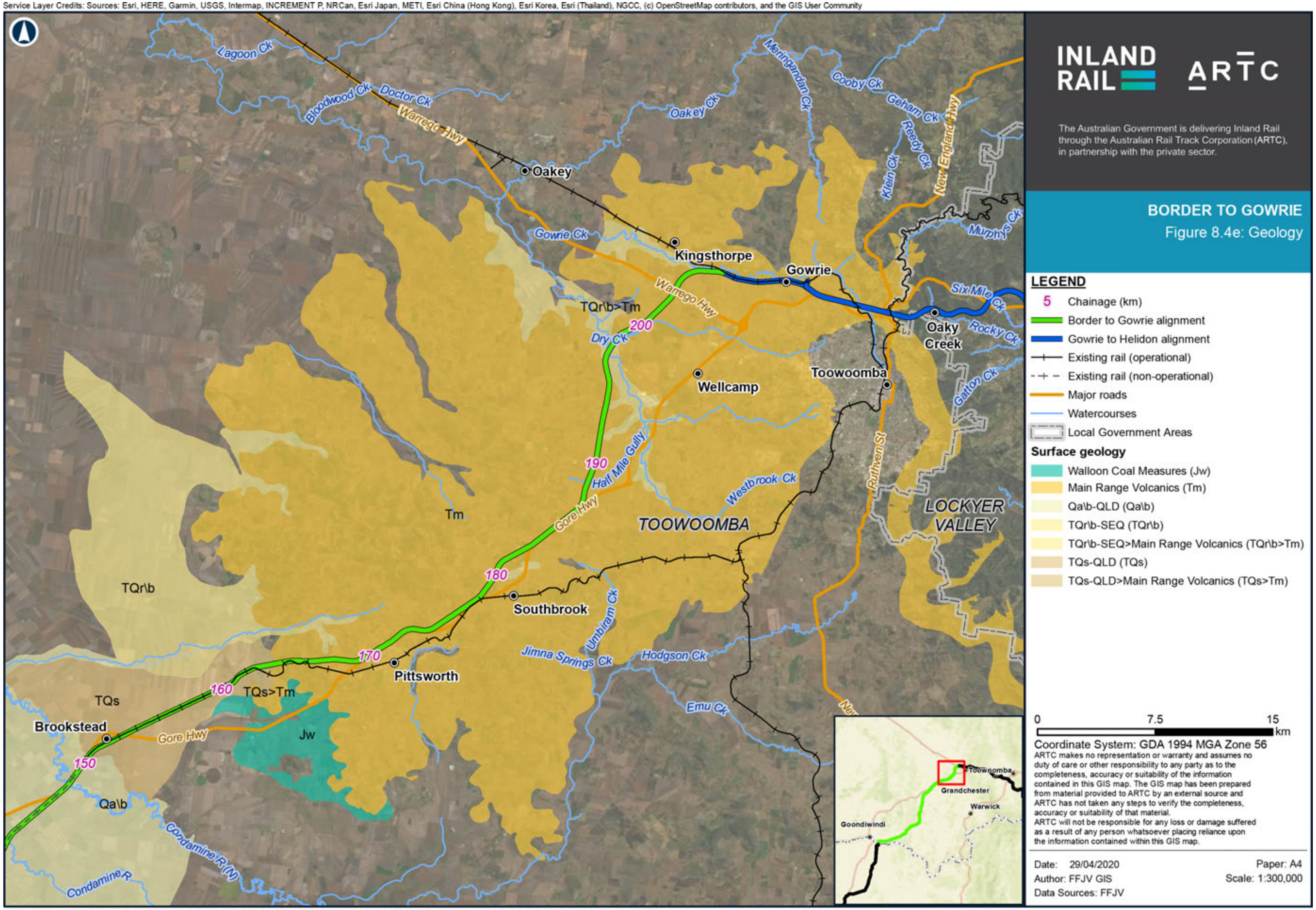

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8.5.1.2 Naturally occurring asbestos

Asbestos is a group of minerals that readily separate into long flexible fibres. Naturally occurring asbestos minerals are commonly associated with specific rock types, as well as in sediment and soils formed from these rock types (NSW Government, 2019). Naturally occurring asbestos can be:

- Blue (crocidolite)
- Brown (amosite)
- Green (anthophyllite tremolite and actinolite)
- White (chrysotile, tremolite and actinolite).

A review of available geological mapping (refer Figure 8.4) indicates that there are no rock types known to contain naturally occurring asbestos minerals in the impact assessment area (DNRME, 2017a).

The geotechnical investigation undertaken along the Project alignment found no naturally occurring asbestos to be present (Golder, 2019b).

8.5.1.3 Aquifers

The main aquifer systems present within the impact assessment area that are of relevance to the Project are introduced below. These aquifer systems are part of the larger Great Artesian Basin and have potential to be sensitive to impacts from Project activities. While the Hutton Sandstone is a regionally significant aquifer, it is not considered to be susceptible to impacts by the Project due to the depth at which it occurs.

The details provided above are intended to give further context to the geological setting within the impact assessment area. Further details of these aquifer systems, including recharge and discharge mechanisms, hydraulic parameters, groundwater levels and flow are provided in Chapter 13: Groundwater.

Alluvium/colluvium (Quaternary/Tertiary)

In the Border Rivers catchment, groundwater is associated with alluvial sediments found along the Dumaresq and Macintyre rivers, Macintyre Brook, and Canning Creek. Much of the region is characterised by an upper and lower alluvial system containing groundwater. East of the Macintyre Brook and Dumaresq River, alluvial sediments are largely confined to narrow valleys of Macintyre Brook and Canning Creek (Golder, 2019c). Collectively, these alluvial sediments are referred to as the Border Rivers Alluvium.

The Quaternary Condamine Alluvium is associated with the floodplain of the Condamine River and associated tributaries. It is incised primarily into the Walloon Coal Measures (WCM) of the Surat Basin and forms the primary bedrock to the alluvium (DNRME, 2016c). The Main Range Volcanics (MRV) underlies the alluvium further to the east.

The Border Rivers Alluvium and Condamine Alluvium consist of colluvial sands and soils derived from slope wash deposition. Near the edge of valleys, the colluvium may be interfingered with alluvium and the two become difficult to distinguish. This colluvium is likely to comprise significant portions of the geological unit mapped as abandoned river terraces (Qs) in Figure 8.4. These units are distributed throughout the impact assessment area.

Main Range Volcanics (Tertiary)

The MRVs are located to the east and southeast of the Condamine Alluvium and forms the main geological unit, which outcrops along the Project alignment between Ch 163.0 km, near Pittsworth, to Ch 206.9 km, near Kingsthorpe. The MRVs is depicted as Tm in Figure 8.4

The MRVs formation consists mainly of Oligocene–Miocene age alkaline olivine basalts, which erupted from fissures that have since become extensively eroded (Office of Groundwater Impact Assessment (OGIA), 2016a). Some portions of the formation are covered by alluvium from tributaries of the Condamine River system (i.e. Westbrook Creek near Ch 196.0 km). The thickness of the MRVs is up to 150 m; however, thinner portions of the formation underlie some areas of the Condamine Alluvium.

The MRVs are comprised of primary permeability in the form of vesicular zones with secondary porosity in the form of cooling joints and fractures (DNRME, 2016c). The vesicular and weathered zones of these basalts can result in aquifer behaviour that ranges between unconfined, semi-confined or confined (DNRME, 2016c). As a result, groundwater occurrence and hydraulic properties of the MRVs are inherently variable due to the nature, location and frequency of the fractures and joints.

The MRVs forms a significant productive aquifer used for irrigation, stock, and town water supplies. A total of 148 of the 283 bores registered on the DNRME Groundwater Database and located within the impact assessment area are screened within the MRVs.

Kumbarilla Beds

The lithology of the Kumbarilla Beds comprises sandstone, siltstone, mudstone, and some conglomerate. The formations within the Kumbarilla Beds lie unconformably over the WCM and are often indistinguishable from each other in this area. The unconformity is likely the result of erosion, as scouring has been observed at the contact between the WCM and lower Springbok Sandstone unit of the Kumbarilla Beds (DNRME, 2016b).

The lower sandstones of the Kumbarilla Beds were deposited by streams flowing generally towards the centre of the basin, frequently in small channels eroded into the uppermost siltstones of the WCM, and occasionally into the coal seams (DNRME, 2016c).

The Project alignment traverses intermittent outcrop and subcrops of the Kumbarilla Beds between approximately Ch 4.0 km and Ch 37.0 km. Several registered groundwater bores in fractured rock located between Ch 30.60 km (North Star to the Border (NS2B) Project) to Ch 38 km are recognised to be screened across the Kumbarilla Beds.

Walloon Coal Measures

The WCM are an important coal resource of the Surat Basin. The WCM comprise claystones, shales, sandstones and coal seams of fluvial and lacustrine origin with an average total thickness of 300 m (Exon, 1976; DNRME, 2016c). The WCM are contiguous between the Surat and Clarence–Moreton Basins forming a continuous unit over the Kumbarilla Ridge, and represent a widespread episode of deposition of river, lake, swamp and marsh sediments. The formation has been either partly eroded, or exposed, over much of the eastern part of the Clarence–Moreton Basin (DNRME, 2016b).

The contact between the Condamine Alluvium and the underlying WCM is characterised by a clay zone of undifferentiated origin, which is often dominated by multi-coloured clay (DNRME, 2016c). On a regional basis, the underlying WCM are considered to be an aquitard, although groundwater is extracted extensively for stock and domestic supplies where the WCM occur at shallow depths (DNRME, 2016b).

The WCM intermittently outcrop and subcrop along the Project alignment between Ch 38.0 km and Ch 126.0 km, along the northern banks of Macintyre Brook and Canning Creek and towards Millmerran. The extent of the WCM are depicted as Jw in Figure 8.4.

A review of data from the 27 registered bores within the impact assessment area indicate the WCM are typically screened at depths shallower than 100 mbgl. Eleven bores established during the Project hydrogeological investigation between Ch 53.0 km and Ch 122.0 km intersected the WCM. In these locations, extremely weathered sandstone and mudstone was encountered from 2 mbgl to 20 mbgl (Golder, 2019a).

8.5.2 Site investigation observations

The Project alignment passes through distinct landscapes that tend to reflect their underlying geological units. Site observations made during geotechnical and soil investigations for the Project are summarised below with respect to the observed variations in landscape.

8.5.2.1 NSW/QLD border to Kurumbul

The Macintyre River channel was observed as deeply incised (on both the river cliff and point bar sides of meander bends) and to shows signs of historic and contemporary bank erosion and bed scour. It incorporates marginal flood channels separated by bars (refer Photograph 8.1 and Photograph 8.2). Some of the bars are tree covered.

The incision may indicate that the channel is largely dissociated with the floodplain above the bank, though high magnitude flooding does extend onto the elevated floodplain.

Incision, bank erosion, channel migration and avulsion of the river and associated creeks on the northern bank have left infilled and partly infilled meanders within the 'meander belt'. The channel banks are subject to active land sliding and flood return gully erosion.

Depositional features that are apparent as levees at the bank crests and sandbars/dunes within the channel indicate a relatively dynamic system through recent geological time.

Exposed soils in the riverbanks reveal sequences of gravel, sand, sandy clay and clay. The overall Quaternary age alluvial profile may be substantially deep. The alluvium is interpreted to cut into and overlie soils representing a lateritised Tertiary age sedimentary sequence of poorly consolidated mudstone and sandstone (refer Photograph 8.3).

The floodplain on the northern side of the Macintyre River comprises a gently undulating terrain of drainage swales and pools. Localised soil landslides and flood return gullies are active at the riverbank.

Soils in this area comprise of sequences of gravel, sand, sandy clay and clay.

The Project alignment passes to the east of an abandoned meander at Rainbow Reserve (refer Photograph 8.4). The transition of the Project alignment from the floodplain onto the stranded river terrace is interpreted at approximately Ch 34.8 km, on the north side of an abandoned, mostly infilled meandering floodplain channel (refer Photograph 8.5 and Photograph 8.6).

PHOTOGRAPH 8.1 MACINTYRE RIVER FLOOD CHANNEL, PARALLEL TO THE MAIN RIVER CHANNEL

Source Golder, 2019a

PHOTOGRAPH 8.2 CHANNEL BARS IN THE MACINTYRE RIVER

Source Golder, 2019a

PHOTOGRAPH 8.3 MACINTYRE ALLUVIUM EXPOSED IN THE RIVERBANK

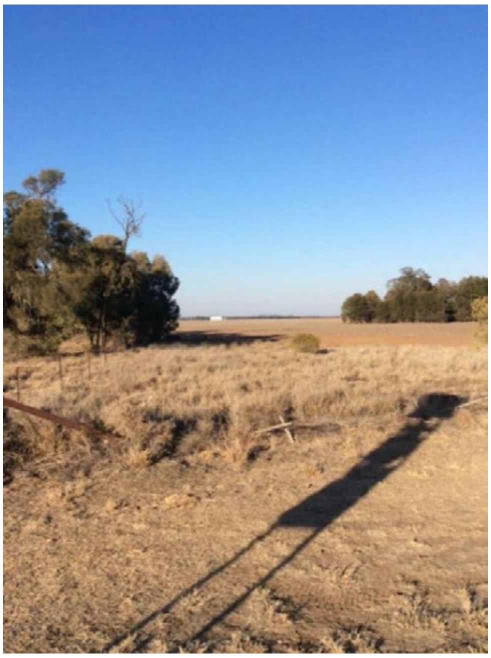
Source Golder, 2019a

PHOTOGRAPH 8.4 OXBOW LAKE AND ABANDONED MEANDERS AT RAINBOW RESERVE

Source Golder, 2019a

PHOTOGRAPH 8.5 GULLY EROSION AT THE MARGIN OF THE MACINTYRE RIVER FLOODPLAIN, RAINBOW RESERVE

Source Golder, 2019a



PHOTOGRAPH 8.6 RIVER TERRACE VISIBLE FROM YELARBON-KURUMBUL ROAD

Source Golder, 2019a

8.5.2.2 Kurumbul to Whetstone

The terrain in this area is characterised by flat landscapes that extend broadly from the north side of the Macintyre River floodplain. The river terrace alluvium typically incorporates series of fining upward sedimentary sequences, dominated by clay and sandy clay. It is assessed to overlie lateritised Kumbarilla beds and, at Yelarbon, Springbok Sandstone.

The area west of Yelarbon represents a stranded river terrace with relatively bare and sparsely vegetated land. Pale grey brown to white (low plasticity) clay surface soils are exposed, notably near Yelarbon (refer Photograph 8.7).

PHOTOGRAPH 8.7 EXPOSED SOILS IN THE YELARBON AREA

Source Golder, 2019a

East of Yelarbon, superficial soils on the low relief landscape are dominated by alluvial sand and conglomerate clast gravelly sand derived from elevated land to the north.

Subsoil of kaolinite (usually medium plasticity clay) and iron stained/ enriched sand are inferred to be a chemical lateritised weathering product. There is potential for a remnant laterite 'cap rock'.

8.5.2.3 Whetstone to Millwood

The Project alignment enters moderately undulating country west of the Macintyre Brook and at Inglewood, remains west of its tributary, the Canning Creek. Superficial soils in this area are mostly sandy: pale orange brown, clayey (low plasticity) fine and medium grained, angular, quartzose sand. There is also potential for alluvial and wind-blown single-size sand. Stream beds have accumulated pebbles.

Observations suggest the soils may be moderately dispersive (sodic).

The underlying, predominantly sandstone strata are typically medium to very coarse grained, well sorted (single grain size), angular, quartzose sandstone with minor interbedded fine-grained sandstone and siltstone with traces of coal/carbonaceous partings (interpreted to represent the Pilliga Sandstone/Eurambah beds). With greater depth, Walloon Coal Measures may be encountered. Where differentiated, by contrast, they comprise thinly bedded claystone, shale, siltstone, lithic and feldspar rich sandstone, with some coal.

Valleys and broad gullies in this area may be infilled with alluvium and colluvium. Rocks in this area have potential to be lateritised; weak rock may overlie a significant leached zone. Photograph 8.8 to Photograph 8.12 show typical examples of the landform, geology and soils of this area.

PHOTOGRAPH 8.8 WEATHERED SANDSTONE EXPOSED AT A ROAD CUTTING IN BRINGALILY STATE FOREST

Source Golder, 2019a

PHOTOGRAPH 8.9 DISPERSIVE (SODIC) SOIL EXHIBITING A WEAK CRUST AND MODERATE GULLY EROSION

Source Golder, 2019a

PHOTOGRAPH 8.10 GRAVEL AND COBBLES OF CRYSTALLINE 'CHERT' AND QUARTZ (RELIC CONGLOMERATE CLASTS) IN CREEK BEDS AND ALLUVIUM

Source Golder, 2019a

PHOTOGRAPH 8.11 SUPERFICIAL SAND AND SANDY CREEK BED, TYPICAL OF THE WHETSTONE TO INGLEWOOD AREA

Source Golder, 2019a

PHOTOGRAPH 8.12 DRY CREEK BED IN BRINGALILY STATE FOREST

Source Golder, 2019a

8.5.2.4 Millwood to Yandilla

Superficial sandy alluvial soils and intervening high-plasticity clays were observed in this area. There is potential for cobbles and boulders of quartzose sandstone and silicified conglomerate (remnants from Tertiary Sandstone) to be present in the Millwood and Canning Creek area (refer Photograph 8.13).

Within the vale and towards the margins of the Condamine River floodplain northeast from Millmerran, towards Yandilla, a Tertiary to Quaternary age, poorly consolidated terrestrial (river alluvium) sequence of sandstone and mudstone is mapped (refer Photograph 8.14). This is typically represented by stiff (hard) sandy clay and clay.

The underlying solid geology comprises the Walloon Coal Measures rocks that are typically lithic and feldspar rich sandstone with thinly bedded siltstone and shale and some coal. Coarser grained sandstone and conglomerate with intervening mudstone may represent the conformably underlying Eurambah beds that are indicated on published geological maps.

The strata are likely lateritised (kaolinised and locally iron enriched, potentially with calcrete nodules).

Coarser grained sandstone recorded at the base of deeper boreholes in the Yandilla area might be representative of the Marburg Subgroup strata.

PHOTOGRAPH 8.13 TERTIARY SANDSTONE BOULDERS, MILLWOOD

Source: Golder, 2019a

PHOTOGRAPH 8.14 VALE AT MILLWOOD, VIEWED NORTH TOWARDS CANNING CREEK AND MILLMERRAN

Source: Golder, 2019a

8.5.2.5 Yandilla to Yarranlea

The surface soils across the Condamine River floodplain are dominated by high plasticity clays (Vertosols). The sandy surface soils tend to occur on active or abandoned levees, which drain better than the lower-lying areas. The lower alluvial areas are covered by Vertosols, which may originate from completely weathered basalt and sedimentary rocks. The Vertosols are susceptible to cracking and severe shrink/swell behaviour.

Observations made within this area recorded a superficial cover of re-worked alluvial (sandy and partly gravelly) amorphous-organic soil, grading to high plasticity heavy clay ('black soils') (refer Photograph 8.15). This superficial soil was found to overlie stiff, very stiff or hard (and correspondingly dense in granular soils) interbedded alluvium sequences. These were assessed to be Quaternary and potentially Tertiary age sequences that are dominated by fine-grained soils.

PHOTOGRAPH 8.15 BLACK SOILS TYPICAL OF THE CONDAMINE RIVER FLOODPLAIN

Source: Golder, 2019a

8.5.2.6 Yarranlea to Gowrie

The higher country northeast from Pittsworth represents the underlying 'cap' of Tertiary age Main Range Volcanics—a mixed sequence, dominated by basalt lava flows, interlayered with intermediate and acidic lavas, tuff and agglomerate pyroclastic rocks. At their margins, a mix of clay, sand, gravel, cobbles and boulders form a colluvium and sediment deposit.

This area is dissected by a radial pattern of watercourses with associated valleys and broad vales that have a covering of high plasticity clay alluvium ('deep cracking clay' black soil). Soils on elevated ground comprise a medium plasticity, typically dark red brown clay, frequently with crystalline volcanic rock (basalt and andesite) corestones (refer Photograph 8.16).

The volcanic rocks and their associated colluvium and alluvial deposits mostly cover interlayered sedimentary rocks dominated by sandstone and siltstone of the Walloon Coal Measures and Marburg Subgroup.

The sedimentary rock sequences remain relatively lightly weathered, not severely impacted by laterisation processes, where they are beneath 'protective' volcanic rocks.

The volcanic rocks in this area are differentially weathered, e.g. basalt flows incorporate weathered (soil strength) layers between competent basalt lobes. Intact basalt/lava strengths vary widely.

PHOTOGRAPH 8.16 ANDESITIC TUFF COBBLES AND BOULDERS (CORESTONES) OF THE MAIN RANGE VOLCANICS, PITTSWORTH

Source: Golder, 2019a

8.5.3 Soils

8.5.3.1 Soil landscape and descriptions

Atlas of Australian Soils

Soil information within the impact assessment area has been sourced from the *ASRIS Atlas of Australian Soils* (CSIRO, 2014b). The Atlas of Australian Soils was compiled by CSIRO in the 1960s to provide a consistent national description of Australia's soils. It comprises a series of 10 maps and associated explanatory notes, compiled by K.H. Northcote and others. The maps are published at a scale of 1:2,000,000 but the original compilation was at scales from 1:250,000.

In reference to the ASRIS Atlas of Australian Soils, soils expected to be encountered along the Project alignment are summarised in Table 8.4 and presented graphically in Figure 8.5.

The soil type varies considerably along the Project alignment and consists of the following broad Australian Soil Classification (ASC) groups:

- Vertosol—shrink/swell properties and are prone to developing strong vertical cracks when dry. Common sub-soil structure features, including slickensides and/or lenticular aggregates (Harris et al., 1999). These soils are important agricultural soils in the region, being very fertile and extensively cultivated (Vandersee, 1975).
- Sodosol—clear or abrupt textural B horizons in which the major part of the upper 0.2 m of the B2 horizon is sodic and is not strongly sub-plastic (Isbell & National Committee on Soil and Terrain, 2016; Harris et al., 1999).
- Dermosol—structured B2 horizon and lacks a strong texture contrast between the A and B horizons (Harris et al., 1999).
- Chromosol—clear or abrupt textural B horizon where the pH is 5.5 (water) or greater in the upper 0.3 m of the B2 horizon (Harris et al., 1999).
- Kandosol—lacks strong texture contrast and have massive or only weakly developed structured B horizons. The B2 horizon is well developed and has a maximum clay content in some parts of the B2 which exceeds 15 per cent. They are also not calcareous throughout (Harris et al., 1999).
- Lithosol—these soils generally have weak pedological organisation throughout the profile apart from the A horizons (Harris et al., 1999).

TABLE 8.4 ASRIS MAPPING ALONG THE PROJECT ALIGNMENT

Chainage	Soil Map Unit	Dominant ASC Group[2]	Soil Description and Principle Profile[1,3]
Ch 30.6 km (NS2B) to Ch 33.0 km	LM1	Kandosol Vertosol Chromosol	River terraces and levees: chief soils are loamy soils having an A2 horizon and red pedal subsoils (Um4.31), and yellow-brown earths (Gn2.43) with a general pattern as follows: younger terraces and levees of (Um4.31), (Um6.12), (Um6.11), and (Uf6.3) soils; older terraces and levee slopes of (Gn2.43), (Dr2.42), (Dr2.63), and smaller areas of (Gn2.8) soils. Associated are sand-ridge formations of (Uc1.2), and (Dy2.43) in areas of restricted surface drainage. As mapped, slopes of adjoining hilly country may be included.
Ch 38.0 km to Ch 7.6 km	CC20	Vertosol	Gently undulating cracking clay plains with moderate to strong (2-4 ft) gilgai microrelief: chief soils are deep grey clays (Ug5.24) with smaller areas of (Ug5.25 and Ug5.28) and some brown clays (Ug5.34). Soil reaction values of these cracking clays vary and comprise alkaline or neutral surfaces with acid subsoils (common), acid throughout (fairly common), and alkaline throughout (rare). In some areas (Dy2.33 and Dy2.43) soils occur on the slightly raised flat areas between gilgai depressions, or adjacent to small drainage lines. As mapped, small areas of units B10, MM1, and Ro4 are included in Queensland.
Ch 33.0 km to Ch 38.0 km (NS2B) Ch 7.6 km to Ch 26.2 km	Ro4	Chromosol Sodosol	Gently undulating plains: dominant soils are hard alkaline brown soils (Db1.33), (Db1.13), (Db1.23), or rarely (Db1.43). Similar (Dr), (Dd), and (Dy) soils are commonly associated. In many instances the deeper subsoils may be extremely acid. A slight (few inches) gilgai microrelief is often present and cracking clays (Ug5.3 and Ug5.2) may then occur as soil complexes. As mapped, small areas of units CC20, Wa13, Fz2, and MM2 are also included.
Ch 26.2 km to Ch 37.8 km	S12	Sodosol	Plain: chief soils are hard alkaline yellow soils (Dy2.43) with pH 10.0 or higher below 10 inches. Very high amounts of exchangeable sodium in the subsoil. Associated soils are (Dy3.43) soils which margin the area. Water and wind erosion have been severe.
Ch 37.8 km to Ch 42.5 km Ch 52.5 km to Ch 55.9 km	Wa13	Sodosol	Flat to gently sloping plains with occasional undulating sandy ridges: chief soils are sandy soils with mottled yellow clayey subsoils (Dy5.41), (Dy5.81), (Dy5.42), and (Dy5.82). Associated are (Dy2.42 and Dy2.43) and (Dy3.43 and Dy3.42) soils, and minor areas of acid hard-setting (Dr2) and (Dr3) soils. Some low hills of unit Fz3 are included.
Ch 42.5 km to Ch 52.5 km Ch 55.9 km to Ch 65.6 km	Fz3	Lithosol	Low hills and dissected low ranges, often with mesa or butte-like remnants: chief soils are shallow stony loamy soils (Um1.43, Um1.42) with less commonly (Uc1 .2, Uc1.4), or (Uf1.43) soils; a variety of shallow stony (D) soils may also occur locally. The associated valley floors and slopes have mainly loamy to sandy-surfaced (Dy2.33, Dy2.43) or (Dy3.33, Dy3.43) soils, with occasional areas of red earths (Gn2.12), sandy-surfaced (Dy5.3 and Dy5.4) soils, or brown loamy soils (Db1.33, Db1.43).
Ch 65.6 km to Ch 100.6 km Ch 104.1 km to Ch 106.6 km	Va24	Sodosol	Gently undulating plains of hard alkaline and neutral yellow mottled soils (Dy3.43 and Dy3.42) and (Dy2.43 and Dy2.42); some acid variants may occur. Associated are (Db1.43) soils; sandy soil (Dy5.41, Dy5.42, Dy5.81, Dy5.82) near drainage lines; and small areas of (Dr2) and (Dr3) soils. Some high stony ridges, scarps, or mesa-like remnants of units Fz2 and Fz3 may occur, as may inclusions of unit CC20.
Ch 100.6 km to Ch 104.1 km Ch 106.6 km to Ch 126.1 km	CB1	Vertosol	Moderately undulating landscape with slight gilgai (few inches) formation: broad ridge tops and upper slopes of moderately shallow grey cracking clays (Ug5.22 and Ug5.23). Associated are: (i) some dark cracking clays (Ug5.13); (ii) various alkaline (D) soils, such as (Db1.43) and (Dd1.33); and (iii) in the lower-lying situations deeper grey cracking clays (Ug5.25 and Ug5.24) with small areas of (Dy3.43) soils. As mapped, small areas of units HG3 and Kb6 are included in some localities.

Chainage	Soil Map Unit	Dominant ASC Group[2]	Soil Description and Principle Profile[1,3]
Ch 126.1 km to Ch 128.2 km Ch 129.7 km to Ch 137.3 km	HG3	Sodosol, Chromosol	Plain, old riverine terrace formation: chief soils are hard alkaline dark soils (Dd1.33), (Dd1.43), (Dd2.33), and possibly (Dd3.33) and (Dd4.43). Associated are small areas of related (Dy) and (D) soils such as (Dy3.23), (Dy3.42), and (Dr3.31).
Ch 128.2 km to Ch 129.7 km	Va32	Sodosol	Low concave or convex hills with some mesas of lateritised rock: chief soils are hard alkaline yellow mottled soils (Dy3.43). Associated are hard neutral gley soils (Dg2.82) on crests of low rises; hard alkaline dark soils (Dd1.43) on concave slopes; and hard acidic yellow and red mottled soils (Dy3.41) and (Dr3.41) on cuesta crests. Small areas of other soils may occur.
Ch 137.3 km to Ch 150.5 km	Kd10	Vertosol	Very gently sloping plains: chief soils are dark cracking clays (Ug5.15) with associate to codominant areas of (Ug5.16), which is common near streams. Associated are small areas of a number of soils including (Uf6.22), (Uf6.11), and (Dd1.33).
Ch 150.5 km to Ch 160.7 km	CC24	Vertosol	Plain: chief soils are grey cracking clays (Ug5.24 and Ug5.28) with some dark cracking clays (Ug5.16). Associated are (Dd1.33) and (Dd1.43) soils with thin crusty surfaces in gilgai complexes throughout the plain, which may be traversed by channels of (Ug5.16) soils also. Small areas of other soils (Uf6.3) occur. As mapped, small areas of unit Kb6 may be included locally.
Ch 160.7 km to Ch 166.6 km	Ke16	Vertosol	Hilly with long concave stepped slopes; some basaltic knolls and ridges: chief soils on the slopes are dark cracking clays (Ug5.16 and/or Ug5.14) in the gilgai depressions and brown cracking clays (Ug5.35) on the gilgai mounds. Associated are gilgai complexes of (Ug5.15) and (Ug5.25) with (Dd2.42) (Dd2.43), and (Dy3.43) soils on slopes; some (Dr2.22) soils occur on platforms within this complex. Also occurring are: (Ug5.12 and Ug5.13) soils with (Um6.21) soils on and around basaltic knolls and ridges; small areas of (Gn2.16) soils on platforms with the (Ug5.16) soils on the slopes; and small areas of (Ug5.28) in complex with (Dd2.33) soils in lower-lying situations.
Ch 166.6 km to Ch 198.2 km Ch 198.6 km to Ch 206.9 km	Kb6	Vertosol	Rolling basaltic uplands: chief soils are dark cracking clays (Ug5.13) in association with many other soils, as follows: (i) crests and steep slopes of the flat-topped and rounded hills at the relatively higher elevations of dark shallow porous loamy soils (Um6.21), shallow friable clays (Uf6.11), and shallow cracking dark clays (Ug5.12); passing to (ii) gentle slopes on flat-topped hills, ridges, steps, and knolls of (Um6.21), red friable earths (Gn3.12), and shallow dark cracking clays (Ug5.12 and Ug5.13); passing to (iii) long gentle slopes of deeper, dark cracking clays (Ug5.13 and Ug5.S) with linear gilgai, also with smaller areas of (Uf6.21) and (Gn3.12) soils; and passing to (iv) narrow valley plains of unit Kd5 soils in the lower-lying situations.
Ch 198.2 km to Ch 198.6 km	Oa7	Dermosol	Plains: chief soils are hard alkaline red soils (Dr2.13) with some dark cracking clays (Ug5.I5). Associated are a variety of (D) soils including (Dr2.23), (Db1.12), (Db4.13), (Dy3.22), (Dr4.63), and (Dd1.23) soils in complex with (Ug5.I) soils.

Table notes:

1. Principle profiles are from *A factual key for the recognition of Australian soils* (Northcote, 1979)
2. Australian classification from *The Australian Soil Classification* (Isbell, 2016)
3. Australian Soil Resource Information System, Level 4 Australian Soil Classification mapping (CSIRO, 2014a)

Land Management Manuals

The ASRIS Atlas of Australian Soils mapping is based on broad-scale surveys with scales from 1:250,000; however, it is presented at a scale of 1:2,000,000. to the loss in sensitivity between scales, additional mapping at a finer resolution was accessed from the following sources:

- Land Management Manuals:
  - *Land Management Manual: Waggamba Shire* (Thwaites, R.N. & Macnish, S.E., 1991)
  - *Land Management Manual: Shire of Inglewood* (Cassidy, G.J. et al, 1988)
  - *Central Darling Downs Land Management Field* Manual (Harris et al., 1999).
- Land Resources Survey and Land System Mapping Reports:
  - Soil Survey of the Eastern Darling Downs Westbrook–Highfield–Oakey Area (1:50,000) (DNRM, 2001b)
  - Soils and Land Use in the Toowoomba Area Darling Downs, Queensland (1:100,000) (Thompson & Beckmann, 1959)
  - The Soils of the Inglewood–Talwood–Tara–Glenmorgan Region, Queensland (1:250,000) (Isbell, 1957)
  - *Land Inventory and Technical Guide, Eastern Downs Area Queensland* (1:250,000) (Vandersee, 1975).

The Land Management manuals divide the Darling Downs area into discrete Land Resource Areas (LRAs). The soils within each LRA are described based on their location within the landscape and relationship with other soils, which can vary based on the geology, slope, relief and vegetation identified (Harris et al., 1999). LRAs are not designed to strictly identify soils in an area but rather predict a range of probable occurrence.

Descriptions of LRAs and associated soils that are likely to occur along the Project alignment are summarised in Table 8.5.

The dominant soil type identified within each LRA has also been further expanded with reference to the relevant land management manual, where drainage, pH, dispersion, sodicity and salinity have been summarised. The allocated ratings are estimates only and, while adequate for the identification of potential issues and mitigation measures, will need to be confirmed with further site reconnaissance and analysis.

TABLE 8.5 SUMMARY OF LAND RESOURCE AREAS AND SOIL PROPERTIES ALONG THE PROJECT ALIGNMENT

				Key physical and chemical soil properties				
Chainage	**LRA**	**Landform description**	**Nearest major soil type**	**Drainage**	**pH**	**Dispersion**	**Sodicity**	**Salinity**
Ch 30.6 km to Ch 25.0 km (NS2B) Ch 43.3 km to Ch 45.8 km Ch 46.6 km to Ch 46.8 km Ch 51.7 km to Ch 54.0 km	Dumaresq[1]	Narrow, alluvial plains (1 to 5 km) of the upper Macintyre, Dumaresq and Weir Rivers (terraces and levees)	Keetah (Uc3.21): duplex soils with poorly structured subsoil. Fine, sandy loam surface soils >60 cm deep, with brown or yellow-brown subsoil.	Imperfectly to moderately well-drained	Surface: 6.5–7.0 Upper subsoil: 8.0 Lower subsoil: 8.5	Moderate to high: >70 cm	Slightly sodic >70 cm	Low to very low
			Bengalla (Dr2.42): duplex soils with poorly structured subsoil. Silty surface soils, approximately 30 to 60 cm deep, with yellow-brown or red-yellow subsoil.	Poorly drained	Surface: 5.5–6.0 Upper subsoil: 6.5 Lower subsoil: 7.0-7.5	High to very high: >50 cm	Sodic to strongly sodic >50 cm	Medium >80 cm
Ch 25.0 km to Ch 10.0 km (NS2B) Ch 7.3 km to Ch 18.2 km Ch 19.1 km to Ch 24.6 km Ch 28.9 km to Ch 29.3 km Ch 35.4 km to Ch 37.6 km	Billa Billa[1]	Eastern belah landscapes: flat plains	Kurumbul (Dy2.33): friable, dark or brown, duplex soil on belah plains in the east. Surface soils <5 to 10 cm.	Imperfectly drained	Surface: 7.0 Upper subsoil: 9.0 Lower subsoil: 8.0–8.5 Acid pH > 90 cm	Moderate (15–30 cm) to high (>30 cm)	Sodic (15–30 cm) to strongly sodic >30 cm	High (30–60 cm) to extreme: >60 cm
Ch 10.0 km (NS2B) to Ch 7.3 km	Commoron[1]	Eastern brigalow–belah landscapes: flat brigalow plains	Wondalli (Ug5.24): self-mulching, dark or grey cracking clay on melonhole gilgai	Imperfectly drained	Surface: 8.0–9.0 Upper subsoil: 9.0 Lower subsoil: 6.0–8.0 Acid pH > 120 cm	High to very high (>20 cm)	Strongly sodic >20 cm	Very high to extreme: >40 cm
		Eastern brigalow–belah landscapes: sloping brigalow lowlands	Calingunee (Ug5.16): self-mulching, dark or grey cracking clay on sloping melonhole gilgai	Imperfectly drained	Surface: 7.0–7.5 Upper subsoil: 9.0 Lower subsoil: 5.5–5.0 Acid pH > 60 cm	High (>40 cm)	Strongly sodic >40 cm	High to very high: >60 cm

Chainage	LRA	Landform description	Nearest major soil type	Key physical and chemical soil properties				
				Drainage	pH	Dispersion	Sodicity	Salinity
Ch 18.2 km to Ch 19.1 km	Serpentine[1]	Alluvial landscapes either as drainage floors of the major creeks, east of the Weir River or as elevated poplar box areas within the wide alluvial plains of the lower Macintyre and Weir Rivers	Oona Vale (Db1.43): sandy, duplex soil with poplar box woodland on higher areas within wide alluvial plains. Surface soils >20 cm deep. Dark, brown or red-brown subsoils.	Moderately well-drained	Surface: 6.0–6.5 Upper subsoil: 8.5–9.0 Lower subsoil: 9.0–10.0	Moderate to high (>35 cm)	Strongly to very strongly sodic >50 cm	Very high: >80 cm
Ch 24.6 km to Ch 28.9 km Ch 29.3 km to Ch 32.9 km	Desert[1]	Fragile, elevated silty plains with a characteristic claypan appearance due to extensive wind erosion and scalding, restricted to the Yelarbon Desert	Yelarbon (Dy2.43): eroded, silty, impermeable duplex soil with stunted vegetation (sparse tea-tree shrubland and spinifex) on relic alluvial plains. Surface soils <10 cm deep. Grey, brown or yellow-brown subsoils.	Poorly drained	Surface: 9.5 Upper subsoil: 10.0 Lower subsoil: 10–11	High to very high (>40 cm). Low below 40 cm.	Strongly to very strongly sodic throughout	High to very high: 70–100 cm
Ch 32.9 km to Ch 35.4 km Ch 42.4 km to Ch 43.3 km Ch 45.8 km to Ch 46.6 km Ch 64.3 km to Ch 66.5 km	N/A—soils developed on sandstone[2]	Forest dominated by bulloak with cypress pine, poplar box, narrow leaf ironbark and mallee box	Texture contrast soils: loam to clay loam surface, occasionally gravelly. Subsoils are coarse blocky or columnar, grey-brown to reddish-brown, commonly mottle, neutral to alkaline, clay subsoil.	Poorly drained	Surface: N/A Lower subsoil: neutral to alkaline	N/A	N/A	N/A
Ch 37.6 km to Ch 42.4 km Ch 48.0 km to Ch 48.6 km Ch 54.0 km to Ch 56.6 km	N/A—soils developed on sandstone[2]	Slopes with shallow soil with rock outcrops	Shallow stony soils (Lithosols) with numerous rock outcrops.	Poorly drained	N/A	N/A	N/A	N/A
Ch 46.8 km to Ch 48.0 km Ch 48.6 km to Ch 51.7 km Ch 56.6 km to Ch 64.3 km	N/A—soils developed on sandstone[2]	Dominated by cypress pine with bulloak narrow-leaved ironbark, tumbledown gum and rusty gum. Grass cover is sparse.	Texture contrast soils: acid, sandy, loose surface soil over a bleached sandy subsurface overlying a tough solonised acid to alkaline, clay subsoil.	Poorly drained	Surface: acid Lower subsoil: acid to alkaline	N/A	N/A	N/A
Ch 66.5 km to Ch 94.4 km	Area not surveyed[2]							

Chainage	LRA	Landform description	Nearest major soil type	Key physical and chemical soil properties: Drainage	pH	Dispersion	Sodicity	Salinity
Ch 94.4 km to Ch 98.5 km Ch 99.1 km to Ch 101.9 km Ch 104.2 km to Ch 105.4 km	Alluvial Plains[3]	Level alluvial plains and stream terraces	Downfall (Db1.13): texture contrast soil with a medium (15–20 cm) hard setting, loam to clay loam surface, over yellowish brown or greyish brown clay subsoils on mixed sandstone/basalt alluvial plains.	Poorly drained	Surface: 6.5 Upper subsoil: 6.5 Lower subsoil: 6.5–8.5	Moderate to high (>30 cm)	Strongly sodic >50 cm	Very low
Ch 98.5.0 km to Ch 99.1 km Ch 101.9 km to Ch 104.2 km Ch 105.4 km to Ch 113.5 km Ch 114.4 km to Ch 126.5 km Ch 128.5 km to Ch 133.0 km	Brigalow Uplands[3]	Undulating to steep, low hills and rises on Walloon sandstone	Moola (Ug5.16): Moderately deep to deep (75–150 cm), self-mulching, grey-brown cracking clays with very shallow gilgai on Walloon sandstone.	Imperfectly drained	Surface: 8.5-9.0 Upper subsoil: 9.0 Lower subsoil: 5.0–6.5	High (>50 cm)	Strongly sodic >20 cm	Very low
Ch 113.5 km to Ch 114.4 km	Basaltic Uplands[3]	Steep hills and mountains	Beauaraba (Ug5.12): very shallow (10–30 cm) dark granular to blocky cracking clays overlying basalt.	Imperfectly drained	Surface: 7.0 Upper subsoil: 7.0 Lower subsoil: 7.5–8.0	N/A	N/A	Very low
Ch 126.5 km to Ch 128.5 km Ch 133.0 km to Ch 138.2 km	Older Alluvial Plains[3]	Broad level plains of mixed basaltic and sandstone alluvium	Millmerran (Ug5.24): Moderately deep to deep (90–150 cm), grey clays with brown to grey, hardsetting, light clay surfaces over grey clay subsoils on mixed alluvial plains.	Imperfectly drained	Surface: 6.0 Upper subsoil: 7.0 Lower subsoil: 8.0–9.0	Very high (>10 cm)	Sodic throughout	Very low
Ch 138.2 km to Ch 148.1 km	Recent Alluvial Plains[3]	Broad level plains of mixed basaltic and sandstone alluvium	Anchorfield (Ug5.17): deep to very deep (80–180 cm), self-mulching, very dark brown cracking clays on mixed basaltic and sandstone alluvium.	Imperfectly drained	Surface: 8.0 Upper subsoil: 8.5–9.0 Lower subsoil: 9.0	High (>50 cm)	Sodic (20–30 cm) to strongly sodic >80 cm	Very low

Chainage	LRA	Landform description	Nearest major soil type	Key physical and chemical soil properties				
				Drainage	pH	Dispersion	Sodicity	Salinity
Ch 148.1 km to Ch 160.2 km	Older Alluvial Plains[3]	Broad level plains of mixed basaltic and sandstone alluvium	Cecilvale (Ug5.26): deep (120–150 cm), grey cracking clays on mixed basalt/sandstone alluvial plains with poor surface structure and coarse blocky subsoils.	Imperfectly drained	Surface: 7.0 Upper subsoil: 8.5 Lower subsoil: 8.5	High (>50 cm)	Sodic (20–60 cm) to strongly sodic >60 cm	Very low
Ch 160.2 km to Ch 165.6 km	Poplar Box Walloons[3]	Undulating rises and low hills on Walloon sandstone	Elphinstone (Ug5.1): deep (100–150 cm), fine self-mulching, dark cracking clays on Walloon sandstone.	Imperfectly drained	Surface: 6.5–7.0 Upper subsoil: 7.0 Lower subsoil: 8.0-9.0	High (>20 cm)	Sodic (20–60 cm) to strongly sodic >60 cm	Very low
Ch 165.6 km to Ch 195.1 km Ch 195.8 km to Ch 196.9 km Ch 198.4 km to Ch 204.8 km	Basaltic Uplands[3]	Undulating rises and rolling low hills	Craigmore (Ug5.15): deep to very deep (100–180 cm), fine to coarse self-mulching, dark greyish brown to black cracking clays with reddish brown or brown subsoil on basalt or basaltic colluvium.	Imperfectly drained	Surface: 8.0 Upper subsoil: 9.5 Lower subsoil: 9.5–10	Moderate (>80 cm)	Sodic (50–120 cm)	Low
Ch 195.1 km to Ch 195.8 km Ch 196.9 km to Ch 198.4 km Ch 204.8 km to Ch 206.9 km	Older Alluvial Plains[3]	Broad level plains of basaltic alluvium	Waco (Ug5.24): deep to very deep (100–180 cm), fine self-mulching, dark brown cracking clays on basaltic alluvium	Imperfectly drained	Surface: 8.0 Upper subsoil: 9.0 Lower subsoil: 9.0	Moderate throughout	Sodic (20–60 cm) to strongly sodic (60-150 cm)	N/A

Table notes:

1. Land Management Manual: Waggamba Shire (Thwaites, R.N. & Macnish, S.E., 1991)
2. Land Management Manual: Shire of Inglewood (Cassidy, G.J. et al, 1988)
3. Central Darling Downs Land Management Field Manual (Harris et al., 1999)

Queensland Soil and Landform Information (SALI)

The ASRIS Atlas of Australian Soils mapping was reviewed against available soil survey data held within the Queensland Government's Soil and Land Information (SALI) database (Queensland Government, 2020d) to verify the applicability of potential soil limitations (refer Table 8.6) to soils that could be encountered within the impact assessment area.

A total of 216 soil survey sites were identified in proximity to the Project alignment, with ASC information available for 173 of these locations. The remaining 43 soil survey sites were unclassified.

A summary of the soil classifications and key findings and observations for the historical soil survey data is presented in Table 8.5. Locations of the historical survey sites are shown on Figure 8.1 and Figure 8.5.

The soil types identified within the impact assessment area from the referenced historical soil survey data have a strong correlation with the ASC mapping, except for several locations classified as ferrosols between Ch 196.3 km and Ch 206.9 km. Ferrosols are typically encountered on the eastern side of Toowoomba, with a few small pockets north of Gowrie Creek (DNRM, 2001b). The discrepancy is attributed to the published scale of mapping between the ASC (1:2,000,000) and the Land Resource Soil Survey of the Eastern Darling Downs Westbrook–Highfield–Oakey Area (1:10,000) (DNRM, 2001b).

TABLE 8.6 SUMMARY OF HISTORICAL SOIL SURVEY DATA OBTAINED FROM THE SALI DATABASE

					Example physical and chemical soil properties			
Approximate chainage	Survey sites	ASC	Example soil survey site	Drainage	pH	Dispersion (field or laboratory test)	Sodicity	Salinity
Ch 7.6 km, Ch 8.3 km Ch 8.9 km, Ch 9.1 km	4	Grey/brown Sodosol	SWLMP 156	Moderately well drained	Surface: 5.5 Upper subsoil: 7.5–8.5 Lower subsoil: 5.5	Some to complete dispersion	No data	High to very high (>60 cm)
Ch 7.8 km, Ch 10.3 km Ch 10.5 km	3	Grey Vertosol	SWLMP 157	Imperfectly drained	Surface: 8.0 Upper subsoil: 8.0 Lower subsoil: 6.0	Some to complete dispersion	No data	High (>90 cm)
Ch 25.3 km to Ch 27.1 km	5	Grey/brown Sodosol	MISSQ 90	Poorly drained	Surface: 9.0–10.2 Upper subsoil: 10–10.5 Lower subsoil: 9.0–10.5	Moderate to high throughout	Strongly sodic	High to very high
Ch 51.1 km, Ch 52.8 km Ch 54.1 km, Ch 54.5 km Ch 54.9 km, Ch 56.5 km Ch 57.1 km	8	Red/black Dermosol	SWLMP 765	Moderately well drained	Surface: 6.5 Upper subsoil: 7.0 Lower subsoil: 6.5	No data		
Ch 51.0 km, Ch 51.5 km Ch 52.2 km, Ch 56.0 km	4	Brown/red Kandosol	SWLMP 764	Moderately well drained	Surface: 6.5 Upper subsoil: 8.0 Lower subsoil: 8.5	No data		
Ch 51.8 km, Ch 52.9 km Ch 54.2 km, Ch 54.6 km	4	Grey/brown Sodosol	SWLMP 759	Imperfectly drained	Surface: 8.0 Upper subsoil: 6.5 Lower subsoil: 6.0	No data		
Ch 97.3 km, Ch 97.4 km	2	Brown Chromosol	SWRES 860	No data	Surface: 6.5 Upper subsoil: 6.5–7.0 Lower subsoil: 6.5–8.5	No data		
Ch 97.4 km	2	Brown Dermosol	SWRES 859	No data	Surface: 6.0 Upper subsoil: 6.0–7.0 Lower subsoil: 8.5–9.5	No data		

					Example physical and chemical soil properties			
Approximate chainage	Survey sites	ASC	Example soil survey site	Drainage	pH	Dispersion (field or laboratory test)	Sodicity	Salinity
Ch 119.5 km	1	Black Vertosol	ABW 22	Imperfectly drained	Surface: 7.2 Upper subsoil: 8.2–9.3 Lower subsoil: 7.7	No data	No data	Medium (>50 cm)
Ch 152.9 km	1	Grey Vertosol	SWRES 365	Imperfectly drained	No data	No data		
Ch 196.1 km to Ch 206.9 km	97	Black/brown Vertosol	EDS 555	Poorly drained	Surface: 7.0 Upper subsoil: 8.0–8.4 Lower subsoil: 8.7–8.8	Moderate to high throughout	Non-sodic	High to very high
Ch 196.3 km, Ch 196.6 km Ch 196.7 km, Ch 196.8 km Ch 200.5 km, Ch 201.2 km Ch 206.9 km	7	Red Ferrosol	EDS 563	Moderately well drained	Surface: 6.5 Upper subsoil: 7.0 Lower subsoil: 8.5	No data		
Ch 196.3 km, Ch 197.6 km Ch 197.9 km	4	Black Chromosol	EDS 149	Moderately well drained	Surface: 7.0 Upper subsoil: 7.5 Lower subsoil: 7.5	No data		
Ch 196.5 km to Ch 206.9 km	31	Red/black Dermosol	EDS 619	Poorly drained	Surface: 8.0 Upper subsoil: 9.0 Lower subsoil: N/A	No data		

Table Notes:

Source: SALI database (Queensland Government, 2020d)

Soil sampling sites

A total of 24 opportunistic soil samples were collected as part of the geotechnical investigations (refer to 8.4.2) and submitted for laboratory analysis, including:

- Soil pH
- Electrical conductivity (EC)
- Cation Exchange Capacity (CEC)
- Sodium Adsorption Ratio (SAR)
- Exchangeable Sodium Percentage (ESP).

The soil sampling locations were intended to provide a preliminary indication of potential soil types that could be encountered along the Project alignment and not to be a comprehensive investigation. A summary of laboratory analysis for the 24 soil sampling sites and the ASC is presented in Table 8.4. The available soil chemical data was compared to the ASC mapping to provide localised validation of the broad-scale mapping (Figure 8.5).

The available data broadly indicates suitable correlation with soil types mapped along the Project alignment. It is acknowledged that the opportunistic sampling locations have only captured specific points along the Project alignment and a complete range of soil physical and chemical properties were not collected; therefore, the investigated locations may not account for local soil and landscape variability or be totally representative of each and every soil type which could be encountered along the Project alignment.

TABLE 8.6 LOCATION OF SOIL SAMPLES AND CORRELATING MAPPED SOIL CLASSIFICATION

Approximate chainage	Mapped Australian soil classification[1] (refer Figure 8.5)	Auger holed ID (Figure 8.5)	Soil depth (m bgl)	pH	CEC (Meq/100g)	SAR	Salinity		Sodicity	
							EC (dS/m)	Salinity rating[3]	ESP (%)	Sodicity rating
Ch 30.6 km to Ch 33.0 km (NS2B)	Kandosol Vertosol Chromosol	270–01–DH2510	0.0-0.25	6.4	9.2	0.8	0.025	Very low	1.0	Non-sodic
			1.0-1.25	7.6	8.7	6.4	0.024	Very low	2.9	Non-sodic
		270–01–DH2511	0.0-0.25	6.7	5.2	0.4	0.085	Very low	0.5	Non-sodic
			1.0-1.25	8.0	13.6	8.7	0.047	Very low	4.6	Non-sodic
		270–01–DH2513	0.0-0.25	5.9	11.0	0.9	0.062	Very low	1.1	Non-sodic
			1.0-1.25	8.1	15.8	13.0	0.189	Low	5.8	Non-sodic
Ch 33.0 km to Ch 36.0 km (NS2B)	Sodosol	270–01–DH2515	0.0-0.25	8.6	18.3	2.5	0.177	Low	1.8	Non-sodic
			1.0-1.25	8.1	17.7	30.3	0.699	Low	20.3	Strongly sodic
		270–01–DH2516	0.0-0.25	6.3	8.3	6.1	0.053	Very low	6.1	Sodic
			1.0-1.25	6.0	14.1	28.3	0.636	Low	0.6	Non-sodic
		270–01–DH2517	0.0-0.25	7.1	10.3	6.0	0.041	Very low	4.6	Non-sodic
			1.0-1.25	8.4	17.1	28.1	0.422	Medium	16.8	Strongly sodic
		270–01–DH2518	0.0-0.25	6.8	10.2	13.6	0.061	Very low	11.8	Sodic
			1.0-1.25	5.9	19.0	37.4	0.619	Medium	0.6	Non-sodic
		270–01–DH2519	0.0-0.25	6.8	15.1	16.4	0.117	Very low	12.7	Strongly sodic
			1.0-1.25	5.8	16.7	32.5	0.776	Low	0.6	Non-sodic
		270–01–DH2520	0.0-0.25	8.4	17.0	8.8	0.307	Low	8.8	Sodic
			1.0-1.25	7.1	20.7	45.6	0.777	Low	0.6	Non-sodic
Ch 36.0 km (NS2B) to Ch 0.0 km	Vertosols	270-01-DH2512	0.0-0.25	6.4	5.8	0.2	0.042	Very low	0.3	Non-sodic
			1.0-1.25	7.6	5.8	3.7	0.023	Very low	<0.2	Non-sodic
		270-01-DH2521	0.0-0.25	8.4	16.1	4.2	0.415	Low	2.1	Non-sodic

Approximate chainage	Mapped Australian soil classification[1] (refer Figure 8.5)	Auger holed ID (Figure 8.5)	Soil depth (m bgl)	pH	CEC (Meq/100g)	SAR	Salinity		Sodicity	
							EC (dS/m)	Salinity rating[3]	ESP (%)	Sodicity rating
			1.0-1.25	8.5	20.2	51.2	0.375	Low	34.2	Strongly sodic
		270-01-DH2522	0.0-0.25	8.4	19.7	17	1.72	High	9.1	Sodic
			1.0-1.25	4.9	27.8	52.2	0.522	Low	0.3	Non-sodic
Ch 45.5 km	Dermosols	310-01-DH2508	0.5 to 0.9	6.4	11.0	13.0	0.136	N/A	23.0	Strongly sodic
			1 to 1.4	7.8	5.7	14.9	0.128	N/A	30.0	Strongly sodic
Ch 47.5 km	Kandosols	310-01-DH25092	0.5 to 0.9	8.4	3.8	9.1	0.177	N/A	55.0	Strongly sodic
Ch 65.0 km	Sodosols	310-01-DH2510	0.5 to 0.9	6.9	1.4	1.3	0.013	N/A	35.2	Strongly sodic
			2.5 to 2.9	8.3	9.6	10.1	0.170	N/A	55.3	Strongly sodic
Ch 113.5 km to Ch 122.0 km	Vertosols	310-01-DH2516	0.5-0.9	8.7	27.4	38.3	0.673	N/A	27.3	Strongly sodic
			2.5-2.9	8.9	32.8	51.7	0.561	N/A	28.5	Strongly sodic
		310-01-DH2517	0.5-0.9	8.9	20.8	35.5	0.132	N/A	27.3	Strongly sodic
			1-1.4	8.9	21.4	56.2	0.733	N/A	31.6	Strongly sodic
		310-01-DH2518	0.5-0.9	6.9	8.0	21.3	0.577	N/A	2.0	Non-sodic
			1-1.4	9.0	25.4	38.0	0.512	N/A	24.4	Strongly sodic
		310-01-DH2521	0.5-0.9	9.0	25.0	54.3	0.663	N/A	32.5	Strongly sodic
			1-1.4	9.2	27.9	55.8	0.670	N/A	33.2	Strongly sodic

Approximate chainage	Mapped Australian soil classification[1] (refer Figure 8.5)	Auger holed ID (Figure 8.5)	Soil depth (m bgl)	pH	CEC (Meq/100g)	SAR	Salinity		Sodicity	
							EC (dS/m)	Salinity rating[3]	ESP (%)	Sodicity rating
Ch 170.0 km to Ch 201.0 km	Vertosols	310–01–DH2533	0.01-0.3	9.0	16.7	2.5	0.034	N/A	2.6	Non-sodic
			0-0.2	8.1	40.1	2.6	0.035	N/A	1.5	Non-sodic
		310–01–DH2536	0.1-0.3	8.0	31.8	4.7	0.047	N/A	3.2	Non-sodic
			0.5-0.9	8.6	48.7	4.9	0.046	N/A	2.4	Non-sodic
		310–01–DH2543	1.5-1.8	8.9	41.9	6.8	0.066	N/A	5.2	Non-sodic
			0.5-0.8	8.4	35.9	2.6	0.058	N/A	1.6	Non-sodic
		310–01–DH2446	1.4-1.6	8.2	21.8	2.3	0.021	N/A	1.3	Non-sodic
			0.01-0.3	9.0	16.7	2.5	0.034	N/A	2.6	Non-sodic

Table notes:
1. Australian Soil Resource Information System (CSIRO, 2014a)
2. No sample beyond 0.9 m bgl was collected from this location
3. Clay content approximated from field texture described on the borelogs
μs/cm = microsiemens per centimetre
dS/m = decisiemens per metre
meq/100g = milliequivalents per 100 grams of soil
CEC = cation exchange capacity, SAR = sodium adsorption ration, EC = electrical conductivity, ESP = exchangeable sodium percentage

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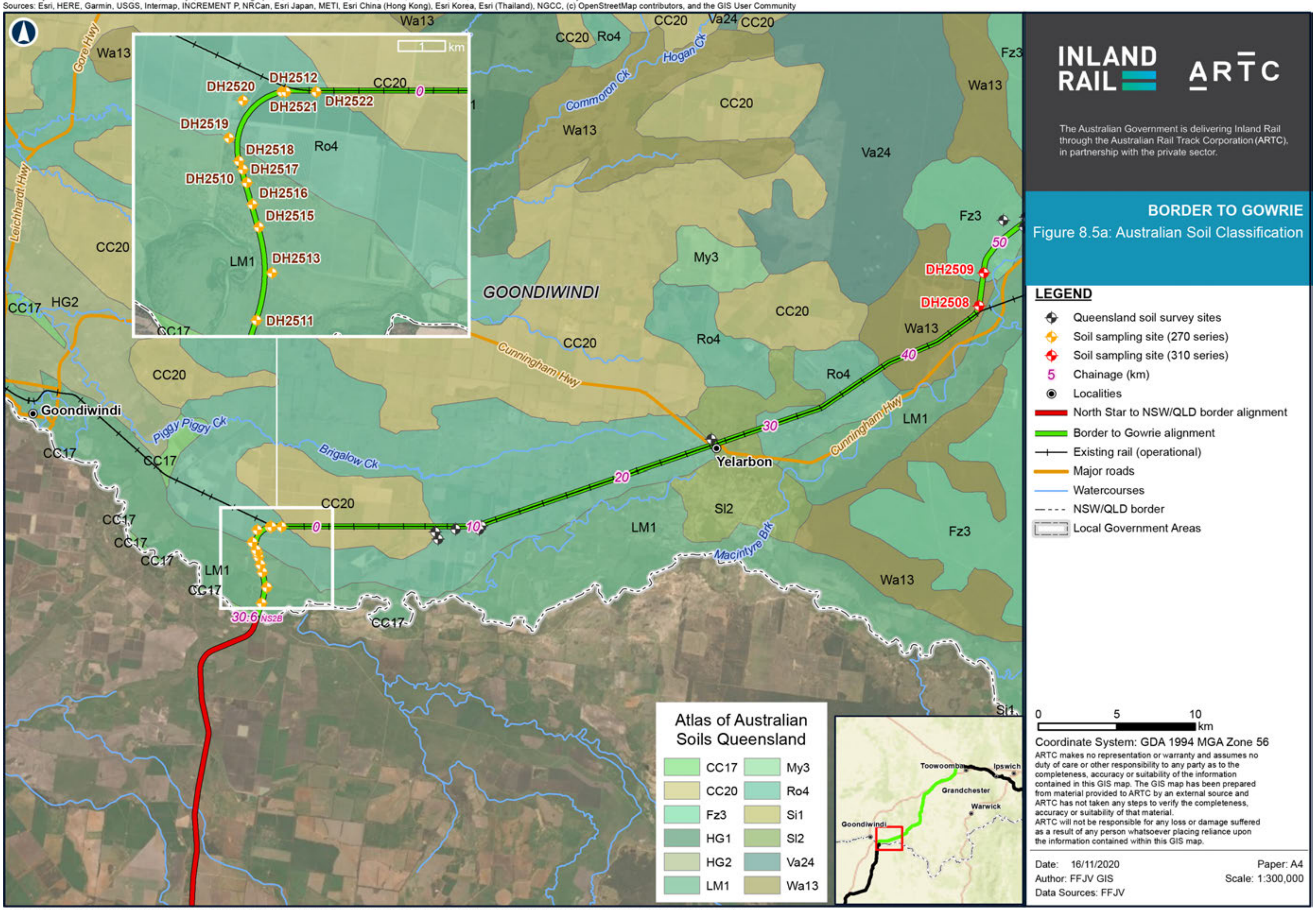

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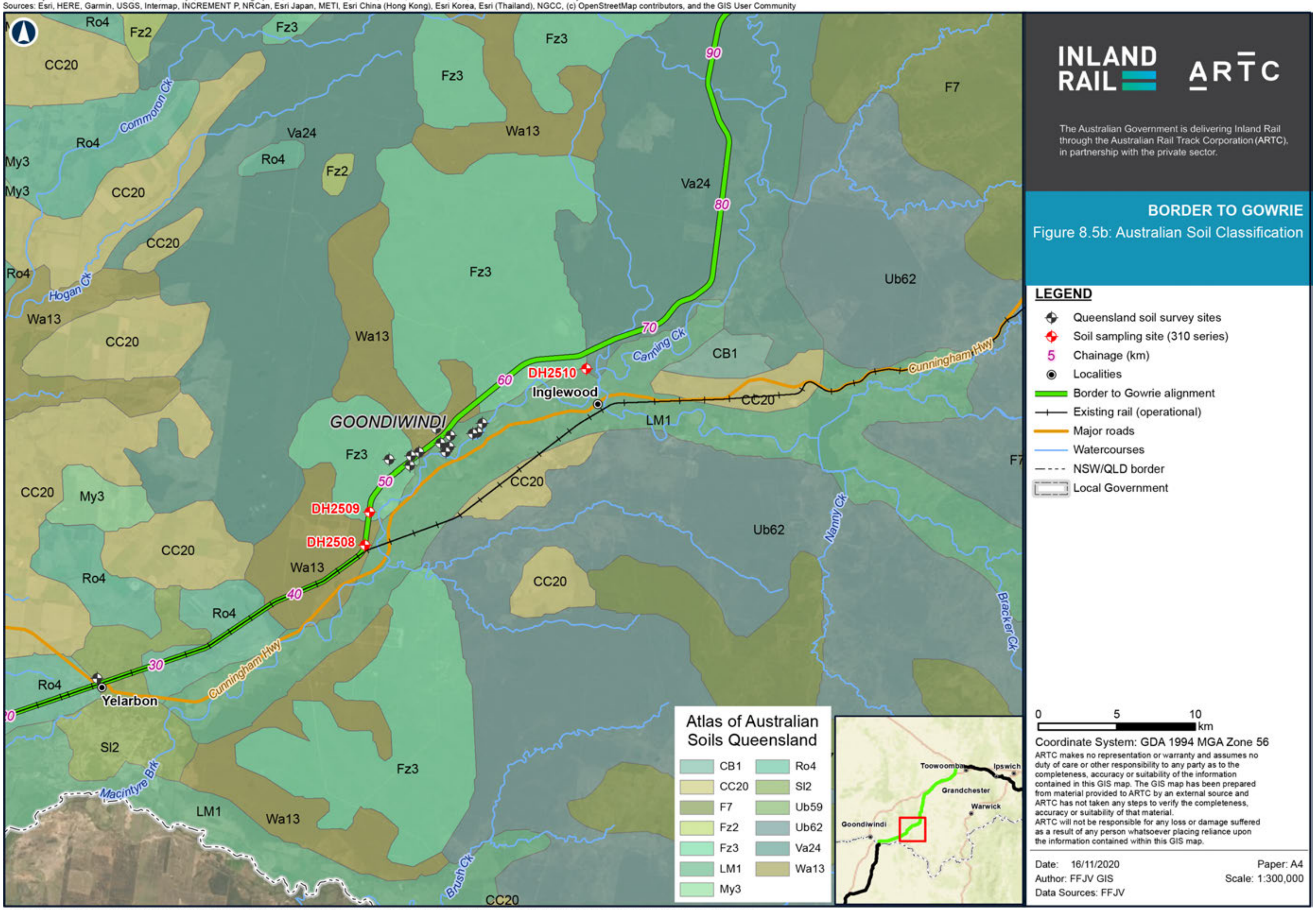

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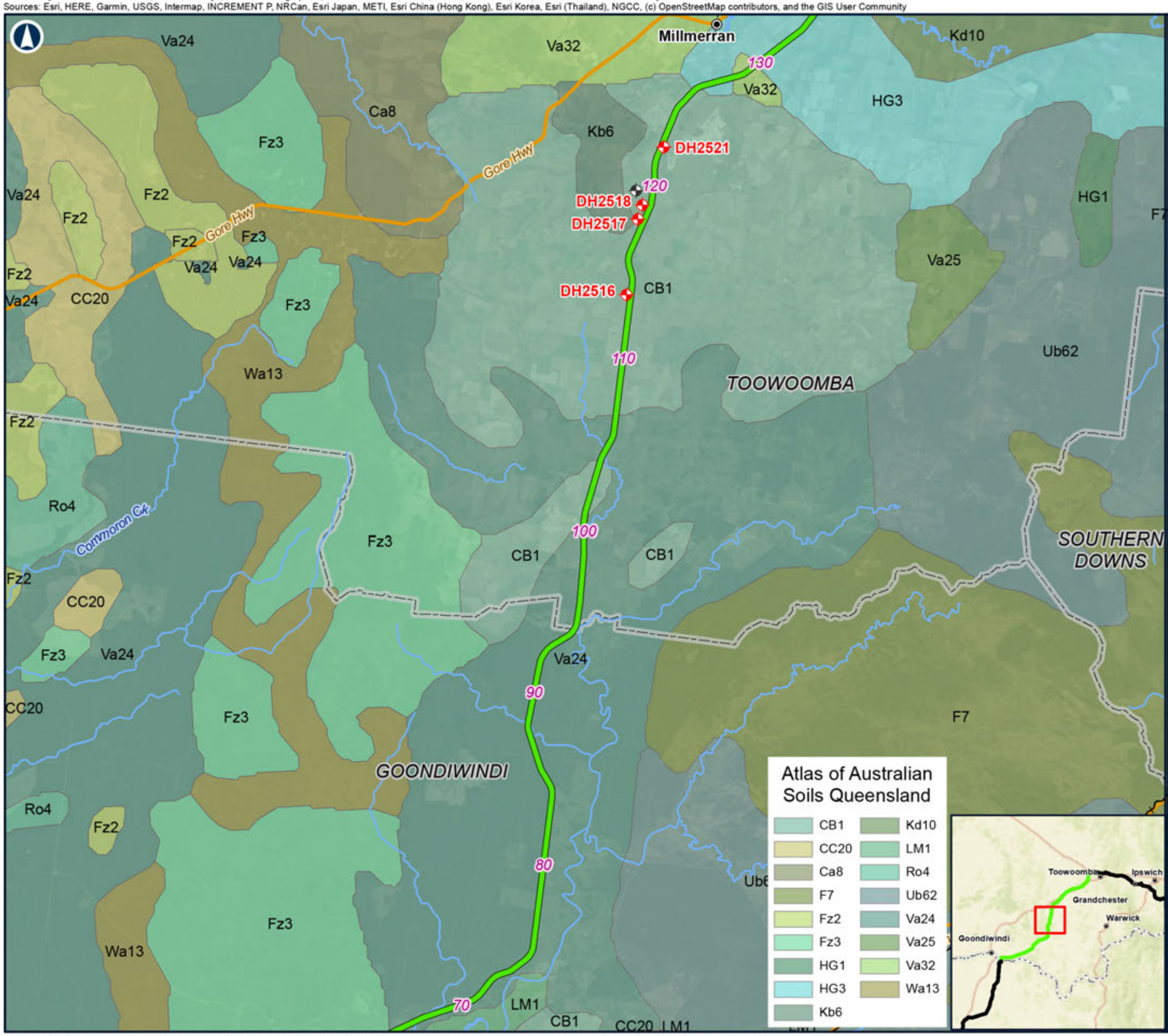

INLAND RAIL ARTC

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

BORDER TO GOWRIE

Figure 8.5c: Australian Soil Classification

LEGEND

- Queensland soil survey sites
- Soil sampling site (310 series)
- Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Watercourses
- Local Government

0 5 10 km

Coordinate System: GDA 1994 MGA Zone 56

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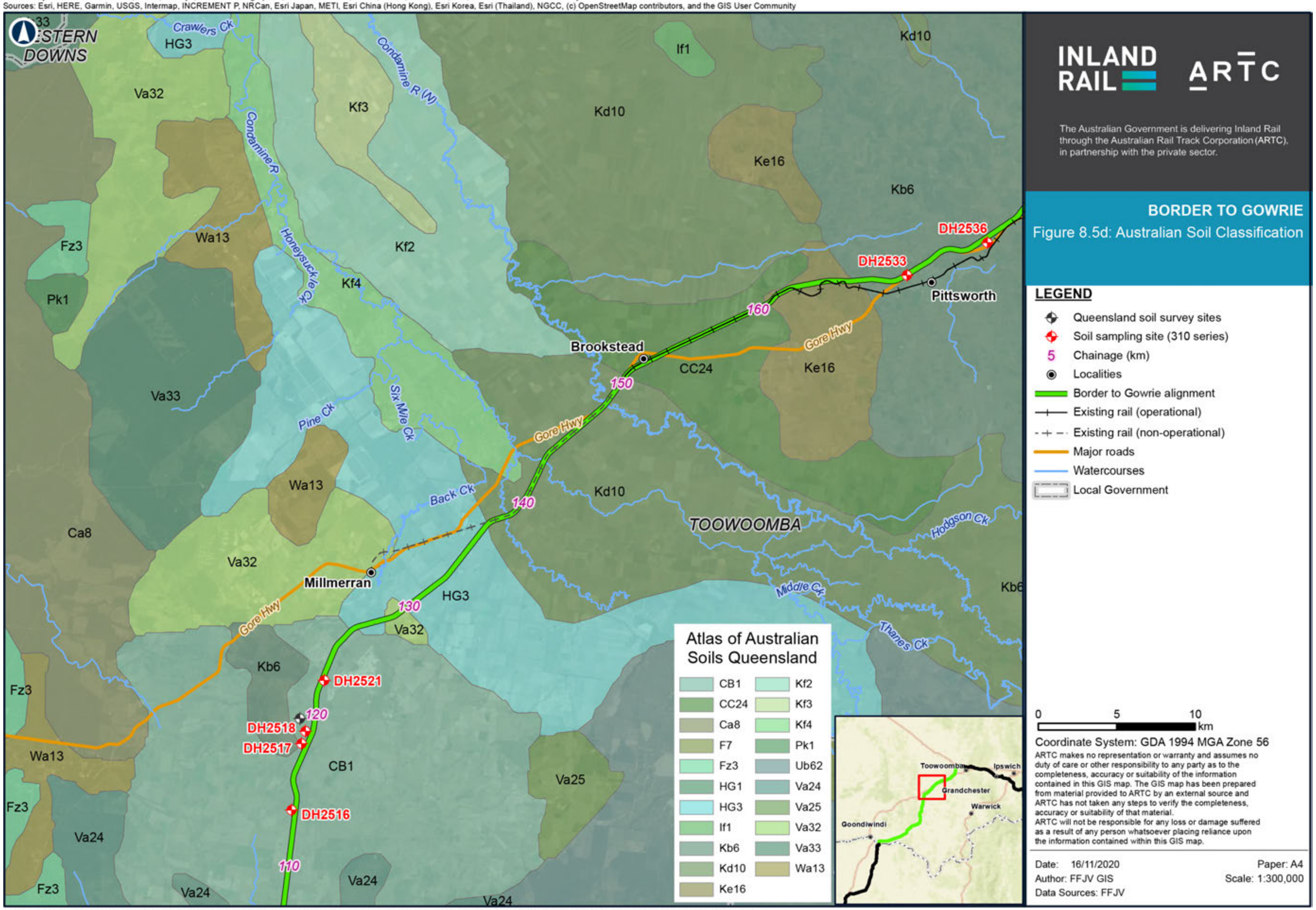

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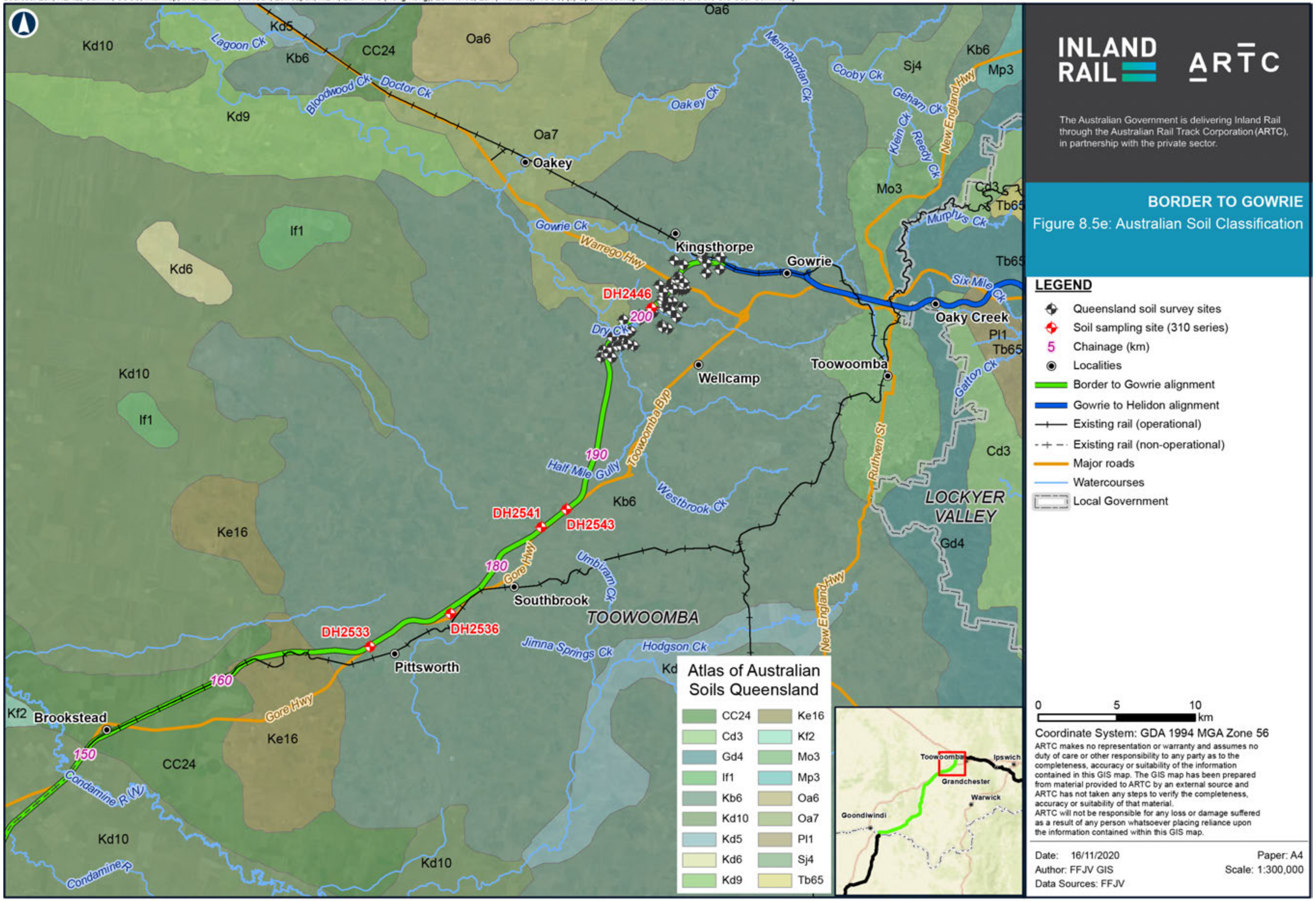

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8.5.3.2 Soil erosion

Soil erodibility is the susceptibility of a soil to erosion by wind and rain, and is interdependent on topography, land use, rainfall intensity and vegetation cover (Zund and Finn, 2015). The most highly erodible soils are those that are most easily detached and transported by erosive forces, such as fine particle soils with sodic and dispersive properties (Houghton and Charman, 1986). Additionally, surface soils with high sand and/or low organic matter content have low cohesion between soils particles, making them susceptible to erosion. The loss of these particles (mainly fine particles) reduces the productive capacity of the soils. On the Darling Downs, unprotected cultivated land in upland areas may lose up to 60 tonnes of soil per hectare in one year (Department of Primary Industries, 1994).

The different soil types traversed by the Project alignment have variable erodibility characteristics. Table 8.7 provides an overview of the erodibility rating associated with each soil type expected to be encountered based on typical Queensland soils described in the DTMR Road Drainage Manual (DTMR, 2019h). The generalised inherent soil erodibility rating of each soil type is shown in Figure 8.6.

TABLE 8.7 TYPICAL ERODIBILITY RATINGS FOR SOILS ENCOUNTERED ALONG THE PROJECT ALIGNMENT

Soil type and ASC	Description of erodibility characteristics	Erodibility rating
Uniform sands and sandy loams—*Rudosols and Tenosols*	Incoherent sand, loamy and sand and clayey sand and coherent sandy loam with single grained massive structure.	Moderate (3)
Uniform loams and clay loams—Massive—*Kandosol* Structured—*Rudosols, Tenosols and Dermosols*	Coherent loams, sandy clay loams and clay loams with massive to strong structure.	Very low (1)
Uniform non-cracking clays—*Dermosols*	Light to heavy clays with strong structure: ▶ Fine aggregates ▶ Coarse aggregates.	 Very low (1) Low (2) to moderate (3)
Uniform cracking clays—*Vertosols*	Light medium to heavy clays that shrink and crack open when dry and swell when wet, gilgai micro relief common.	Low (2) to moderate (3)
Sandy gradational soils—*Kandosols*	Texture gradually increases from a sandy surface to sandy clay loam or sandy light clay with depth; single grain to massive structure.	Moderate (3)
Loamy gradational soils—*Dermosols and Kandosols*	Texture gradually increases from a loamy surface to sandy clay loam or clay with depth; massive to strong structure.	Low (2)
Texture contrast soils (non-dispersive)—*Chromosols*	Sandy or loamy surface abruptly overlaying non-dispersive and generally friable clay subsoil.	Moderate (3)
Texture contrast soils (dispersive)—*Chromosols and Sodosols*	Sandy or loamy surface abruptly overlying a hard, dispersive clay subsoil with: ▶ ESP ≥6 and/or Ca:Mg <15 ▶ ESP ≥15 and/or Ca:Mg <0.1	 High (4) Very high (5)

Source: DTMR Road Drainage Manual (DTMR, 2019h)

An estimate of the long-term soil loss from both sheet and rill erosion can be calculated using the Revised Universal Soil Loss Equation (RUSLE) (IECA, 2008). ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity, to inform the development of the detail design. Additional soil data will be used to refine the assessment of soil erosion potential within the Project footprint using the RUSLE with the objective of ensuring that the design of erosion control measures (temporary and permanent) are reflective of site-specific soil conditions.

Sodic Soils

A soil is considered sodic when sodium reaches a concentration where is starts to affect soil structure. This commonly occurs in Australian soils when the ESP is greater than 6 per cent (Northcote and Skene, 1972). There are categories for sodicity corresponding to different ESPs, including: non-sodic (<6%), sodic (6-15%) and strongly sodic (>15%).

When the clay particles in sodic soils are exposed to water, the hydraulic radius of sodium ions attached to clay particles expand and force the clay to disperse or slake (Zund and Finn, 2015):

- Slaking is the breakdown of the soil into smaller fragments, but without the soil particles detaching
- Dispersion is the detachment of individual clay particles from peds when placed into water.

While some soils are not inherently dispersive (e.g. Vertosols), they can still be susceptible to erosion. The aggregates of Vertosols retain some of their natural structure after they have been removed by runoff (Zund and Finn, 2015). These relatively large particles are readily deposited when runoff velocity is reduced, such as in a contour bank or waterway, and they generally travel only a limited distance.

Within the Project footprint, dispersive sodic clay soils have been identified as having the highest erodibility rating (Table 8.7) and are associated with texture contrast Sodosols. Analysis of surface soil samples collected during geotechnical investigations reported sodic or strongly sodic subsoil in 20 out of 48 primary samples analysed (refer Table 8.4), indicating that a significant portion of the Project alignment contains sodic surface or sub-soils.

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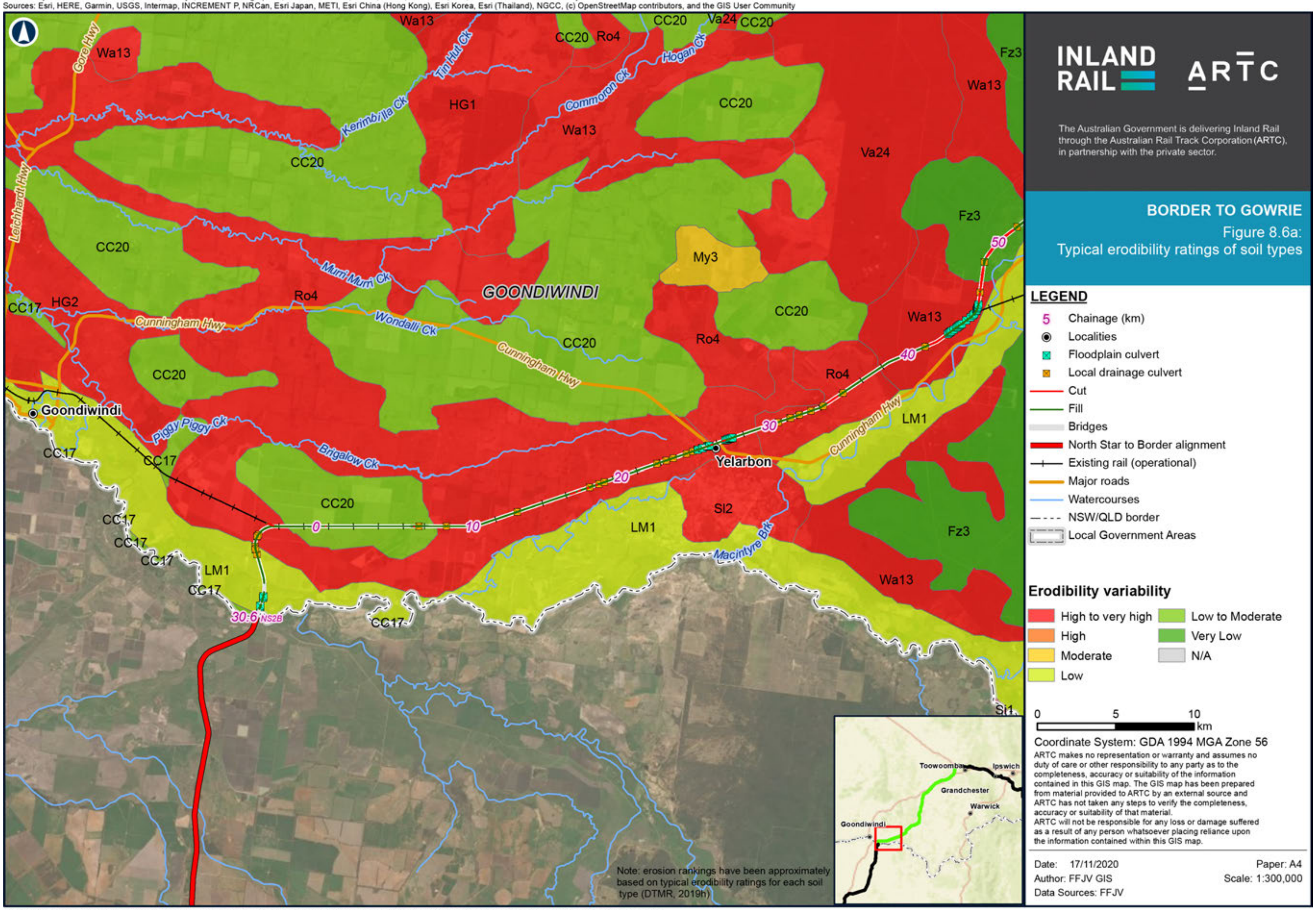

BORDER TO GOWRIE

Figure 8.6a: Typical erodibility ratings of soil types

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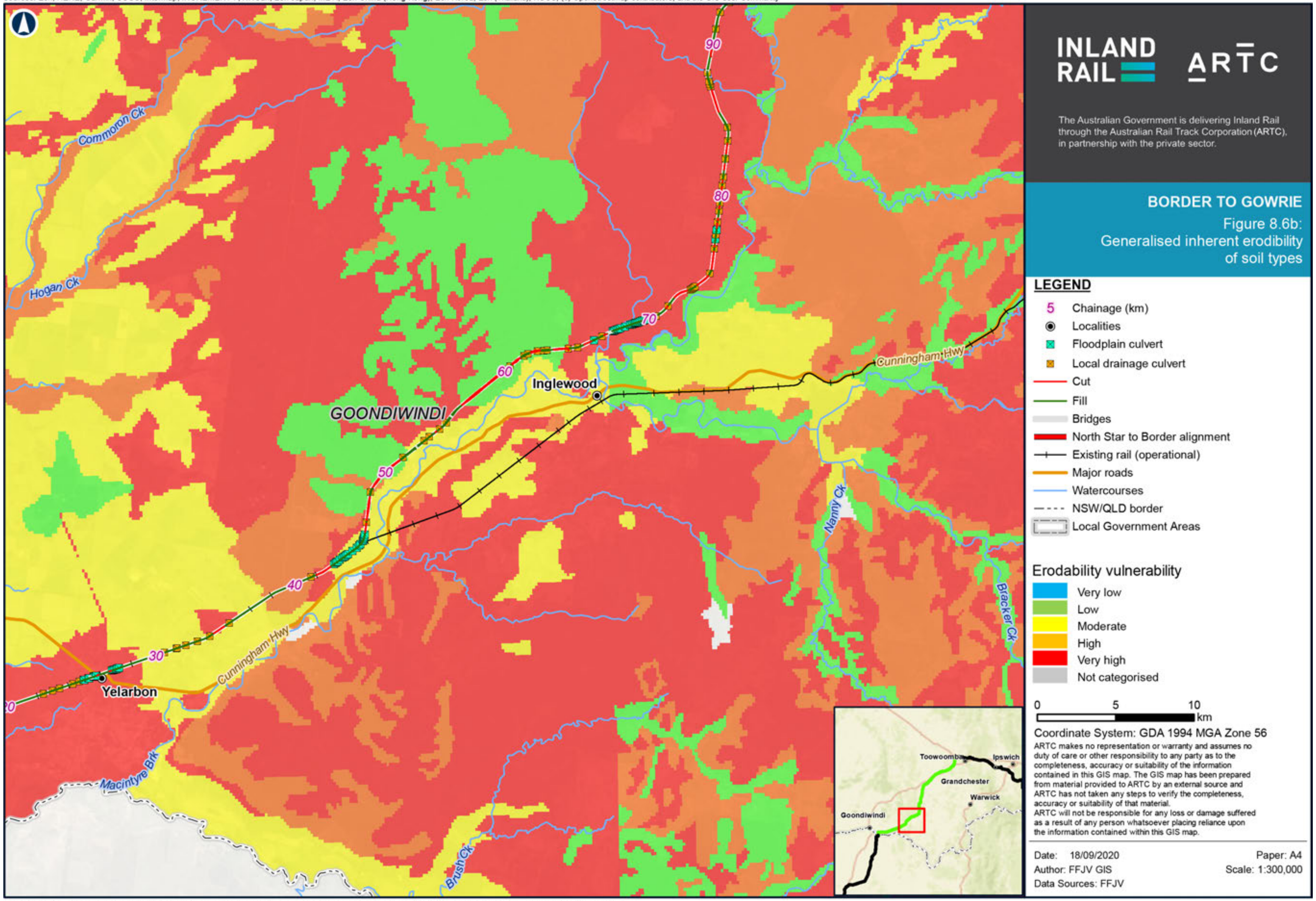

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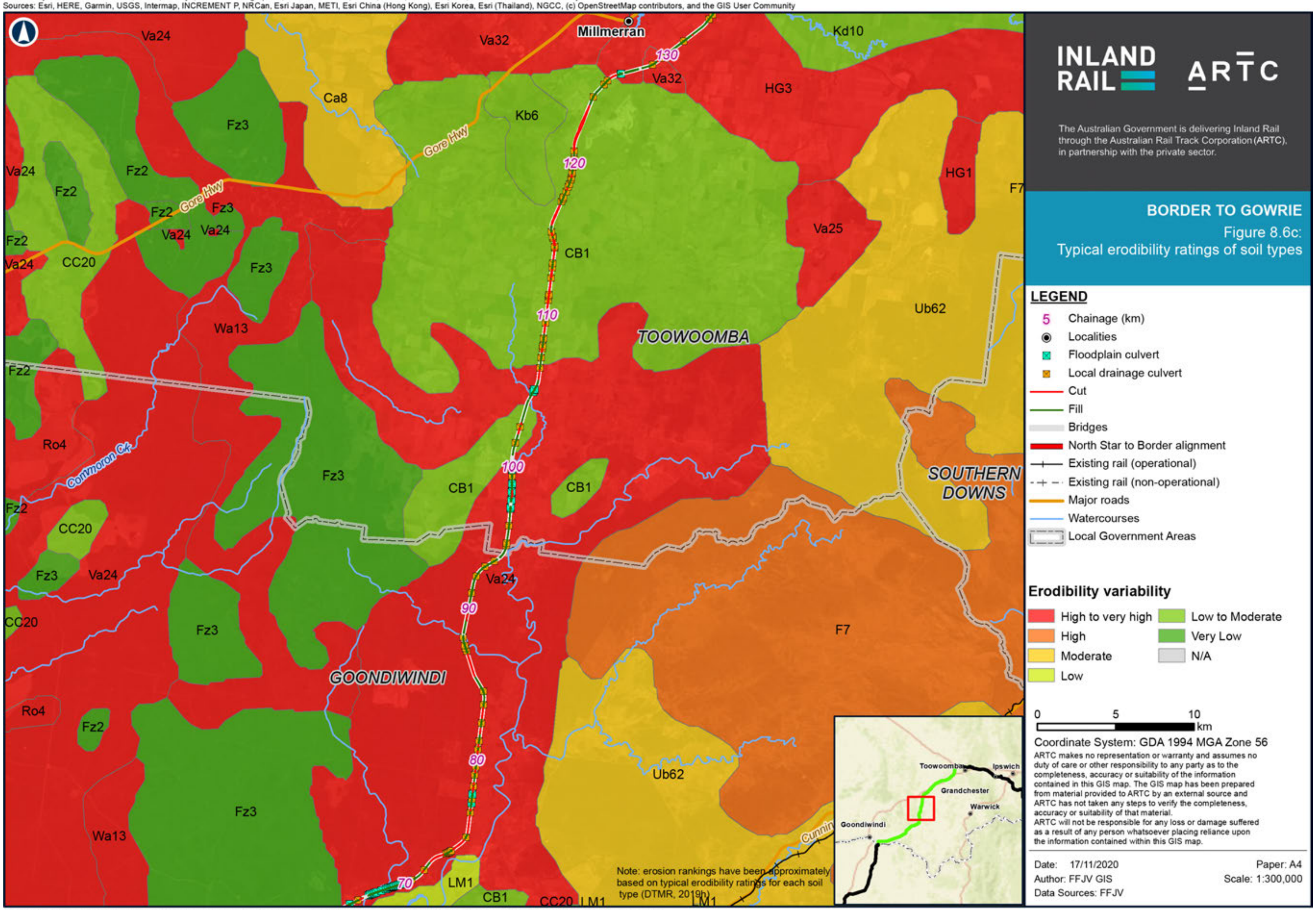

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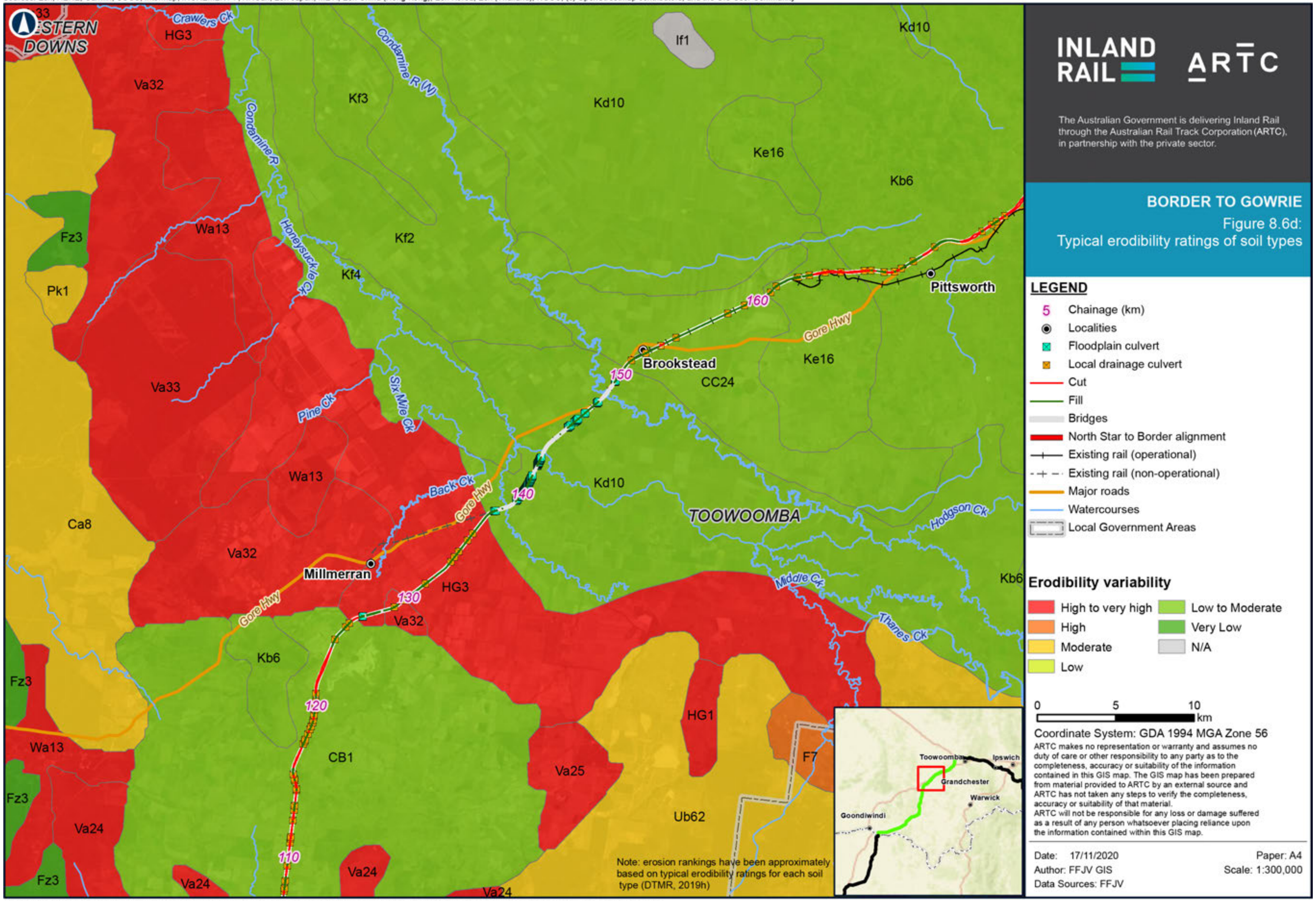

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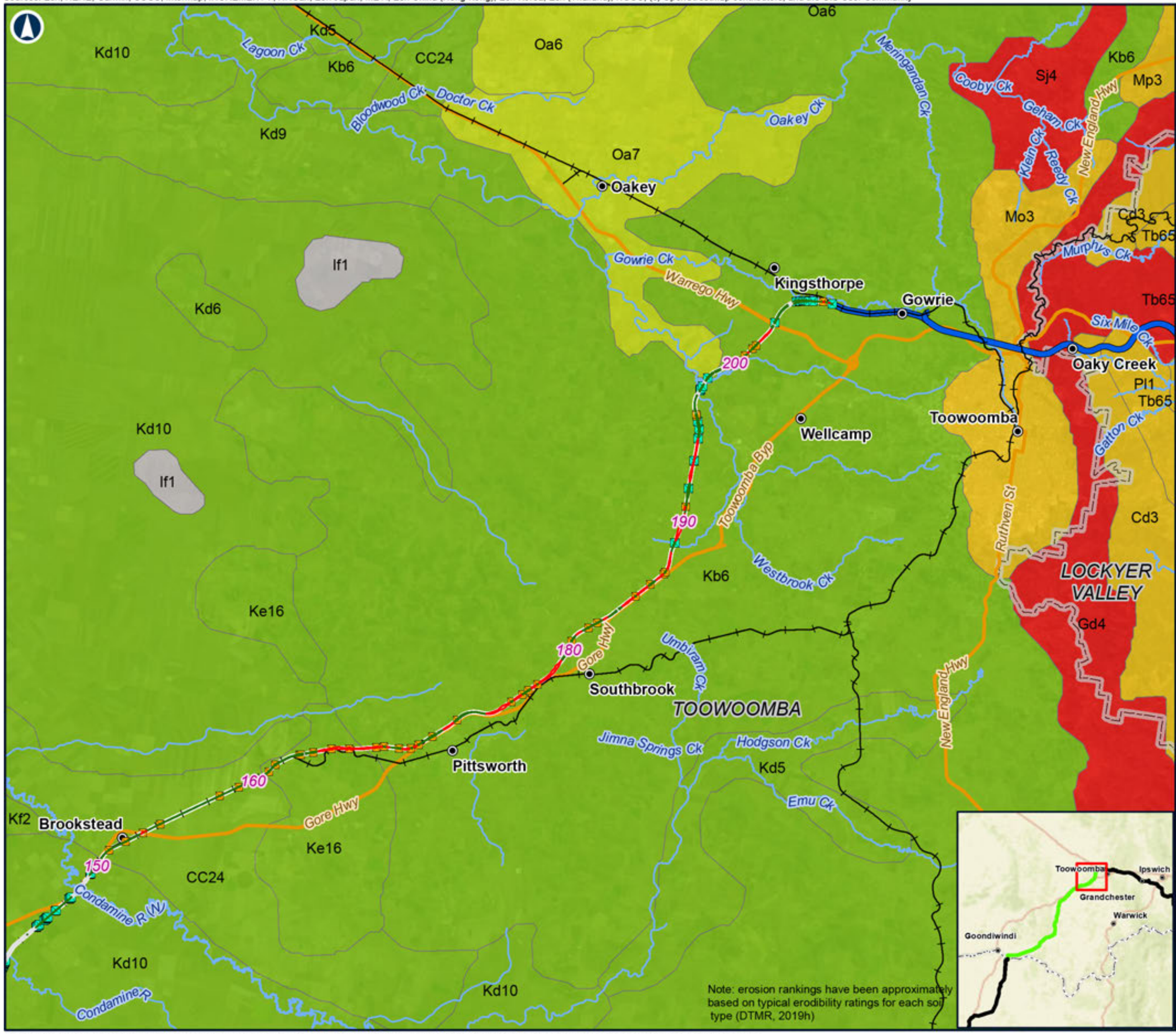

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BORDER TO GOWRIE

Figure 8.6e: Typical erodibility ratings of soil types

LEGEND

- 5 Chainage (km)
- Localities
- Floodplain culvert
- Local drainage culvert
- Cut
- Fill
- Bridges
- North Star to Border alignment
- Gowrie to Helidon alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Watercourses
- Local Government Areas

Erodibility variability

- High to very high
- High
- Moderate
- Low
- Low to Moderate
- Very Low
- N/A

0 5 10 km

Coordinate System: GDA 1994 MGA Zone 56

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8.5.3.3 Soil acidity

Queensland has more than 500,000 hectares of agricultural and pastoral land that has acidified or is at risk of acidification. Soils most at risk are lighter-textured sands and loams with low organic matter levels, and the naturally acidic red clay loam soils. Soils least at risk are the neutral-to-alkaline clay soils (e.g. brigalow soils and the black clay soils of the Darling Downs and Central Queensland) (Soil Quality, 2020).

Many soils are naturally acid, but agricultural practices have contributed to the increasing acidification of many neutral-to-slightly acid soils (NSW Agriculture, 2000). These practices include:

- Use of some ammonium fertilisers, particularly ammonium sulfate
- The production of legumes that fix nitrogen, if that nitrogen is leached, rather than being taken up by plants
- The removal of nutrients in the form of produce.

Acidic soils cause significant losses in production, and where the choice of crops is restricted to acid-tolerant species and varieties, production opportunities may be reduced. In pastures grown on acidic soils, production will be reduced, and some legume species may fail to persist (Soil Quality, 2020).

Soil pH is a measure of the concentration of hydrogen ions in the soil solution. The lower the pH of soil, the greater the acidity. A soil with a pH of 4 has 10 times more acid than a soil with a pH of 5 and 100 times more acid than a soil with a pH of 6. Plant growth and most soil processes, including nutrient availability and microbial activity, are favoured by a soil pH range of 5.5–8.0 (Soil Quality, 2020).

Assessment of surface soil acidity within the impact assessment area has been undertaken in reference to ARIS soil pH mapping (CSIRO, 2014a). This mapping is presented in Figure 8.7. Surface soil pH values along the Project alignment are presented in Table 8.8 by chainage range, coloured to correlate with Figure 8.7.

TABLE 8.8 SOIL ACIDITY ALONG THE PROJECT ALIGNMENT

Approximate chainage start (km)	Approximate chainage end (km)	Soil pH[1]
30.6 (NS2B)	34.9 (NS2B)	4.8-5.5
34.9 (NS2B)	19.9	5.5-6.0
19.9	20.0	6.0-6.5
20.0	25.0	5.5-6.0
25.0	28.0	7.0-7.5
28.0	28.5	5.5-6.0
28.5	30.0	6.5-7.0
30.0	33.5	5.5-6.0
33.5	35.3	4.8-5.5
35.3	37.0	6.5-7.0
37.0	42.8	4.8-5.5
42.8	46.2	6.0-6.5
46.2	49.0	4.8-5.5
49.0	51.7	3.0-4.8
51.7	55.0	6.0-6.5
55.0	98.0	4.8-5.5
98.0	100.0	6.5-7.0
100.0	102.0	4.8-5.5
102.0	104.2	6.5-7.0
104.2	105.3	4.8-5.5
105.3	114.0	6.5-7.0
114.0	114.2	7.0-7.5

Approximate chainage start (km)	Approximate chainage end (km)	Soil pH[1]
114.2	126.3	6.5-7.0
126.3	129.0	6.0-6.5
129.0	133.0	6.5-7.0
133.0	138.0	6.0-6.5
138.0	148.2	6.5-7.0
148.2	160.0	5.5-6.0
160.0	165.5	6.5-7.0
165.5	196.9	6.0-6.5
196.9	198.9	6.5-7.0
198.9	204.8	6.0-6.5
204.8	206.9	6.5-7.0

Table notes:
1. Source: ARIS soil pH mapping (CSIRO, 2014a)

The lowest soil pH, 3.0 to 4.8, occurs over a distance of 2.7 km of Project alignment, south of the Yarranbrook Feedlot, bordering Whetstone State Forest (Ch 49.0 km to Ch 51.7 km).

Soils with low pH (4.8 to 5.5) also occur within the Macintyre River floodplain (Ch 30.6 km (NS2B) to Ch 34.9 km (NS2B) and intermittently from Ch 33.5 km to Ch 105.3 km. The mapping of acidic soils over this 71.8 km section of the Project alignment closely correlates with areas of production forestry, associated with Whetstone and Bringalily State forests.

Soils with the highest pH are only mildly alkaline in nature (pH 7.0 to 7.5) and are encountered in two isolated locations; for 3 km in the Yelarbon area (Ch 25.0 km to Ch 28.0 km) and for 200 m between Millwood and Clontarf (Ch 114.0 km to Ch 114.2 km).

The Yelarbon area (approximately from Ch 20 km to Ch 30 km) is known for its alkaline, Sodosol soils attributed to the upwelling of sodium bicarbonate rich groundwater (Biggs et al., 2010a).

The occurrence of mildly alkaline soils between Millwood and Clontarf is associated with Tertiary/Quaternary colluvium (refer Figure 8.4).

Further discussion of soil salinity is presented in Section 8.5.3.6.

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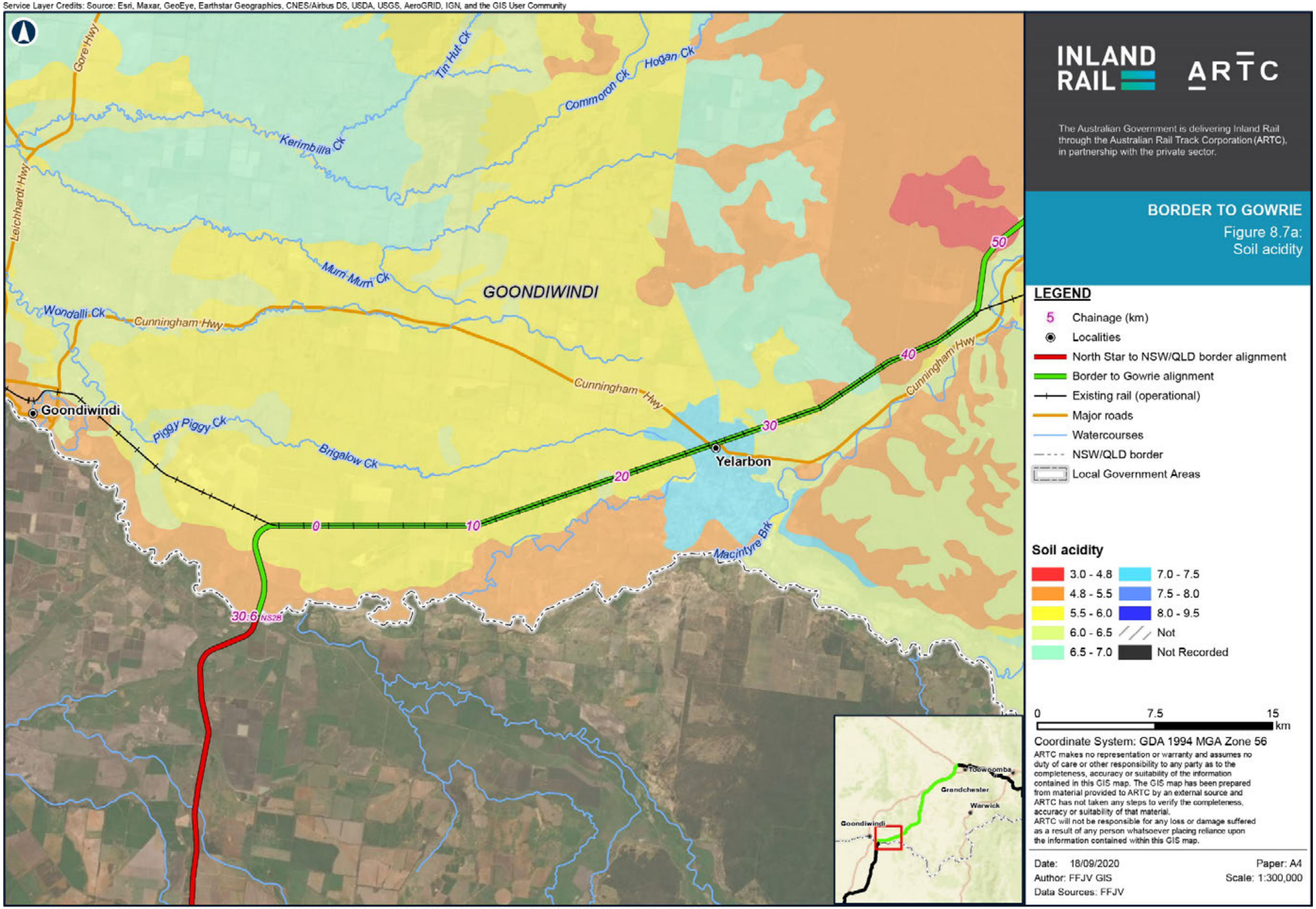

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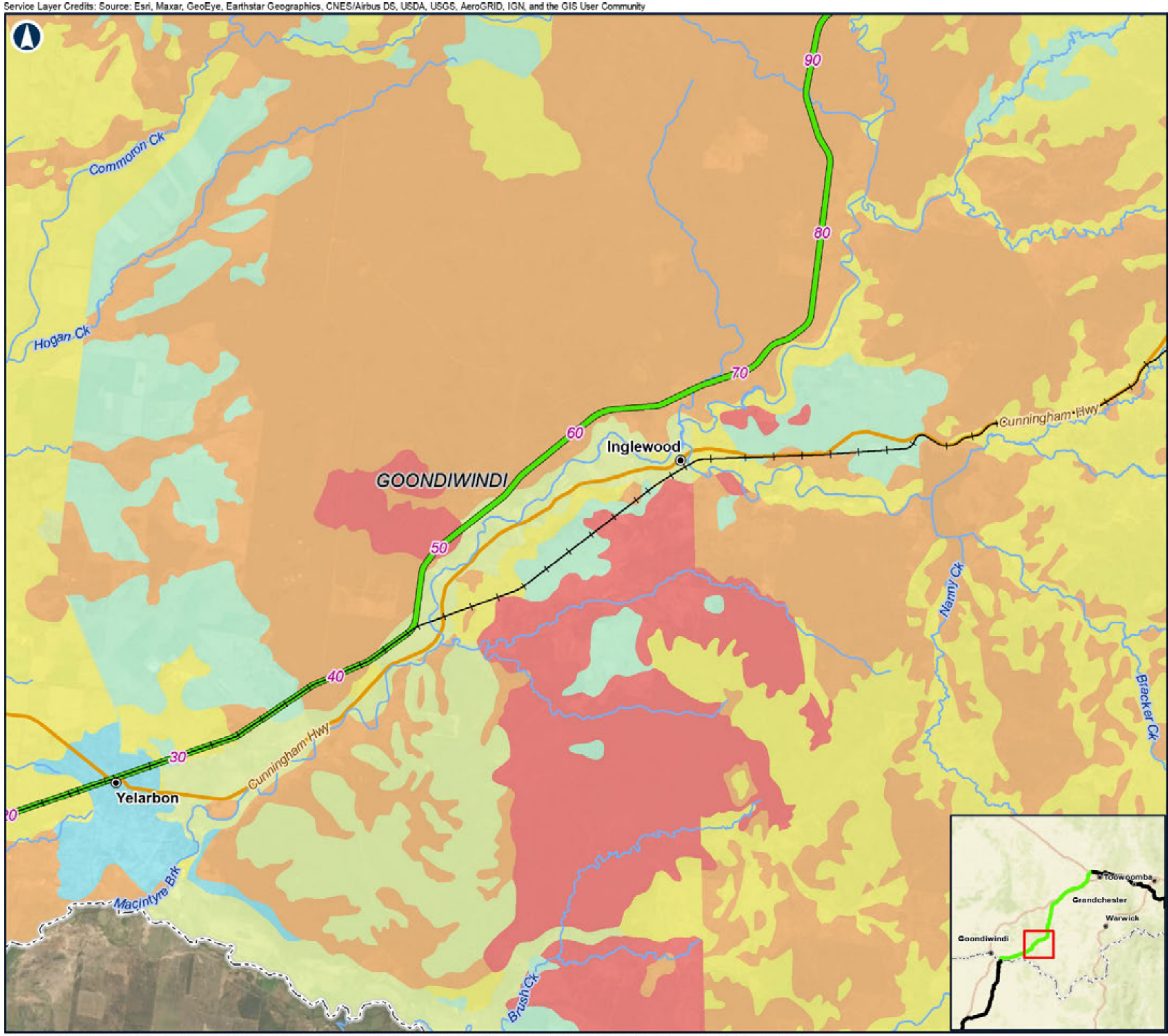

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BORDER TO GOWRIE

Figure 8.7b: Soil acidity

LEGEND

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

Soil acidity

- 3.0 - 4.8
- 4.8 - 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- 7.0 - 7.5
- 7.5 - 8.0
- 8.0 - 9.5
- Not
- Not Recorded

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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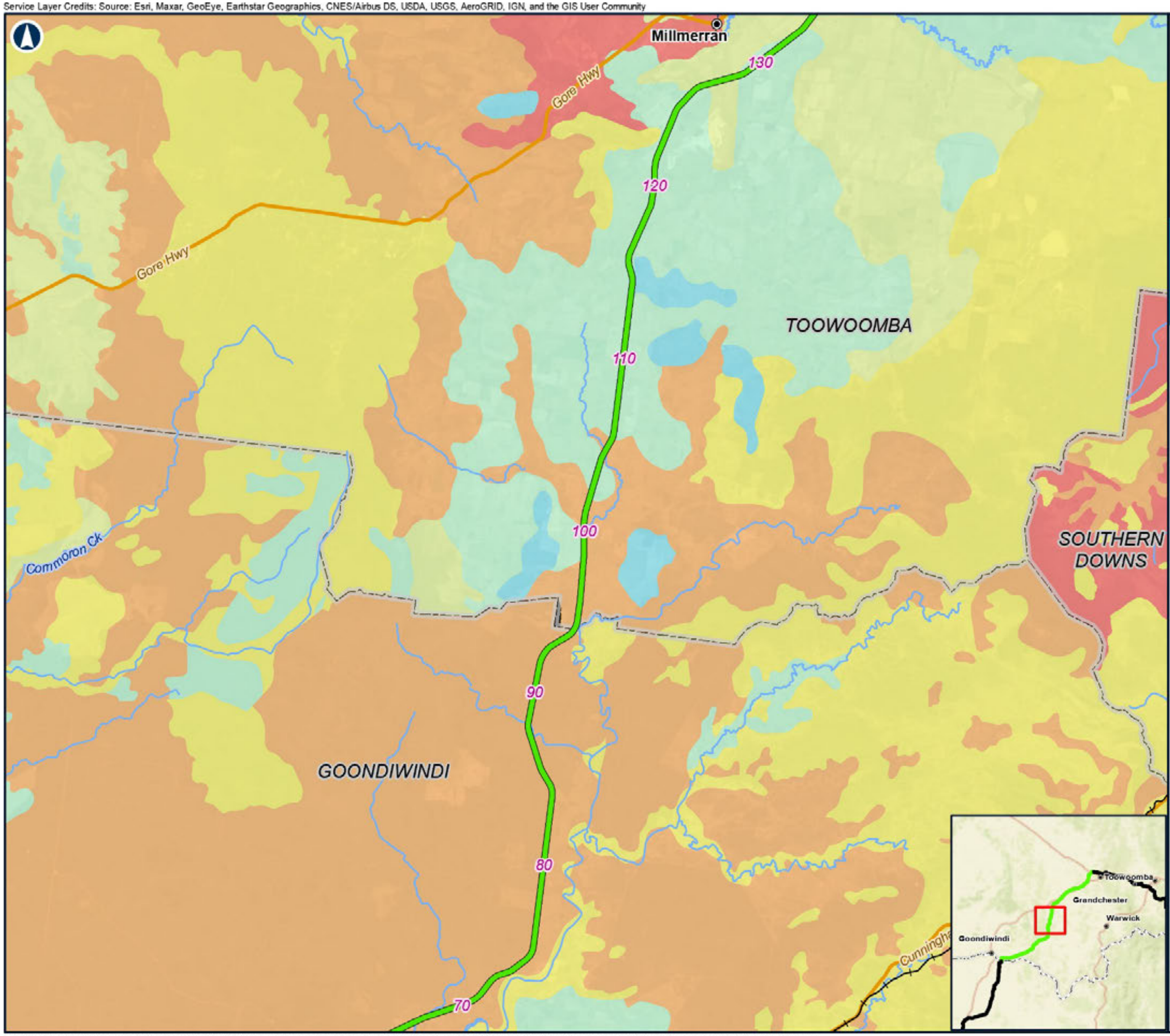

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BORDER TO GOWRIE

Figure 8.7c: Soil acidity

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Watercourses
- Local Government Areas

Soil acidity

- 3.0 - 4.8
- 4.8 - 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- 7.0 - 7.5
- 7.5 - 8.0
- 8.0 - 9.5
- Not
- Not Recorded

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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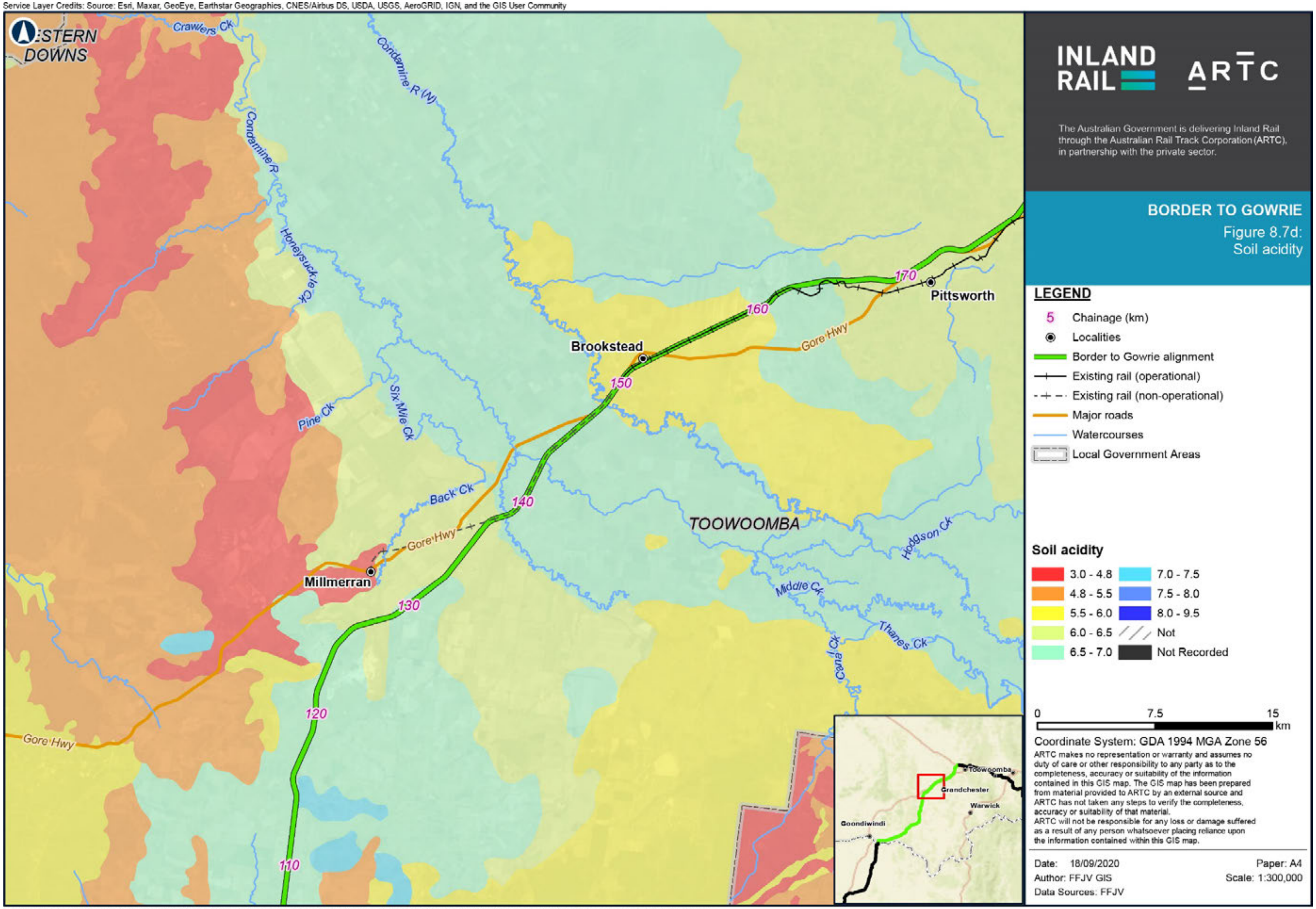

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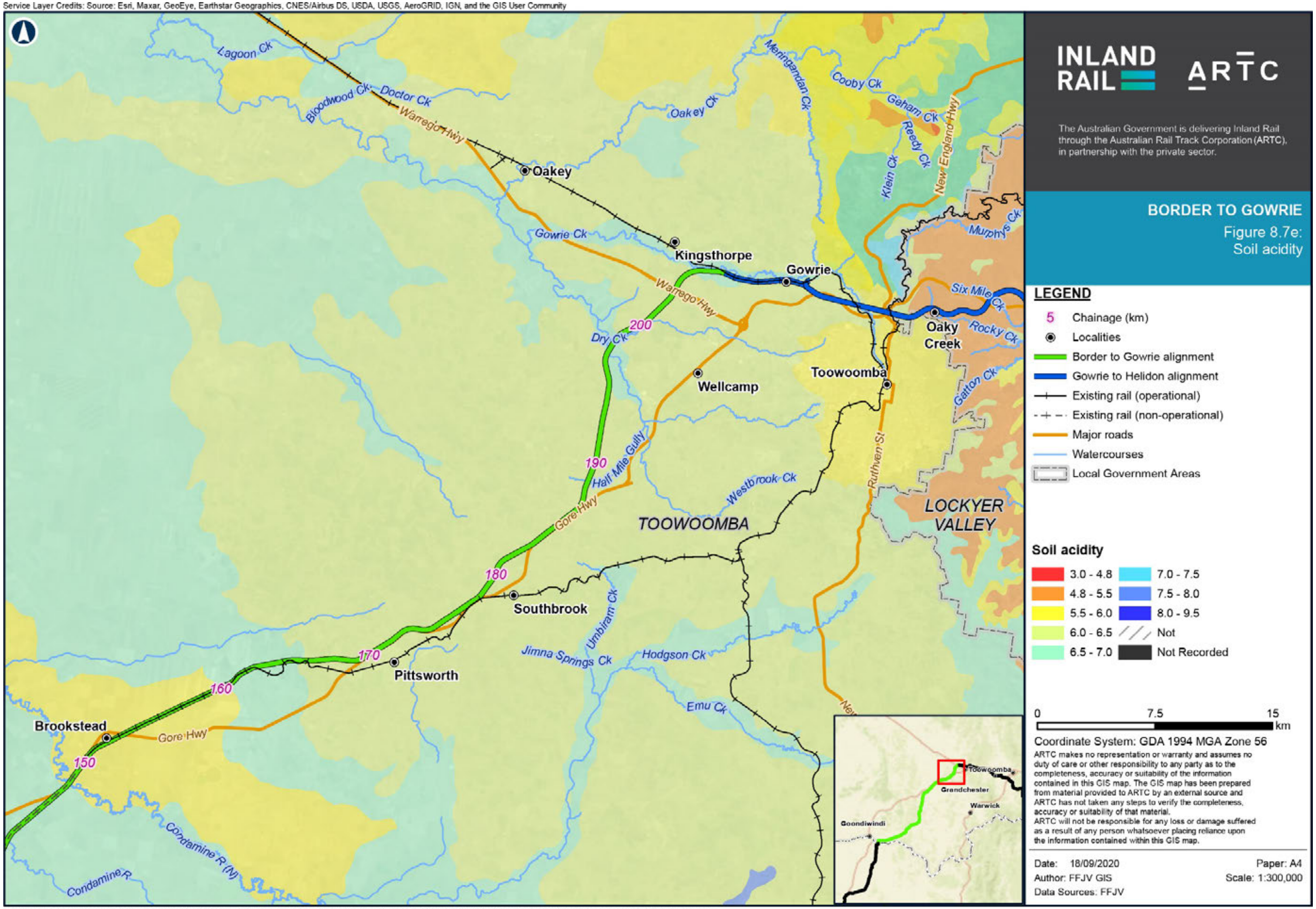

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8.5.3.4 Acid sulfate soils and acid rock

ASS are predominantly a coastal and near-coastal soil, sediment or other materials containing iron sulfides, which generate acidic conditions when exposed to oxygen. ASS, in general, have a field pH of 4 or less and can be visually identified through the presence of jarosite or iron oxide in the soil horizon. They are often associated with low-lying areas below 5 metres Australian Height Datum (mAHD), such as alluvial plains where groundwater is generally close to the surface and materials are in reducing condition along coastal regions. ASS in non-coastal areas are commonly known as inland ASS (DSITIA, 2014a).

In Queensland, inland ASS can also be found in parts of central Queensland, at elevations above 5 mAHD if an anoxic, aqueous environment that consists of sulfate-reducing bacteria and available sulfate ions exist (DSITIA, 2014a; EPHC and NRMMC, 2011). Inland ASS is generally associated with poorly drained inland basins with stagnant water bodies in distinctly seasonal, arid climates but are not widely distributed in Queensland. However, inland ASS are known to occur in landscapes with high levels of salt, where significant concentrations of sulfate reside.

ASS have been found in effluent ponds and in several north-draining streams and wetlands just north of the Granite Belt, in the uppermost reaches of the Condamine River catchment (NRMMC, 2011).

The *National guidance for the management of acid sulfate soils in inland aquatic ecosystems* (National Guidance on Acid Sulphate Soils) (EPHC and NRMMC, 2011) (National Guidance on Acid Sulfate Soils) provides a protocol for assessing the likelihood of an aquatic ecosystem containing acid sulfate soils. This assessment protocol requires consideration to be given to presence and permanency of surface water in an area, in addition to the pH and salinity of those waters.

An assessment, consistent with assessment protocol in the National Guidance on Acid Sulfate Soils, has been undertaken using surface water sampling data collected to inform the development of this draft EIS. This assessment is presented in Table 8.9. Application of the assessment protocol indicates that, based on the pH and salinity of the surface waters in the area and the known flooding history of the region, there is a low risk of presence of ASS in the majority of the inland aquatic ecosystems within the impact assessment area.

Surface water sampling data is summarised in Chapter 12: Surface Water and Hydrology and presented in full in Appendix P: Surface Water Quality Technical Report.

TABLE 8.9 SUMMARY OF ASS PARAMETERS AT SELECT AQUATIC ECOSYSTEMS

Sub-catchment, basin and sample location ID	pH	Electrical conductivity (µS/cm)	Hydrological characteristics	Comments
Sub-catchment: Macintyre Barwon **Floodplain basin:** Queensland Border Rivers Basin **Sample sites:** 1R, 2 and 2R	6.77 to 7.76	211 to 299	Permanent waterway	Based on water-quality data, low ASS risk for the aquatic ecosystem. except for within permanent waterways
Sub-catchment: Lower Macintyre Brook **Basin:** Queensland Border Rivers Basin **Sample sites:** Site 3 to 8	5.58 to 7.97	334 to 449	Permanent waterway	Based on water-quality data, low ASS risk for the aquatic ecosystem. except for within permanent waterways
Sub-catchment: Canning Creek **Basin:** Queensland Border Rivers Basin **Sample sites:** 9 to 20	7.00 to 8.39	160 to 1,255	Include several ephemeral watercourses, found dry at time of survey	Low or no ASS risk for the aquatic ecosystem except for within permanent waterways
Sub-catchment: Southern Condamine **Basin:** Condamine River Basin **Sample sites:** 21 to 26	7.18 to 8.18	267 to 580	Include several ephemeral watercourses, found dry at time of survey	Low or no ASS risk for the aquatic ecosystem except for within permanent waterways

Sub-catchment, basin and sample location ID	pH	Electrical conductivity (µS/cm)	Hydrological characteristics	Comments
Sub-catchment: Central Condamine **Basin:** Condamine River Basin **Sample sites:** 27 to 33	7.70 to 9.13	212 to 588	Include several ephemeral watercourses, found dry at time of survey	Low or no ASS risk for the aquatic ecosystem except for within permanent waterways
Sub-catchment: Oxley Creek **Basin:** Condamine River Basin **Sample sites:** 34 to 43	8.12 to 8.54	680 to 2,632	Include several ephemeral watercourses, found dry at time of survey	Low or no ASS risk for the aquatic ecosystem except for within permanent waterways

Additionally, an assessment of ASS using the ASRIS *Atlas of Australian Sulfate Soils* (CSIRO, 2014b) has been undertaken, with mapping presented on Figure 8.8. indicated a 'low probability' of ASS to occur within the floodplain of Macintyre River and Macintyre Brook, as well as between Millmerran and Yandilla.

Isolated areas of 'high probability' ASS occur throughout the impact assessment area. These localised occurrences are, for the most part, associated with natural and man-made surface water storages or impoundments.

No visual indications of presence of ASS or acid rock were identified during geotechnical investigations for the Project, which included site walkovers.

Based on the underlying geology of the impact assessment area, the surface water quality data as well as existing ASS mapping, there is considered to be a low risk of inland ASS or potential inland ASS present within the majority of the impact assessment area. Further sediment assessment will be necessary to establish the location-specific risk of ASS occurrence where construction activities are required within permanent waterways along the Project alignment.

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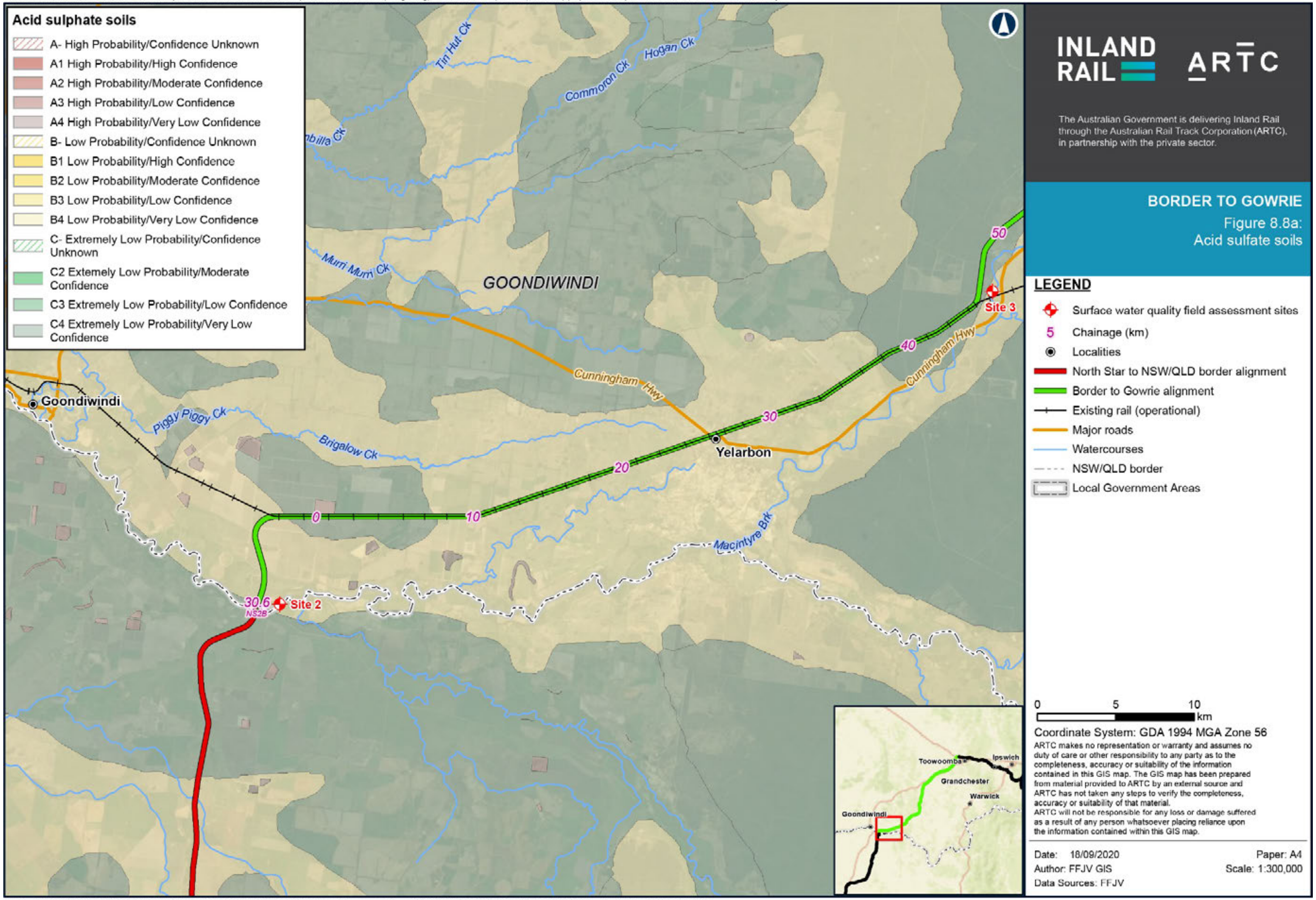

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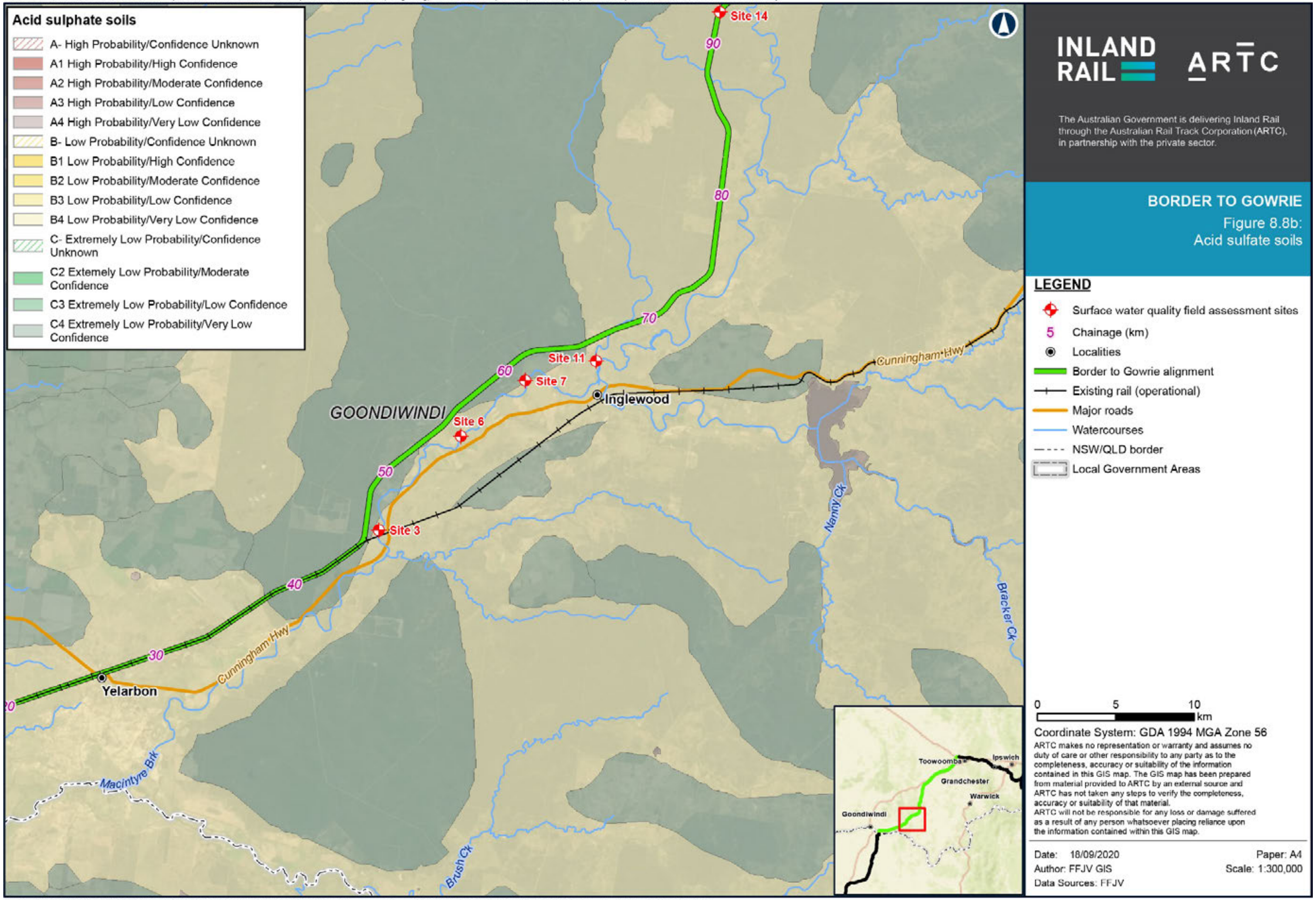

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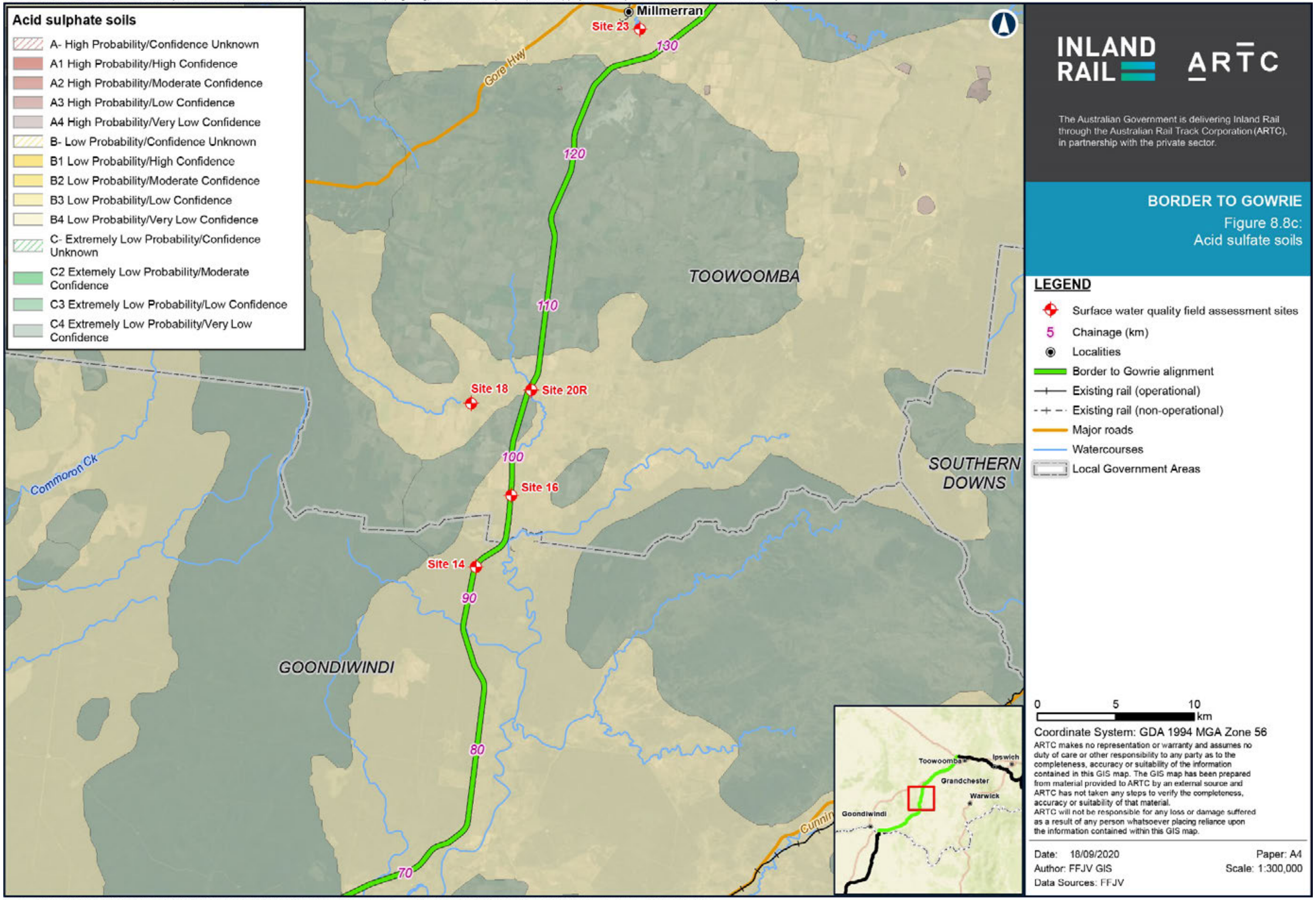

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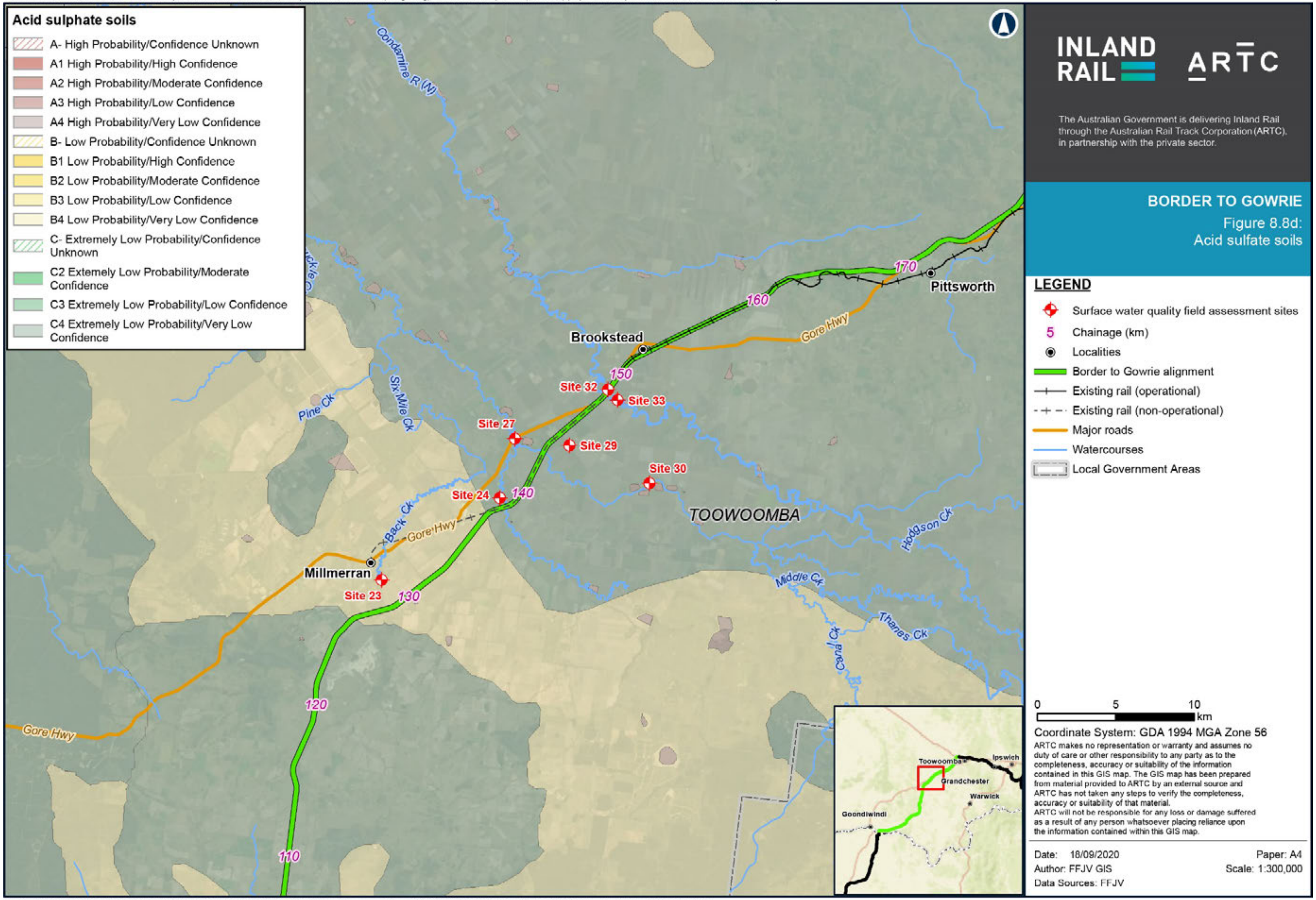

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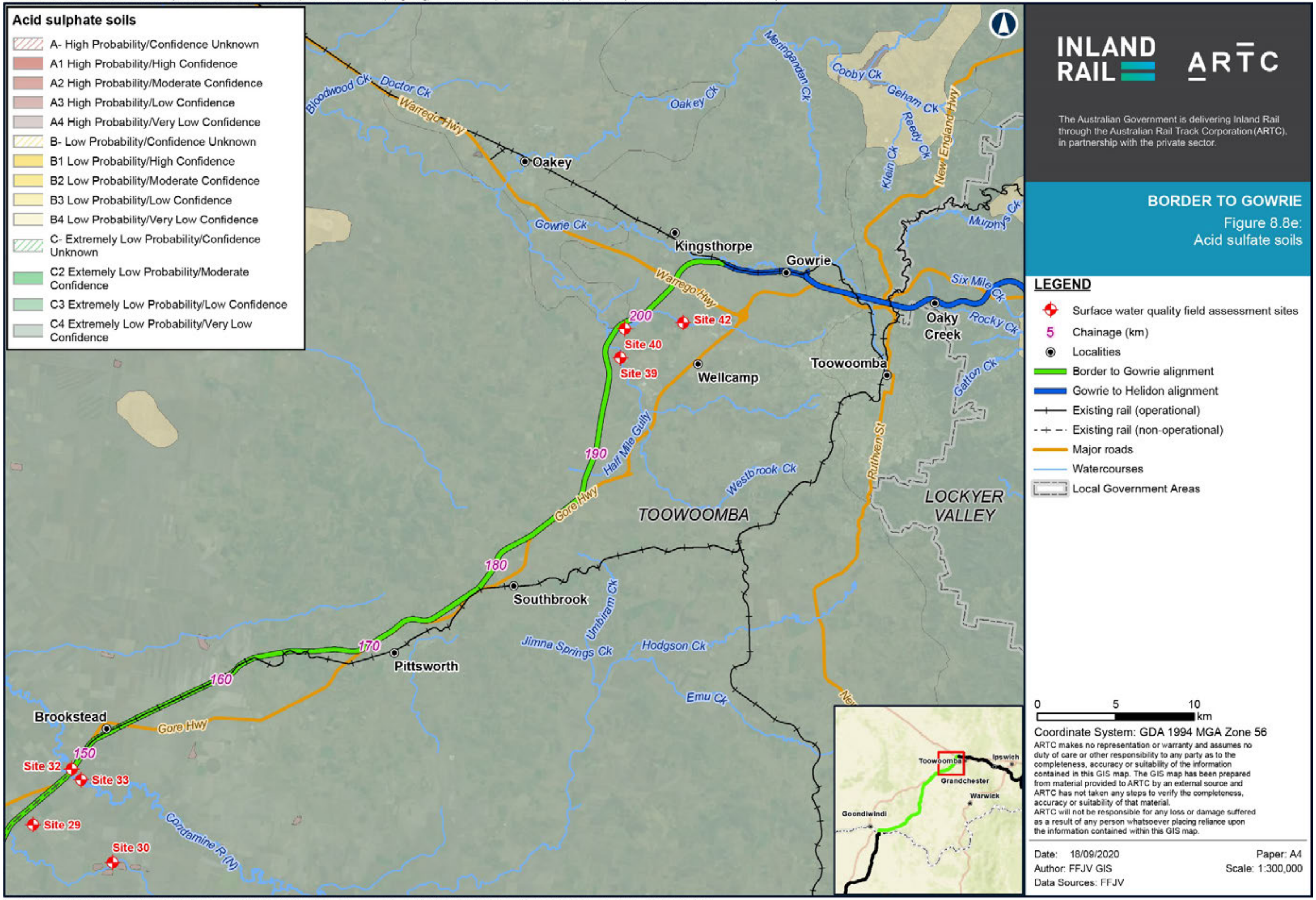

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8.5.3.5 Soil texture

Soil texture as a guide to the proportions of gravel, coarse sand, fine sand, silt and clay in the soil. Texture is important, because it affects the movement and availability of water and nutrients in the soil (NSW Agriculture, 2000). Soil particles are grouped into five main size ranges: gravel, coarse sand, fine sand, silt and clay. A soil with a relatively even mix of particle sizes is called a loam.

An assessment of surface soil texture, using ASRIS mapping (CSIRO, 2014a) identified that soil textures within the A-horizon of soils in the impact assessment area is variable, ranging from heavy clays (>45 per cent clay content) to sandy loams (10-to-20 per cent clay content).

Sandy loams to clay loams are the significant feature along much of the Project footprint between Kurumbul and Canning Creek. From Canning Creek to Kingsthorpe, heavy clays are dominant, as indicated by the prevalence of Vertosols through these areas (refer Figure 8.5).

Data obtained from the land-management manuals and historical soil surveys (SALI database) identified that the majority of the soils within the impact assessment area demonstrate one, or more, characteristics of hard-setting surfaces, self-mulching, periodic cracking and subsoil sodicity, as well as displaying gilgai development (refer Table 8.5 and Table 8.6).

Areas of hard-setting surfaces, cracking clays and gilgai development are typically associated with areas of Vertosols, such as around Kurumbul, as well as from Kooroongarra to Clontarf and from Yandilla to Kingsthorpe.

Areas of highly sodic and saline soils with hard-setting surfaces are typically associated with areas of Sodosols, which occur within the Macintyre River floodplain, north of Inglewood along Millmerran–Inglewood Road and from Clontarf to Yandilla (refer Figure 8.5).

8.5.3.6 Soil salinity

Salinity is the amount of salt in the soil or water. The dominant salt in most saline soil is sodium chloride (NaCl), although varying amounts of calcium, magnesium and potassium chlorides and sodium sulfates can also occur. There are two main types of salinity:

- Primary—naturally occurring salinity
- Secondary—resulting from human activities.

Primary salinity occurs naturally in soils and waters, where there are groundwater fluctuations, where salty water is discharged, or where topsoil is removed to reveal saline scalds; however, in many cases, human intervention is responsible for salinity problems (secondary salinity), in both irrigation and dryland areas (NSW Agriculture, 2000).

It is estimated that 107,000 hectares of land in Queensland are seriously affected by existing salinity issues; however, there are extensive areas of the State where salinity could emerge and impact on land and water resources, environmental values or infrastructure. A number of factors determine the salinity hazard of an area, and these can be combined to form a salinity hazard map. An area with a high salinity hazard will become saline only if there is a change in management practices that affect the water balance and mobilise salt in the landscape (DNRME, n.d.).

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) and the *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007). The Murray–Darling region salinity risk assessment provides coverage of the impact assessment area between the Macintyre River and east of Millmerran State Forest (Biggs et al., 2010b). The Condamine catchment salinity risk assessment provides coverage of the impact assessment area from east of Millmerran State Forest to Gowrie (Searle et al., 2007).

The Murray–Darling region salinity risk assessment identified 58 known salinity expression areas affected by secondary salinity, including the Yelarbon Desert in the Border Rivers catchment. As acknowledged in Section 8.5.3.3, 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).

Within the Border Rivers catchment, the Murray–Darling region salinity risk assessment identified the use of saline groundwater, leaking dams and dissolution of salts as the most common salinity types. The risk assessment concluded that salinity in the region will have a low risk to rail infrastructure (Biggs et al., 2010b); however, it was acknowledged that there is a need for further research regarding secondary salinity formation and the impact of that salinity on infrastructure assets.

The Condamine catchment salinity risk assessment identified more than 170 salinity expression sites, with most influenced by climatic conditions. The 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, resulting in an increased salt load exported from the catchment.

The Condamine catchment salinity risk assessment identified the Millmerran area as having a very low to low risk of secondary salinity, while the Pittsworth to Kingsthorpe area is considered to have moderate risk of secondary salinity.

An area of high salinity risk intersects the Project near Southbrook and presents a 'current' threat, through salinity, to infrastructure assets in the area (Searle et al., 2007).

The sections below provide a discussion of the salinity hazard assessment that has been undertaken for the Project.

Desktop salinity hazard assessment

A targeted salinity hazard assessment was undertaken for the impact assessment area to understand the existing primary salinity within the landscape, as well as potential for secondary salinity formation as a result of Project activities.

Primary salinity is the presence of salts within a landscape where salts are stored within the geology or soils and moved by the water that flows through a catchment area. Each catchment has a different level of stored salts, and how each landscape is managed will depend on how severe the salinity may be. Predicting areas at risk from salinity is a complex exercise that requires both determining the inherent salinity hazard in a landscape and the effects of past, present and future land-management practices.

A desktop salinity hazard assessment was conducted adopting the assessment methodology described in *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007) in order to meet the requirements of Part B of the *Salinity Management Handbook* (Department of Environment and Resource Management, 2011).

The approach adopted for the Project to assess overall salinity hazard included collecting and analysing data that relates salinity risk to biophysical hazard. Biophysical hazard is the inherent capacity of the landscape to develop salinity and is often determined through factors such as geology, soil, topography and groundwater availability or flow. Five component factors were used to relate salinity risk to biophysical hazard, which included the occurrence of:

- Soil salt store
- Basalt contact potential expression areas (PEA)
- Catena PEAs
- Artificial restriction PEAs
- Confluence of streams PEAs.

PEAs are locations where salinity has potential to be expressed, either through natural or anthropogenic processes.

The impact assessment area was broken down by the Australian Hydrologic Geospatial Fabric Catchment GIS layer (BoM, 2015), into smaller sub-catchments to enable a more precise analysis for the Project. In doing so, consideration was given to how construction activities for the Project may alter the hydrological processes within the impact assessment area.

Inherent soil salt store

Each sub-catchment through which the Project alignment traverses was overlain with ASC mapping (CSIRO, 2014b) (verified by land management manuals, data from Project soil surveys and with observations from historical soil surveys (refer 8.5.3.1)) to derive the dominant soil type in each sub-catchment.

Inherent salt store ratings for each soil type were adopted from the *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007) and applied to assign a low, moderate, or high soil salt store hazard rating to each soil type. This salt store categorisation is summarised in Table 8.10 and illustrated in Figure 8.9.

TABLE 8.10 SOIL TYPE AND SOIL SALT STORE

Soil type	Soil salt store hazard category
Chromosol	High
Black Dermosols	Low
Brown Kandosol	Low
Black Vertosol	Moderate
Brown Sodosol	Moderate
Grey Vertosol	High

Source: Searle et al., 2007

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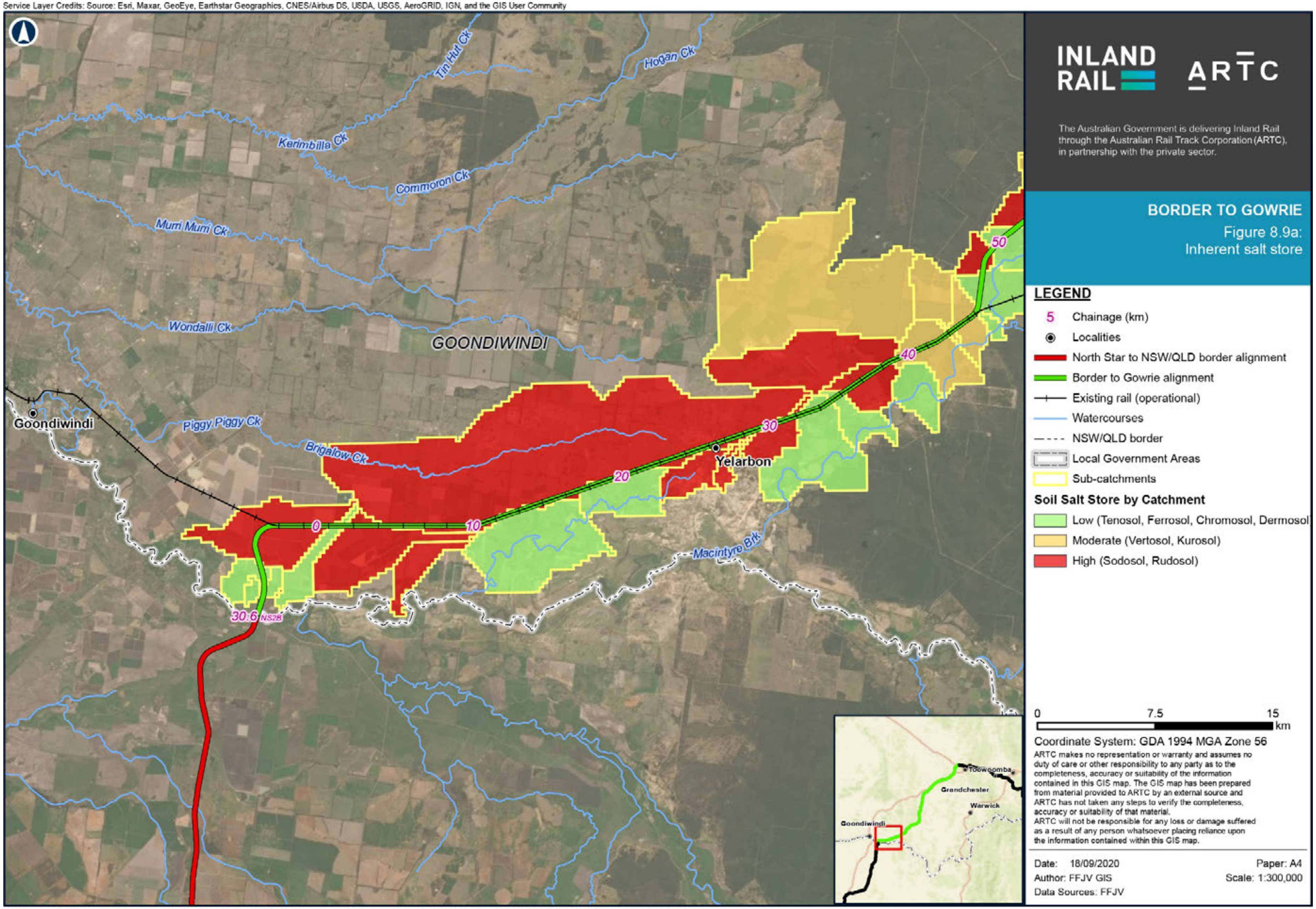

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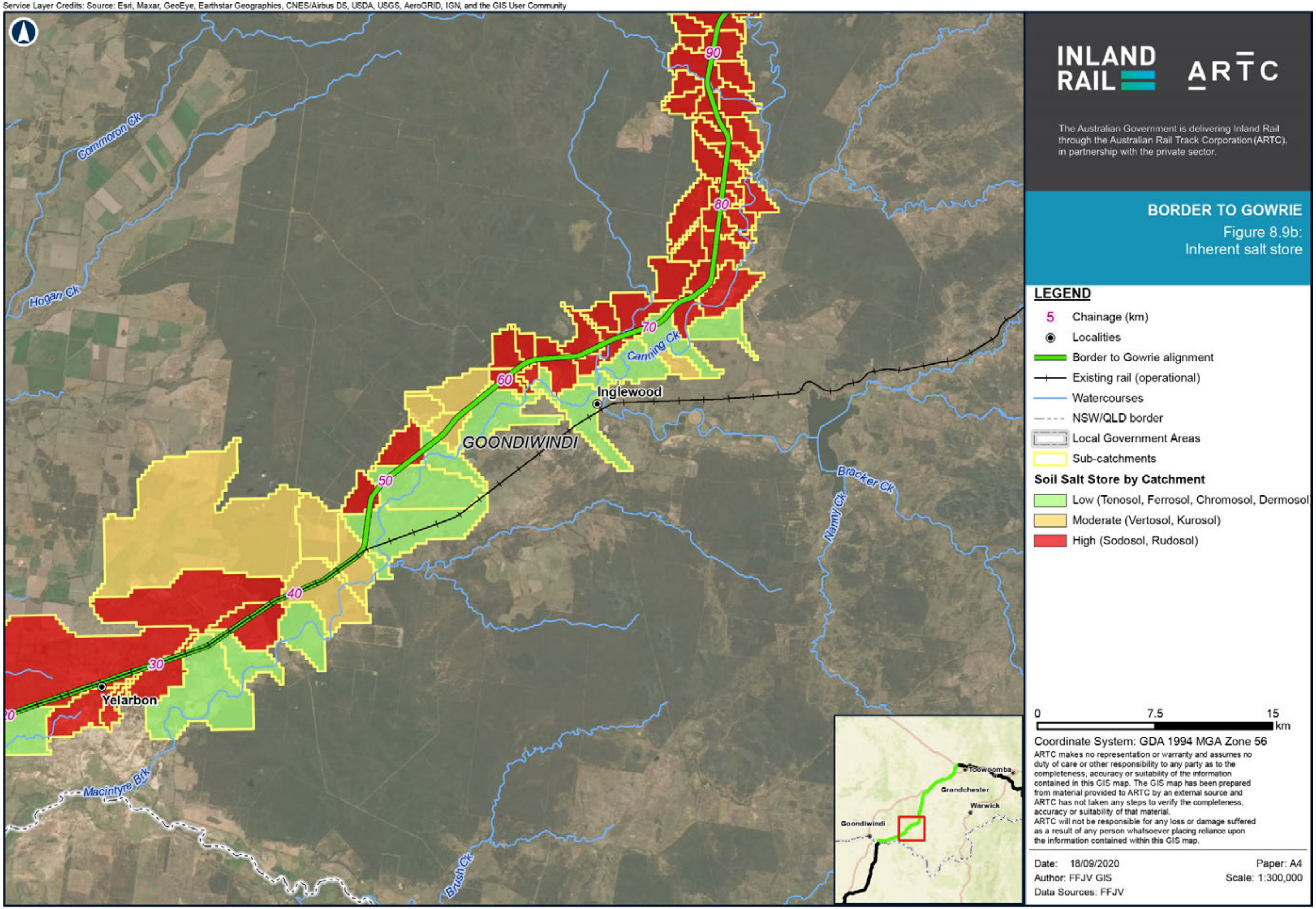

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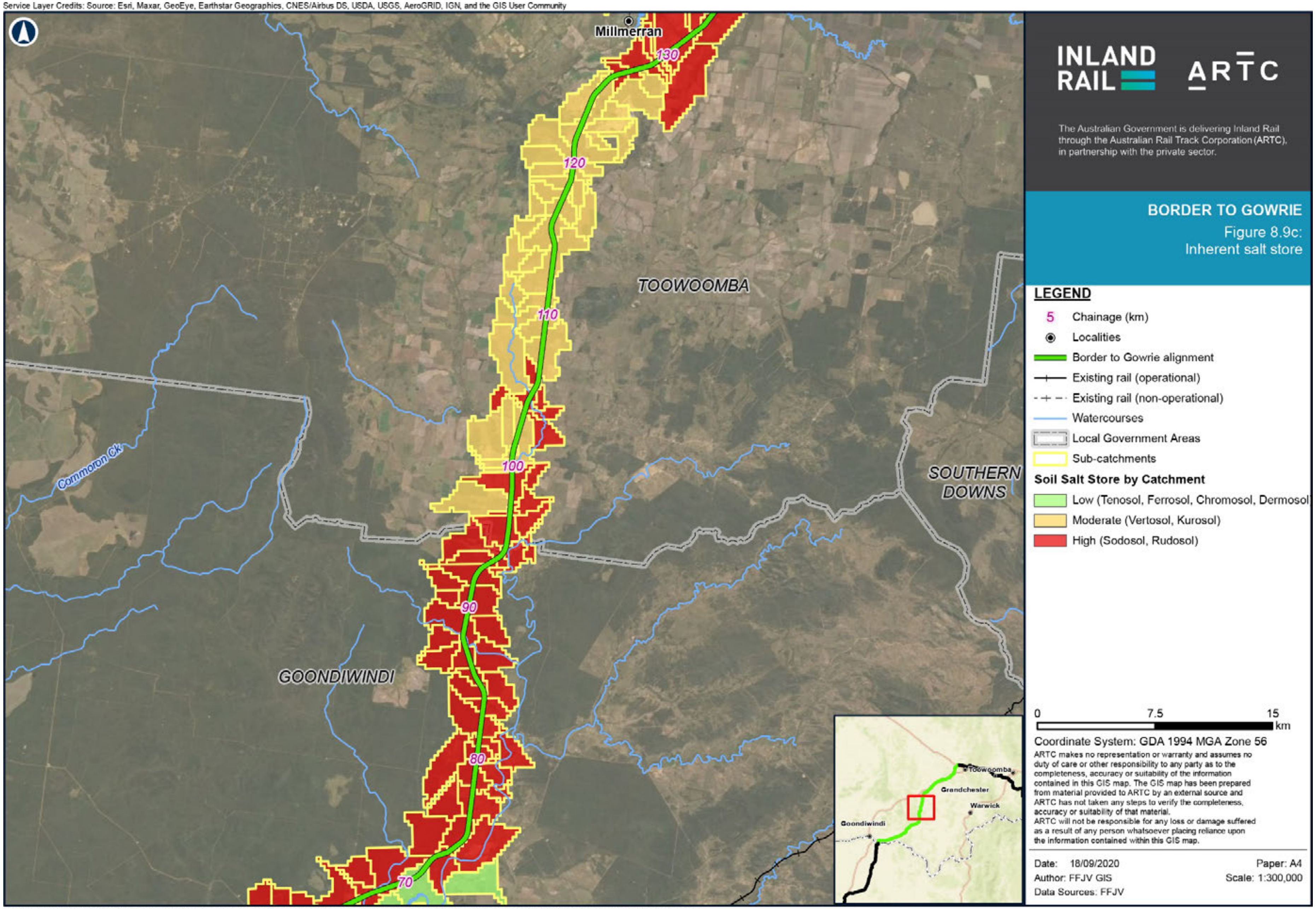

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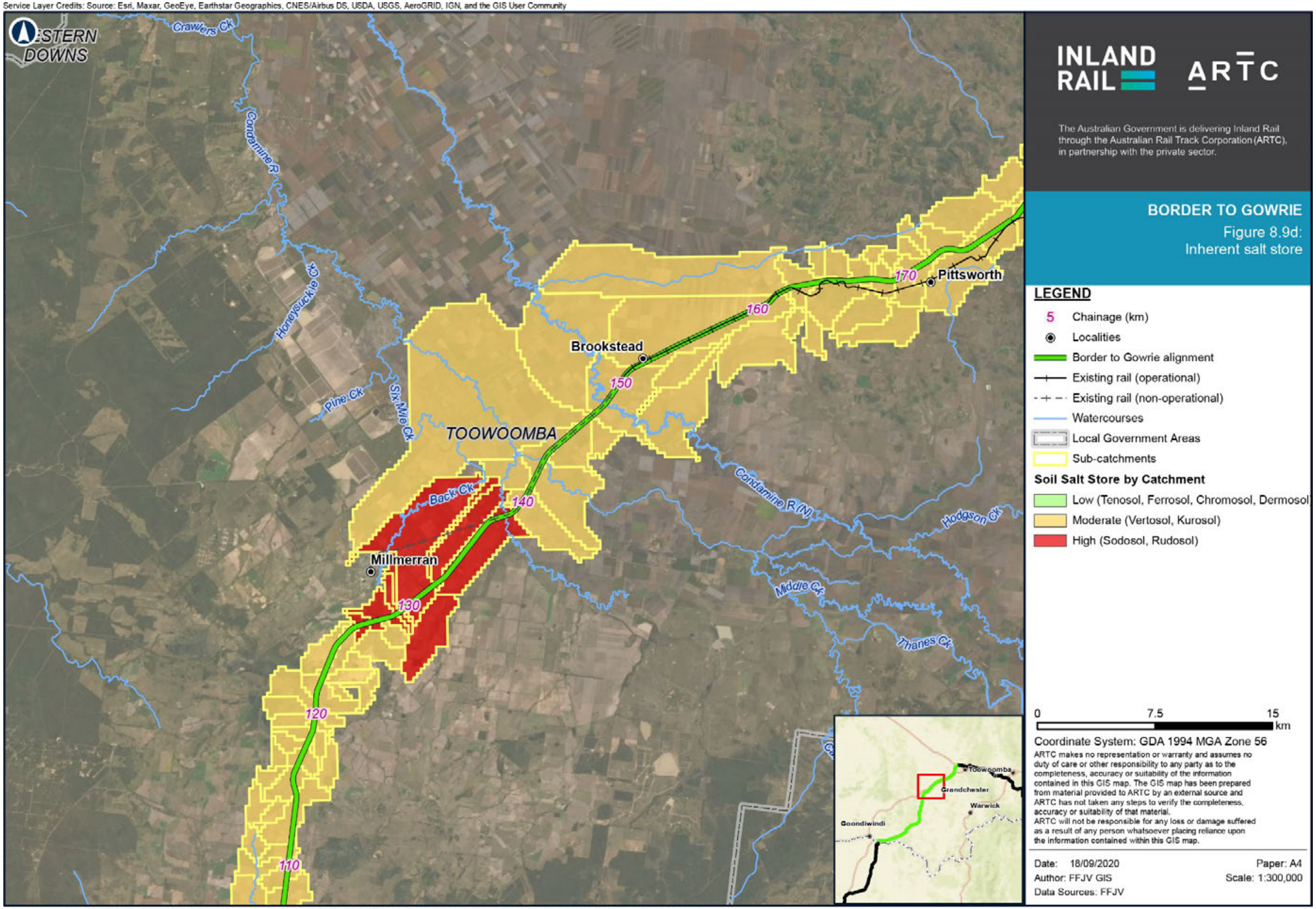

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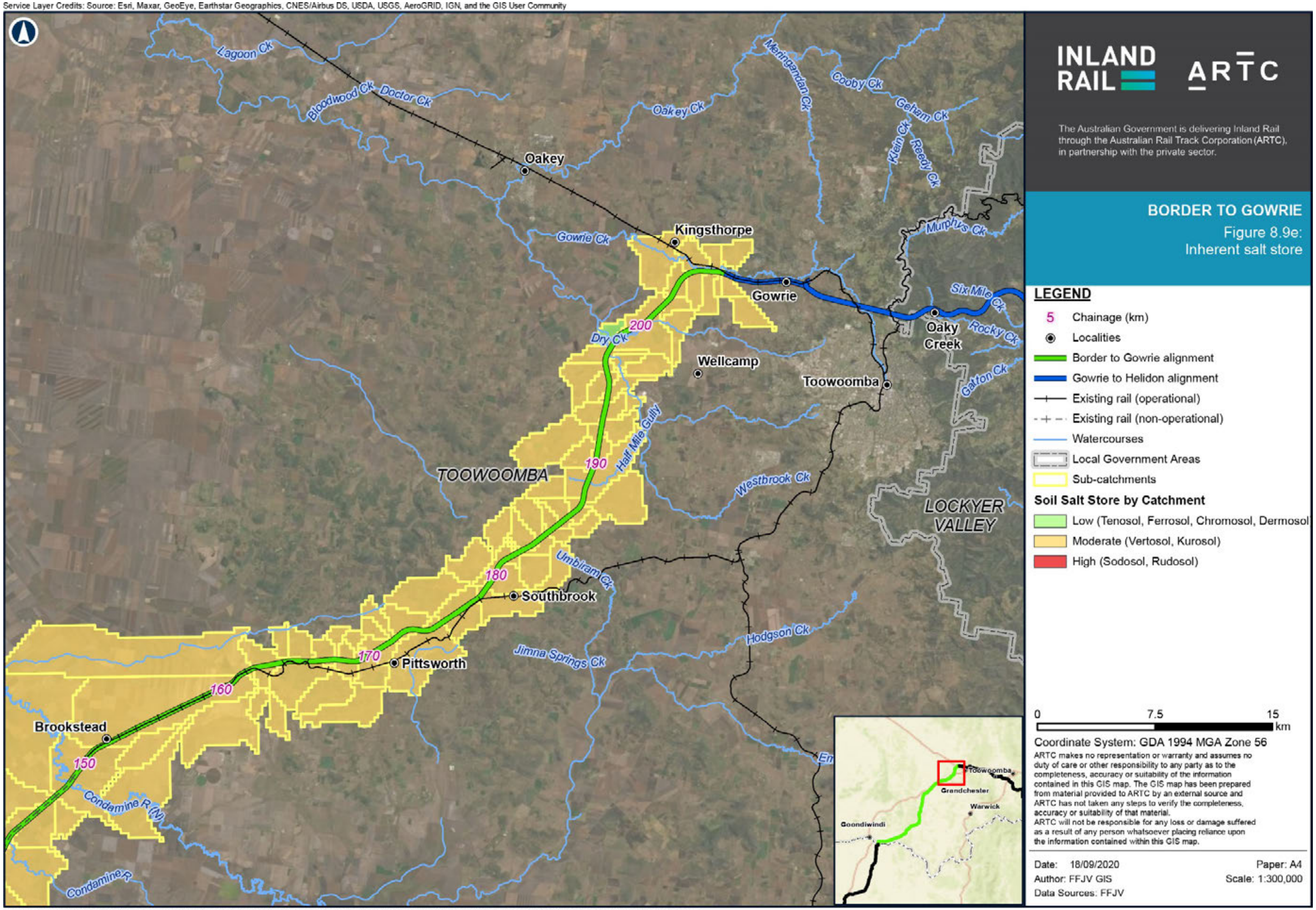

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Potential expression areas: Basalt and sandstone contact

The underlying geology of the impact assessment area features PEAs of basalt and sandstone contact. These PEAs are indicative of locations where salts may be transported through underlying basalt layers towards surface soils in an area of basalt and sandstone contact (Department of Natural Resources, 1997). Salinity in a basalt layer forms when both recent and highly weathered layers overlay a less permeable sandstone and mudstone layer at fairly shallow depths. Seepage and the visible expression of salt can occur at the contact point between the two rock types.

The analysis for basalt and sandstone contact PEAs was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation and the Gatton Sandstone geological units (refer Figure 8.4), which were identified as the geological units within the impact assessment area where basalt and sandstone contacts may occur.

Basalt and sandstone contact PEAs are predicted to occur where the prevailing geological conditions are present and the following conditions also apply (Searle et al., 2007):

- Tangential curvature is less than 0 (i.e. the downhill slope shape is concave-flow tends to slow and converge)
- Relative elevation is greater than two (i.e. there is typically a distinct break of slope)
- Slope is greater than 1 per cent and less than 10 per cent (i.e. typically mid-slope positions).

Calculation and analysis of tangential curvature, relative elevation (kernel size 90) and slope percentage for relevant geological units within the impact assessment area was undertaken in reference to the 25 m digital elevation model (DEM) developed for the Project, using ArcGIS analysis functions.

When analysing the risk of basalt and sandstone contact PEAs within the sub-catchments, a low-to-high hazard category rating can be applied based on the percentage of occurrence, as shown in Table 8.11.

TABLE 8.11 POTENTIAL EXPRESSION AREA: BASALT AND SANDSTONE CONTACT

Percentage of each sub-catchment containing basalt and sandstone contact PEAs (per cent)	Hazard category
0	None
0 to 2	Low
2 to 5	Moderate
Greater than 5	High

Source: Searle et al. (2007)

The basalt and sandstone contact PEA hazard category for each sub-catchment within the impact assessment area was calculated and is illustrated in Figure 8.10. The mapping in Figure 8.10 shows that there is a high basalt and sandstone contact PEA hazard classification associated with the following:

- The WCM along the southern edge of Bringalily State Forest and Millmerran–Inglewood Road, to approximate Ch 98.0 km
- The WCM in the Clontarf area (approximately Ch 118.0 km to Ch 127.0 km)
- The MRVs, from Yarranlea to Kingsthorpe (approximately Ch 164.0 km to Ch 126.9 km).

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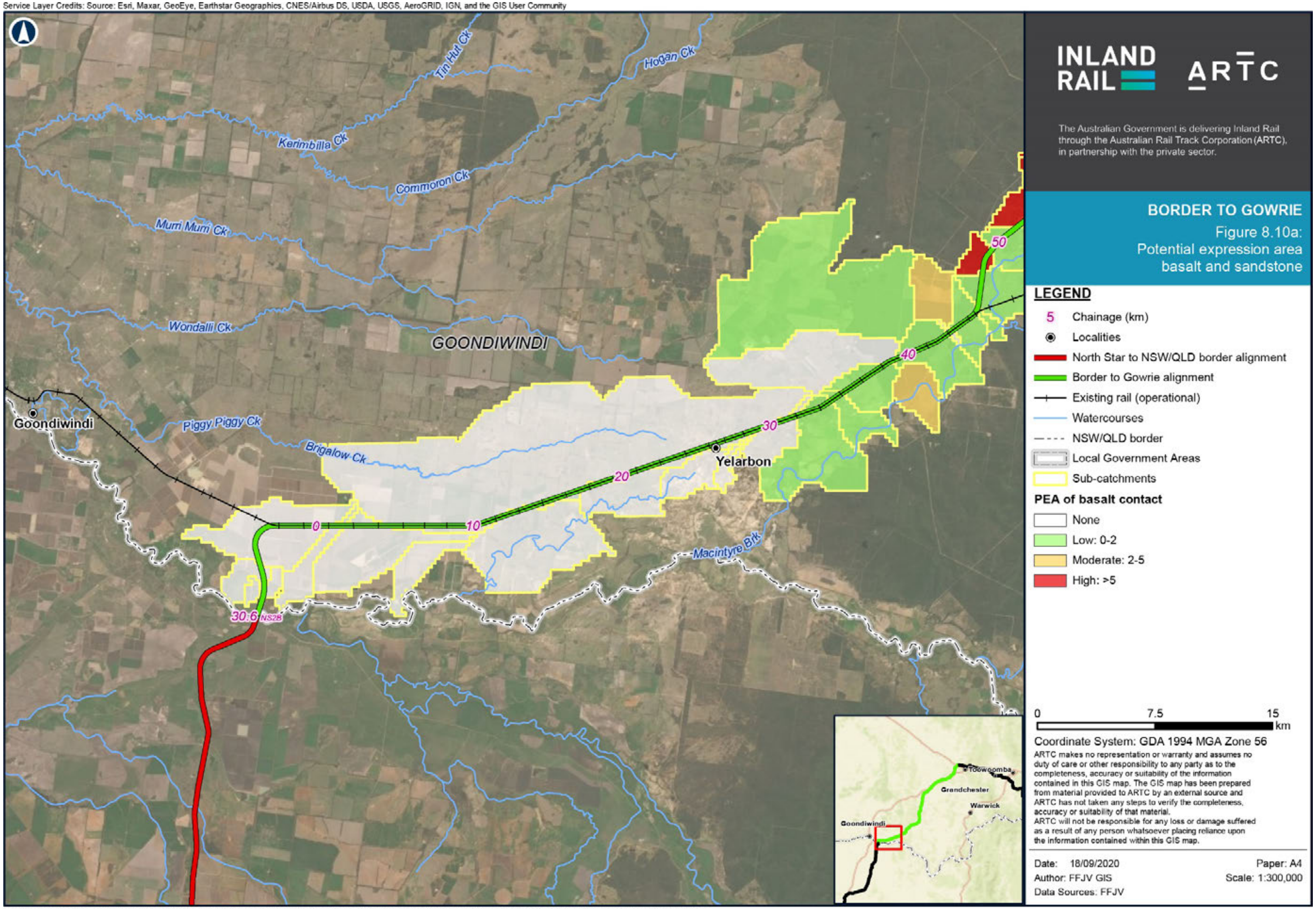

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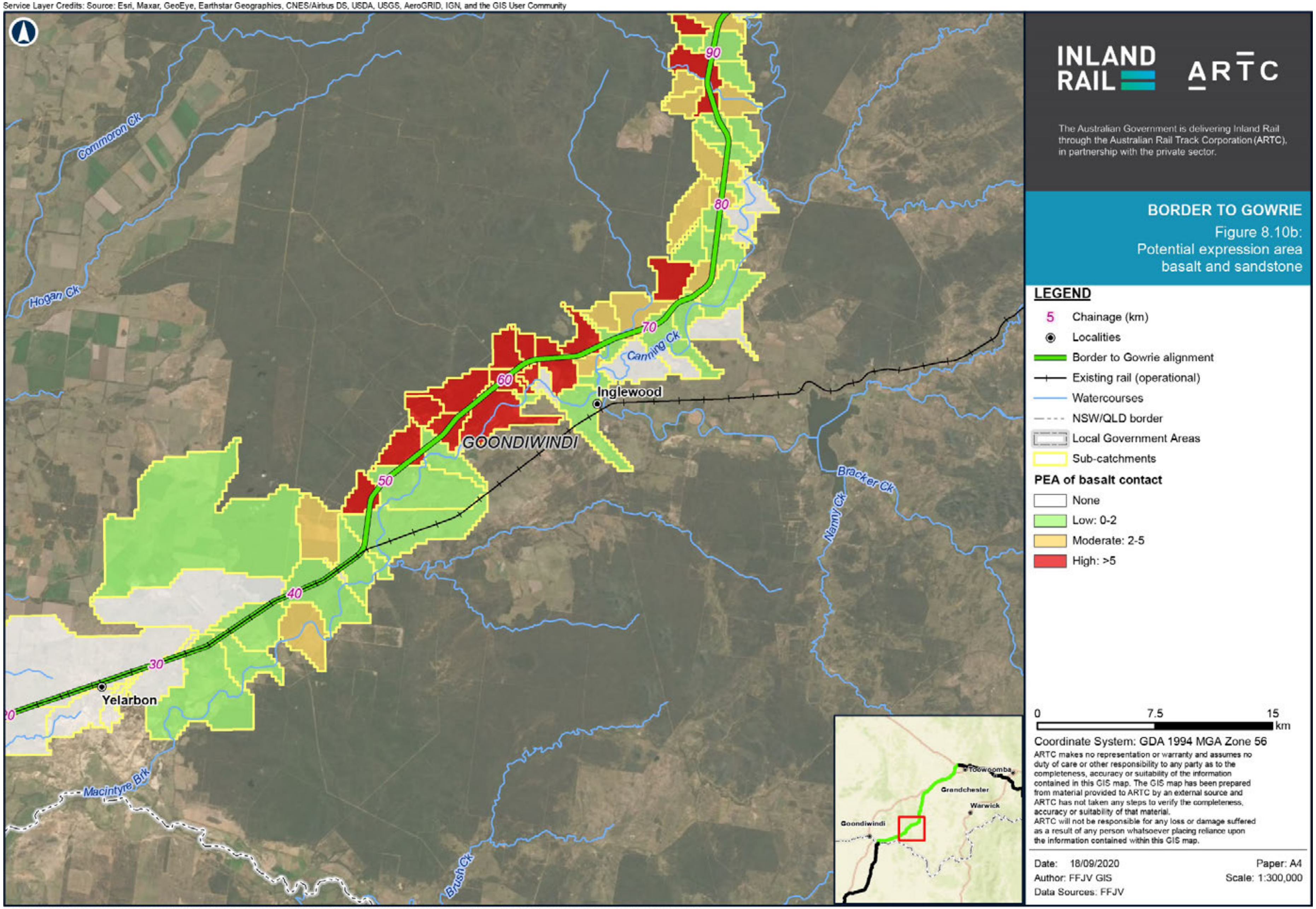

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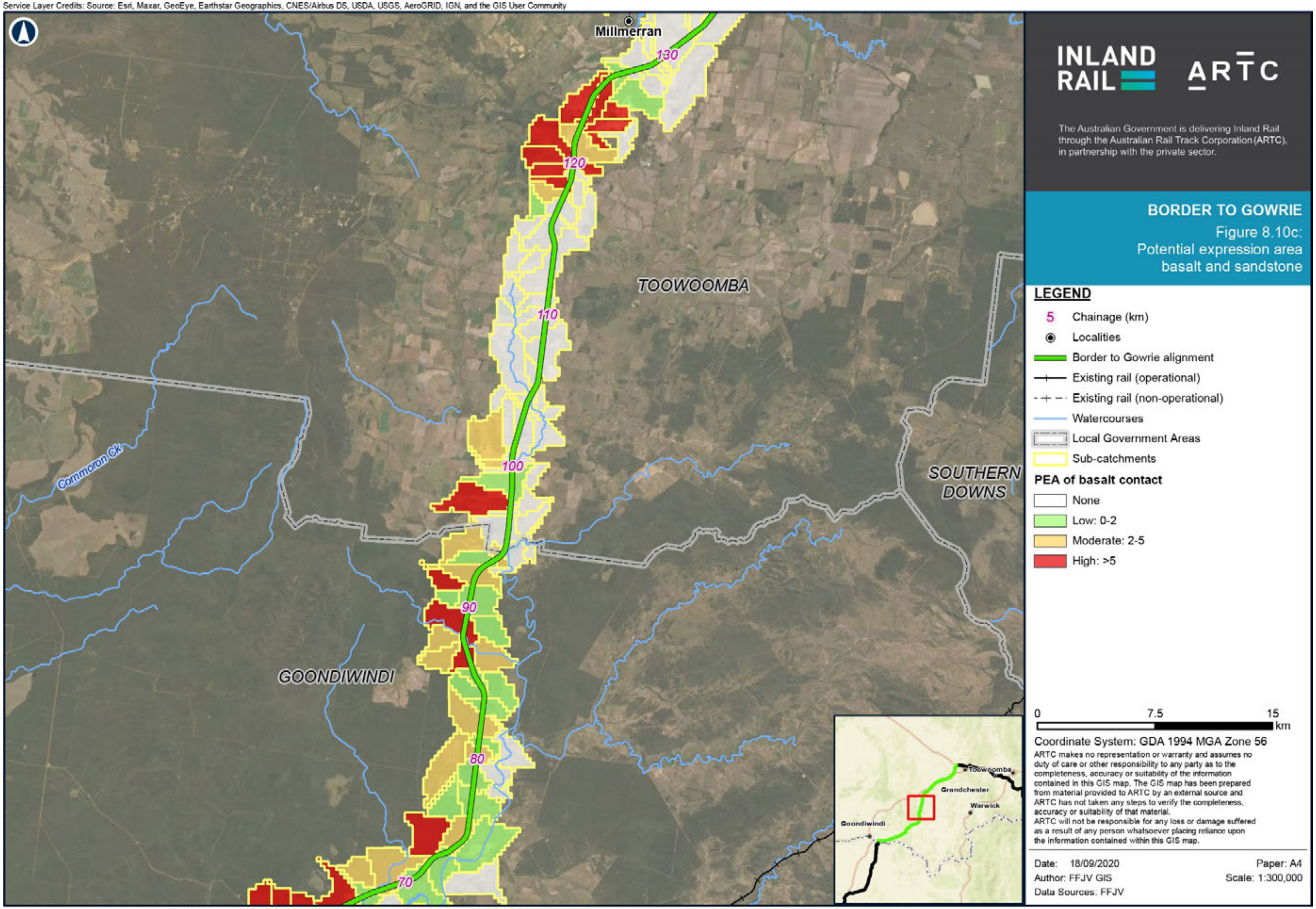

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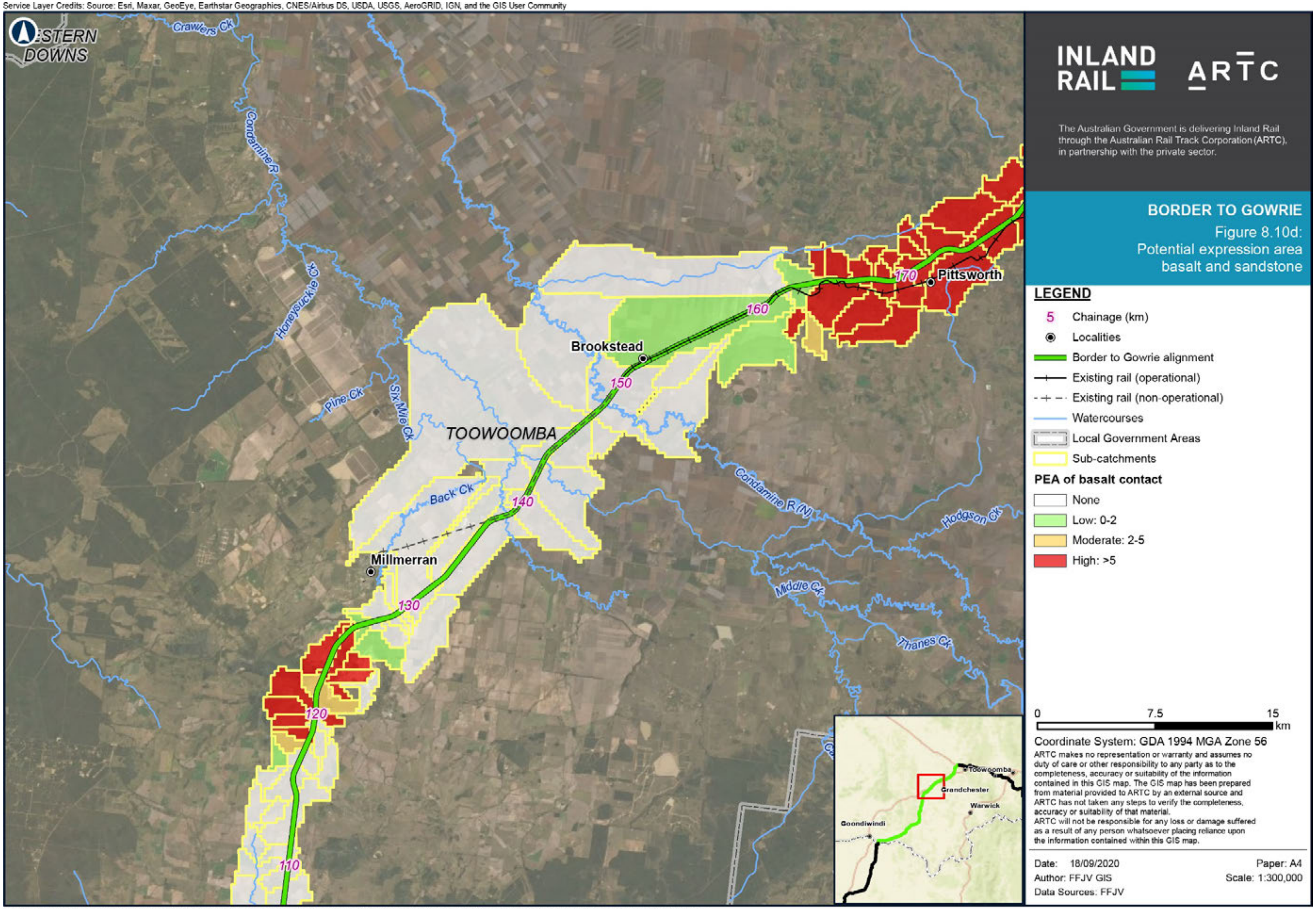

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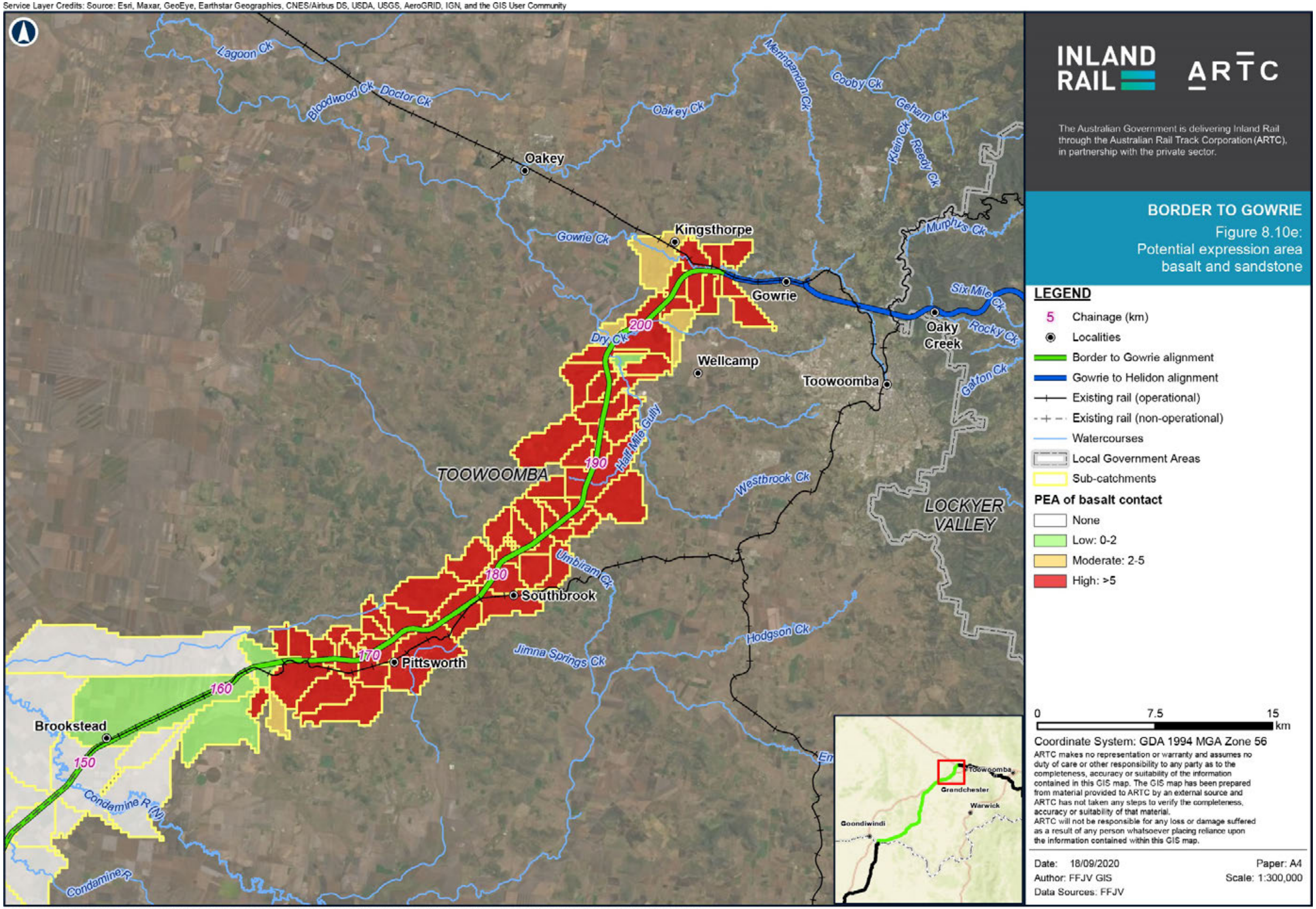

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Potential expression area: Catena form

The impact assessment area also features PEAs of catena form. Catena form PEAs occur when shallow soils located upslope overlie weathered parent material, which then extend out into flat heavy clay alluvial areas. These alluvial areas are characterised by high sodicity due to restricted permeability and result in the formation of salt as well as changing soil properties and water movement (Department of Natural Resources, 1997).

Calculation of catena form was based on an analysis of the 20 m digital elevation model (DEM) developed for the Project. Two DEM derivatives were used in this spatial analysis:

- Slope (per cent)
- Multi Resolution Valley Bottom Floor index, as described by Gallant and Dowling (2003).

The Multi Resolution Valley Bottom Floor index identifies areas that are both relatively flat and low in the landscape at different scales, which is interpreted as a map of valley bottom areas. This index is used to separate upland terrain dominated by erosional processes from lowland depositional terrain (Searle et al., 2007).

This analysis was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation and the Gatton Sandstone, which were identified as the geological units within the impact assessment area that are most susceptible to catena form salinity.

When analysing the risk of catena form PEAs within the sub-catchments, a low-to-high hazard category rating can be applied based on the percentage of occurrence, as shown in Table 8.13.

TABLE 8.12 POTENTIAL EXPRESSION AREA: CATENA FORM

Percentage area of sub-catchments containing catena PEAs (per cent)	Hazard category
0	None
1 to 3	Low
4 to 5	Moderate
Greater than 5	High

Source: Searle et al. (2007)

The catena form PEA hazard category for each sub-catchment within the impact assessment area was calculated and is shown in Figure 8.11. The mapping in Figure 8.11 shows that there is a high catena form PEA hazard classification associated with the following approximate chainage ranges:

- Ch 40.0 km to Ch 43.0 km and Ch 51.0 km to Ch 56.0 km: Macintyre Brook floodplain at the southern extent of Whetstone and Bringalily state forests
- Ch 65.30 km to Ch 94.0 km: From Inglewood to the local government area (LGA) boundary between Goondiwindi and Toowoomba
- Ch 120.0 km to Ch 127.0 km: Clontarf
- Ch 168.0 km to Ch 170.0 km: Between Yarranlea and Pittsworth
- Ch 181.0 km: North of Southbrook
- Ch 198.0 km to Ch 206.9 km: From Westbrook Creek up to Kingsthorpe.

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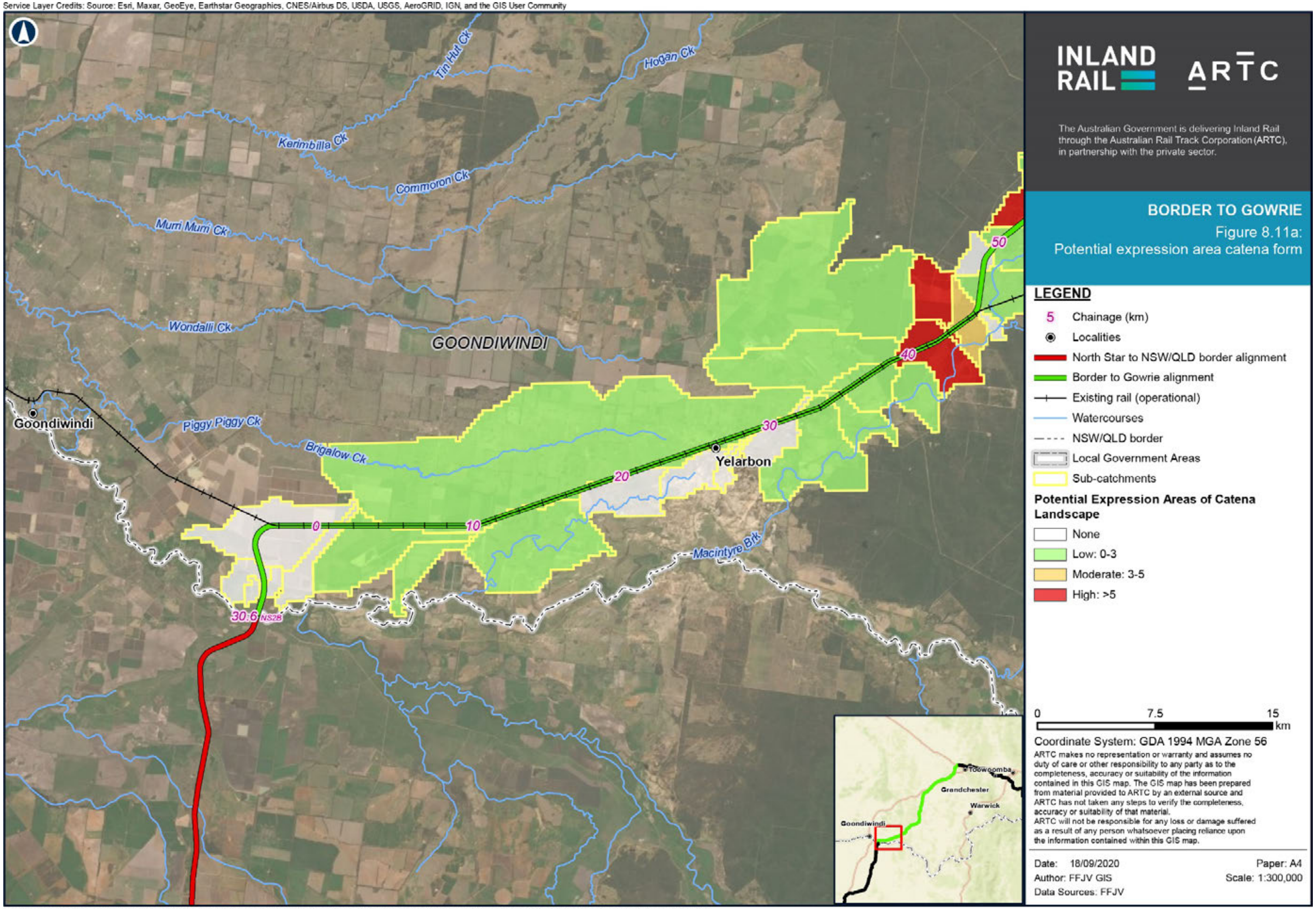

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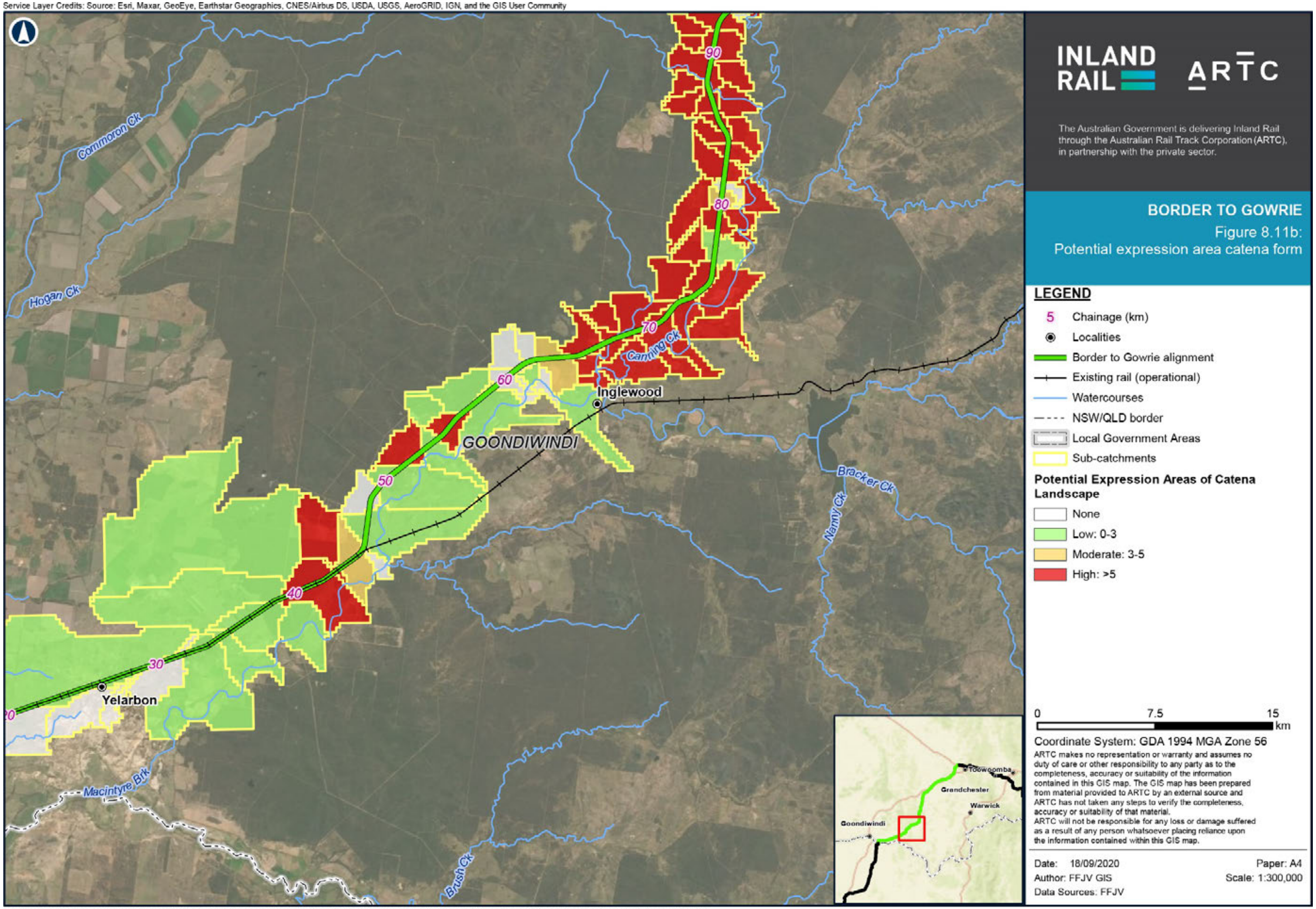

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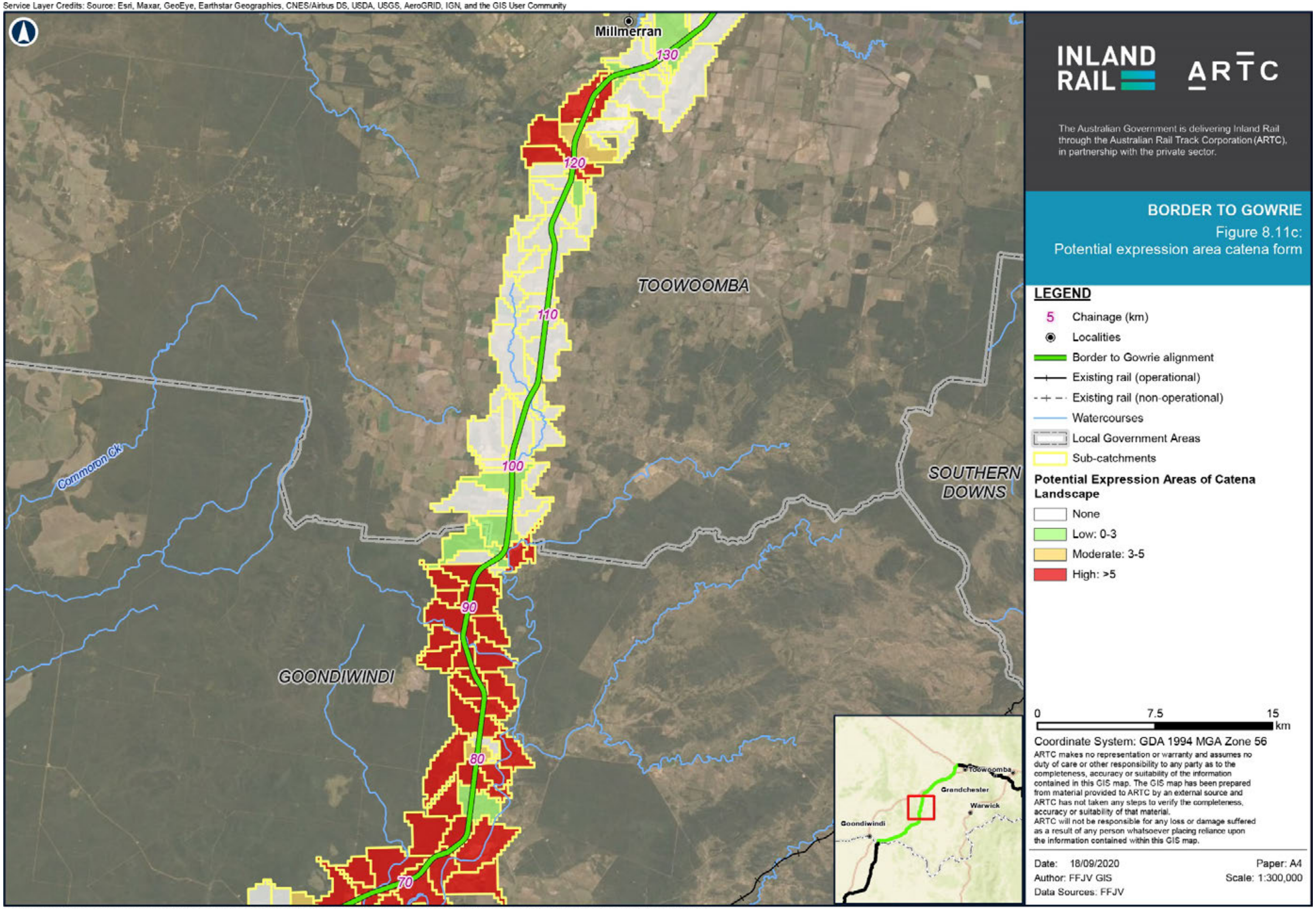

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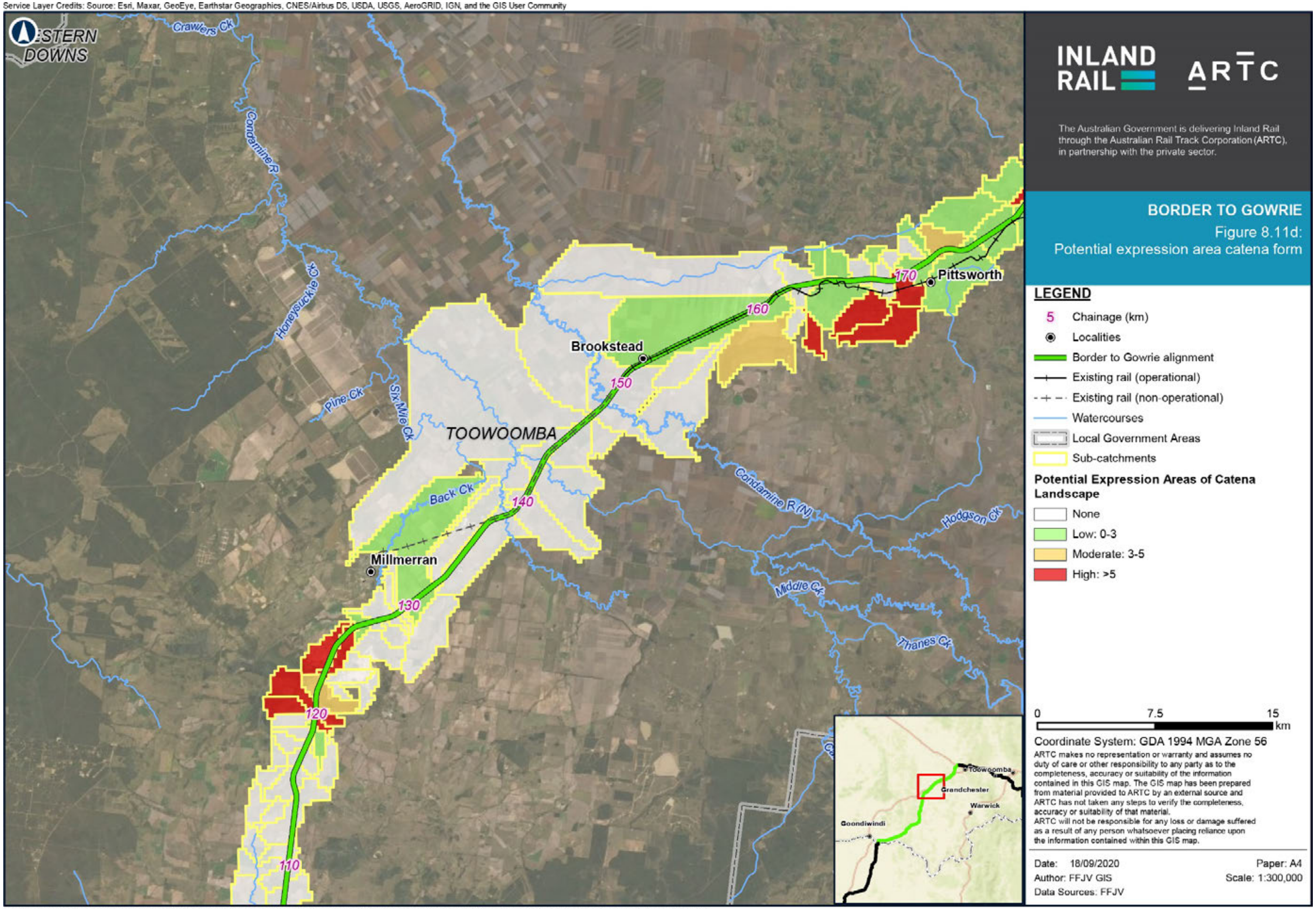

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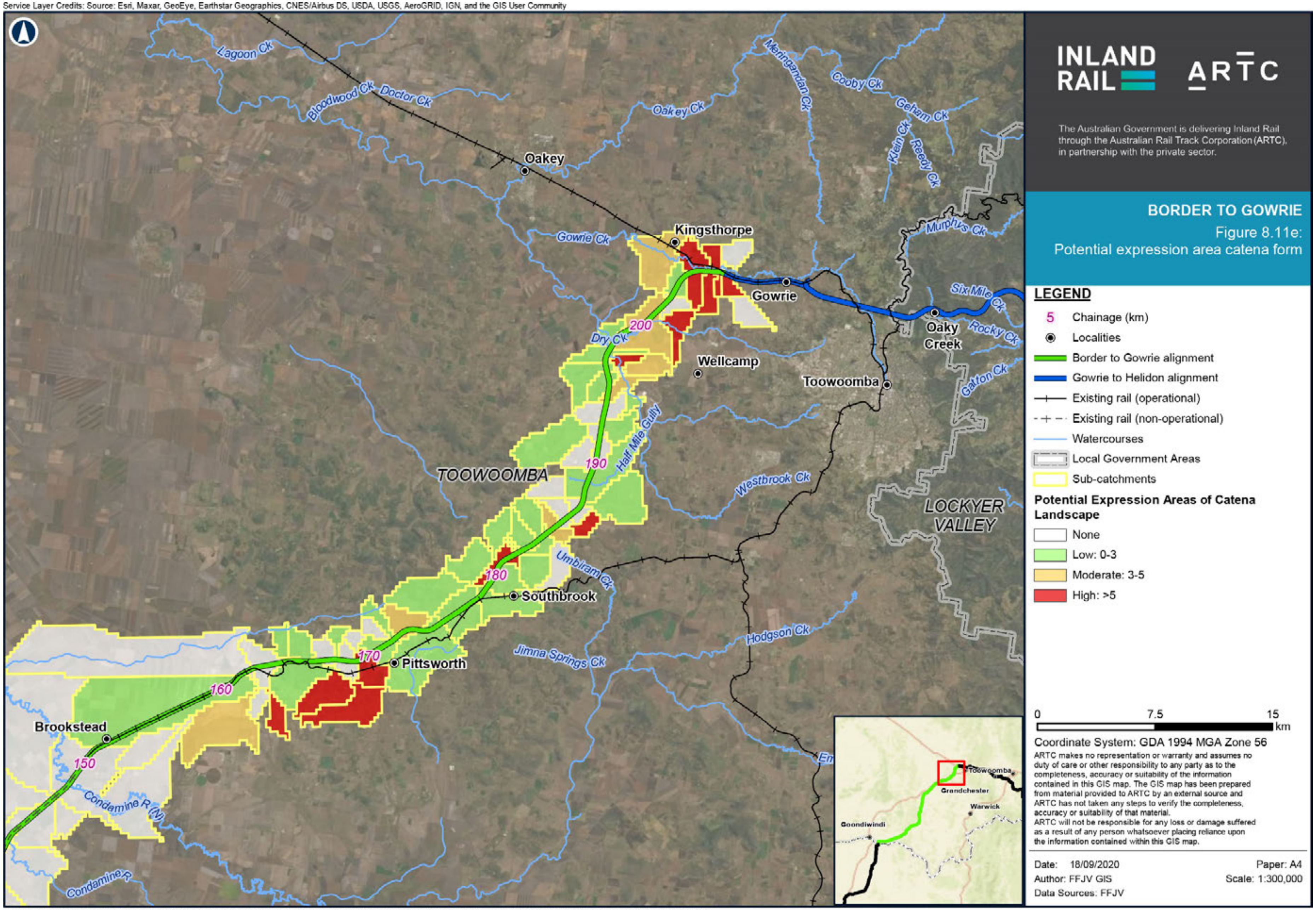

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Potential expression area: Roads

The establishment of roads within a landscape can restrict water flow as well as impede the underlying soils' ability to transmit water, leading to the uprising of groundwater with dissolved salts and, in turn, waterlogging. This form of salinity is often associated with hillslopes consisting of textural contrast soils or shallow, sandy soils within drainage lines (Searle et al., 2007). The establishment of new railways, as with this Project, may result in similar concerns if the necessary soil and topographical conditions are present.

Determination of where the construction of roads in the landscape could potentially create salinity was done through analysis of the 20 m DEM developed for the Project. Two DEM derivatives were used in this spatial analysis, as suggested in *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007):

- Compound Topographic Index (Moore, et al., 1991). The Compound Topographic Index delineates those areas in a landscape that have high contributing area and relatively low slopes. In a general sense, these would tend to be the wetter areas within a landscape.
- Slope (per cent).

For this analysis, the DEM was generalised to 200 m for the slope calculations and 1,000 m for the Compound Topographic Index calculations. The analysis selected the areas that are generally low slope and where there is a general convergence of flow, low in the landscape. These areas are predicted to occur where:

- Slope is greater than 1 per cent
- Compound Topographic Index is greater than two.

When analysing the risk of PEAs due to artificial restrictions within the sub-catchment, a low-to-high hazard category rating can be applied based on the number of occurrences, as shown in Table 8.14.

TABLE 8.13 NUMBER OF ROAD POTENTIAL EXPRESSION AREAS ALONG IMPACT ASSESSMENT AREA CATEGORIES

Number of road PEAs within sub-catchments	Hazard category[1]
0	None
1 to 50	Low
51 to 100	Moderate
>100	High

Source: Searle et al. (2007)

The road placement PEA hazard category for each sub-catchment within the impact assessment area was calculated and is shown in Figure 8.12. The mapping in Figure 8.12 shows that there is a high road PEA hazard classification associated with the following approximate chainage ranges:

- Continuously from Ch 30.6 km (NS2B) to Ch 6.0 km: NSW/QLD border to Whetstone
- Intermittently from Ch 67.0 km to Ch 100.0 km: Inglewood to Millwood
- Ch 120.0 km: Clontarf
- Ch 129.0 km to Ch 163.0 km: Millmerran to Yarranlea
- Ch 17.0 km to Ch 175.0 km: Pittsworth area.

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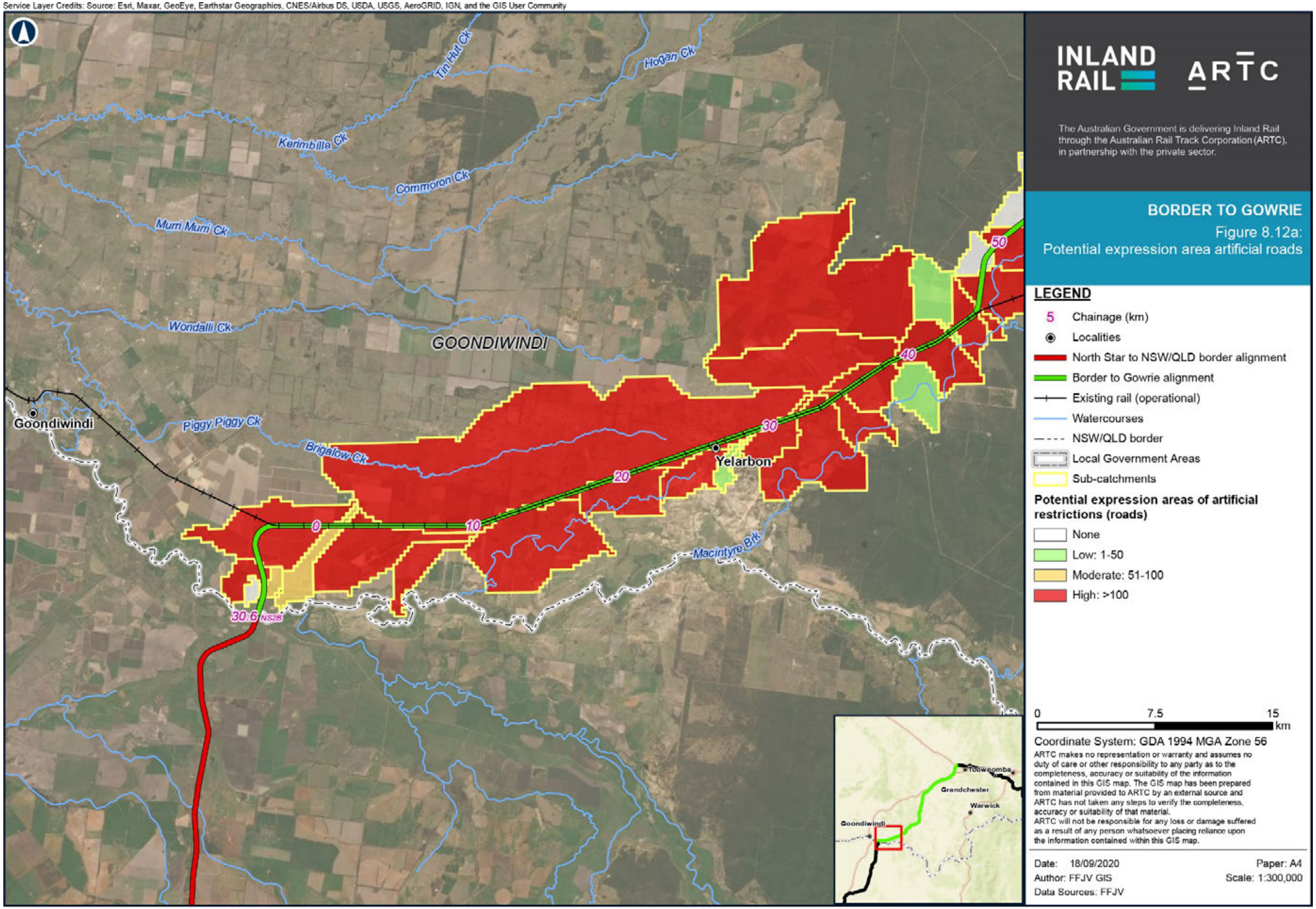

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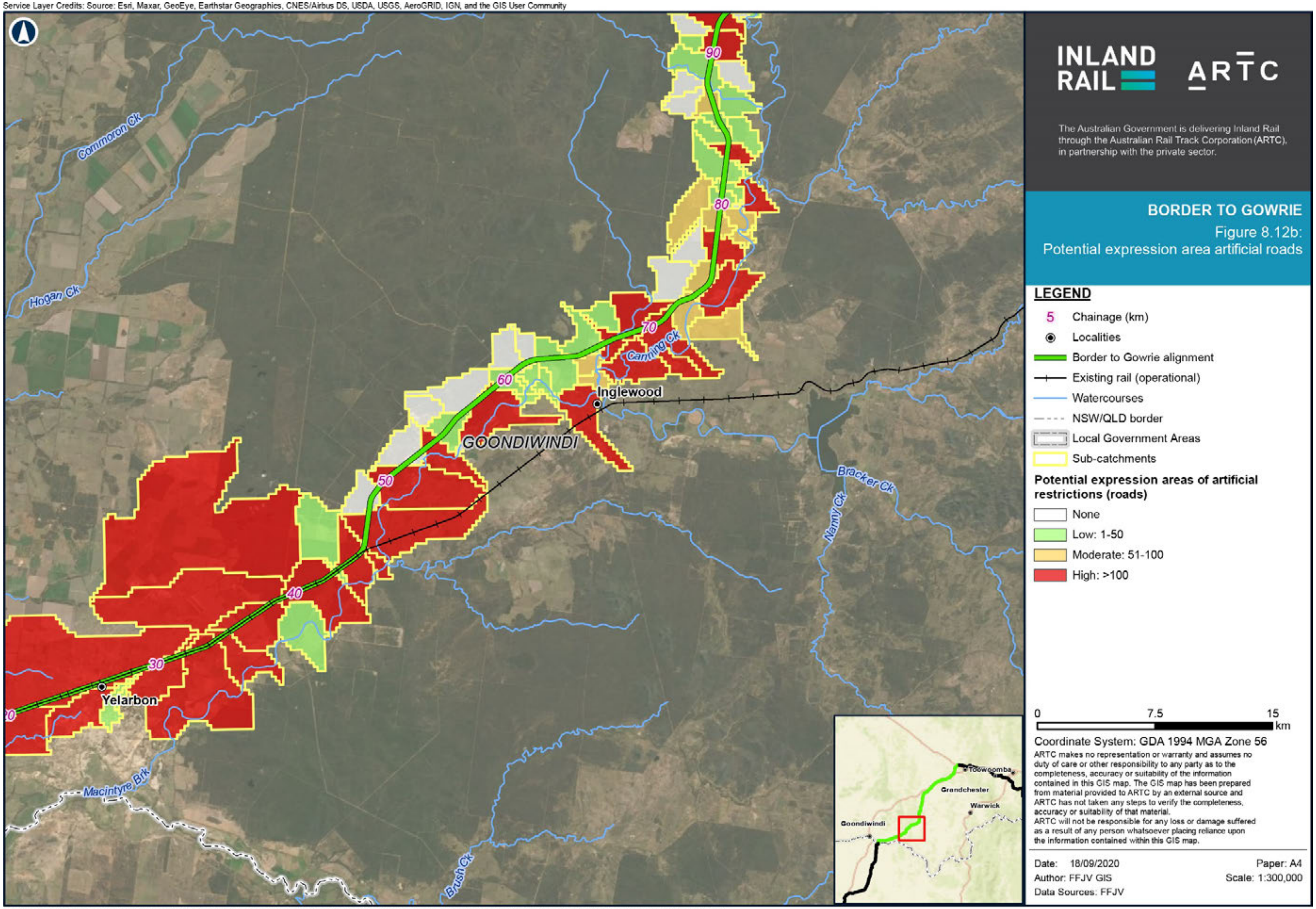

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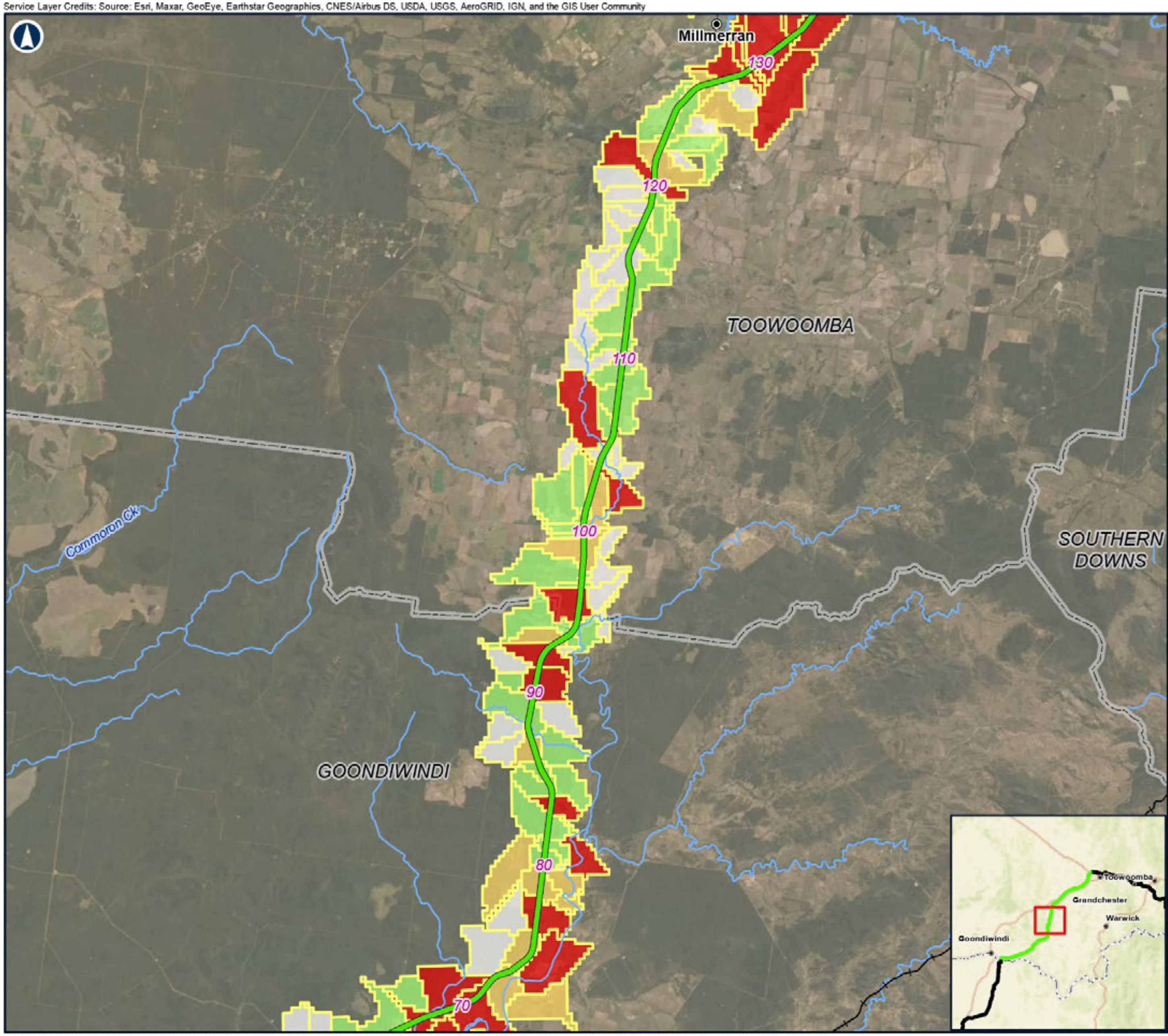

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BORDER TO GOWRIE

Figure 8.12c:
Potential expression area artificial roads

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Watercourses
- Local Government Areas
- Sub-catchments

Potential expression areas of artificial restrictions (roads)

- None
- Low: 1-50
- Moderate: 51-100
- High: >100

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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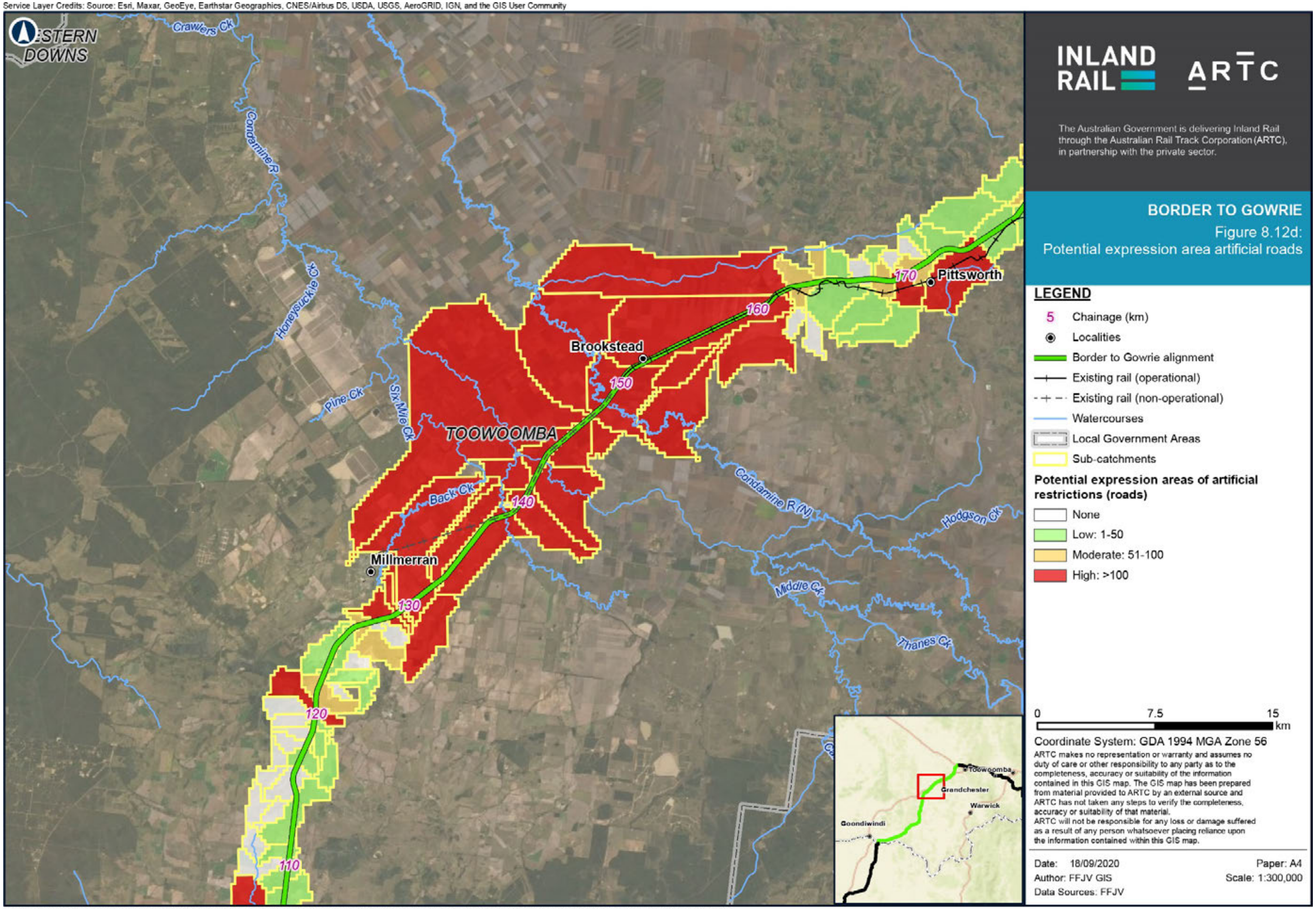

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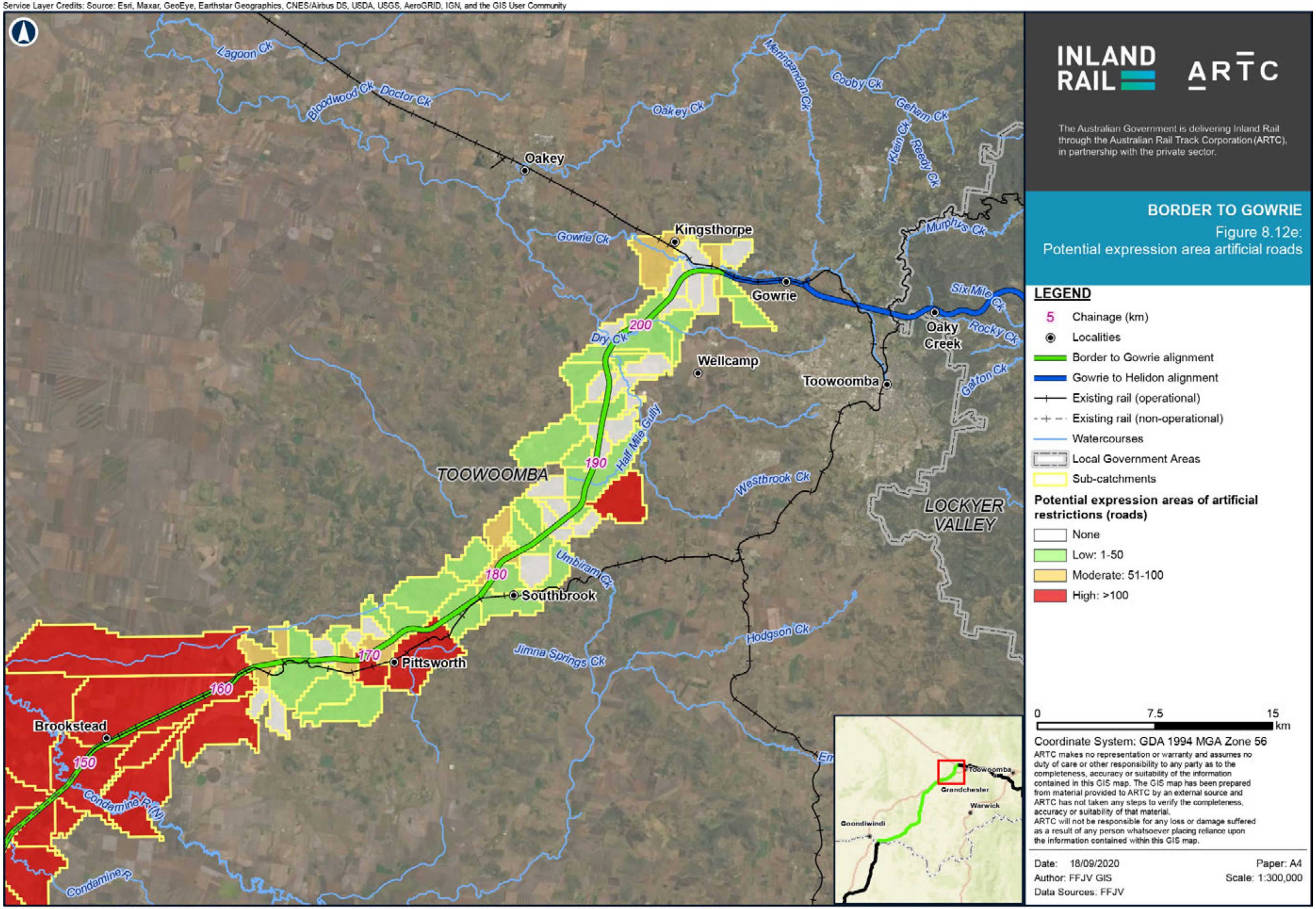

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Potential expression area: Confluence of streams

The confluence of streams are often correlated with PEAs, specifically where a major stream intersects with a minor stream. This intersection can create a reduction in flow velocity and a resultant deposition of the suspended particles at the junction, including a precipitation of salts (Searle et al., 2007).

Confluence of streams were identified through manual interpretation of the Australian Hydrological Geospatial Fabric mapped streams layer (BoM, 2015), where watercourses intersected. The number of watercourse intersections were identified within a sub-catchment. When analysing the risk of PEAs due to the confluence of streams within the sub-catchment, a low-to-high hazard category rating can be applied, as shown in Table 8.14.

TABLE 8.14 POTENTIAL EXPRESSION AREA: CONFLUENCE OF STREAMS

Number of stream confluences in a sub-catchment	Hazard category
0	None
1 to 3	Low
4 to 5	Moderate
Greater than 5	High

Source: Searle et al. (2007)

The stream confluence PEA hazard category for each sub-catchment within the impact assessment area was calculated and is shown in Figure 8.13. The mapping in Figure 8.13 shows that there are no sub-catchments with a high hazard category for the confluence of streams.

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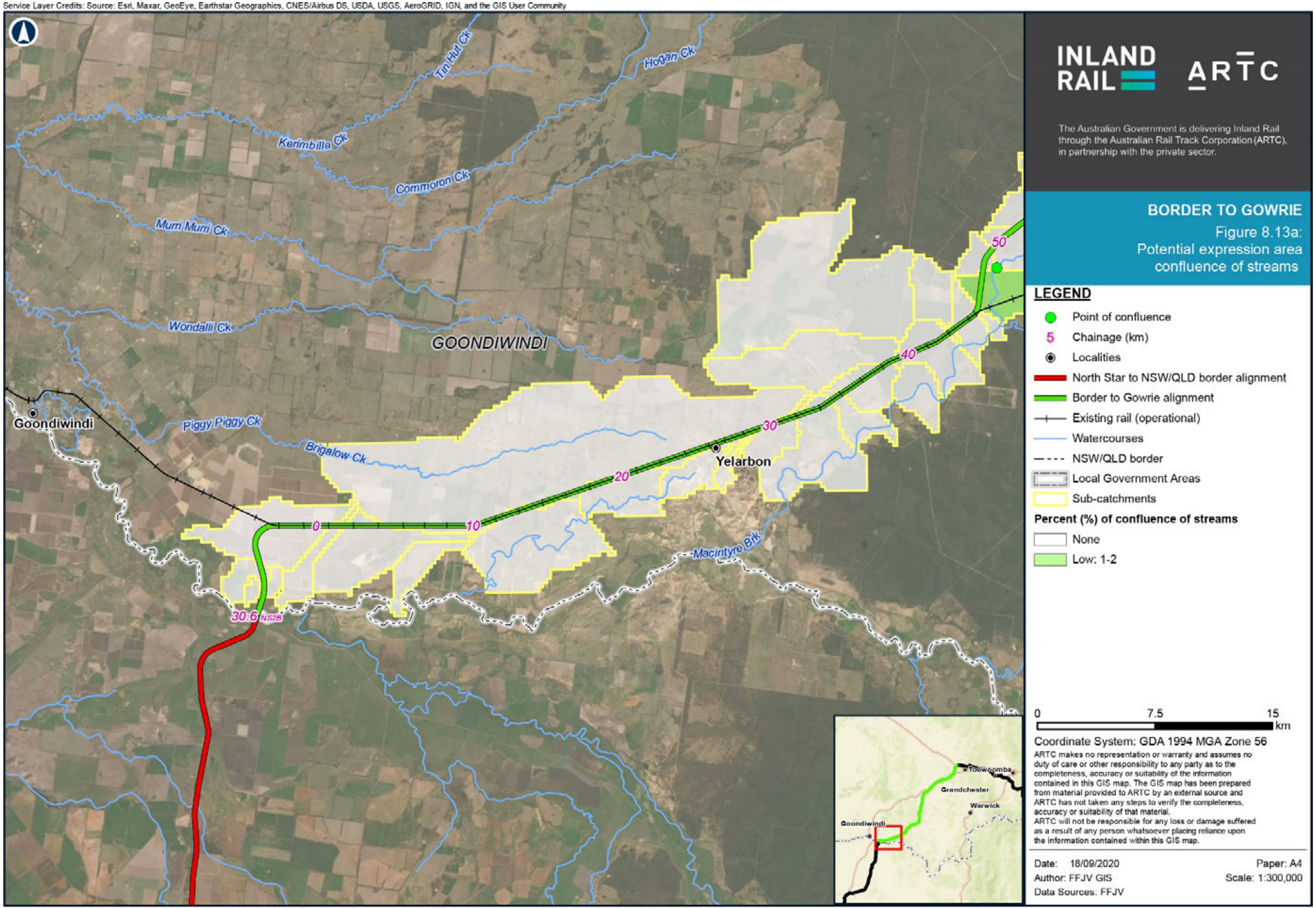

BORDER TO GOWRIE

Figure 8.13a: Potential expression area confluence of streams

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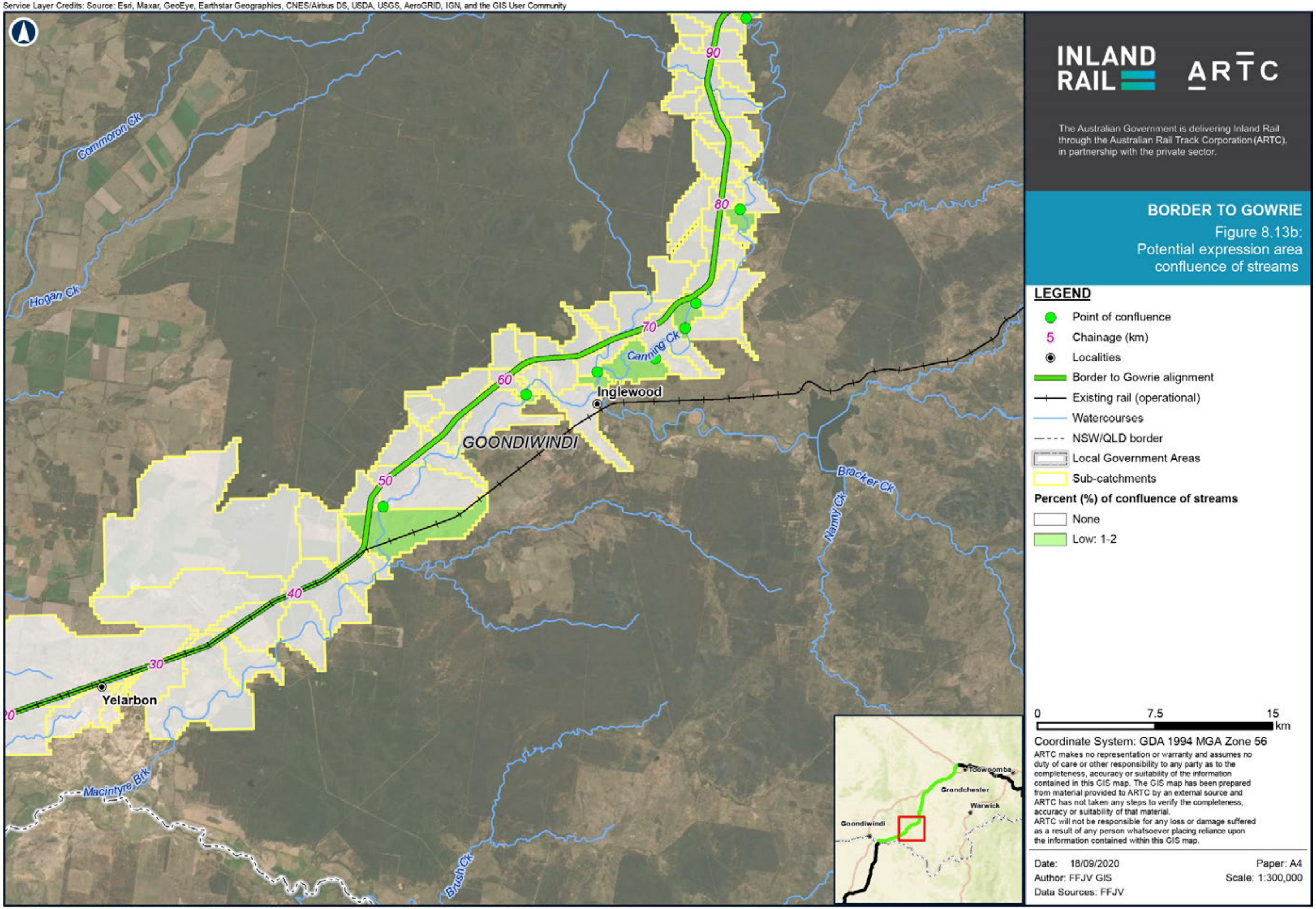

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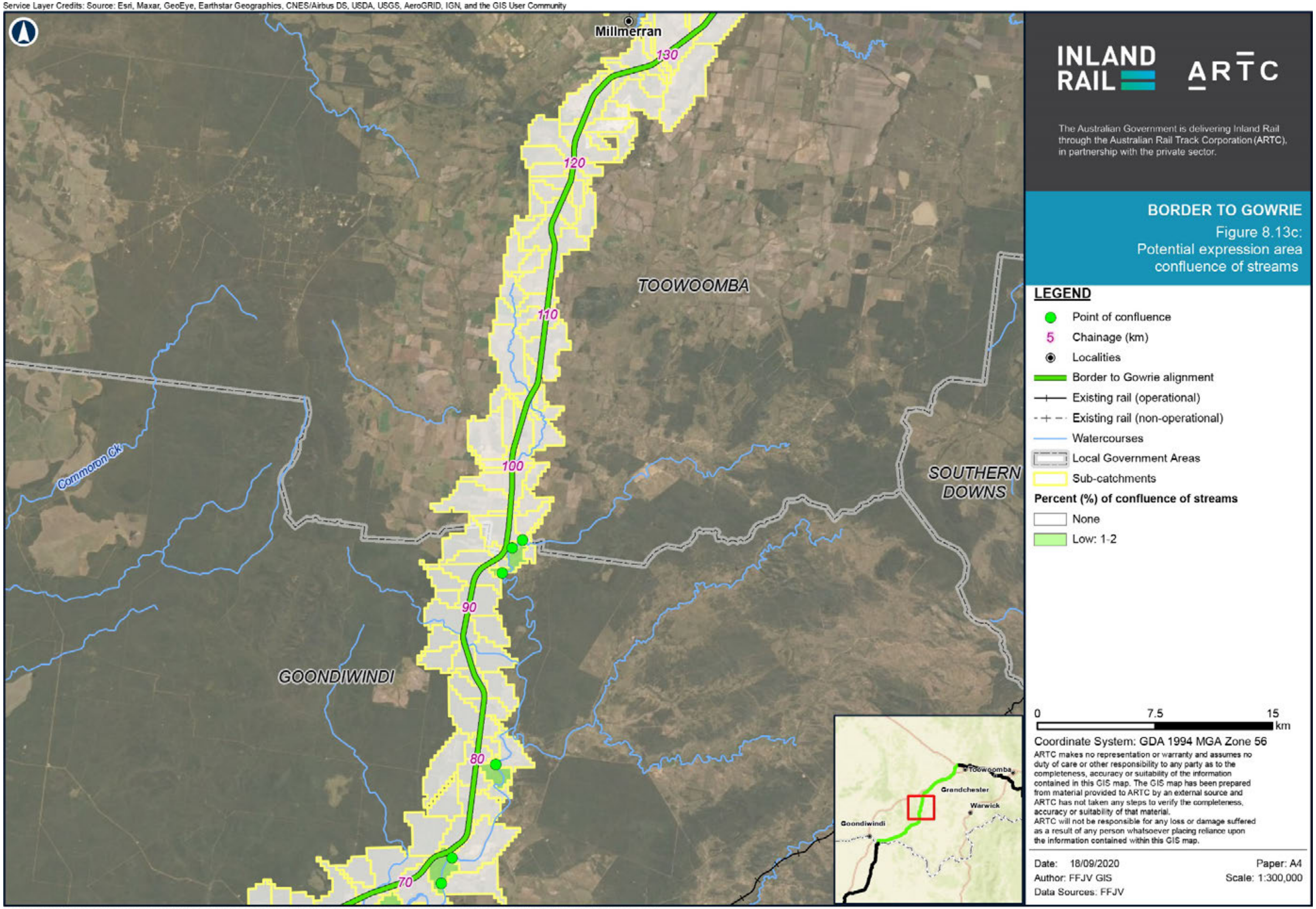

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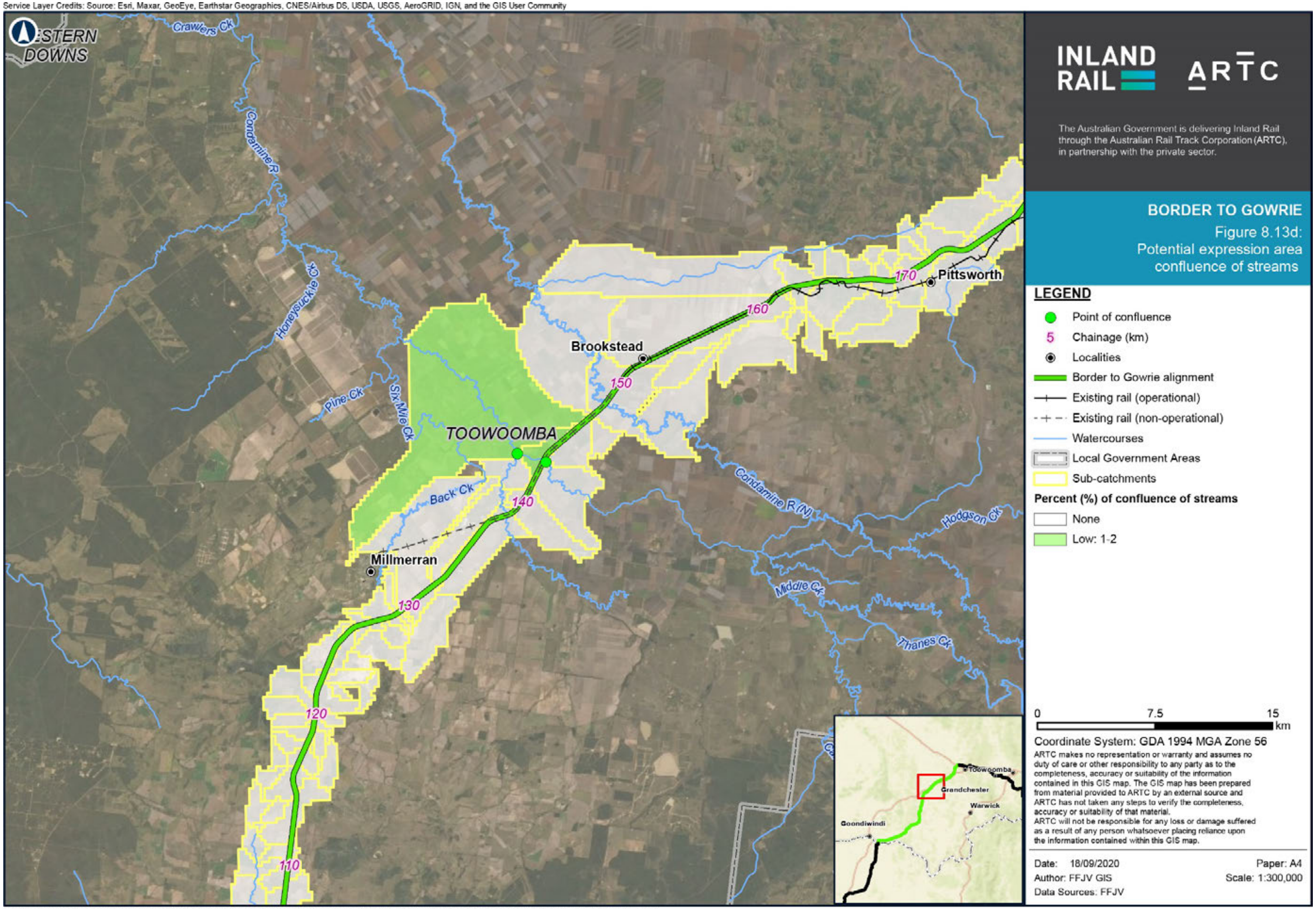

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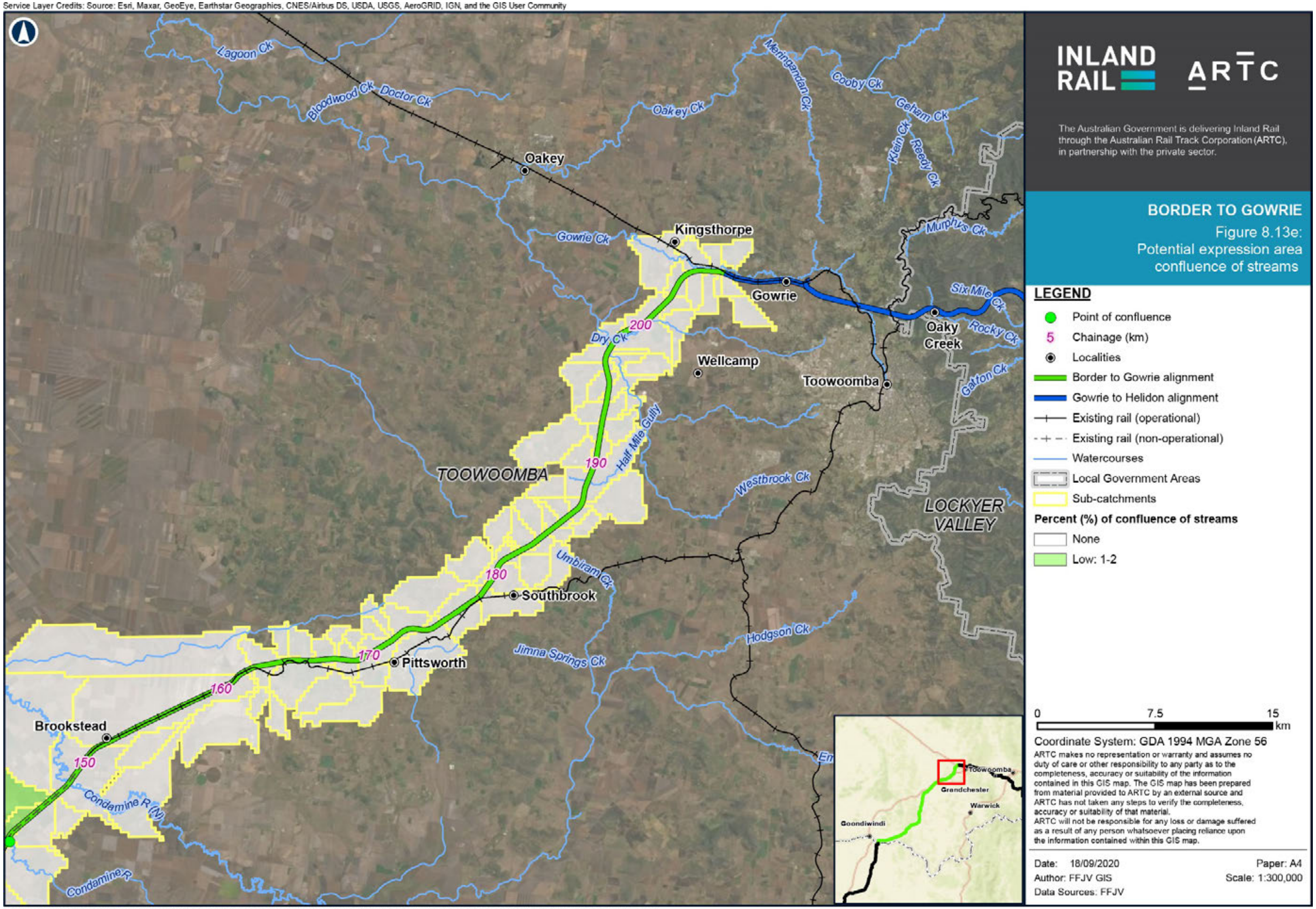

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Electrical conductivity

Salinity hazard within the impact assessment area was also assessed using the ASRIS electrical conductivity mapping layer (CSIRO, 2014a). In general, soils within the impact assessment area are mapped as having a low electrical conductivity, of less than 1 decisiemens per metre (dS/m). Soils with medium to high electrical conductivity, between 1 to 2 dS/m, are mapped as occurring from Bringalily through to Pittsworth, as well as an isolated occurrence at Yelarbon.

Analysis results from surface soil samples recorded a minimum electrical conductivity of 0.013 dS/m (13 μS/cm) and a maximum electrical conductivity of 0.77 dS/m (777 μS/cm) (refer Table 8.4). The results also indicate that there is horizontal and vertical variance in electrical conductivity of soils within the impact assessment area and that this variance cannot be closely correlated with soil classification mapping.

Overall salinity hazard

The overall salinity hazard categorisation of sub-catchments within the impact assessment area has been assessed in reference to the inherent soil salt store, the hazard categorisation for each of the five PEA types and soil analysis results from Project investigations.

The salinity hazard assessment also considered additional data of known salinity sites in South-East Queensland (SEQ), provided by the Department of Natural Resources, Mines and Energy for the assessment (received March 2020). No known salinity sites were recorded in this dataset as occurring within the impact assessment area.

To enable the mapping of salinity hazard ratings within the impact assessment area, a mean hazard score has been derived for each sub-catchment based on each of the five contributing PEA hazard categories. The mean hazards salinity ratings for each sub-catchment have been mapped and are shown on Figure 8.15. The mean salinity hazard mapping shows that each sub-catchment is considered to have either a moderate or a high hazard rating, when risks from each of the five individual PEAs was combined. The sub-catchments where a high mean salinity hazard rating has been determined generally correlate with the risk areas identified by the *Salinity Risk Assessment for the Queensland Murray–Darling Region* (Biggs et al., 2010b) and the *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007).

In particular, the mean salinity hazard confirms the known risk associated with the Yelarbon area, and its surrounds. The Yelarbon area has an identifiable 'scald' and is underlain by Sodosols, which are known to be a salinity prone soil (refer Section 8.5.3.3). In addition, the Peel Fault offset, which underlies the Yelarbon area, is noted to have allowed saline groundwater to leak up to the soil zone over a period of time (refer Figure 8.14).

The soils of the scalded areas have been mapped by Northcote et al. (1960–1968) as hard-setting loamy duplex soils with alkaline reaction trends with yellow (Dy) or brown (Db) subsoils (Knight, M.J. et al., 1989). The yellow subsoil indicates a strong bleaching and very high amounts of exchangeable sodium. Because of the high amounts of exchangeable sodium at Yelarbon, the soil is highly dispersive and erodible, which is further exaggerated by grazing land use.

The primary salinity in this area is not a result of human influence, but rather geology; however, the saline soil scald that has resulted at Yelarbon is now beginning to erode severely, due to the soil's dispersibility, and this has been aggravated by overgrazing (Knight, M.J. et al., 1989).

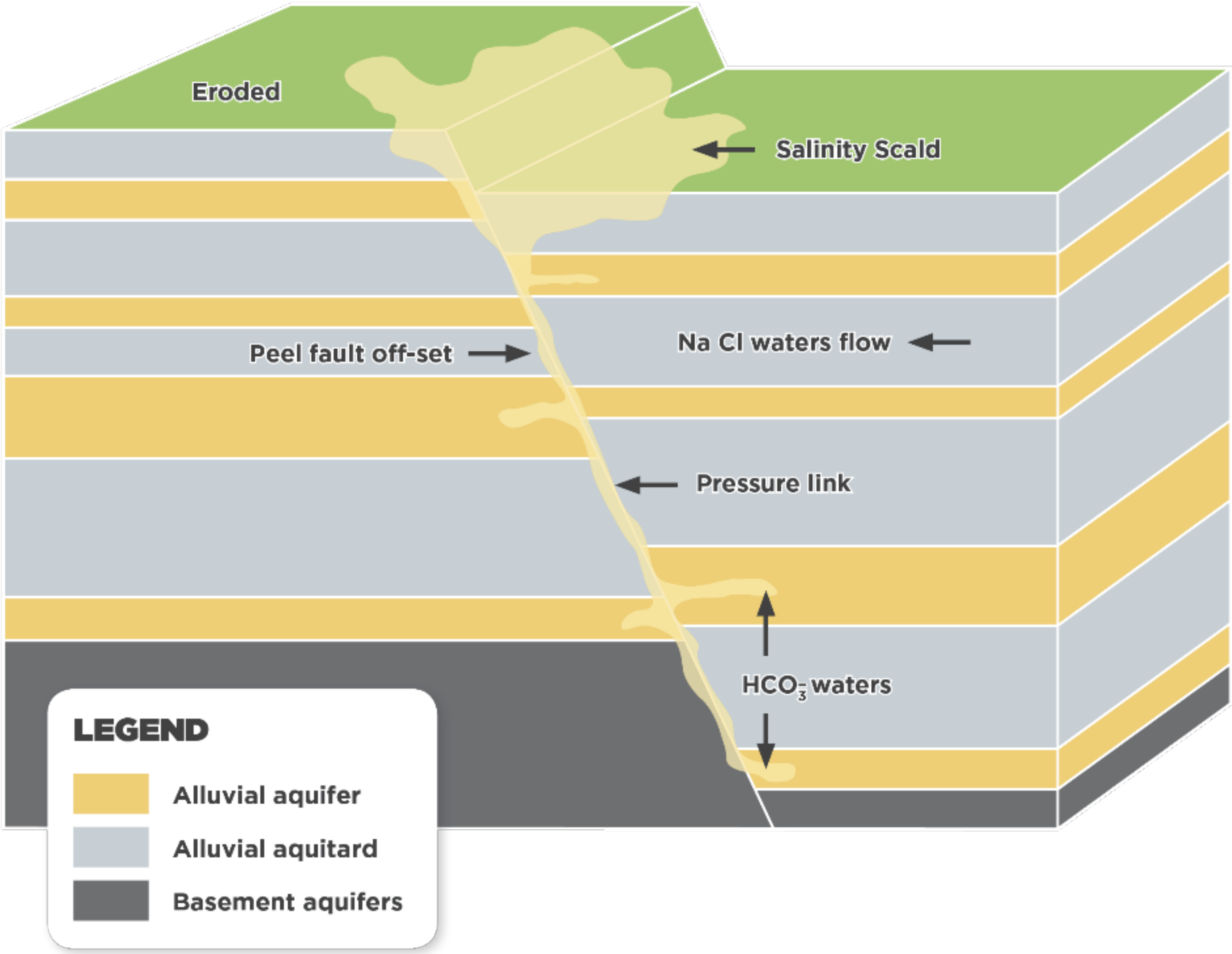

FIGURE 8.14 RELATIONSHIP BETWEEN PEEL FAULT OFFSET, GROUNDWATER LEAKAGE AND THE YELARBON SCALD

Source: Knight et al. (1989)

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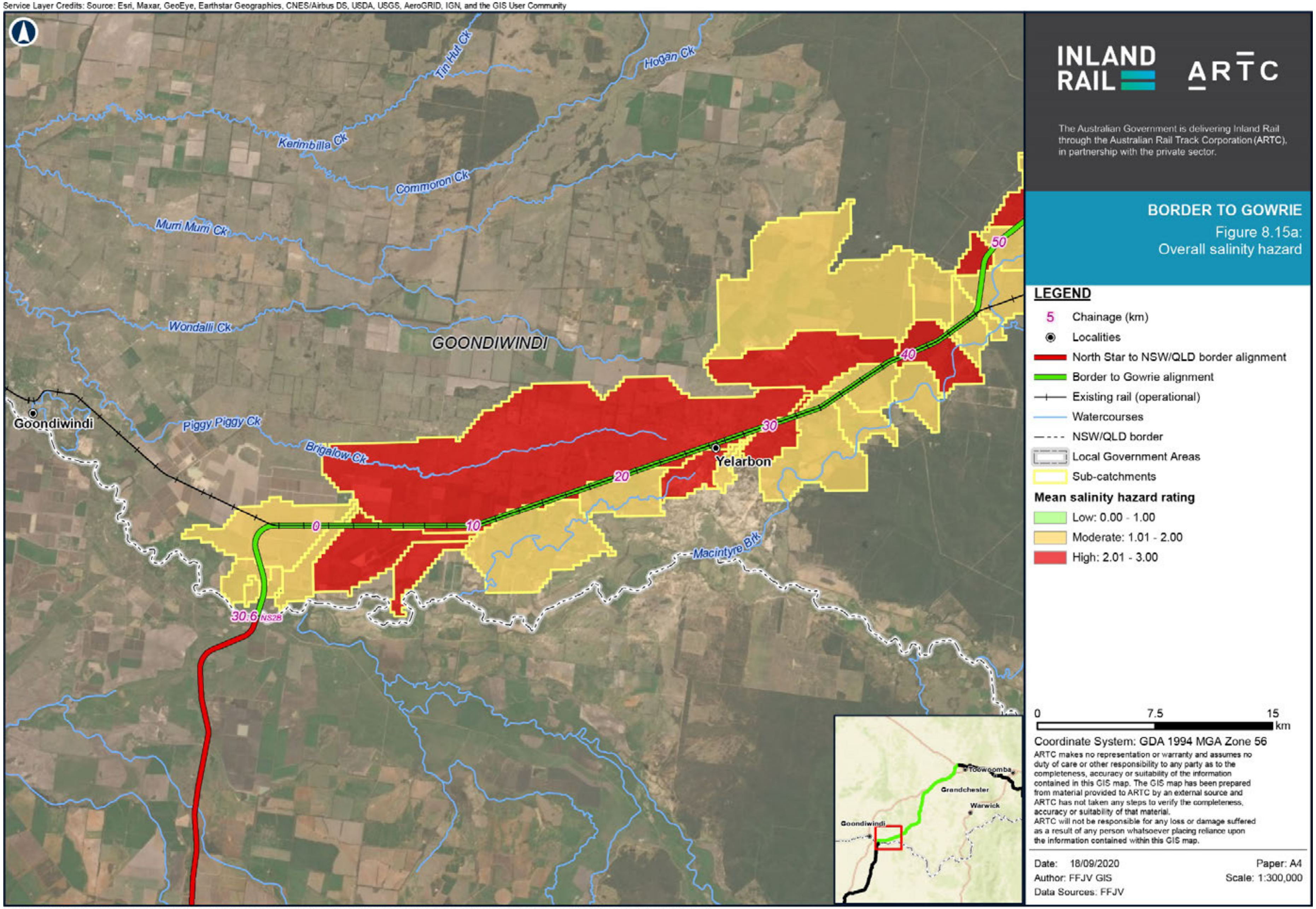

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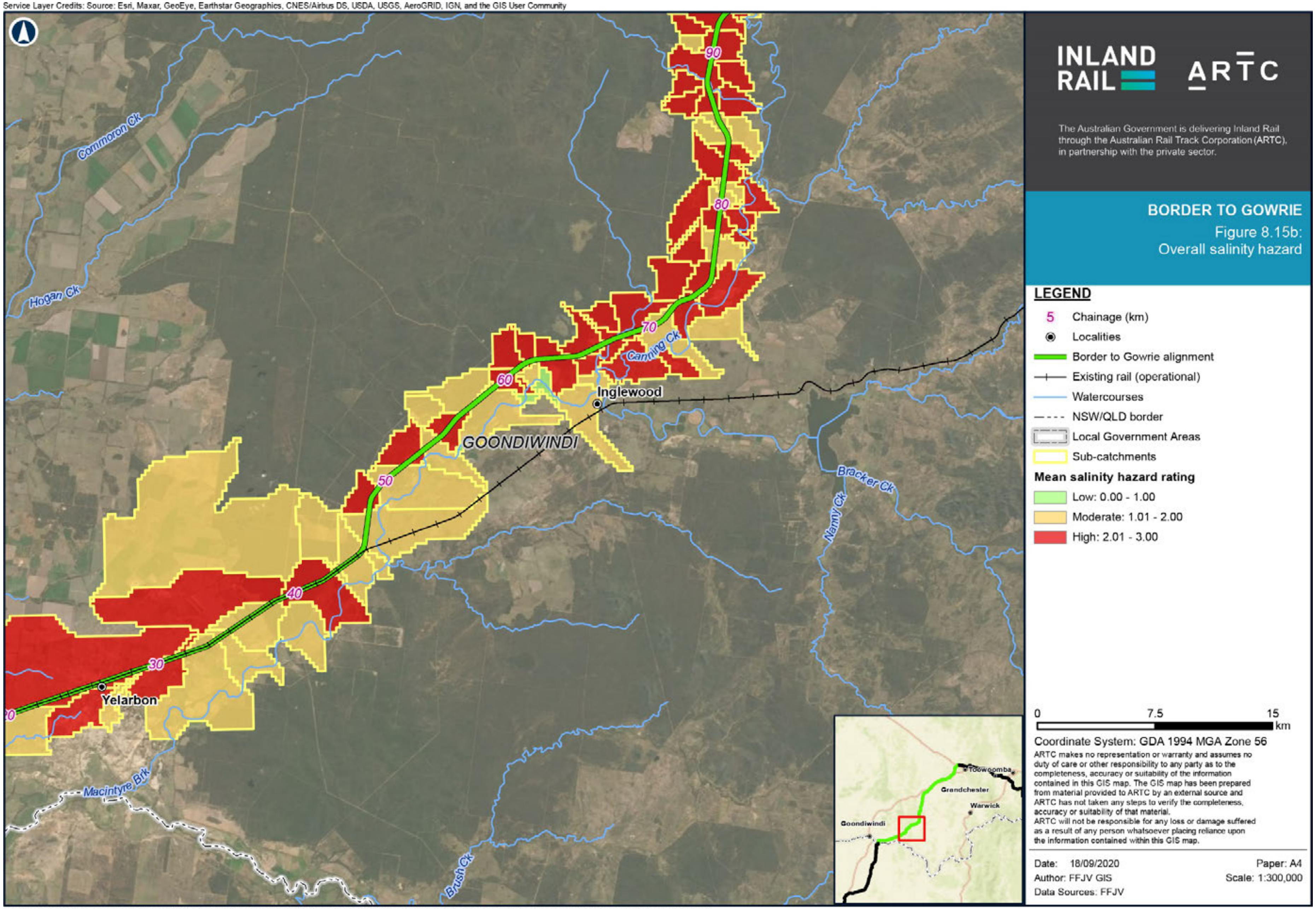

BORDER TO GOWRIE
Figure 8.15b: Overall salinity hazard

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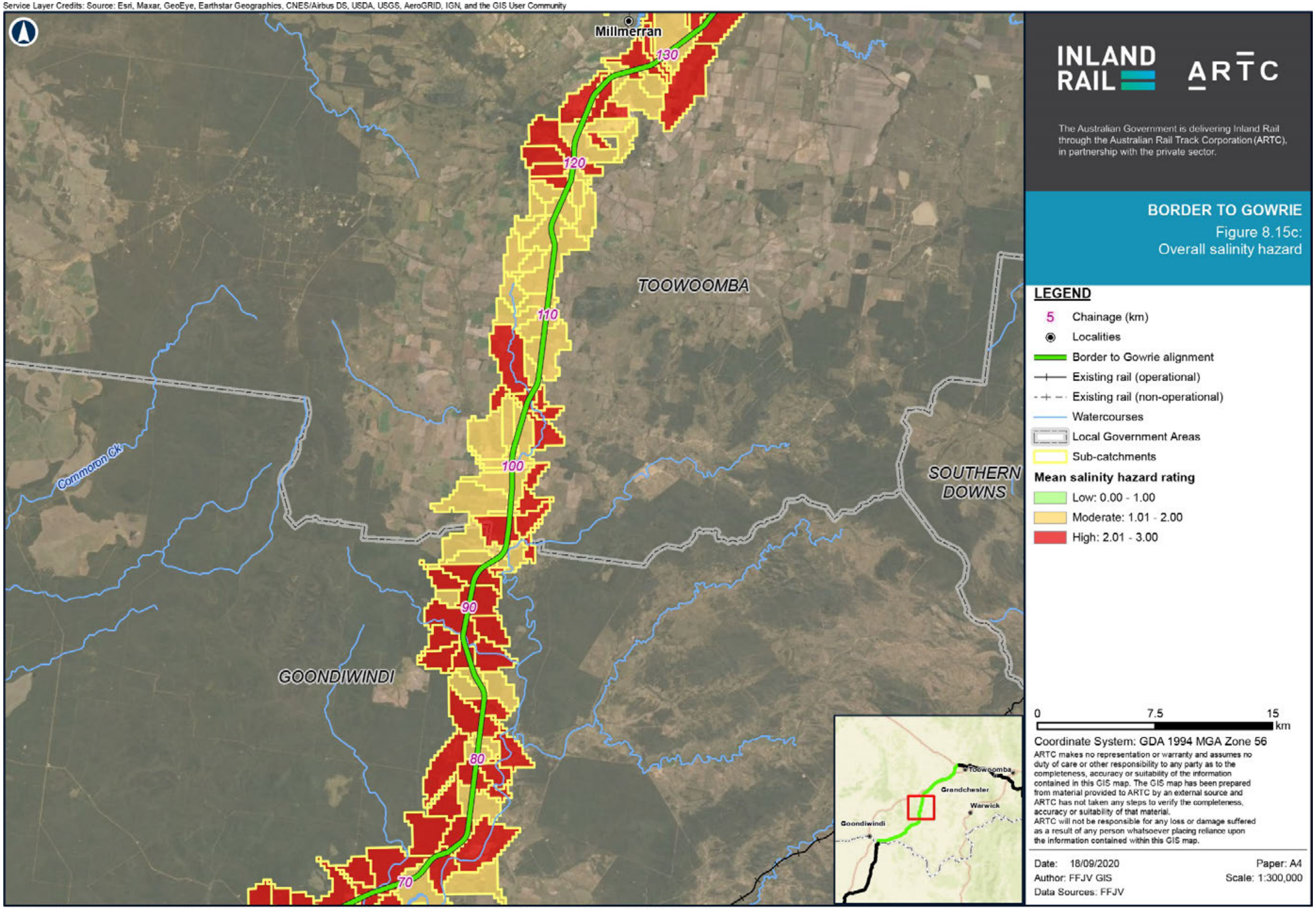

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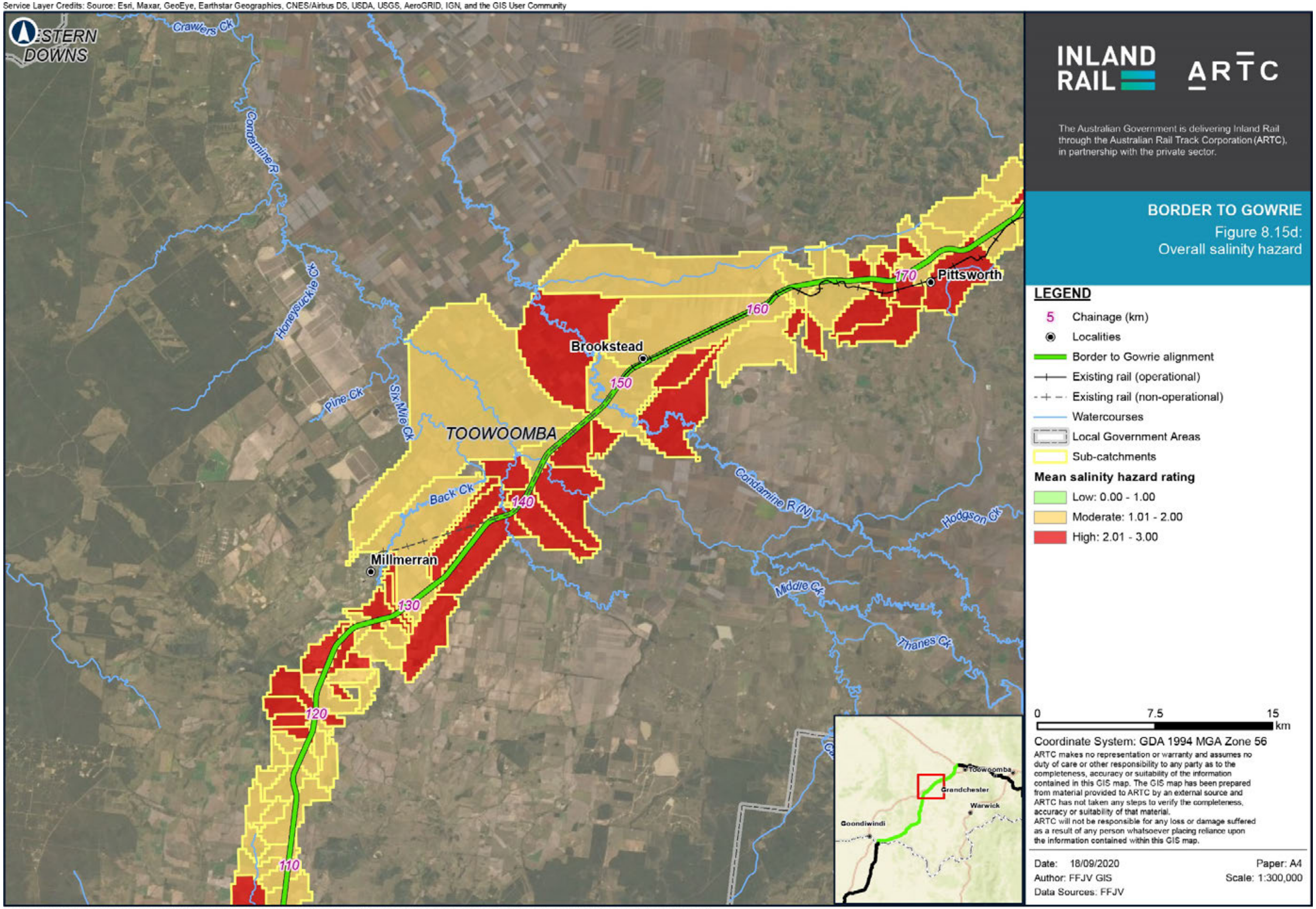

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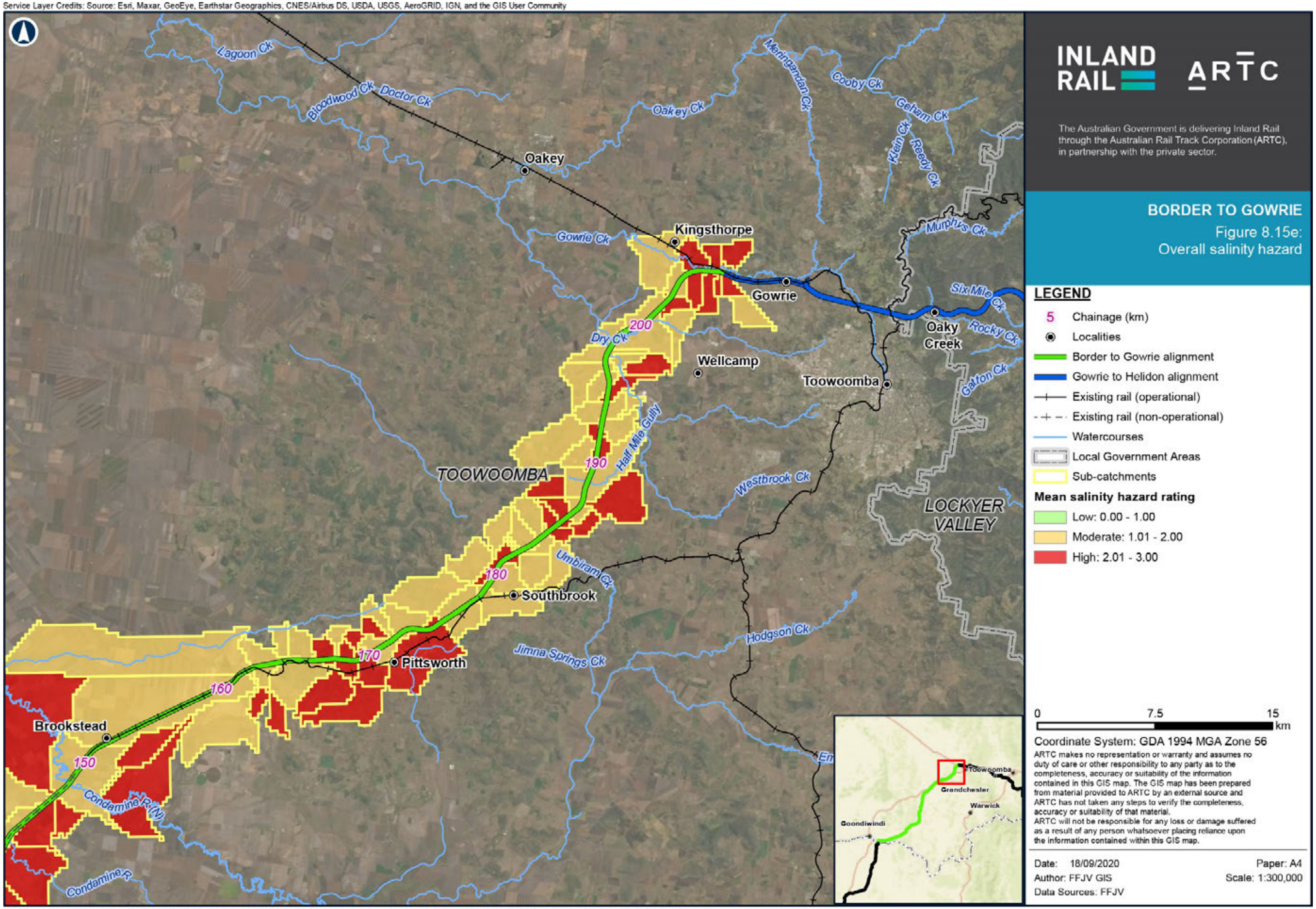

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8.5.4 Agricultural land

The Queensland Agricultural Land Audit 2013 (the Audit) identifies land important to current and future agricultural production in Queensland. The Audit identifies agricultural potential using a rule-based approach, which combines biophysical characteristics of the land, such as soil, climate and landform, as well as native vegetation, and socio-economic spatial data. The characteristics of land/soil resources are a fundamental determinant of potential for most agricultural land uses. Soils are classified using a four-tier hierarchy ranging from Class A (arable land) through to Class D (land that is unsuitable for agriculture) (DAFF, 2013). Agricultural land classified as Class A or Class B is the most productive land in Queensland, with soil and characteristics that allow successful crop and pasture production.

The Audit also identifies important agricultural areas (IAAs). IAAs are defined by the Audit as land that has all the requirements for agriculture to be successful and sustainable, is part of a critical mass of land with similar characteristics and is strategically significant to the region or the State. The Audit is based on the 12 statutory regional planning boundaries of Queensland. Of these 12 regions, the Project is located within the Darling Downs region for the entire length of the Project alignment and SEQ region for 16 km between Kingsthorpe and Gowrie Junction, as the two regions overlap with one another.

There are four areas identified as IAAs in the Darling Downs region, two of which are traversed by the Project footprint, being the Border Region IAA and the Eastern Darling Downs IAA.

The Border Region IAA is located in the southern area of the Darling Downs (near the NSW border) and is located in the Project footprint between Kurumbul and Yelarbon. A total of 337.58 ha of this IAA is located within the permanent footprint for the Project and 142.28 ha is located in the temporary footprint for the Project.

The Border Region IAA supports a variety of broadacre cropping and grazing land. The combination of biophysical attributes exhibited in this area (including slope and water-holding capacity) enables this region to support large areas of broadacre cropping.

The Eastern Darling Downs IAA is located in the Project footprint between Canning Creek and Gowrie Junction. A total of 1,839.37 ha of this IAA is located within the permanent footprint for the Project and 261.28 ha is located in the temporary footprint for the Project.

The Eastern Darling Downs IAA supports some of Queensland's best cropping lands, producing over 30 per cent of the State's cropping commodity value. The area supports extensive broadacre cropping, horticulture and significant intensive livestock businesses. Cropping in the Eastern Darling Downs IAA is dependent on the high-quality Vertosol soils unique to the area.

The Project footprint does not traverse any of the IAAs identified in the SEQ region.

Class A and Class B agricultural land also features throughout the entirety of the impact assessment area. Areas that are not considered Class A or B agricultural land are those around Yelarbon, within Bringalily State Forest, and between Westbrook Creek and Kingsthorpe. The omission of Yelarbon from Class A or B agricultural land mapping coincides with the alkaline, Sodosol soils that occur in the area (refer Section 8.5.3.3).

Mapping of IAAs and Class A and Class B agricultural land, relative to the Project alignment, is shown on Figure 8.16.

Pasture production is dominant along the complete extent of the impact assessment area. The dominant scale of pasture production is medium (1,500 to 3,500 kilograms per hectare (kg/ha)) with one distinct section of high pasture production (>3,500 kg/ha) between Bringalily and Millmerran. Areas of low pasture production (<1,500 kg/ha) occur at Yelarbon and again between Carisbrooke and Bringalily. These low-yield areas are reflective of the Class A or B agricultural land mapping.

Sown pastures, which are pastures where the introduction of grasses and legumes is undertaken to rejuvenate run-down native pastures, is found within the impact assessment area (DAF, 2018b). Sown pastures in the Darling Downs region have increased native pasture production due to the conditions of the area and, as a result, have been implemented successfully in the region (DAFF, 2013).

The Audit identifies the Darling Downs region as a diverse region with 97 per cent of land use under agricultural production, with grazing and broadacre cropping being the predominant industries. The Border Rivers catchment, which the impact assessment area traverses through, is identified as an area with fertile soils and reflected by the dominance of Class A land, Class B land and IAA (DAFF, 2013).

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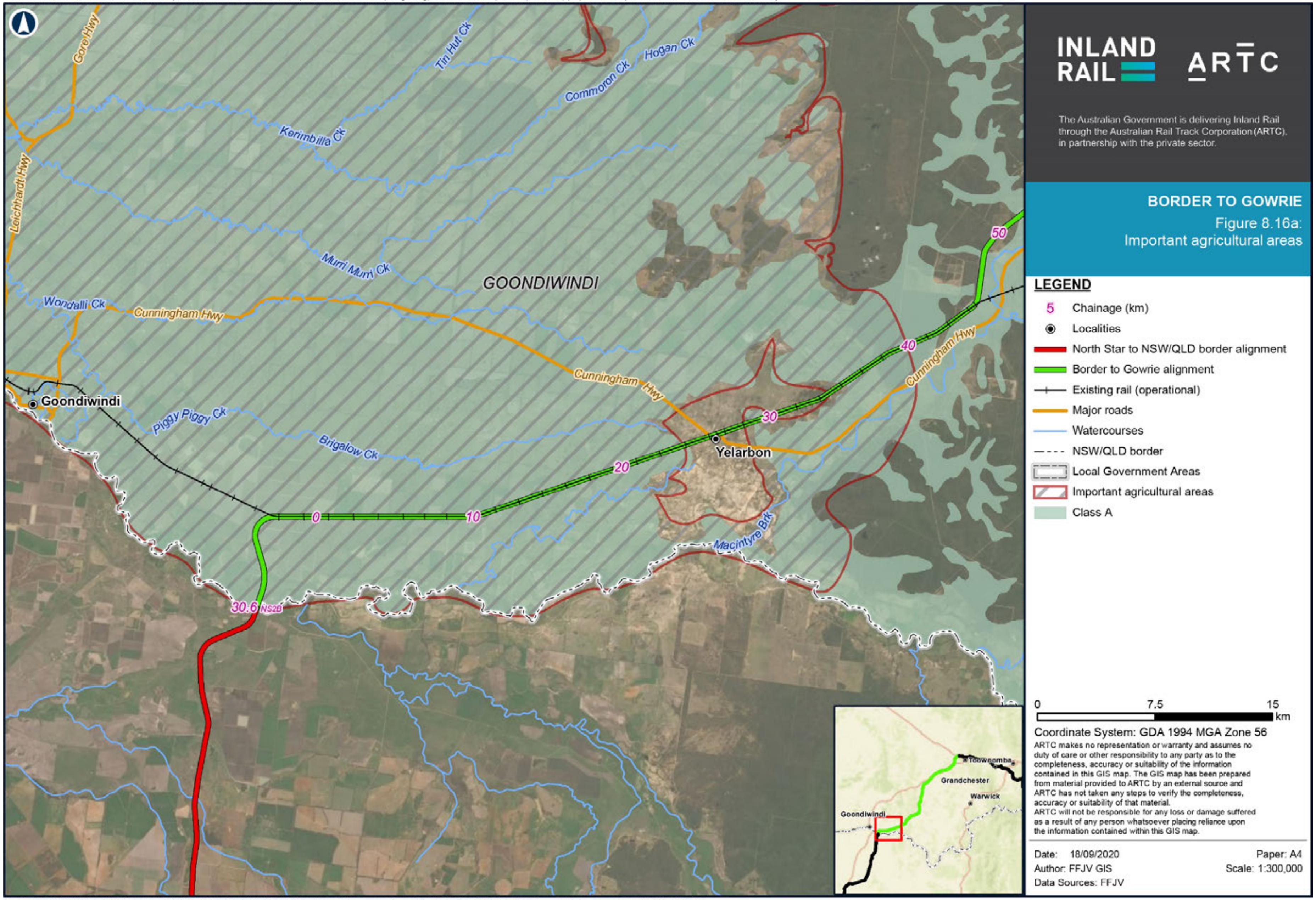

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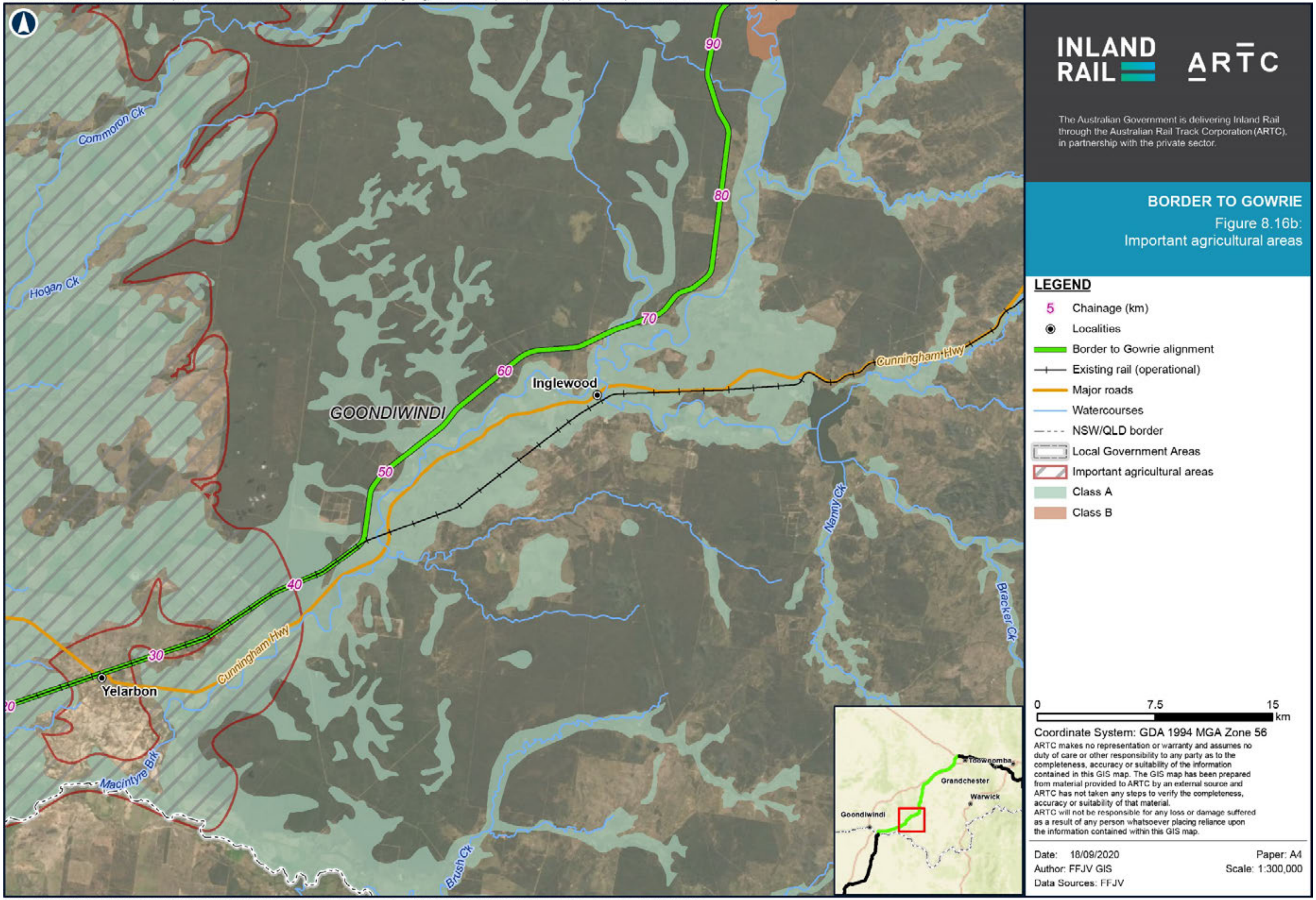

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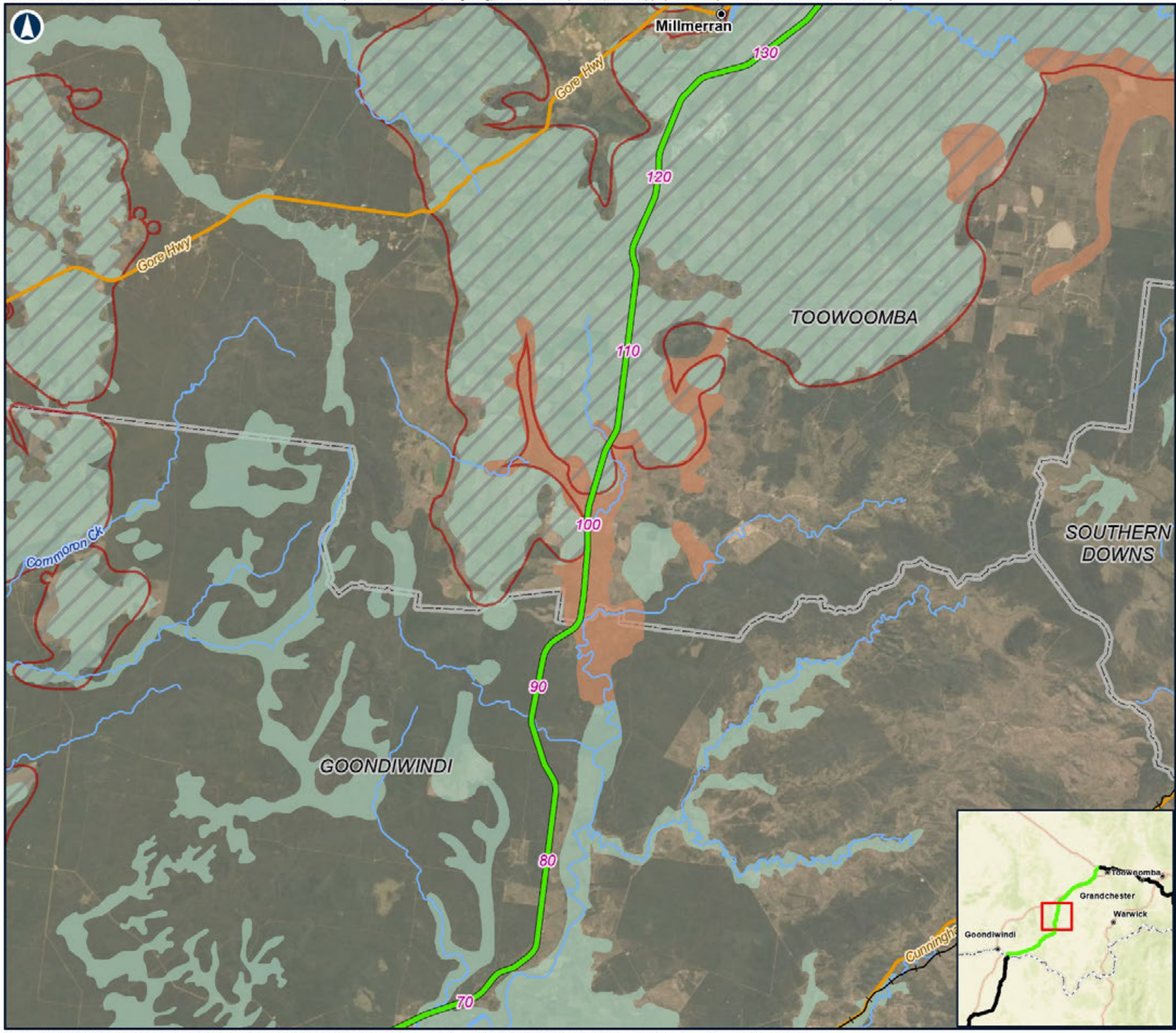

INLAND RAIL

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BORDER TO GOWRIE

Figure 8.16c:
Important agricultural areas

LEGEND

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Watercourses
- Local Government Areas
- Important agricultural areas
- Class A
- Class B

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 18/09/2020 Paper: A4
Author: FFJV GIS Scale: 1:300,000
Data Sources: FFJV

Map by: LUC/DTH/MEF/LS/GN Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201902201142_Land_Resource_Figures\310-EAP-201902201142_Fig8.16_ImportantAgric_v9.mxd Date: 18/09/2020 11:07

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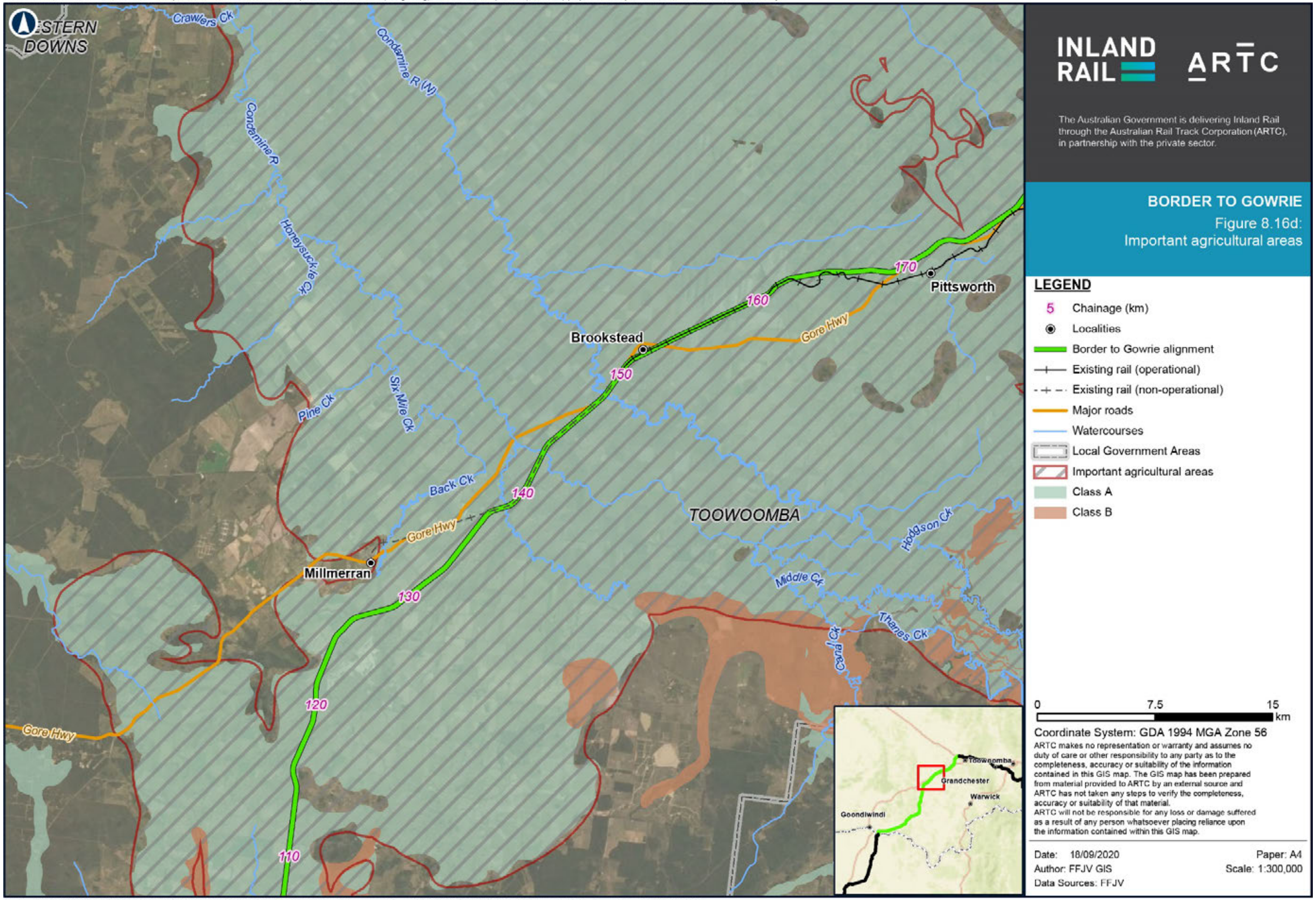

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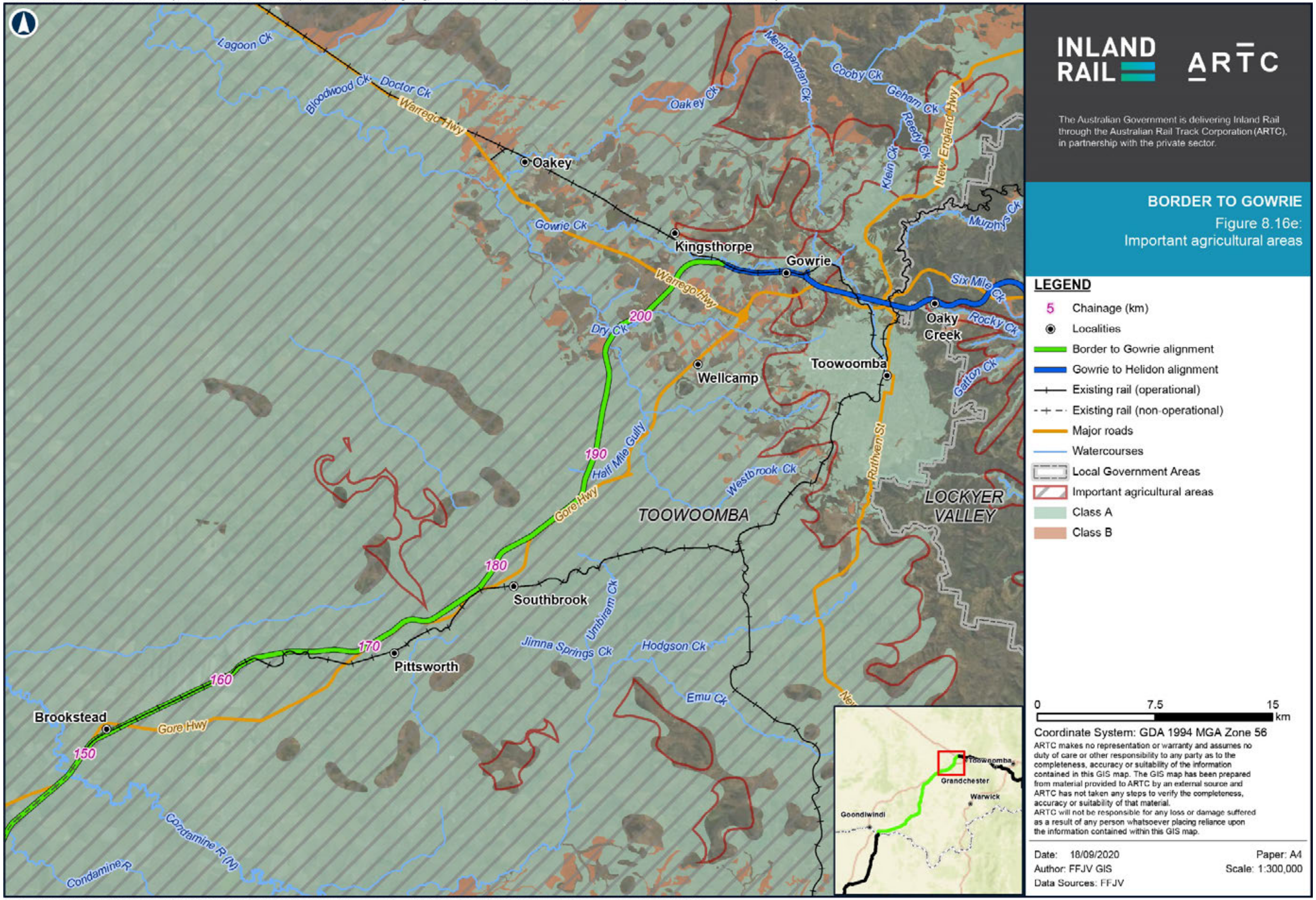
Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap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



Map by: LUC/DTH/MEF/LS/GN Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201902201142_Land_Resource_Figures\310-EAP-201902201142_Fig8.16_ImportantAgric_v9.mxd Date: 18/09/2020 11:07

8.5.5 Soil conservation plans

Soil conservation plans are approved under the *Soil Conservation Act 1986* (Qld) and are intended to facilitate the implementation of soil erosion control measures by landowners in Queensland through the use of property plans and project area plans. Soil conservation plans can cover the whole of a property or just part of it (DSITI, 2015). Soil conservation plans aim to ensure soil capability is not exceeded and no adverse impacts occur onsite or offsite, such as polluting water resources and degrading aquatic habitats.

The preparation of a soil conservation plan requires consideration of many issues, including soil types, topography, current and proposed land use and management, remnant vegetation, property infrastructure and run-off coordination with neighbouring properties, and road and rail drainage. The planning process also provides opportunities to improve the overall property layout to achieve greater efficiencies in managing the property.

Approved property and project area plans are binding on all present and future owners and the Crown. Approved property and project area plans can be modified to accommodate circumstances that differ from those applying at the time of approval. Plans may be amended, or their approval may be revoked. This involves similar procedures to those used in the initial approval process.

Multiple soil conservation plans exist for properties within the impact assessment area. The distribution of these plans relative to the Project alignment are shown on Figure 8.17. Table 8.15 provides a list of soil conservation plan numbers and associated properties that feature within the impact assessment area.

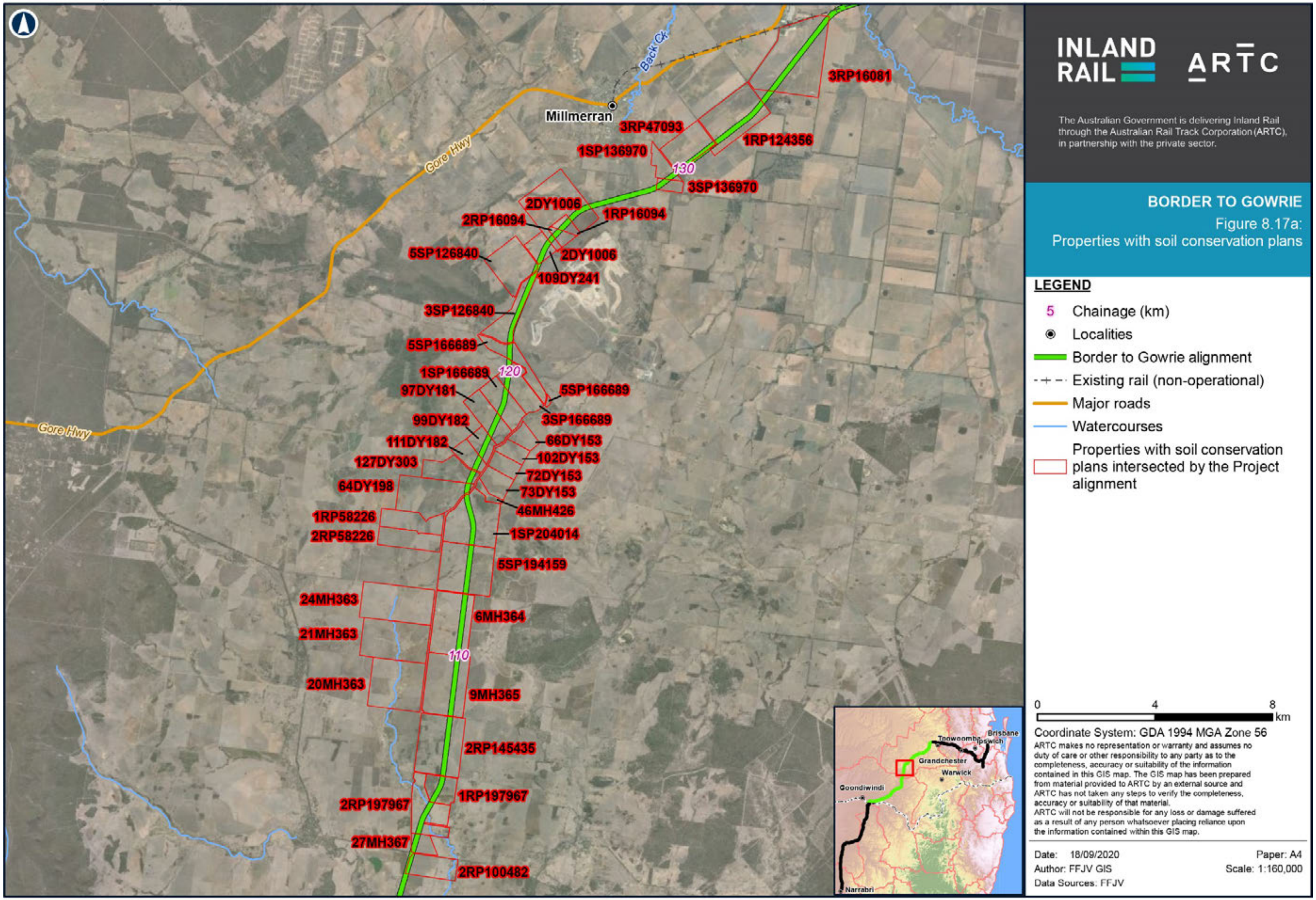
TABLE 8.15 SOIL CONSERVATION PLANS AND ASSOCIATED PROPERTIES TRAVERSED BY THE PROJECT ALIGNMENT

Soil conservation plan number	Soil conservation farm code	Properties covered by the soil conservation plan that are traversed by the Project alignment	
SC301112	Bringalily 10/G	2RP100482	27MH367
SC300371	Bringalily 6/D	2RP197967	
SC305330	Bringalily 6/H	1RP197967	
SC305097	Bringalily 6/C	2RP145435	
SC305428	Bringalily 6/E	9MH365	
Bringalily 1 Project Plan	Bringalily 1/I	6MH364	
	Bringalily 1/H	5SP194159	1SP204014
	Bringalily 1/F	64DY198	127DY303
Back Ck 2 Project	Back Ck 2/G	111DY182	
	Back Ck 2/H	99DY182 97DY181	1SP166689
	Back Ck 2/I	3SP166689	
Back Ck 4 Project	Back Ck 4/G, 4/F	5SP166689	3SP126840
	Back Ck 4/E	5SP126840	
SC305370	Back Ck 5/A	109DY241	
	Back Ck 5/D	1 & 2RP16094	2DY1006
No plan	-	3SP136970	1SP136970
No plan	-	3RP47093	
No plan	-	1RP124356	
No plan	-	3RP16081	
SC305382	Hermitage 5/E Hermitage 5/A	1/RP53657 1RP7474	3822A341940
SC300986	Rocky Ck 4/H	1RP7478	3RP7482
SC300533	Rocky Ck 4/E	1RP7482	
-	-	3829A342007	
SC300475	Rocky Ck 4/D	3RP7480	
SC305105	Rocky Ck 3/B	1RP7470 1AG4028	5RP7446

Soil conservation plan number	Soil conservation farm code	Properties covered by the soil conservation plan that are traversed by the Project alignment	
SC300292	Rocky Ck 3/C	2SP256680	8RP208616
SC300766	Rocky Ck 3/F	2RP212352	7RP212353
SC301011	Rocky 3/G	62SP146089	61SP146089
SC300227	Rocky Ck 1/D	3RP212365 6RP212368	12RP212366 15RP212368
No plan	-	2437A341136	
No plan	-	2RP205146	
SC300973	Perriers Gully 1/N	2RP142680	
SC305324	Perriers Gully 1/O	20 & 21RP913044	19 & 22SP125605
Draft Plan SC300951	*Perriers Gully 1/M, Umbiram 1/P*	1789A34919	2718A341307
SC300180	Umbiram 1/B	5RP841180 6RP203202	3 & 4RP203202
SC301016	Umbiram 1/S	2RP110779	
SC300925	Umbiram 1/H	2RP50027	1495A34822
SC301108	Umbiram 1/C	2RP215348	
No Plan	-	3 & 4RP215320	
No plan	-	1RP215319	
SC301087	Umbiram 2/O	2RP215383	
SC301088	Umbiram 2/N	2RP215357	(2RP213922—not part of Plan)
SC305110	Lower Westbrook Ck 6/K, Lower Westbrook Ck 6/A	2RP172596	5 & 6SP158473
Draft Plan SC305441	*Lower Westbrook Ck 6/I*	*1RP194766*	
No plan	-	2RP155499	
SC305009	Lower Westbrook Ck 5/B	863A34637	
SC300589	Lower Westbrook Ck 4/C Lower Westbrook Ck 4/L	15RP36572	16RP36572
SC305398	Lower Westbrook Ck 4/B Lower Westbrook Ck 4/A	17AG1935	18 & 19RP36572
SC300878	Lower Westbrook Ck 4/T	20RP36572	2RP149961
SC301089	Lower Westbrook Ck 3/G	2AG3200 5RP47487	2RP48192
SC305633	Lower Westbrook Ck 10/H	1RP48192 2RP48191	1RP155674
SC300536	Lower Westbrook Ck 11/H	14RP24607	
Draft plan, SC300772	Lower Westbrook Ck 10/D	15RP24607	
SC300923	Lower Westbrook 10/F *Draft Plan Gowrie 2/S*	4 & 5SP215309 3RP124408	3AG3669
SC305411	Gowrie 2/B	11SP285307	
SC300904 & SC301201	Gowrie 2/K upgraded with subdivision to 2/W, 2/X	43 & 44AG109	2RP55460
SC300778	Gowrie 9/A	29 & 33SP294200	

Table notes:
Soil conservation plan list provided by DNRME in January 2020

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



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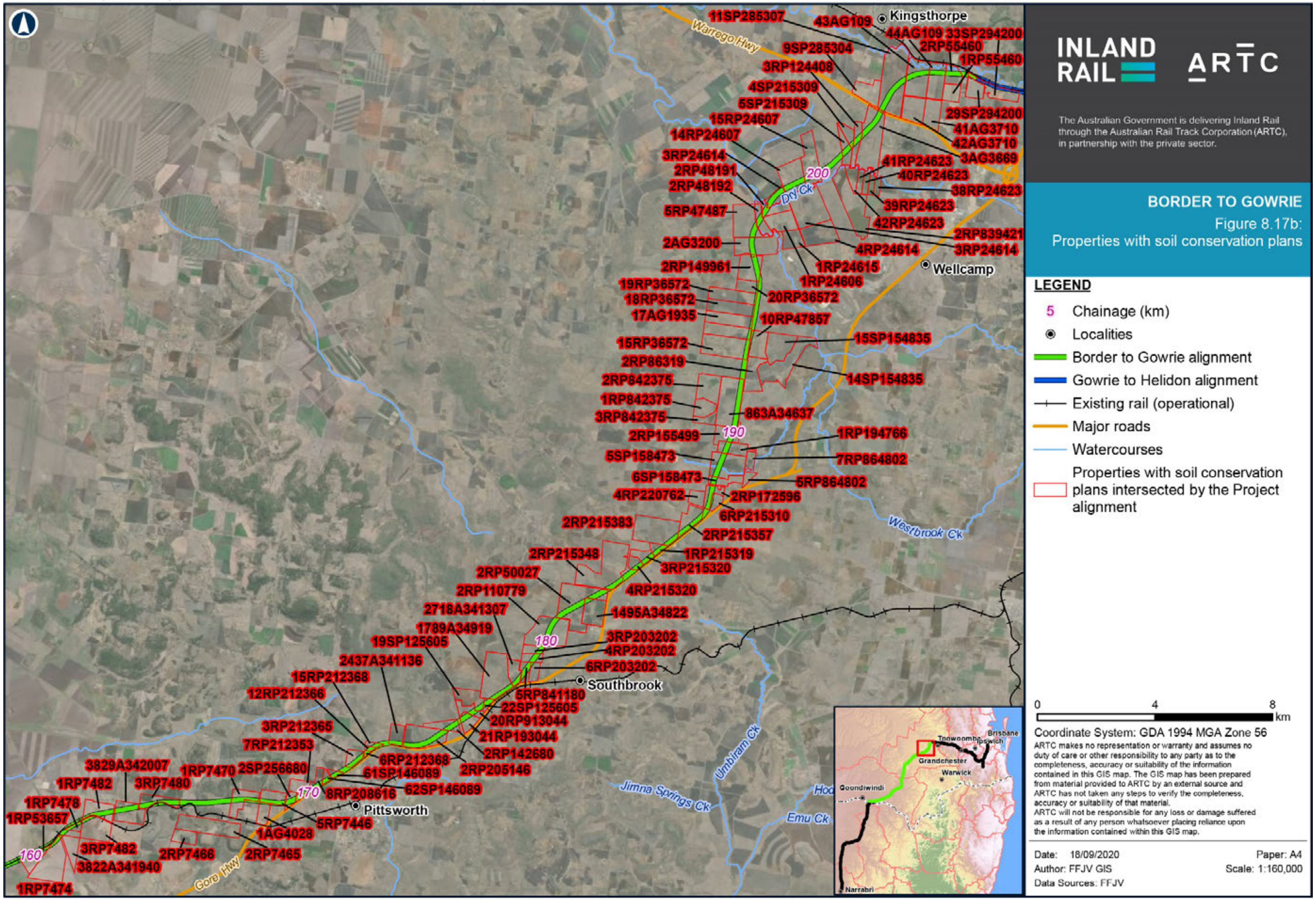
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: GN/LS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201902201142_Land_Resource_Figures\310-EAP-201902201142_Fig8.17_Properties_soil_conserv_plans_v5.mxd Date: 18/09/2020 11:05

8.5.6 Contaminated land

This section provides discussion on the potential for contaminating activities and contamination to be present in proximity to the Project. While contamination in soil is the primary consideration, the potential for contamination to migrate into surface water and groundwater is also discussed, where relevant. The potential impacts of contamination of surface water and groundwater are discussed in Chapter 12: Surface Water and Hydrology and Chapter 13: Groundwater, respectively.

8.5.6.1 Contaminated land assessment methodology

An assessment of contaminated land within the impact assessment area was undertaken using a contaminated land risk assessment based on a contaminant (source)-pathway-receptor methodology, whereby:

- Contaminant (source): A substance present in or on land, water or site at above background concentrations that presents, or has the potential to present, a risk to human health, the environment or any environmental value
- Pathway: The route by which the source is brought into contact with the receptor. This can include the transport of contamination via water (i.e. surface and groundwater), aeolian deposition, vapours, excavation and deposition.
- Receptor: Humans, other living organisms, physical systems and built structures that could be affected by the source. A receptor will only be affected if a pathway from the source to the receptor is present. Groundwater and surface water systems can be considered as receptors in their own right as their quality is regulated by statutory bodies, as well as being pathways for contaminant migration to other receptors.

The source-pathway-receptor relationship allows an assessment of potential environmental risk to be carried out, based on the nature of the source, the degree of exposure of a receptor to a source, and the sensitivity of the receptor.

The fundamental concept of a contaminated land risk assessment is that an exposure pathway linking the source of contamination and the exposed population (humans or the environment) must be present for a risk to exist (National Environment Protection Council (NEPC), 2013).

Identification of potential sources of contamination within the impact assessment area was carried out through desktop assessment, supplemented by site inspections (including walkover) of the impact assessment area, undertaken as part of the geotechnical investigations.

A targeted contaminated land investigation will be undertaken following completion of detail design, where the Project footprint intersects areas of medium-to-high contamination risk, in order to determine the likelihood of occurrence of contaminated soils, the potential for risks to human health and the environment, and required management measures.

The desktop assessment identified potential sources of contamination within the impact assessment area, through:

- An assessment of historical aerial imagery for possible notifiable activities, environmentally relevant activities (ERAs) and other areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas, etc.)
- A search of the EMR and CLR
- A search of the Department of Defence (2017) online mapping for UXOs
- A search of Queensland mining leases
- A search for key resource areas and other resource interests.

Land is listed on the EMR or CLR when DES are notified, or become aware, that notifiable activated (as defined under Schedule 3 of the *Environmental Protection Act 1994* (Qld) (EP Act) are, or have been, carried out on the land or if the land is affected by a hazardous contaminant.

Results or the assessment, including potential sources of contamination are detailed in the sections below.

8.5.6.2 Potential sources

Based on the land uses within the impact assessment area, findings of a desktop assessment and field investigations, the potential sources of contamination in the vicinity of the Project alignment are considered to include:

- Agricultural activities: Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, asbestos and lead paint, arsenic (cattle dips) and landfilling
- Quarries: Hydrocarbons (fuel and oil storage and use), metals/metalloids and hazardous materials
- Landfilling, waste disposal: Hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides
- Existing rail corridor: Metals, asbestos, hydrocarbons and pesticides/herbicides
- Road crossings: Metals and hydrocarbons
- Unknown fill material: Asbestos, metals/metalloids and hydrocarbons.

No visual indicators of gross contamination were observed during geotechnical and soil investigation. However, pieces of asbestos containing material were encountered at one borehole location within the Millmerran Branch Line rail corridor, between Grasstree Creek and Millmerran–Leyburn Road.

Environmentally relevant activities

The assessment of potential sources of contamination identified 16 properties within the impact assessment area that are outside of the existing rail corridors and subject to current ERAs or hold a mining lease. Of the 16 properties, only 3 of these properties are listed on the EMR. These properties are recorded on the EMR for the following activities:

- Landfill (Pittsworth waste facility)
- Service station (Zimms Corner)
- Commodore Mine (mine wastes).
- Details of these properties are provided in Table 8.16 and locations shown in Figure 8.18. EMR certificates for each of these operations are provided in Appendix H: EMR Certificates and Soil Laboratory Certificates.

TABLE 8.16 PROPERTIES LISTED IN THE ENVIRONMENTAL MANAGEMENT REGISTER LOCATED WITHIN THE IMPACT ASSESSMENT AREA

Lot and Plan	Location	Listing details	Approximate distance of activity to the Project alignment
1 RP835800	Tip Road, Pittsworth	Landfill (Pittsworth waste facility)	0.3 km south
2 SP225174	Warrego Highway, Kingsthorpe	Service station (Zimms Corner)	1.1 km east
8 SP126840	Rocky Creek Road, Millmerran	Mine wastes (Commodore Mine)	0.13 km east

All properties with a current EA for ERA have been discussed in Chapter 7: Land Use and Tenure.

A total of 71.2 km of the Project alignment is located within existing rail corridor associated with the Southern Western Line and Millmerran Branch Line. The operation of railway yards is a listed notifiable activity under Schedule 3 of the EP Act, and therefore should be listed on the EMR; however, the operation of a railway is not considered a notifiable activity and therefore is unlikely to be listed on the EMR unless the land is known to be affected by a hazardous contaminant.

Due to the total length of railway, and that they are not a notifiable activity, it was not considered necessary to search each land parcel of the rail corridor on the EMR/CLR. Instead, a precautionary approach has been adopted, whereby land within the rail corridor will be assumed to be contaminated, until proven otherwise.

Potential contaminating activities that may be associated with rail land include:

- Disposal of ash material
- Stockpiling of fill and ballast
- Maintenance activities and the use of chemicals (including solvents)
- Leaks and spills from freight and locomotive machinery
- Use of herbicides/pesticides
- Petroleum product and oil storage.

Unexploded ordnance

A search of the Department of Defence (2017) online mapping identified no areas of UXO potential within the impact assessment area (Department of Defence, 2017).

Mining activity

A search of the DNRME (2017b) current and historical mines identified that there is one granted mining lease within the Project footprint, near the localities of Clontarf and Domville. This mining lease is associated with the open cut Commodore Mine and is traversed by the Project alignment between chainage Ch 121.0 km to Ch 127.24 km.

Resource areas

The Kildonan key resource area (KRA) (KRA No. 120) is located approximately 18 km south–east of Goondiwindi on Kildonan–Old Warwick Road. KRAs are locations containing important extractive resources of State or regional significance worthy of protection for future use (DILGP, 2017a).

At its closest point, the permanent footprint is located approximately 355 m west of the resource/processing area and 170 m to the west of the southeast corner of the separation area for KRA 120, avoiding land within the separation and processing areas.

The temporary footprint includes allowance for a temporary haulage route to be established between the Project and KRA 120 to enable material to be sourced from this location, if agreement to obtain material from this location can be reached with the owner/operator. As a result, this nominated temporary haulage route encroaches marginally into the separation area and the western boundary of the resource/processing area for KRA 120. If agreement is not reached, then there may not be a need for this temporary haulage route.

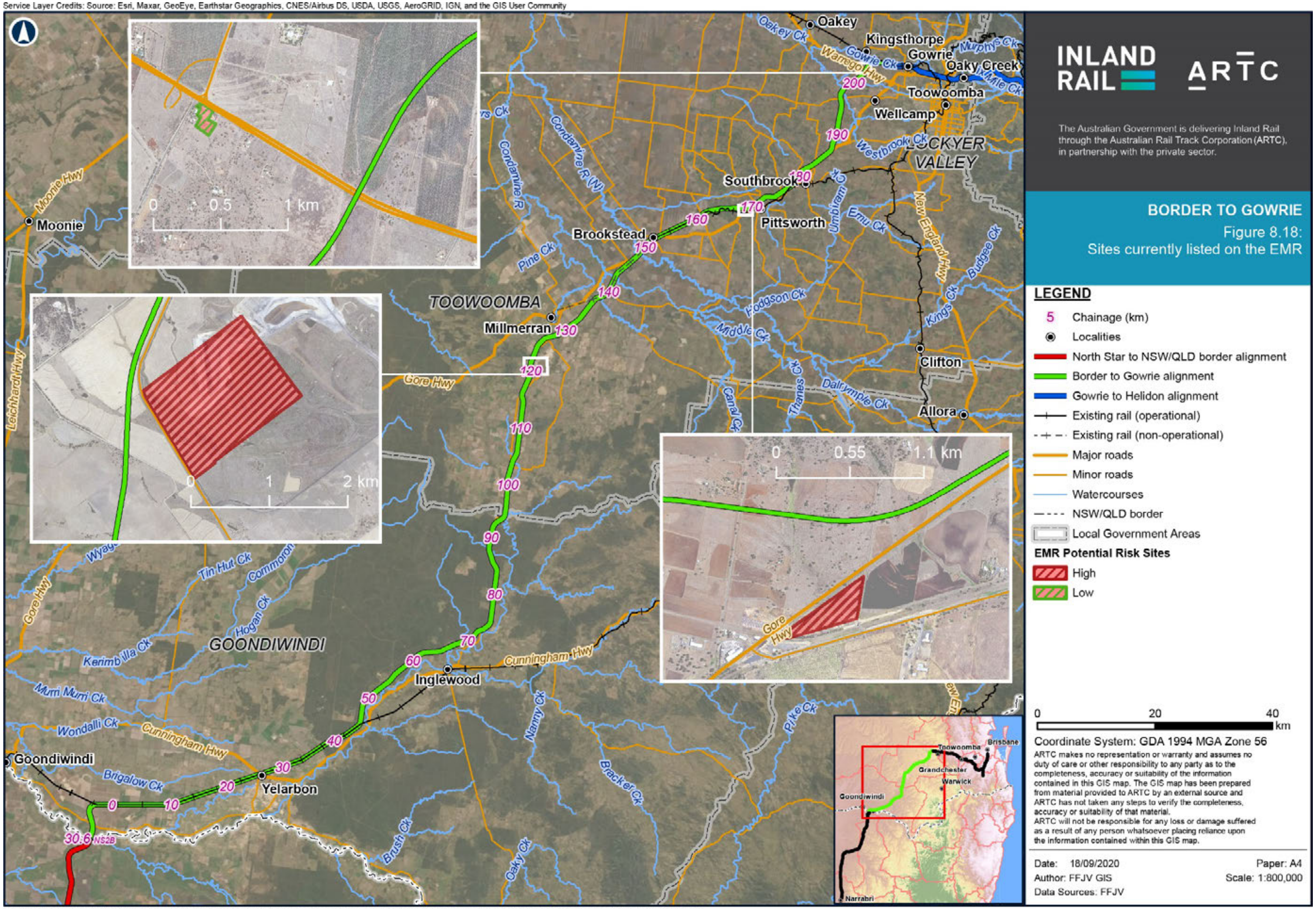
The quarry is considered a low contamination risk to the Project due to the separation distance as well as the existing environmental management processes that would be required to be implemented on site. Further detail on KRA 120 is provided in Chapter 7: Land Use and Tenure.

8.5.6.3 Historical aerial imagery

An assessment of historical aerial imagery of areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas, etc.) was undertaken to further investigate current potential sources, as well as historical sources of contamination within the impact assessment area.

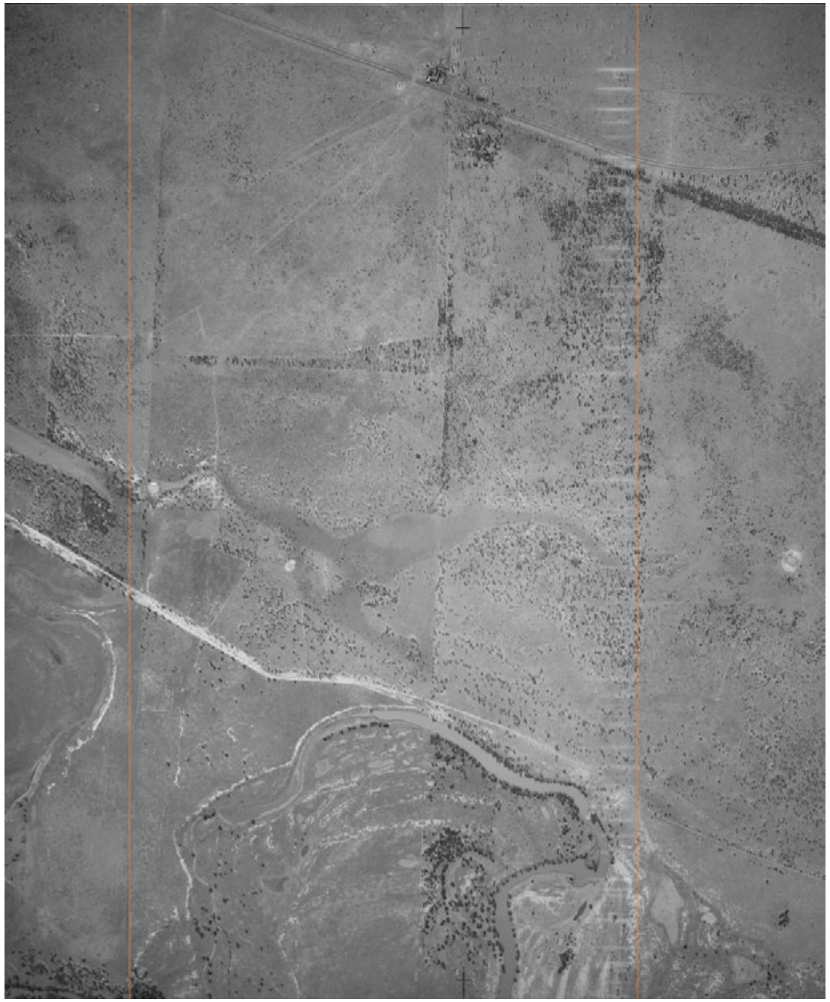
The review of historical aerial imagery along the Project footprint is presented in Table 8.17.

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



Map by: CS/DTH/MEF/LS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201902201142_Land_Resource_Figures\310-EAP-201902201142_Fig8.18_SitesListedOnEMR_v8.mxd Date: 18/09/2020 11:02

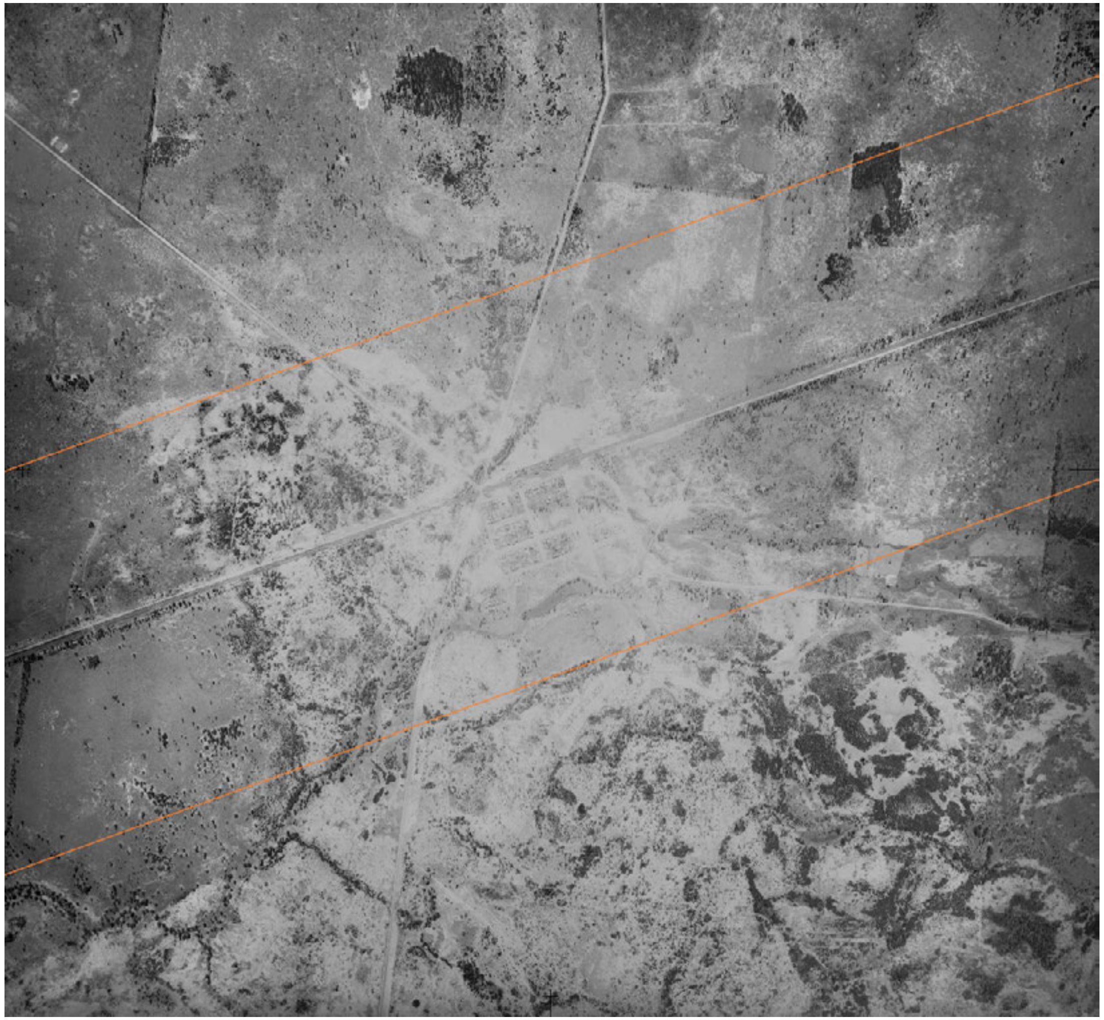
TABLE 8.17 REVIEW OF HISTORICAL AERIAL PHOTOGRAPHY ALONG THE PROJECT FOOTPRINT

Impact assessment area[1]	Details
Kurumbul area (Ch 30.6 km to Ch 6.0 km)	
	**Year:** 1949 **Direction:** Aerial **Details:** The aerial image displays the existing South Western Line running from Goondiwindi to Kurumbul. It is evident from the aerial image that the landscape is dominated by grazing pastures with scattered dense bushland either side of the rail corridor and around waterways. Several ephemeral waterways that drain into the Macintyre River (further south) exist within the impact assessment area. Potential dirt road networks have been established in the region with several residential properties spread across the approximate impact assessment area. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1972 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area between the Macintyre River and Kurumbul. Several waterbodies have emerged within the landscape as well as distinct cropping pastures along the western boundary of the impact assessment area. Potential alluvial plains are emerging south of the large ephemeral waterbody draining into the Macintyre River. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1997 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area between the Macintyre River and Kurumbul. The region has transformed into a cropping pasture dominant landscape, with pastures within the approximate impact assessment area and immediate surrounds. Several residential properties have also been constructed. Paved roads have been constructed throughout the region. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area between the Macintyre River and Kurumbul. No significant changes have occurred in the region aside from cropping pastures extensively covering the landscape. **Source:** ESRI (2019).

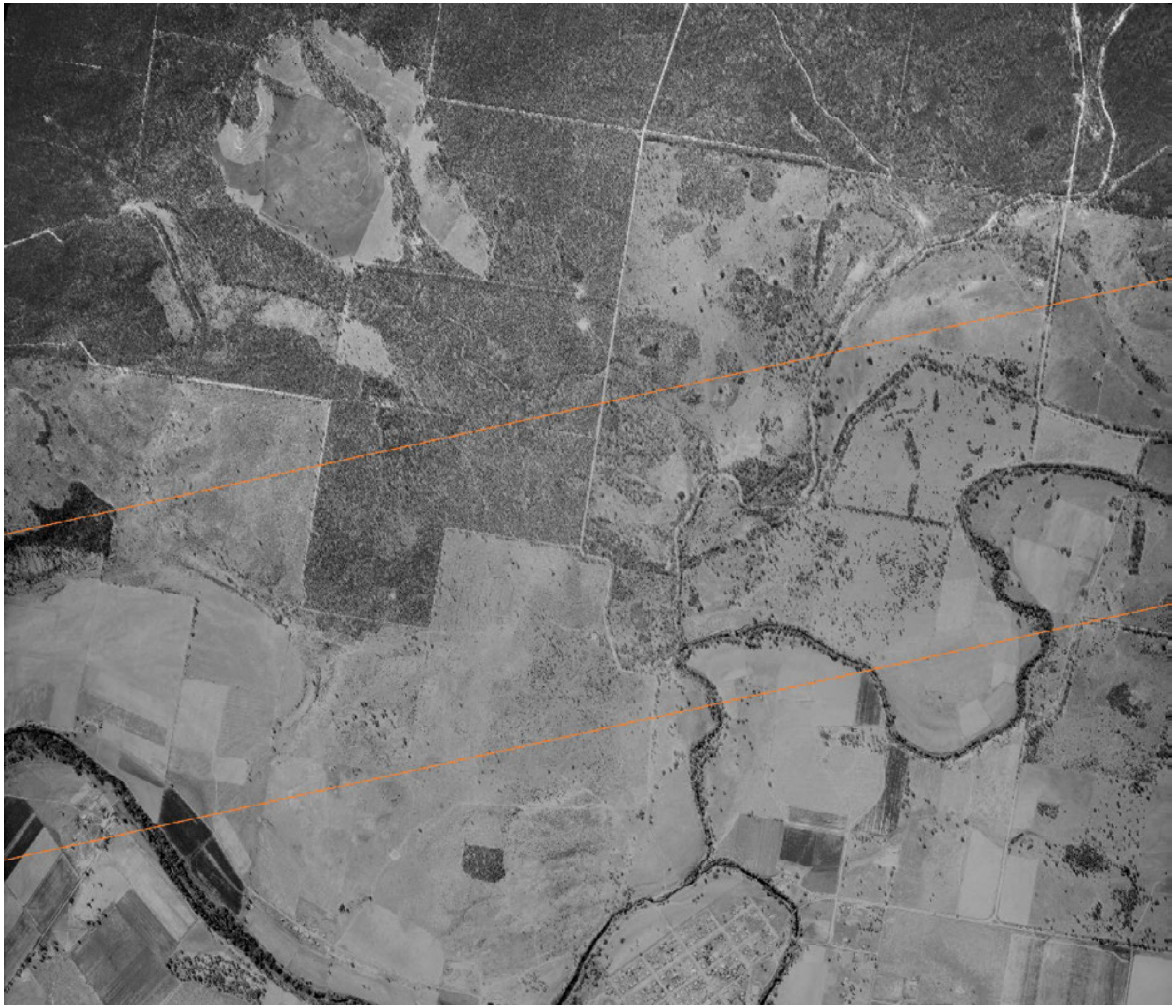
Impact assessment area[1]	Details
Yelarbon area (Ch23.0 km to Ch 30.0 km)	
	**Year:** 1949 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Yelarbon with the South Western Line running parallel to the town. The landscape of the area is dry with large areas of natural salt scalds evident. Sub-division of lots has occurred for the potential construction of the Yelarbon town centre. Road networks have been established in the region with scattered areas of dense bushland featuring throughout the landscape. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1962 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Yelarbon with the South Western Line running parallel to the town. No significant changes have occurred from the previous aerial image aside from the town centre expanding in size and residential housing occupying a concentrated area of the landscape. **Source:** QImagery (State of Queensland, 2019).

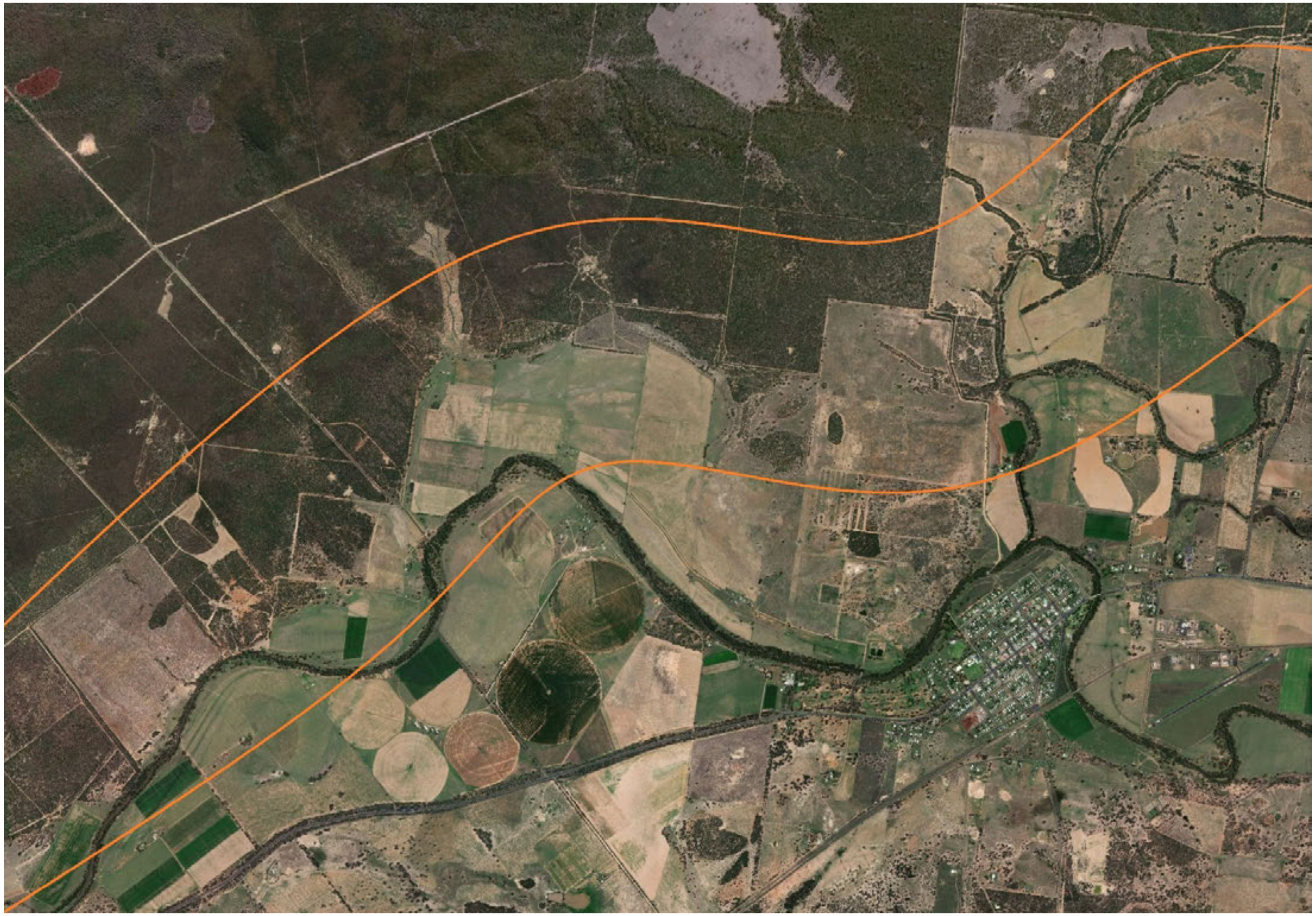
Impact assessment area[1]	Details
	**Year:** 1997 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Yelarbon with the South Western Line running parallel to the town. No significant changes have occurred from the previous aerial image, with the exception of residential dams emerging within the approximate impact assessment area. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Yelarbon with the South Western Line running parallel to the town. No significant changes have occurred from the previous aerial image, with the exception of unidentifiable structure emerging north of the town centre. **Source:** Esri (2019).

Impact assessment area[1]	Details
Inglewood area (Ch 62.0 km to Ch 69.0 km)	
	**Year:** 1949 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling north of Inglewood, along the edge of the Bringalily State Forest. The approximate impact assessment area intercepts Pariagara Creek and Canning Creek while traversing landscapes of forest and dense bushland. Road infrastructure and the Inglewood town centre has already been well established. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1974 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling north of Inglewood, along the edge of the Bringalily State Forest. Sub-division of land for cropping pastures is evident along the western border of the image. Patches of scattered forestry have been cleared. No further significant changes can be observed within the approximate impact assessment area from the previous aerial image. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1996 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling north of Inglewood, along the edge of the Bringalily State Forest. Cropping pastures have emerged extensively throughout the region and compose much of the approximate impact assessment area in the region. Inglewood town centre has expanded in size as well as many residential properties featuring throughout the landscape to the south. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling north of Inglewood, along the edge of the Bringalily State Forest. No significant changes can be observed from the previous aerial image aside from an increase in cropping pastures throughout the region. The area has also seen a rise in residential properties and dams. **Source:** Esri (2019).

Impact assessment area[1]	Details
Millmerran area (Ch 121.0 km to Ch 136.0 km)	
	**Year:** 1999 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing south of Millmerran. The Millmerran town centre has already been well established with road networks and residential properties featuring. The dominant surrounding land use appears to be cropping pastures. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2005 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing south of Millmerran. The Millmerran town centre has expanded infrastructure into surrounding areas. Grazing pastures have emerged throughout the landscape, however cropping pastures remain the dominant land use. South of Millmerran, Commodore Mine has begun operation as well as Millmerran Power Station. **Source:** QImagery (State of Queensland, 2019).

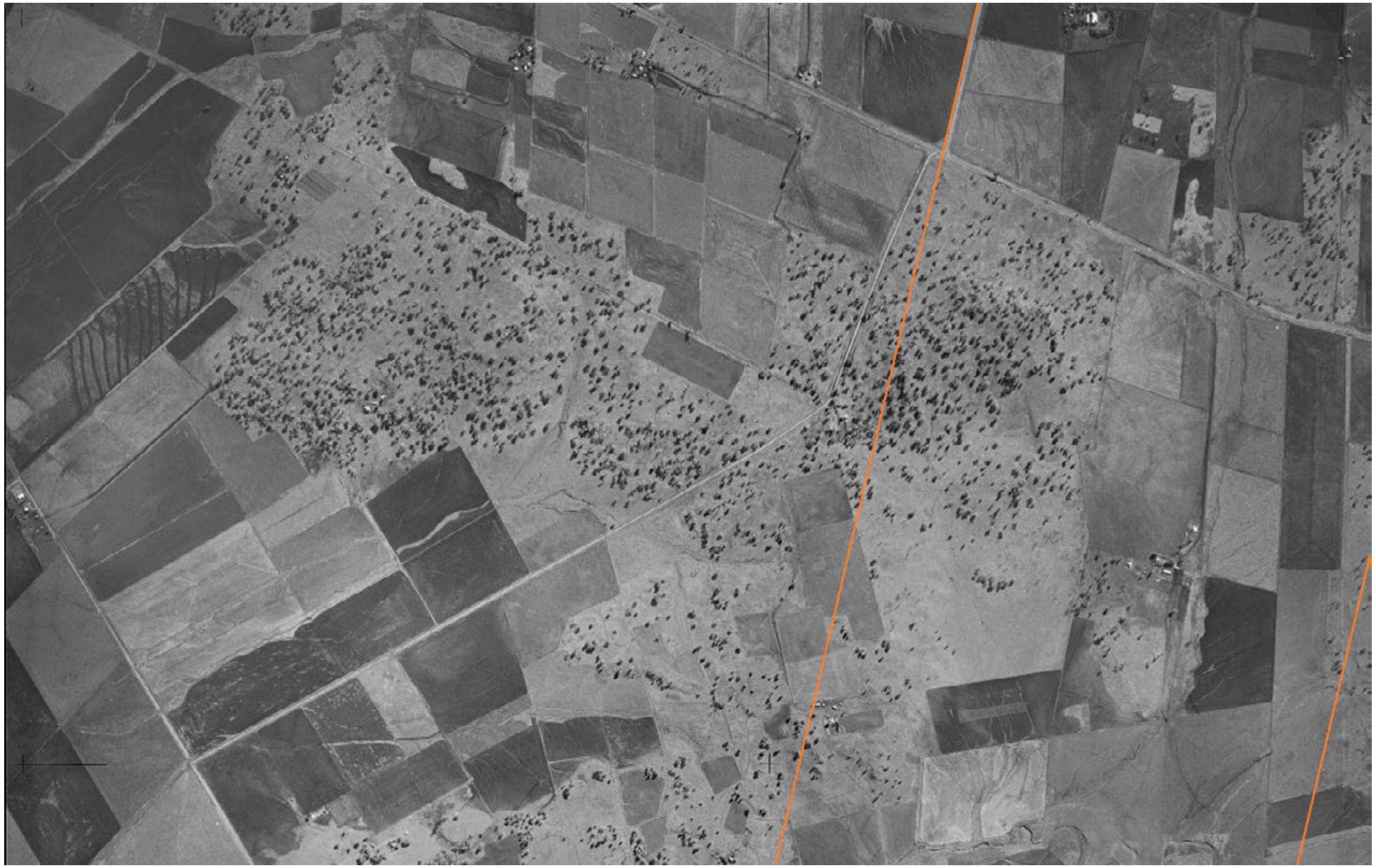
Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing south of Millmerran. The aerial image shows the expansion of Commodore Mine and rehabilitation of existing areas. **Source:** Esri (2019)

Impact assessment area[1]	Details
Pittsworth area (Ch 168.0 km to Ch 175.0 km)	
	**Year:** 1955 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Pittsworth. The Pittsworth town centre has already been well established with road networks and residential properties featuring to the east of the approximate impact assessment area. Cropping pastures are the dominant land use with smaller areas of grazing pastures featuring to the south. The South Western Line is already operational and traverses the impact assessment area along the southern portion. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1988 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Pittsworth. Pittsworth town centre has expanded in size either side of the South Western Line. More residential dams also feature throughout the landscape in comparison to the previous aerial image. The current location of the IOR Petroleum Diesel Depot is occupied by potentially residential properties. No other significant changes can be observed within the impact assessment area or the wider landscape. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2005 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Pittsworth. The EMR listed property, Pittsworth Landfill, has undergone earth works with infrastructure closely resembling the current layout of the site present. No other significant changes can be observed within the impact assessment area or the wider landscape. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traveling through Pittsworth. The IOR Petroleum Diesel Depot has become fully operational. No significant changes can be observed within the impact assessment area or the wider landscape, with the exception of the Pittsworth Landfill site being fully operational. **Source:** Esri (2019)

Impact assessment area[1]	Details
Kingsthorpe area (Ch 199.0 km to Ch 206.9 km)	
	**Year:** 1955 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing the landscape south of Kingsthorpe. Cropping pastures are the dominant land use in the area, with small, scattered patches of grazing pastures featuring throughout. Road networks have already been established as well as several residential properties being present within the approximate impact assessment area. Potential ephemeral waterways exist to the south within the approximate impact assessment area. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 1988 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing the landscape south of Kingsthorpe. Gowrie Mountain, east of the impact assessment area, is well established with clusters of residential development and road networks presents. The lot of the EMR listed service stations, Zimms Corner, has been developed, however land use is unconfirmed. North of the present-day service station, the Old Gowrie Homestead and Boutique Winery has expanded development. Contour banks are evident in the cropping pastures to the north of the impact assessment area. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2005 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing the landscape south of Kingsthorpe. The present-day site of the EMR listed service station has been developed into Zimms Corner Service Station. Further south, residential properties have also been constructed. South of Gowrie Creek, Performance Feeds have potentially begun operations. No other significant changes can be observed within the impact assessment area or wider landscape. **Source:** QImagery (State of Queensland, 2019).

Impact assessment area[1]	Details
	**Year:** 2019 **Direction:** Aerial **Details:** The aerial image displays the approximate impact assessment area traversing the landscape south of Kingsthorpe. More residential development has occurred in the Gowrie Mountain area. The Performance Feeds property has undergone expansion with several above ground storage tanks evident. No other significant changes can be observed within the impact assessment area or wider landscape. **Source:** Esri (2019)

Table note:

1. Approximate impact assessment area indicated in orange.

8.5.6.4 Contamination risk summary

An assessment of potential sources and associated risks of contamination in proximity to the Project have been identified through review of existing land uses, ERAs, UXO potential, mining activities and resource areas within the impact assessment area. Assessment has also considered historical aerial imagery and field investigation observations.

Based on this assessment, the activities and potential contaminants that may be encountered within the Project footprint are summarised in Table 8.18.

TABLE 8.18 POTENTIAL EXISTING SOURCES AND IDENTIFIED CONTAMINATION RISKS

Activity	Location	Potential contaminants	Likelihood of occurrence within the impact assessment area
Agricultural land	Multiple throughout the impact assessment area	Hydrocarbons (fuel and oil storage and use) (agricultural storage and use)	▶ Possible, due to proximity to agricultural buildings
		Pesticides and herbicides (agricultural storage and use)	▶ Possible, due to proximity to cropping land
		Asbestos and lead paint (agricultural buildings/structures)	▶ Possible, due to distance to agricultural buildings
		Livestock dips or spray races arsenic, dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD) (agricultural storage and use)	▶ Possible, due to aerials identifying presence of livestock dips or spray races (historic or current)
		Landfilling (agricultural)	▶ Unlikely, due to no identification of agricultural landfills (historic or current)
Housing/sheds/ other	Multiple throughout the impact assessment area	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos (agricultural and residential storage and use, and commercial enterprise)	▶ Possible, despite EMR listed property (service station) Lot 2 SP225174 located outside impact assessment area
Landfilling (municipal)	Multiple throughout the impact assessment area	Hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides (local government or commercial enterprise)	▶ Possible, due to EMR listed property (landfill) Lot 1 RP835800
Mining	Commodore Mine	Acid mine drainage, metals/metalloids (commercial enterprise)	▶ Possible, due to EMR listed property (mine wastes) Lot 8 SP126840
Existing/ permanent rail corridor	▶ South Western Line from Kurumbul to Whetstone ▶ Millmerran Branch Line from Yandilla to Yarranlea	Metals/metalloids, asbestos, hydrocarbons and pesticides/herbicides (railway land use)	▶ Possible, due to identified presence (historic or current)
Roads	Refer to Chapter 18: Traffic, Transport and Access	Metals, hydrocarbons and pesticides/herbicides (public roads)	▶ Possible, due to identified presence
Unknown fill material	Existing rail corridor	Asbestos, metals/metalloids, hydrocarbons.(railway land use)	▶ Unlikely, anthropogenic materials not observed during geotechnical investigation

For potential impacts to occur, there must be a linkage between the three following components:

- Source of contamination
- An exposure pathway
- Environmental values (receptor) that may be affected by this exposure.

Should one or more of these above components be unavailable, or no complete linkage exist between the three, the risk of exposure to an environmental value is likely to be either minimal or non-existent. Where activities have been identified as posing a potential contamination risk, these activities or risks have been advanced for further assessment in Section 8.6.8.

8.6 Potential impacts

This section provides a discussion of the potential impacts that may arise during construction, operation and maintenance of the Project based on the existing land resource features and conditions that are known to occur within the impact assessment area, as established through Section 8.5.

8.6.1 Permanent change to landform and topography

Landform and topography are valuable for their ability to retain and move water within a soil catchment system. Project activities have the potential to permanently change the landform and topography of each sub-catchment the Project alignment traverses, through increased erosion and landslip associated with specific landscapes. This is particularly the case for the 145 km of new rail corridor that will be established for the Project.

Changes to landform and topography will be an unavoidable result of the Project, due to the need to achieve a 1:100 (target) maximum operation gradient for the railway. Achieving this operating grade will require a combination of cut (maximum depth of 29.7 m) and fill (maximum height of 24.5 m) across the undulating landscape. These impacts will be limited within established rail corridor, where the existing landform is already conducive to achieving the operating grade for the Project.

These modifications to landform will be confined to the rail corridor, which is generally a minimum width of 40 m. There is one exception to this where the Project uses the existing rail corridor for the South Western Line parallel to Yelarbon–Kurumbul Road from Ch 7.5 km to Ch 10.0 km. The rail corridor may be as narrow as 25 m through that section to minimise impacts to Yelarbon–Kurumbul Road, adjoining land uses and their access arrangements. The rail corridor would extend out to a maximum of 230 m. Wider sections of corridor are required to accommodate earthworks, drainage structures, rail infrastructure, access tracks and fencing.

Road and rail components of the Project are expected to require a total of 12,525,037 m^3 of cut. Rail components are expected to require 12,250,669 m^3 of fill, while road components are expected to require 1,096,670 m^3 of fill. These volumes are based on the reference design and are subject to change through the detail design process.

The mass haul estimations for the Project are presented in Appendix Y: Spoil Management Strategy and locations of cut and fill are shown on the design drawings provided in Volume 3 of the draft EIS.

Slopes of 1 vertical (V):2 horizontal (H) and the application of topsoil and seeding have been assumed for the reference design. The appropriateness of this gradient and erosion protection will require confirmation through trials and further testing, as part of the detail design. Best practice guidelines recommend, for dispersive soils, to flatten cut batters to 1V:3H with soil amelioration and a minimum 200 mm of topsoil as preferred surface treatment. Alternatively, erosion control matting can be installed to retain the topsoil (200 mm for dispersive soils) on steeper (1V:2H) batters to promote vegetation growth.

Preliminary opportunities for batter slopes optimisation for respective material types likely to be encountered over the route are provided in Table 8.19.

TABLE 8.19 SUMMARY OF PROPOSED CUT GEOMETRY AND OPTIMISATION OPPORTUNITIES

Geology	Cutting profile model	Further opportunity for slope batter optimisation[1]
Sedimentary Rock (Walloon Coal Measures/ Koukandowie Formation)	Stiff sandy clay	1V:3H to 1V:2H slopes in dispersive soil may require amelioration and erosion control matting as surface protection. Slopes may be flattened to 1V:3H to minimise the risk of erosion. 1V:2H to 4V:1H with soil nail and shotcrete.
	Moderately weathered sandstone	High tensile steel mesh and bolts—subject to further to localised geotechnical stability considerations.
	Slightly weathered to fresh sandstone	High tensile steel mesh and bolts—subject to further to localised geotechnical stability considerations.
Alluvium (Qa/Qs)	Stiff sandy clay	1V:3H to 1V:2H slopes in dispersive soil may require amelioration and erosion control matting as surface protection. Slopes may be flattened to 1V:3H to minimise the risk of erosion. 1V:2H to 4V:1H with soil nail and shotcrete.
Main Range Volcanics (Basalt)	Residual soil to highly weathered basalt	1V:3H to 1V:2H slopes in dispersive soil may require amelioration and erosion control matting as surface protection. Slopes may be flattened to 1V:3H to minimise the risk of erosion. 1V:2H to 4V:1H with soil nail and shotcrete.
	Slightly weathered to fresh basalt	High tensile steel mesh and bolts—subject to further to localised geotechnical stability considerations.

Table Note:

1. Maximum batter slopes are those required to maintain geotechnical stability and assumes that the slope profile is maintained and appropriately protected from erosion.

Alterations to landform may cause secondary impacts to surface water, in floodplain areas, and groundwater, where deep cuts intersect the groundwater table. The potential impacts of landform on surface waters, hydrology and groundwater are discussed in Chapter 12: Surface Water and Hydrology and Chapter 13: Groundwater, respectively.

8.6.2 Loss of soil resources

The loss of soils, as a resource, from construction and operation of the Project may broadly arise due to:

- Direct, permanent loss of productive soils due to change in land use from agriculture to rail corridor or road reserve
- Reduced production value of soils that are subject to disturbance by construction activities
- Indirect loss of soils due to erosion that is either caused or exacerbated by Project activities.

8.6.2.1 Loss of productive soils within the permanent footprint

The Project will sterilise productive agricultural land located within the Project footprint. Land classified by the Audit (DAF, 2017a) located within the Project footprint is summarised in Table 8.20.

TABLE 8.20 AGRICULTURAL LAND IDENTIFIED BY THE AUDIT WITHIN THE PROJECT FOOTPRINT

	Permanent footprint		Temporary footprint	
Agricultural Land Audit Theme	Area (ha)	% of permanent footprint	Area (ha)	% of temporary footprint
Land Class A	1,913.24	71.9	421.69	76.6
Land Class B	93.94	3.5	19.01	3.5

The existing rail and road corridors are mapped as containing Class A land and Class B land but no agricultural activities are undertaken, and infrastructure is already established. The permanent footprint will use existing rail and road corridors for approximately 592.24 ha, within which no agricultural activities are undertaken despite it being mapped for these uses. On this basis, it is important to assess land proposed within the permanent footprint where located outside of the existing rail and road corridors.

Approximately 1,766.89 ha of land within the permanent footprint, outside of existing rail and road corridor, is classified as Class A agricultural land. A further 93.94 ha of land is classified as Class B agricultural land. This equates to a total of 1,860.83 ha of land within the permanent footprint (outside of existing rail and road corridors) as being classified as Class A or Class B agricultural land and which will be sterilised. These areas are primarily used for grazing and cropping, as well as some irrigated cropping and irrigated perennial horticulture uses.

Permanent impacts on agricultural land, and their productive soils, at a local government level have been assessed and details provided in Table 8.21.

TABLE 8.21 CLASS A AND CLASS B AGRICULTURAL LAND WITHIN THE PERMANENT FOOTPRINT (OUTSIDE OF EXISTING RAIL AND ROAD CORRIDORS)

	Goondiwindi LGA		Toowoomba LGA	
Land classification	Area of land (ha)	% permanent footprint	Area of land (ha)	% permanent footprint
Class A	389.19	18.9	1,377.69	66.8
Class B	5.88	0.3	88.07	4.3

To assist in identifying the significance of this impact on agricultural land within the region, Table 8.22 identifies the percentage of Class A and Class B agricultural land that the Project footprint traverses, relative to the total area of these land classes within each of the LGAs.

TABLE 8.22 PERCENTAGE OF CLASS A AND CLASS B LAND WITHIN LGA BOUNDARIES TRAVERSED BY THE PERMANENT FOOTPRINT (OUTSIDE OF EXISTING RAIL AND ROAD CORRIDORS)

Land classification	Area within permanent footprint (ha)	Total area within LGA (ha)	% of land traversed by Project footprint within LGA
Goondiwindi LGA			
Class A	389.19	1,332,102.63	Less than 0.1
Class B	5.88	1,290.47	0.5
Toowoomba LGA			
Class A	1,377.69	701,672.28	0.2
Class B	88.07	57,072.94	0.2

As identified in Table 8.22, the permanent footprint will traverse less than 0.1 per cent of the Class A agricultural land and 0.5 per cent of the Class B land mapped within the Goondiwindi LGA.

The permanent footprint will traverse 0.2 per cent of Class A agricultural land and Class B agricultural land within the Toowoomba LGA.

8.6.2.2 Reduced production value of soils

The Project footprint includes land required on a temporary basis to enable construction of the Project, including for construction laydown, stockpile and storage areas, temporary erosion control structures, concrete batching and movement of construction traffic. Purchasing or leasing arrangements for land within the temporary footprint will be investigated in consultation with relevant landowners.

The temporary use of land for construction activities has the potential to result in damaged topsoil structure as well as compacted subsoil, due to increased traffic (vehicles, plant and pedestrians) and heavy loads. This is a particular risk in areas of clayey and silty soils, such for the Vertosols shown on Figure 8.5, when wet (Queensland Government, 2013).

Soil compaction can lead to:

- Poor root growth, which reduces crop yield through poor water and nutrient uptake
- Difficulties with soil cultivation and seedbed preparation
- A decrease in water entering the soil either as rain or irrigation
- A decline in soil structural stability
- A decline in fertiliser efficiency—as the large blocks of compacted soil provide few surfaces to retain and release fertiliser for crop growth
- A soil that requires more horsepower (and fuel) to cultivate—planting implements are less effective in compacted soil and poor germination is the result
- In the first instance, structural impacts to soils will be minimised by restricting the construction footprint to what is required to enable safe and efficient construction of the Project. Opportunities will also be considered to schedule construction activities so that high traffic and heavy load works within areas of clayey and silty soils are restricted, as much as possible, during wet periods.
- Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner.

8.6.2.3 Loss of soils to erosion

Soils of particular concern for management and stability will be those that are dispersive, erosion-prone soils i.e. Sodosols and, to a lesser extent, chromosols; however, regardless of soil type, erosion risk will be increased where the following activities occur:

- Clearing of vegetative cover
- Changes in topography, drainage patterns and localised concentration of stormwater flows due to construction of both access tracks and the rail corridor
- Excavation or cuttings and stockpiling of material
- Construction during high rainfall events, particularly erosive rainfall events
- Constructing through areas with high to very high soil erodibility risks, as shown in Figure 8.6
- The types of erosion that have the potential to naturally occur within the impact assessment area due to a combination of landform, underlying geology and soil type are specified in Table 8.23, with Project related influences that may initiate or exacerbate each erosion type.

TABLE 8.23 POLICIES, STANDARDS AND GUIDELINES RELEVANT TO THIS ASSESSMENT EROSION TYPES, TYPICAL OCCURRENCE AND PROJECT RELATED INFLUENCES

Erosion type	Typical occurrence	Project related influences
Sheet	Occurs on hill slopes when thin layer of topsoil is removed over a hillside	Sheet erosion has potential to occur during construction where batters are temporarily exposed to rainfall and overland flow, prior to the application of a surface stabilization treatment. The greatest risk of occurrence will be where these cut and fill batters coincide with soil types that have a high or very high inherent erodibility (refer Figure 8.6).
Gully	Occurs when a strong concentrated runoff of water detaches and moves soil particles, creating gullies	Gully erosion has potential to occur at locations where culverts and bridges over waterways are provided, if appropriate scour protection is not incorporated into the detail design. The greatest risk of occurrence will be where these structures coincide with soil types that have a high or very high inherent erodibility (refer Figure 8.6).
Rill	Occurs on hill slopes when surface runoff forms small channels as it concentrates down a slope	Rill erosion has potential to occur during construction where batters are temporarily exposed to rainfall and overland flow, prior to the application of a surface stabilization treatment. The greatest risk of occurrence will be where these cut and fill batters coincide with soil types that have a high or very high inherent erodibility (refer Figure 8.6). Rill erosion may also occur in longitudinal drains within the Project footprint if a surface stabilization treatment is not provided.
Aeolian	Occurs predominantly in arid grazing lands of inland Queensland when winds blow over light textured soils	This type of erosion is unlikely to be initiated or exacerbated by construction or operation of the Project

Erosion type	Typical occurrence	Project related influences
Tunnel	Removal of subsoil when water travels through a soil crack or hole where a root decay has caused the soil to disperse.	Tunnel erosion may be exacerbated by the removal of vegetation to enable construction of the Project. The greatest risk of occurrence will be where vegetation removal to establish sections of new rail corridor (greenfield) coincides with Sodosols, due to their dispersive subsoil (refer Figure 8.5).

The loss of soils to erosion may result in the following impacts:

- Agricultural land:
  - Reduced ability of the soil to store water and nutrients
  - Exposure of subsoil, which often has poor physical and chemical properties relative to the lost topsoil
  - Higher rates of runoff, shedding water and nutrients otherwise used for crop growth
  - Loss of newly planted crops
  - Deposits of silt in low-lying areas.
- Waterways:
  - Siltation of watercourses and water storages
  - Reduction in water quality, due to increased turbidity and/or concentrations of nutrients, fertilisers, herbicides and pesticides that migrate into waterways with eroded soil.
- Structural integrity and stability issues for built infrastructure.

Based on the above, soil loss to erosion is most likely to occur in locations where the underlying soil type has a high or very high inherent erodibility (refer Figure 8.6) and a Project related influence is present (refer Table 8.23). The consequences of soil loss to erosion will be greatest where it occurs on, or adjacent to agricultural land (particularly cropping land), in proximity to waterways or in a manner that affects the integrity of existing infrastructure (Queensland Government, 2013).

8.6.3 Soil stability

Underlying soil conditions have the potential to cause structural integrity issues for elements of the Project, such as embankments, culverts and bridge foundations. Such issues may arise through processes that include differential settlement, particularly over soils with shrink-swell characteristics (Vertosols), and corrosion of sub-surface elements, where high levels of sodicity occur (Queensland Government, 2016a).

Significant ground improvement measures are likely to be required to mitigate areas where geotechnically unsuitable materials occur in the surface and subsurface materials underlying the Project alignment, including dark cracking clays (i.e. Vertosols) and dispersive soils (i.e. Sodosols). Which are encountered through a large portion of the Project footprint (refer Figure 8.5).

8.6.4 Soil conservation plans

A fundamental principle when planning for soil conservation is that land should not be used in ways that exceed its capability. If land were to be used beyond its capability, land degradation may occur and result in offsite impacts, such as polluting water resources and degrading aquatic habitats.

As discussed in Section 8.5.5, multiple soil conservation plans are traversed by the Project alignment. Each of the soil conservation plans that are traversed by the Project are listed in Table 8.24, with a summary of the soil conservation works that may be affected by the Project and other features or requirements of the soil conservation plans. This summary of potential impacts has been compiled through consultation with DNRME.

Some of the plans listed in Table 8.24 are more than 10 years old, and the soil conservation measures may not have been maintained during this period, or the agricultural land use may have changed. Consequently, the currency of all soil conservation plans within the Project footprint will need to be verified through detail design to confirm the likelihood of impacts.

Management measures and precautions will depend on the specific Project activity and the nature and extent of impact to the soil conservation works. They may include management activities such as establishing special groundcover vegetation, reforming the land surface or constructing contour banks.

TABLE 8.24 IMPACTS TO SOIL CONSERVATION PLANS THAT ARE TRAVERSED BY THE PROJECT FOOTPRINT

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
SC301112	Bringalily 10/G	2RP100482 27MH367	Minor impact	[E] existing contour bank	Contour banks discharge away from fill—potential to direct corridor drain to contour bank
SC300371	Bringalily 6/D	2RP197967	Significant impact	[W] existing contour banks & waterway	Approx. 15 ha contour-banked catchment discharges via farm waterway to Ch 104.10—potential culvert
SC305330	Bringalily 6/H	1RP197967	Some impact	[W & E] existing contour banks & waterway	Westside: Approx. 30 ha contour-banked catchment discharges via farm waterway to Ch 105.11 Eastside: Approx. 6 ha catchment via farm waterway to Ch 105.75—potential culvert
SC305097	Bringalily 6/C	2RP145435	Minor impact	[W] existing contour banks & waterway	Approx. 75 ha contour-banked catchment to culvert at Ch 107.22 Approx. 6 ha contour-banked catchment to culvert at Ch 107.81
SC305428	Bringalily 6/E	9MH365	Significant impact	[W & E] existing waterway & contour banks	Approx. 20 ha contour-banked catchment discharges via farm waterway to fill near Ch 108.30—potential culvert and potentially impacted Westside: Contour banks Ch 108.9 to Ch 108.70, discharge away from cutting/fill—potential to direct corridor drain to contour bank Approx. 25 ha contour-banked catchment to culvert at Ch 108.46. Eastside: Contour banks Ch 108.9 to Ch 108.50 discharge to cutting/fill—potential for waterway for 15 ha. Contour banks Ch 109.95 to Ch 109.50 discharge to fill—potential for waterway for 25 ha + 20 ha from Lot 6MH364 (Bringalily #1 Proj. Plan)
Bringalily 1 Project Plan	Bringalily 1/I	6MH364	Significant impact	[W] existing contour banks & waterway	Westside: Approx. 20 ha contour-banked catchment discharges to cutting from Ch 110.60 to Ch 110.00—potential waterway for corridor drain to discharge across boundary to Lot 9MH365 at proposed private crossing or alternatively, culvert at Ch 110.00 Approx. 12 ha contour-banked catchment from Ch 111.50 to Ch 111.3 discharges to cutting—potential for waterway/ corridor drain

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
	Bringalily 1/H	▸ 5SP194159 ▸ 1SP204014	Some impact	[E & W] existing contour banks & waterway	Eastside: Approx. 15 ha contour-banked catchment to Ch 113.00 Westside: Approx. 6 ha contour-banked catchment discharges to cutting Ch 114.50 to Ch 114.40—potential for waterway/ corridor drain Eastside: Contour banks, Ch 114.70 to Ch 114.85, discharge away from cutting—potential to direct corridor drain to contour banks Approx. 20 ha catchment to Ch 115.00
	Bringalily 1/F	▸ 64DY198 ▸ 127DY303	Minor impact	[E] existing contour banks	Approx. 4 ha contour banks discharge to cutting/fill, Ch 116.00 to Ch 115.70 across laydown area—potential for waterway
Back Ck 2 Project	Back Ck 2/G	▸ 111DY182	Some impact	[W & E] existing contour banks	Westside: Contour banks discharge away from cutting—potential to direct corridor drain to contour banks Eastside: Contour banks discharge to cutting—potential for waterway, Ch 116.45 to Ch 116.80 to on-farm waterway
	Back Ck 2/H	▸ 99DY182	Some impact	[W & E] existing contour banks	Westside: Contour banks discharge away from cutting—potential to direct corridor drain to contour banks Eastside: Contour banks discharge to cutting—potential for waterway, Ch 117.01 to Ch 117.40 to farm dam
		▸ 97DY181	Minor impact	[W] existing contour banks	Contour banks for approx. 12 ha above Ch 118.09 discharge to Ch 117.69
		▸ 1SP166689	Minor impact	[W] existing contour banks	Contour banks for approx. 15 ha above Ch 118.89, discharge to farm waterway at Ch 119.02 Contour banks for approx. 4 ha above Ch 119.29, discharge to farm waterway at Ch 119.37
	Back Ck 2/I	▸ 3SP166689	Minor impact	[W] existing contour banks	Contour banks for approx. 10 ha above Ch 119.86 and Ch 119.74, discharge to farm waterway and watercourse at Ch 119.37

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
Back Ck 4 Proj.	Back Ck 4/G, 4/F	▸ 5SP166689 ▸ 3SP126840	Significant impact	[W] existing contour banks	Approx. 75 ha contour-banked catchment to Ch 120.75. Approx. 120 ha contour-banked catchment to Ch 121.43—potential culvert or stabilised diversion waterway to Ch 120.75
	Back Ck 4/E	▸ 5SP126840	No impact	[W] existing contour banks	Clarify cross-drainage requirements for approx. 15 ha catchment under Commodore Peak Road diversion at Ch 123.77
SC305370	Back Ck 5/A	▸ 109DY241	Minor impact	[E] existing contour banks	Contour banks discharge to fill—potential for waterway Ch 124.15 to Ch 124.44
	Back Ck 5/D	▸ 1 & 2RP16094	Some impact	[W] existing contour banks	Contour banks for approx. 15 ha discharge to fill—potential for waterway Ch 124.90 to watercourse near Ch 125.47
		▸ 2DY1006	Significant impact	[E] existing contour banks & waterway	Approx. 24 ha contour-banked catchment discharges to on-farm waterway discharging to Ch 125.70—potential culvert or relocation to Ch 125.82 to waterway
No plan	-	▸ 3SP136970 ▸ 1SP136970	Some impact	[S] existing contour banks	Approx. 10 ha contour banks discharge to cutting/fill—potential for waterway from Ch 129.30 to culvert at Ch 128.88 Approx. 25 ha catchment discharges to farm waterway discharging to Ch 129.70—potential relocation to Ch 129.63
No plan	-	▸ 3RP47093	Some impact	[N] existing contour banks	Approx. 26 ha contour banks discharge to fill from Ch 130.50 to Ch 131.35—potential for waterway to discharge across Lovell Road
No plan	-	▸ 1RP124356	Some impact	[N] existing contour banks	Approx. 250 ha catchment to watercourse Ch 131.39. Approx. 15 ha contour banks discharge to fill—potential for waterway from Ch 132.80 to Ch 133.55 and culvert across Lindenmayer Road
No plan	-	▸ 3RP16081	Minor impact	No contour banks	Exclude Ch 135.28, potential for waterway to dam and extending to Ch 135.82
SC305382	Hermitage 5/E	▸ 1/RP53657 ▸ 1RP7474	No impact	[S] existing contour banks	Contour banks discharge away from fill— potential to direct corridor drain to contour banks
	Hermitage 5/A	▸ 3822A341940	No impact	[S] existing contour banks	Contour banks discharge to south, away from Desmonds Lane
SC300986	Rocky Ck 4/H	▸ 1RP7478 ▸ 3RP7482	Significant impact	[S] existing contour banks & waterway	Approx. 50 ha contour-banked catchment to farm dam near culvert at Ch 161.53—potential to direct corridor drain into contour banks away from fill

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
SC300533	Rocky Ck 4/E	1RP7482	Some impact	[S] existing contour banks & waterway	Approx. 95 ha contour-banked catchment to fill near Ch 162.90, potential for waterway to culvert at Ch 163.01
No plan	-	3829A342007	Some impact	[S] existing contour banks & waterway	Contour banks near Ch 163.40 discharge away from fill Approx. 40 ha catchment to waterway Ch 163.79
SC300475	Rocky Ck 4/D	3RP7480	Significant impact	[N] existing contour banks & waterway	Approx. 10 ha catchment to Murlaggan/Glen Devon Road connection near Ch 164.80 Total catchment to Ch 164.83, approx. 18 ha
SC305105	Rocky Ck 3/B	1RP7470	Some impact	[S] existing contour banks & waterway	Approx. 28 contoured catchment to Ch 167.32
		1AG4028 5RP7446	Minor impact	[S] existing contour banks & waterway	Contour banks, Lot 1AG4028, discharge away from fill—potential to direct corridor drain into contour banks
SC300292	Rocky Ck 3/C	2SP256680	No impact	No contour banks	No impact
		8RP208616	Minor impact	[N] existing contour banks	Contour banks discharge to fill, potential for waterway along corridor for approx. 4 ha
SC300766	Rocky Ck 3/F	2RP212352 7RP212353	Some impact	[N] existing contour banks	Contour banks discharge to fill, potential for waterway from Ch 169.90 to Ch 169.70 adjacent to maintenance access road
SC301011	Rocky 3/G	62SP146089	Minor impact	[N] existing contour bank	Contour bank discharging onto maintenance access road
		61SP146089	Some impact	[N] existing contour banks	Contour banks discharge to fill, potential for waterway from Ch 171.30 to Ch 170.94 and cross-drain under Oakey–Pittsworth Road
SC300227	Rocky Ck 1/D	3RP212365	No impact	[N] existing contour banks	Contour banks discharge away from cutting/fill—potential to direct corridor drain into contour banks
		6RP212368 12RP212366 15RP212368	No impact	No SC works	No impact
No plan	-	2437A341136	No impact	[N] existing contour banks	Contour banks discharge away from fill—potential to direct Project drainage and McEwan Road/Paint Mine Road connection onto contour banks

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
No plan	-	2RP205146	Significant impact	[N] existing contour banks	Approx. 25 ha contour banks discharge to cutting/fill, potential for waterway along cutting/ fill
SC300973	Perriers Gully 1/N	2RP142680	Minor impact	[N] existing contour banks & waterway	Contour banks discharge away from cutting/fill. Approx. 65 ha contour-banked catchment to Ch 175.61
SC305324	Perriers Gully 1/O	20 & 21RP913044 19 & 22SP125605	Significant impact	[N & S] existing contour banks/waterway	Contour banks northside discharge away from fill. Upper contour-banked 45 ha catchment diverted to culvert at Ch 176.36, total catchment 58 ha Existing diversion structure (waterway 05–06) at Ch 176.40 Contour banks southside discharge to cutting/fill—potential for waterway approx. Ch 176.15 to Ch 176.35
Draft Plan SC300951	Perriers Gully 1/M	1789A34919	Significant impact	[N] existing contour banks	Approx. 28 ha contour-banked catchment discharge to cutting at about Ch 177.70—potential for waterway from Ch 177.70 to culvert at Ch 177.35
	Umbiram 1/P	2718A341307	No impact	No soil conservation works	No impact
SC300180	Umbiram 1/B	5RP841180 6RP203202 3 & 4RP203202	Some impact	[W & E] existing contour banks & waterway	Contour banks discharge away from cutting/fill Westside: Approx. 70 ha contour-banked catchment, northside, intercepts maintenance access road approx. Ch 179.60. Eastside: Approx. 28 ha contour-banked catchment discharges to corridor drain at Ch 179.40—potential for waterway from Ch 179.40 to Ch 179.90
SC301016	Umbiram 1/S	2RP110779	Some impact	[W] existing contour banks & waterway	Approx. 98 ha contour-banked catchment to culvert at Ch 179.93 Proposed soil conservation works not implemented for approx. 35 ha catchment to culvert at Ch 180.50

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
SC300925	Umbiram 1/H	▸ 2RP50027 ▸ 1495A34822	Some impact	[N] existing contour banks & waterway	Approx. 8 ha contour discharge to corridor drain about Ch 181.40 Northside: Waterway (H13-H14) discharges approx. 6 ha catchment to culvert at Ch 128.28 Southside: contour banks discharge to fill—require waterway from Ch 182.60 to Ch 182.25
SC301108	Umbiram 1/C	▸ 2RP215348	No impact	[N]	Proposed soil conservation works to discharge away from fill and Bushy Lane/Biddeston–Southbrook Connection not implemented
No plan	-	▸ 3 & 4RP215320	Minor impact	[N] existing contour banks	Contour banks discharge away from cutting—potential to direct corridor drain into contour banks
No plan	-	▸ 1RP215319	Minor impact	[N] existing contour banks	Approx. 120 ha contour-banked catchment to Ch 184.87. Contour banks at Ch 185.20–Ch 185.00 discharge away from cutting
SC301087	Umbiram 2/O	▸ 2RP215383	Minor impact	[N] existing contour banks	Contour banks at Ch 185.70–Ch 185.85 discharge away from fill—potential to direct corridor drain into contour banks
SC301088	Umbiram 2/N	▸ 2RP215357 ▸ 2RP213922—not part of plan	Some impact	[N] existing contour banks	Contour banks discharge to waterway Purcell Road. Approx. 40 ha contour-banked catchment discharges across Purcell Road to about Ch 187.09
SC305110	Lower Westbrook Ck 6/K	▸ 2RP172596	Some impact	[W] existing contour banks	Contour banks discharge to cutting—potential for waterway from about Ch 187.60 to about Ch 188.00—potential culvert for 8 ha contour-banked catchment; or alternatively discharge across Athol School Road to near Ch 188.72
	Lower Westbrook Ck 6/A	▸ 5 & 6SP158473	Some impact	[W & E] existing contour banks	Westside: contour banks discharge away from cutting/fill—potential to direct corridor drain into contour banks. Eastside: contour banks discharge to cutting/fill & across private crossing—potential for waterway from Ch 189.10 to about Ch 188.75, or alternatively, resurvey contour banks to discharge away from cutting/fill
Draft Plan SC305441	Lower Westbrook Ck 6/I	▸ *1RP194766*	No impact	[E] existing contour banks	Contour banks discharge away from cutting
No plan	-	▸ 2RP155499	Some impact	[E] existing contour banks	Contour banks discharge to cutting—potential waterway for 10 ha from Ch 189.80 to Ch 190.10

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
SC305009	Lower Westbrook Ck 5/B	▸ 863A34637	Minor impact	[E & W] existing contour banks	Contour banks discharge to cutting/fill—potential for waterway to continue from Ch 190.10 to Ch 190.80 for extra 10 ha Westside: banks near Ch 191.40 to Ch 191.60 discharge away
SC300589	Lower Westbrook Ck 4/C	▸ 15RP36572	Some impact	[W] existing contour banks	Contour banks discharge to cutting—potential for waterway for 30 ha contour-banked catchment (Ch 192.55 - Ch 193.17)
	Lower Westbrook Ck 4/L	▸ 16RP36572	Minor impact	[W] existing waterway	Require waterway to continue from Ch 193.17 to near Ch 193.38
SC305398	Lower Westbrook Ck 4/B	▸ 17AG1935	Significant impact	[W] existing contour banks & waterway	Contour banks discharge to a waterway discharging to cutting at Ch 193.55—potential culvert for 24 ha contour-banked catchment, or alternatively negotiate with owner Lot 16RP36572 for waterway to Ch 193.41
	Lower Westbrook Ck 4/A	▸ 18 & 19RP36572	Minor impact	[W] existing contour banks	Contour banks discharge away from—potential for direct corridor drain into contour banks
SC300878	Lower Westbrook Ck 4/T	▸ 20RP36572 ▸ 2RP149961	Significant impact	[W] existing contour banks & waterway	Approx. 16 ha contour-banked catchment discharges to fill at Ch 194.80 to Ch 195.19, approx. 12 ha contour-banked catchment discharges to fill from Ch 195.19 to culvert at Ch 195.64. Laydown area at Toowoomba–Cecil Plains Road Bridge (near Ch 196.10) is across Four Mile Gully catchment (approx. 1,200 ha)
SC301089	Lower Westbrook Ck 3/G	▸ 2AG3200 ▸ 5RP47487 ▸ 2RP48192	Some impact	[W] existing contour banks & waterway	Approx. 8 ha discharges via waterway to fill at about Ch 196.31—potential corridor drain a as waterway to Ch 196.20 (end of embankment) Contour banks from Ch 196.70 to Ch 197.00 discharge away from fill and access road
SC305633	Lower Westbrook Ck 10/H	▸ 1RP48192 ▸ 2RP48191 ▸ 1RP155674	No impact	No soil conservation works	Floodplain
SC300536	Lower Westbrook Ck 11/H	▸ 14RP24607	Some impact	[N] existing contour banks & waterway	Approx. 6 ha discharges to fill corridor drain, Ch 199.22 to Ch 198.75 (end of embankment)—potential to require co-ordination with Brimblecombe Road drainage Approx. 12 ha catchment discharges to fill at Ch 199.50—potential relocation to Ch 199.55 to Ch 199.50

Soil conservation plan number	Soil conservation farm code	Properties intersecting alignment	Potential impact on soil conservation works	Affected soil conservation works[1]	Interaction with reference design and future design opportunities to avoid/minimise impacts
Draft plan, SC300772	Lower Westbrook Ck 10/D	▸ 15RP24607	Some impact	[N] existing contour banks & waterway	Approx. 12 ha contour-banked catchment discharges to waterway at Ch 199.96
SC300923	Lower Westbrook 10/F Draft Plan Gowrie 2/S	▸ 4 & 5SP215309 ▸ 3RP124408 ▸ 3AG3669	Significant impact	[W & E] existing contour banks & waterway	Westside: Approx. 40 ha contour-banked catchment discharges to waterway near culvert at Ch 201.52 Eastside: Approx. 8 ha contour-banked catchment discharges to fill—require waterway from Ch 201.80 to farm waterway near Ch 201.53 Westside: Approx. 35 ha contour-banked catchment discharges to cutting at Ch 202.62—potential for culvert at Ch 202.62
SC305411	Gowrie 2/B	▸ 11SP285307	Significant impact	[E & W] existing contour banks & waterway	Eastside: Approx. 5 ha catchment discharges to Ch 203.17. Balance from Ch 203.90 to sedimentation pond (Ch 204.45) discharges to farm waterway along Chamberlain Road—potential to direct corridor drain into contour banks Westside: require waterway along fill for 6 ha catchment from Ch 204.10 to farm waterway near Ch 204.40
SC300904 & SC301201	Gowrie 2/K upgraded with subdivision to 2/W, 2/X	▸ 43 & 44AG109 ▸ 2RP55460	Significant impact	[S] existing contour banks & waterway	Approx. 275 ha contour-banked catchment directed by farm waterways to culvert at Ch 207.87—potential to upgraded cross-drainage
SC300778	Gowrie 9/A	▸ 29 & 33SP294200	Minor impact	[S] existing waterway	Approx. 260 ha catchment discharges to watercourse at Ch 206.94

Table notes:

1. Lettering in brackets denotes orientation of soil conservation works relative to the Project alignment. N = north, E = east, S = south, W = west.
   - Impacted land parcels as of January 2020
   - Actual impact will depend on final width of rail corridor, including formation batters and cuttings.
   - Assessment of existing works based on Queensland Globe imagery 2015–2017

8.6.5 Degradation of soil resources through invasive flora

During construction and operation of the Project, introduction of new weeds or exacerbation of existing weed infestations may present a potential risk to land resources, through alteration of the region's biogeomorphology, which is the relationship between biology and geomorphic processes and landforms (NSW Scientific Committee, 2019).

Weed material may be introduced to, or spread throughout, the Project footprint on vehicles, plant, work personnel (e.g. boots) or through material importation and movement. Ove the long term, weeds can cause soil erosion, particularly if native flora growing on cracking clays are replaced by an invasive flora species with a weaker root system, no longer binding the soil.

Some invasive flora species have the capacity to intrinsically alter soil properties to benefit their own continued competitive growth, potentially through competition for resources (especially in newly disturbed landscapes), resulting in flora dieback and reduction of groundcover (NSW Scientific Committee, 2019; Fei, et al., 2014; Weidenhamer & Callaway, 2010).

Further detail on the potential impacts associated with weeds is provided in Chapter 10: Flora and Fauna.

8.6.6 Acid sulfate soils and acid rock

The desktop assessment and field investigations concluded a low probability of encountering ASS (including inland ASS) and/or acid rock within the impact assessment area, except for within permanent waterways (aquatic ecosystems). Permanent waterways that are intersected by the Project alignment are Macintyre River, Macintyre Brook, Condamine River and Oxley Creek. Therefore, if present, ASS would only be encountered during works that involve sub-surface disturbance within, or immediately adjacent to, these waterways. Additional geotechnical investigation undertaken during the detail design phase will target these locations in order to provide further details on the likelihood of occurrence of inland ASS in proximity to these waterways.

ASS have the potential to degrade ecosystems, as metals, such as iron and aluminium, are mobilised under acidic conditions (Hicks et al., 1999). The mobilised metals, combined with acidic conditions, can result in degraded water quality, toxicity for fish and impacts to plant growth.

Project activities may expose potential ASS to oxygen through soil disturbance, which, in turn, may result in the creation of sulfuric acid. In addition to the above-mentioned biological impacts, acidic conditions have the potential to corrode infrastructure built from concrete, steel and other materials (EPHC & NRMMC, 2011). Potential ASS may be located within the impact assessment area, however under general conditions, reside below the water table and present a risk during excavation of cuts.

Acid rock occurs when sulphide minerals are exposed to air and water. This process is accelerated through excavation activities that increase rock exposure to air, water, and microorganisms. Acid rock has potential to produce neutral-to-acidic drainage, which may occur with dissolved heavy metals and significant sulfate levels. Based on the geological conditions within the impact assessment area, the likelihood of encountering acid rock is considered to be low.

Visual examination of surface outcrops along the Project alignment for sulphide minerals or remnant products, indicative of sulphide mineralisation, will occur prior to the commencement of construction.

In the unlikely event ASS or acid rock is encountered during construction of the Project, an unexpected finds protocol/procedure within the Soil Management Sub-plan will be implemented (refer Section 8.7.2).

8.6.7 Salinity hazard

The salinity hazard assessment in Section 8.5.3.6, undertaken in accordance with Part B of the *Salinity Management Handbook* (DERM, 2011), concluded that sub-catchments within the impact assessment have either a moderate or high overall salinity hazard rating, when calculated from the mean hazard rating from the five PEA types that may occur (refer Figure 8.15). In addition to existing salinity, Project activities have the potential to cause secondary salinisation, through processes such as the removal of vegetation, alteration of waterways, application of water (e.g. for material compaction) and general land use changes (DERM, 2011). Leakage from longitudinal drainage channels, if ponding were to occur, may also contribute to rising water tables and the vertical movement of salts in the soil profile.

Salinisation, either primary or secondary, can cause:

- Water table salting
- Irrigation water salting
- Erosion scalding
- Stress or die-back of native vegetation
- Ecological health of waterways
- Reduced agricultural yield in affected areas
- Corrosion and reduction of lifespan for infrastructure, such as building foundations, road pavements, pipes and other underground services.

Detailed investigations of areas of proposed disturbance within the finalised Project footprint will be required during the detail design phase to ensure that the physical and chemical characteristics of soils and subsurface materials is understood.

The potential for existing salinity to impact on the structural lifespan of Project elements will need further assessment through the detail design phase, once the location or works, depth of disturbance and structure type are confirmed. This understanding, coupled with soil data obtained through detailed investigations, will enable appropriate selection of materials and protection for Project elements that may otherwise be subject to accelerated degradation in saline conditions.

The potential for Project activities to cause secondary salinisation can, for the most part, be adequately managed through the implementation of the following principles:

- Minimising the extent of clearing required to enable safe and efficient construction, operation and maintenance of the Project
- Ensuring that temporary earthworks and permanent landform for the Project are designed to avoid unwanted ponding of water. This objective will be achieved through surface levelling and use of cross-drainage and longitudinal drains within the rail corridor.
- Where retention of water is required, ensuring that the retention structure is lined
- Where possible, avoiding through design the need for interactions with, or alterations to waterways
- Efficient water application so as to avoid prolonged oversaturation of soils within and adjoining the Project footprint
- Ensuring that water used for construction purposes is not sodic (a high level of sodium salts compared to calcium and magnesium salts).

Based on the above, the likelihood of secondary salinisation occurring as a result of Project activities is considered to be low, if managed and monitored in an appropriate manner.

Similarly, the risk of existing, primary salinity to structural elements of the Project is considered to be low, if appropriate design measures, informed by detailed investigations, are incorporated.

8.6.8 Disturbance of existing contaminated land

Construction activities for the Project have the potential to disturb existing contaminated land. The disturbance of contaminated soil or groundwater during Project activities has the potential to contaminate previously unaffected soil or groundwater, degrade ecosystem health and affect human health through dermal contact or ingestion of contaminants.

Potential sources of land contamination within the impact assessment area have been identified and summarised in Table 8.18. As discussed in Section 8.6.6, for potential impacts from contaminated land disturbance to occur, there must be a linkage between a source of contamination, an exposure pathway and environmental values (receptor) that may be affected by this exposure. Should one or more of these components be unavailable, or no complete linkage exist between the three, the risk of exposure to an environmental value is likely to be either minimal or non-existent.

The source–pathway–receptor linkage for each of the potential sources of contamination within the impact assessment area is presented in Table 8.25.

TABLE 8.25 POTENTIAL EXISTING CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Located within the Project footprint	Contaminants	Potential pathway	Potential receptor
Agricultural land	Yes	Pesticides and herbicides (agricultural storage and use)	▶ Direct contact ▶ Dispersion of soil and dust from wind and water ▶ Surface water runoff	Human health: ▶ Ingestion, inhalation, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▶ Terrestrial—direct contact and consumption (including bioaccumulation) ▶ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
		Hydrocarbons (fuel and oil storage and use) (agricultural storage and use)	▶ Direct contact ▶ Dispersion of soil and dust from wind and water ▶ Surface water runoff	Human health: ▶ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▶ Potential exposure to surrounding cropping lands. ▶ Aquatic ecosystems.
		Asbestos and lead paint (agricultural buildings/structures)	▶ Direct contact ▶ Ingestion ▶ Inhalation ▶ Dispersion of soil and dust from wind and water ▶ Surface water runoff	Human health: ▶ Current and future site users, construction workers, site visitors, surrounding land users.
		Livestock dips or spray races arsenic, DDT, DDE, DDD (agricultural storage and use)	▶ Direct contact ▶ Ingestion ▶ Dispersion of soil and dust from wind and water ▶ Surface water runoff	Human health: ▶ Ingestion, inhalation, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▶ Terrestrial—direct contact and consumption (including bioaccumulation) ▶ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

Potential source	Located within the Project footprint	Contaminants	Potential pathway	Potential receptor
Housing/sheds/other	Yes	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos (agricultural and residential storage and use, commercial enterprise)	- Direct contact - Ingestion - Inhalation - Dispersion of soil and dust from wind and water - Surface water runoff	Human health: - Landowners, current and future site users, construction workers, site visitors, surrounding land users Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Mines e.g. Lot 8 SP126840	No	Acid mine drainage, metals/metalloids (commercial enterprise)	- Direct contact - Ingestion - Inhalation - Dispersion of soil and dust from wind and water - Surface water runoff	Human health: - Landowners, current and future site users, construction workers, site visitors, surrounding land users Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Existing rail corridor	Yes	Metals/metalloids, asbestos, hydrocarbons, pesticides/herbicides (railway land use)	- Direct contact - Dispersion of soil and dust from wind and water - Surface water runoff	Human health: - Ingestion, inhalation, dermal contact - Current and future site users, construction workers, site visitors, surrounding land users. Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Landfill (municipal) e.g. Lot 1 RP835800	No	Hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides (local government or commercial enterprise)	- Direct contact - Dispersion of soil and dust from wind and water - Surface water runoff - Leaching.	Human health: - Current and future site users, site workers, site visitors, surrounding land users. Ecological: - Terrestrial—direct contact and consumption (including bioaccumulation) - Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Roads	Yes	Metals, hydrocarbons, pesticides/herbicides (public roads)	- Direct contact - Dispersion of soil and dust from wind and water - Surface water runoff	Human health: - Ingestion, inhalation, dermal contact - Current and future site users, construction workers, site visitors, surrounding land users. Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

The Project footprint and construction methodology will be subject to confirmation through the detail design phase. Following confirmation of these aspects, a further assessment will be required to identify potential contaminated land that is within the Project footprint and will be disturbed by construction activities. Potentially contaminated sites, including existing rail corridor that will be disturbed, will require specific management controls to be developed by a suitably qualified person to outline the process to identify, document and manage contamination in these locations. In some instances, further environmental site investigation may be warranted, in accordance with ASC NEPM.

Depending on the type and levels of contamination encountered, contaminated material may be reused for construction activities within the rail corridor, such as through encapsulation within zoned embankment. In some instances, contaminated material may require treatment prior to being suitable for reuse. The onsite management and remediation of contaminated soil would be further informed by a review of sampling results, exposure risks, onsite treatment or encapsulation opportunities and requirements for ongoing management.

A disposal permit from DES would also be required for the transportation of contaminated soil by a licensed service provider to an appropriately licensed facility.

The disposal and management of spoil is further detailed in Chapter 20: Waste Management, as well as Appendix Y: Spoil Management Strategy.

8.6.9 Creation of contaminated land

Land contamination may be newly created by activities undertaken during the construction, operation and maintenance of the Project. Broadly, the potentially contaminating activities through these Project phases include:

- Movement of contaminated materials (soil or water) from a source of contamination to an uncontaminated location, for example:
  - The stockpiling of contaminated material on land that is not contaminated
  - The discharge or dispersion of contaminated water onto land that is not contaminated.
- Accidental leaks or spills leading to migration of contaminants through surface water, soil and/or groundwater. Such incidents may arise due to inappropriate storage of dangerous goods and hazardous materials or poor handling of these materials.

The storage and handling of hazardous chemicals at laydown areas introduces the potential for impacts associated with material properties such as flammability, corrosiveness and toxicity. Significant releases of hazardous chemicals can impact property, people and environmental receptors. Generally, low volumes of hazardous chemicals would be stored at construction work fronts and laydown areas near to points of use. Laydown areas are situated next to the rail corridor to facilitate direct access to/from the laydown to the rail corridor. The quantities stored will be equivalent to the demand for construction activities within that area of the rail corridor. Details of the dangerous goods and hazardous materials that may be stored and used on site during construction, operation and maintenance are specified in Chapter 5: Project Description and Chapter 19: Hazard and Waste.

During the construction phase, the following facilities are expected to be provided for storage and distribution of construction chemicals:

- Laydown areas will be located approximately every 5 km along the Project alignment, in addition to bridge and turnout locations onto the Queensland Rail (QR) network. Small quantities of lubricants and oil (e.g. drum and intermediate bulk container package stores) will be stored at these locations.
- Diesel fuel depots will be located at approximately 20 km intervals along the Project alignment, which will provide for 40,000 litres bulk storage of diesel.

Each laydown has been positioned to avoid or minimise potential impacts to environmental constraints and social receptors. The locations of the laydown areas are provided in Chapter 5: Project Description and have been chosen to avoid areas that are within the 1% AEP floodplains where possible. However, by virtue of the requirement of laydown areas for constructing bridges, some laydown areas must be located within floodplains and near water sources. In such instances, the following precautions will be taken:

- The potential site will be surveyed prior to site establishment, to understand the exact extent of potential flooding impact to facilities and storage areas
- Earthworks and temporary drainage for each laydown site will be designed to minimise flooding impacts
- Critical equipment will be placed on earthworks and plinths that raise it above the predicted 1% AEP water level.

Operational usage of chemicals is expected to be on an 'as required' basis and will typically involve limited quantities during specific maintenance activities (e.g. application of pesticides in accordance with ARTC rail corridor maintenance protocols).

Controls for the transport, storage, handling, use and disposal of dangerous goods and hazardous materials during construction and operation are specified in Section 8.7.2.

Table 8.26 provides details on the potential source, pathway and receptor linkages resulting from activities during the construction and operation phases of the Project.

TABLE 8.26 POTENTIAL CREATION OF CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Contaminants	Potential pathway	Potential receptor
Construction			
Stockpiled contaminated material	Metals/metalloids, asbestos, hydrocarbons, pesticides/herbicides (railway land use)	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Dispersal/ discharge of contaminated water	Metals, hydrocarbons, pesticides/herbicides (public roads)	▸ Direct contact ▸ Dispersion of water ▸ Surface water runoff	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Hydrocarbon leaks and/or spills	Hydrocarbons	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.

Potential source	Contaminants	Potential pathway	Potential receptor
Leaks and or spills from waste storage areas/ facilities (including storage tanks, sewage)	Metals/metalloids, pesticides/herbicides other chemicals	▶ Direct contact	Human health: ▶ Ingestion, inhalation, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▶ Terrestrial—direct contact and consumption ▶ Aquatic ecosystems—direct contact and consumption.
		▶ Overland flow/runoff to surface water bodies ▶ Migration to groundwater	Human health: ▶ Ingestion, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▶ Terrestrial—direct contact and consumption ▶ Aquatic ecosystems—direct contact and consumption.
Operation			
Hydrocarbon leaks and/or spills	Metals and hydrocarbons	▶ Direct contact	Human health: ▶ Ingestion, inhalation, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▶ Terrestrial—direct contact and consumption ▶ Aquatic ecosystems—direct contact and consumption.
		▶ Overland flow/runoff to surface water bodies ▶ Migration to groundwater	Human health: ▶ Ingestion, dermal contact ▶ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▶ Terrestrial—direct contact and consumption ▶ Aquatic ecosystems—direct contact and consumption.

8.7 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 8.7.1), as well as those measures that are proposed to be adopted for future phases of Project delivery (refer Section 8.7.2).

8.7.1 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 the Project, are summarised in Table 8.27.

TABLE 8.27 INITIAL MITIGATION MEASURES OF RELEVANCE TO LAND RESOURCES

Aspect	Initial mitigation measures

Land and soil	▸ The Project has been aligned to be co-located with existing rail and road infrastructure, where possible, minimising the need to develop land that has not previously been subject to disturbance for transport infrastructure purposes
	▸ The quantity of spoil to be generated by the Project has been reduced through development of the reference design to achieve as close to a net balance in earthworks as is practicable. For the most part, this has been achieved through:
	  ▸ Aligning the Project to avoid, where possible, steep terrain and topographical constraints to minimise earthworks and provide for more efficient track geometry and grade
	  ▸ Considering the shape and size of batters to encourage cut-and-fill balancing
	  ▸ Optimising the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements.
	▸ A draft spoil management strategy (refer Appendix Y: Spoil Management Strategy) has been developed to guide the decision-making process for the management of spoil material generated by the Project. The purpose of the spoil management strategy is to provide overarching principles to guide the storage, treatment, reuse or disposal of material (including contaminated material) generated during construction of the Project.
	▸ Geotechnical investigations have been undertaken within the Project footprint to determine geotechnical conditions. Investigations have been targeted to specific locations, such as:
	  ▸ Locations of bridge abutments
	  ▸ Locations of significant cuts
	  ▸ Locations of significant fill.
	▸ Geotechnical and soils data has been used to derive design criteria for structures, rail formation and scour protection. This has enabled the Project to be designed to cater for field-verified geotechnical and soil conditions.
	▸ Design and ratings of earthworks in support of culverts, viaducts, and bridges are in accordance with *AS 5100 Bridge Design* (Standards Australia, 2017b) and *AS 7363 Railway Structures* (Standards Australia, 2013b) and other applicable Australian Standards
	▸ The Project has been aligned to avoid the current and future operational footprint of the Commodore Mine. This has been achieved through consultation with the mine owner and operator, Intergen. This separation distance is intended to avoid the sterilisation of coal resource and to ensure that activities undertaken within the mine will not influence the construction or operation of the Project.
	▸ The Project has been aligned to avoid steep slopes, where possible. Where slopes could not be avoided, the railway will be positioned in cut in order to negate the natural steep topography and achieve an operational gradient that is compatible with the maximum compensated operational gradient of 1:80 for general alignment (1:50 for medium speed alignment standards or mountainous terrain).

Aspect	Initial mitigation measures

Erosion and sediment control	▸ Cross-drainage structures have been incorporated into the reference design where the Project intercepts existing drainage lines and watercourses. The type of cross-drainage structure in the design depends on various factors, such as the natural topography, rail formation levels, design flow and soil type.
	▸ Bridges are proposed at all major waterway crossings to avoid disturbance to the existing flow regime. In some instances, bridges are provided in locations that may have multiple drainage features passing under the rail corridor, such as across the Condamine River floodplain.
	▸ 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 *Austroads 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 were predicted to fit within the rail corridor.
	▸ The reference design includes 17 sediment basins within the Project footprint. The number of sediment basins required for the final earthworks design will be confirmed during detail design. All sediment basins are passive, which allows surface runoff from a catchment to flow into the sediment basin without the need for pumping.

8.7.2 Proposed mitigation measures

In order to manage and mitigate Project risks, 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 8.28 identifies the relevant Project phase, the aspect to be managed and the proposed mitigation measure. The mitigation measures presented in Table 8.28 have then been factored into the assessment of residual risk, as documented in Table 8.29.

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

TABLE 8.28 LAND RESOURCE MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures
Detail design	Additional investigations	▸ Additional geotechnical investigations will be undertaken to inform the design of earthworks and foundations for structures, suitability of borrow and quarry material, and construction planning for the Project. Additional geotechnical investigations will specifically target locations where: ▸ The design includes: - Cuts - Embankments - Bridge piers and abutments. ▸ Potential/actual acid sulphate soils (ASS), specifically material within Macintyre River, Macintyre Brook, Condamine River and Oxley Creek, may be disturbed by construction. ▸ Detailed soil investigations will be undertaken at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale. Detailed soil investigations will enable identification of potential/actual problematic soils, including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants. Examples of soils that will require specific design consideration include: ▸ The high naturally occurring sodicity of soils in the Yelarbon area (Sodosols) ▸ Cracking clays of the Condamine River floodplain (Vertosols). ▸ The methodology for the detailed soil investigation will be developed in consultation with DNRME and will be in accordance with the *Guidelines for surveying soil and land resources* (McKenzie et al., 2008), the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015) ▸ Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner ▸ Additional soil data will be incorporated into the Final EIS and used to ensure that the design of structures, embankments, erosion control measures (temporary and permanent), soil treatment and management and site rehabilitation planning are reflective of site-specific soil conditions.
	Landform and material use	▸ Optimise the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements ▸ Review cut-and-fill balance for the Project based on the detail design, to minimise the external sourcing of fill. Based on reviewed cut--and-fill balance, determine the number of borrow pits and volumes from each that is required to supply the confirmed material demand for the Project. ▸ Undertake an initial desktop assessment of the viability and feasibility of accessing material from the preferred borrow pit locations (determined after review) to meet location-specific material demands. Undertake further site assessment, including geotechnical testing, at potentially viable borrow pit locations to determine material usability, volumes, environmental and social impacts and potential secondary approval triggers. ▸ Review and update the draft spoil management strategy (refer Appendix Y: Spoil Management Strategy) for the Project to reflect anticipated cut-and-fill quantities at the end of the detail design process.

Delivery phase	Aspect	Proposed mitigation measures
Detail design (continued)	Landform and material use (continued)	▸ Explore, through detail design, the viability of opportunities for: ▸ Re-use of local sources of aggregate and treatment of dispersive and reactive materials to improve mass haul ▸ Re-use of material excavated below the rail embankment for less critical parts of infrastructure ▸ Re-use of excavated material as a stabilised structural fill ▸ Re-use of ballast as high-quality general fill or structural fill to minimise the import of rock amour. ▸ Cut batter angles will need to be appraised during detail design, based on material strengths and other geotechnical properties. Stability analysis will be required to assess the factor of safety of these cut slopes. Slopes of 1V:2H and the application of topsoil and seeding have been assumed for the reference design. The appropriateness of this gradient and erosion protection will require confirmation through trials and further testing, as part of the detail design. ▸ Opportunities for slope batter optimisation, as identified in Section 8.6.1, will be assessed through the detail design. ▸ Stability of creek/waterway banks will be assessed, and treatment measures be designed to control erosion and sediment movement.
	Soil management	▸ Develop a Soil Management Sub-plan as a component of the CEMP that includes the following procedures and protocols relevant to potential impacts on land resources: ▸ Soil/land conservation objectives for the Project to minimise impacts on soil conservation plans and viable productive land, and include: - Appropriate design measures to ensure velocity of flow remains low enough to avoid erosion of contour banks and waterways - Consideration of land slope, land use, soil type, rainfall, trafficability and farm type when designing new contour banks - Stabilisation of banks with good vegetation or artificial lining. ▸ Management of problem soils, such as: - ASS - Erosive or dispersive soils, such as Sodosols, that 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 (refer Figure 8.5) - Cracking/expansive clays (Vertosols) that are expected to be encountered between Koorongarra and Millmerran and from Yandilla to Gowrie (refer Figure 8.5) - Saline soils, particularly in high salinity hazard areas such as between Kurumbul and Yelarbon. ▸ Minimising exposure of dispersive subsoils through methods such as staging construction disturbance, topsoil replacement or rehabilitation immediately following construction ▸ Appropriate design considerations will be implemented where cracking/expansive clays feature, as well as minimising shrink swell characteristics through methods such as keeping constant soil moisture ▸ Specification of the type and location of erosion and sediment controls (see below) ▸ 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	Proposed mitigation measures
Detail design (continued)	Acid sulfate soils	▸ If ASS are identified through further geotechnical investigations and will be disturbed by construction activities, an ASS Management Plan will be developed, if required, in accordance with the *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines v4.0* (DSITI, 2014a) and the *State Planning Policy*.
	Soil conservation plans	▸ Confirm the currency and accuracy of soil conservation plans that may be impacted by the Project. Confirmation will involve discussion with DNRME in addition to the holders of each soil conservation plan. ▸ If a soil conservation plan is found to be current and materially affected by the Project, ARTC will consider options for amending or modifying that plan in accordance with the *Soil Conservation Act 1986* (Qld). If required, this would be progressed in consultation with DNRME and the holder of the soil conservation plan.

	Erosion and sediment control	▸ Where possible, further reduce the Project footprint to that required to safely and efficiently construct, operate and maintain the Project. Opportunities to do so are primarily located along greenfield sections of the Project alignment. Bulk earthworks for both excavation and filling activities will be carried out in a controlled and programmed manner.
		▸ The Soil Management Sub-plan will include erosion and sediment controls as a component of the CEMP. The erosion and sediment control measures will be developed by a certified practitioner in erosion and sediment control, in accordance with the *Best Practice Erosion and Sediment Control* (IECA, 2008) and with reference to Soil Conservation Guidelines for Queensland (DSITI, 2015) and will be implemented during construction of the Project. The Soil Management Sub-plan will include:
		  ▸ Locations for specific temporary/permanent erosion and sediment control measures, such as:
		    - Sediment retention basins
		    - Scour protection (included in the reference design)
		    - Sediment fencing
		    - 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.
		▸ Where practical, plan to use existing tracks. Design new access tracks (permanent and temporary) with the aim of minimising disturbance of substrate and vegetation.

	Secondary salinity	▸ Ensure that temporary earthworks and permanent landform for the Project are designed to avoid unwanted ponding of water. This objective will be achieved through surface levelling and use of cross-drainage and longitudinal drains within the rail corridor. ▸ Design water retention structures, such as sediment basins, to prevent downward leakage of water, with the use of lining or similar. ▸ Avoid, where possible, the need for diversions or alterations to waterways. ▸ The ultimate water sourcing strategy for the Project will be documented in a Construction Water Plan. The quality of water from available sources will be considered in the development of the Plan.

Delivery phase	Aspect	Proposed mitigation measures
Detail design (continued)	Rehabilitation	▸ 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. Outside of the rail corridor, property-specific and township-specific rehabilitation and landscaping requirements may apply. Within the rail corridor, maintaining operational safety and rail formation stability will be the driving factors. ▸ 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). ▸ Native flora species endemic to the Darling Downs and Toowoomba regions or other suitable species appropriate to the landscape context and nursery/seed stock sources ▸ Consideration for maintenance or performance issues of rehabilitation e.g. use of groundcover that does not grow and obscure signals or impact the longevity of rail infrastructure ▸ 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.
	Contamination, land and soil	▸ A Contaminated Land Management Sub-plan will be developed by a suitably qualified person, as recognised under the EP Act, and incorporated into the CEMP. This sub-plan will: ▸ Be developed based on the contaminated land strategy presented in Figure 8.19 ▸ Specify management controls for works on land that is known or suspected of being contaminated and will outline the process to identify, document and manage contaminated sites ▸ Seek to minimise soil disturbance in areas listed on the EMR, e.g. Lot 1 RP835800 and Lot 8 SP126840 (refer Table 8.17). A Soil Disposal Permit under the EP Act is required if contaminated soil is to be moved from a lot listed on the EMR. ▸ Establish the methodology and sampling and analysis plan for environmental site investigation where soil disturbance is required on an EMR site in the potentially contaminated area, e.g. Lot 1 RP835800 and Lot 8 SP126840 ▸ Establish an unexpected finds protocol/procedure in the event that potentially contaminated materials, including UXO, are encountered during construction activities. ▸ A contamination assessment of EMR listed sites and other areas of potential contamination will be undertaken once detail design, Project footprint and the cut-and-fill balance are finalised, in accordance with the requirements of ASC NEPM.

Delivery phase	Aspect	Proposed mitigation measures
Detail design (continued)	Hazardous materials and dangerous goods	▶ A Hazardous Materials Management Sub-plan will be prepared and implemented as a component of the CEMP. The sub-plan will be required to: ▶ Identify the materials and chemicals required to be stored and used in support of construction, including volumes of each, such as: - Fuel and oil - Greases - Blasting chemicals - Concreting - Welding gases - Pesticides. ▶ Identify the laydown areas that will be used for storage of hazardous materials and designated locations for storage of hazardous within the bounds of those laydown areas ▶ Specify how dangerous goods and hazardous materials will be handled, stored and transported for the Project ▶ Describe the response procedures in the event of an incident involving hazardous materials or dangerous goods ▶ Establish the waste storage and disposal procedures for hazardous materials and dangerous goods.
Pre-construction	Soil conservation plans	▶ Undertake minor civil works (e.g. re-shaping existing contour banks), as required by the modification of soil conservation plans for properties adjoining the Project (refer above).
	Hazardous materials and dangerous goods	▶ A survey of infrastructure that will be removed or disturbed by the Project will be conducted prior to the commencement of construction to identify potential hazardous or contaminated materials, including asbestos. ▶ Where identified, asbestos-containing materials will be removed prior to the commencement of construction. Asbestos removal and handling will be conducted in accordance with: ▶ National Environmental Protection (Assessment of Site Contamination) Measure 2013 ▶ Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia or equivalent ▶ Safe Work Australia Model Code of Practice—How to Manage and Control Asbestos in the Workplace 2016 ▶ Safe Work Australia Model Code of Practice—How to Safely Remove Asbestos 2018. ▶ If removal of more than 10 m^2 of asbestos is required, the necessary license will be obtained from Workplace Health and Safety Queensland, as follows: ▶ A Class Licence—Removal of loose (friable) asbestos ▶ B Class Licence—Removal of bonded asbestos. ▶ Asbestos-containing materials will be transported by a licensed service provider and disposed of at an appropriately licensed facility, in accordance with the requirements of the *Waste Reduction and Recycling Act 2011* (Qld) and the EP Act.

Delivery phase	Aspect	Proposed mitigation measures
Construction	Contamination	▶ Suspected contaminated soils or materials, if encountered, will be managed in accordance with the unexpected finds protocol/procedure documented in the Contaminated Land Management Sub-plan (refer above) ▶ Opportunities to treat and re-use contaminated materials within the rail corridor will be assessed and subjected to a risk assessment.
	Erosion and sediment control	▶ Implement the Soil Management Sub-plan, including erosion and sediment controls (refer above) ▶ Install permanent erosion control measures, such as sediment retention basins and scour protection, in accordance with the detail design ▶ Excavation will be undertaken in a manner to prevent erosion or landslip, working faces shall be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion ▶ 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.
	Secondary salinity	▶ Surface levelling of the site will occur, to prevent inadvertent ponding of water ▶ Water that is dispersed for vegetation establishment, landscaping and rehabilitation will 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) ▶ Ensure efficient water application, so as to avoid prolonged oversaturation of soils within and adjoining the Project footprint.

	Hazardous materials and dangerous goods	▶ Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social (e.g. residential areas) and environmental receptors (e.g. watercourses) 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 *Australian Code for the Transport of Dangerous Goods by Road & Rail* 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 WHS Act and Regulation
		  ▶ *AS 2187—Part 1: 1998, storage of explosives* (Standards Australia, 1998)
		  ▶ *AS 2187—Part 2, use of explosives* (Standards Australia, 2006)
		  ▶ *Australian Code for the Transport of Explosives by Road and Rail, 3rd edition* (AEC3) (Workplace Relations Ministers Council, 2009)
		  ▶ *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.
		▶ Safety data sheet information will be obtained from the supplier of chemicals and stored in an easily accessible location.

Delivery phase	Aspect	Proposed mitigation measures
Construction (continued)	Hazardous waste	▸ Contaminated waste must be transported and disposed of in accordance with the EP Act and procedures within the Waste Management Sub-plan (refer Chapter 20: Waste) ▸ Asbestos containing materials will be transported by a licensed service provider and disposed of at an appropriately licensed facility, in accordance with the requirements of the *Waste Reduction and Recycling Act 2011* (Qld) and the EP Act.
	Rehabilitation	▸ Reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively, consistent with the Rehabilitation and Landscaping Management Sub-plan.
Operation	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 Operational EMP ▸ Controls that are found to be failing or not performing as intended will either be modified or replaced, as required ▸ Rail embankment slopes will be maintained to prevent slope face 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.

The approach for the further assessment and investigation of contaminated land within the Project footprint will be documented in the Contaminated Land Management Sub-plan and will be based on the strategy presented in Figure 8.19.

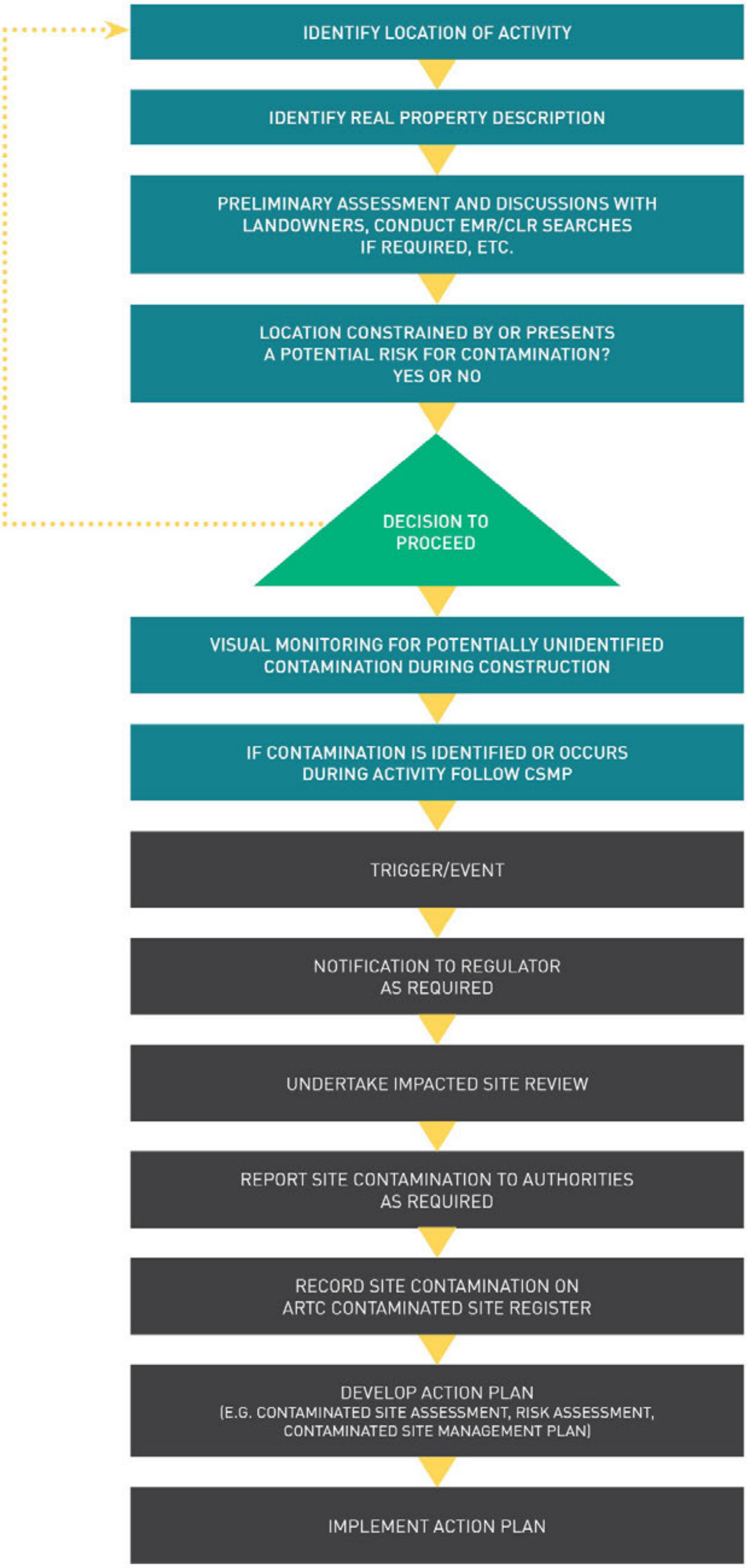


FIGURE 8.19 STRATEGY FOR THE ASSESSMENT AND INVESTIGATION OF CONTAMINATED LAND WITHIN THE PROJECT FOOTPRINT

8.8 Impact assessment summary

Potential impacts associated with land resources during construction, operation and maintenance of the Project are outlined in Table 8.29. These impacts have been subjected to risk assessment as per the methodology in introduced in Chapter 4: Assessment Methodology and summarised in Section 8.4.4.

The initial risk assessment is undertaken on the assumption that the design considerations (or initial mitigation measures) factored into the reference design phase (refer Table 8.27) have been implemented.

Additional mitigation and management measures were then applied as appropriate to the phase of the Project to reduce the level of potential impact (refer Table 8.28). The residual risk level of the potential impacts was then reassessed.

The pre-mitigated risk levels are presented next to the residual risk levels in Table 8.30 to assess the effectiveness of the mitigation and management measures.

TABLE 8.29 RISK ASSESSMENT FOR LAND RESOURCES

Aspect	Potential impact	Phase	Initial risk[1] Likelihood	Initial risk[1] Consequence	Initial risk[1] Risk	Residual risk[2] Likelihood	Residual risk[2] Consequence	Residual risk[2] Risk
Land and soil	Change to landform and topography: ▶ Erosion ▶ Topography	Pre-construction and construction	Likely	Moderate	High	Likely	Minor	Medium
		Operation	Possible	Minor	Low	Possible	Minor	Low
	Disturbance of: ▶ Existing ASS ▶ Potential ASS ▶ Acid rock ▶ Acid rock drainage	Pre-construction and construction	Unlikely	Moderate	Low	Unlikely	Minor	Low
		Operation	Unlikely	Moderate	Low	Unlikely	Minor	Low
	Primary salinity	Pre-construction and construction	Possible	Moderate	Medium	Possible	Minor	Low
		Operation	Likely	Moderate	High	Possible	Minor	Low
	Contribution to secondary salinity	Pre-construction and construction	Possible	Minor	Low	Unlikely	Minor	Low
		Operation	Possible	Moderate	Medium	Possible	Minor	Low
Erosion	Loss of soil resources: ▶ Loss of Class A, Class B and IAAs within Project footprint ▶ Decline in soil fertility ▶ Loss of groundcover ▶ Soil inversion	Pre-construction and construction	Likely	Moderate	High	Possible	Moderate	Medium
		Operation	Likely	Moderate	High	Possible	Moderate	Medium
	Disturbance of soil resources through invasive flora: ▶ Invasion ▶ Reuse ▶ Erosion ▶ Disturb native species ▶ Alter soil properties or groundwater flow ▶ Infiltration	Pre-construction and construction	Likely	Minor	Medium	Likely	Not significant	Low
		Operation	Likely	Minor	Medium	Likely	Not significant	Low

Aspect	Potential impact	Phase	Initial risk[1] Likelihood	Consequence	Risk	Residual risk[2] Likelihood	Consequence	Risk
Contamination land and soil	Disturbance of existing contaminated land: ▶ EMR listed properties ▶ Roads ▶ Housing/sheds ▶ Existing rail ▶ Agricultural activities	Pre-construction and construction	Likely	Moderate	High	Likely	Minor	Medium
		Operation	Possible	Moderate	Medium	Possible	Minor	Low
Material handling and storage	Creation of contaminated land: ▶ Leaks or spills ▶ Permanent and mobile fuel and chemical storage ▶ Waste storage areas and facilities ▶ Project infrastructure	Pre-construction and construction	Possible	Moderate	Medium	Possible	Minor	Low
		Operation	Possible	Minor	Low	Possible	Minor	Low

Table notes:

1 Includes implementation of initial mitigation measures specified in Table 8.28

2 Assessment of residual risk once the mitigation measures identified in Table 8.29 have been applied

8.9 Cumulative impacts

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 land resources. 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 Border to Gowrie 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.

For the purposes of land resources, projects that directly interface the Border to Gowrie Project and will have temporal overlap in construction or expansion activities are considered to have potential to result in cumulative impacts. Only 5 of the initial 23 projects identified meet these criteria. These projects are listed in Table 8.30.

TABLE 8.30 PROJECTS CONSIDERED FOR THE CUMULATIVE IMPACT ASSESSMENT

Projects	Location	Description	Construction dates
InterLinkSQ	13 km west of Toowoomba The northern limit of the Project is situated adjacent to the InterLinkSQ site	A 200-ha 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
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
North Star to NSW/QLD Border (Inland Rail)	Rail alignment from North Star, NSW to the NSW/QLD border. Adjoins the Project at its southern limit	New 37 km rail corridor to connect North Star (NSW) to the QR South West Rail Line just over the NSW/QLD border.	2021–2024
Gowrie to Helidon (Inland Rail)	Rail alignment from Gowrie to Helidon, Queensland Adjoins the Project at its northern limit	New 26 km dual-gauge track between Gowrie (northwest of Toowoomba) and Helidon (east of Toowoomba), extending through the LGAs of Toowoomba and Lockyer Valley. The Project includes a 6.38 km tunnel to create an efficient route through the steep terrain of the Toowoomba Range.	2021–2025
Asterion Medicinal Cannabis Project	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

An assessment of cumulative impacts that may arise from these projects in combination with the Project is presented in Table 8.31.

Cumulative impacts on land resources are considered to be of low-to-medium significance. Where cumulative impacts have been assessed as low significance there are unlikely to be long-term cumulative impacts, providing that all assessable projects apply mitigation measures that are consistent with those proposed for this Project (refer Table 8.28).

Matters including loss of soil resources, changes to landform and topography, erosion and weed management have been assessed as medium significance. Initial controls for the management of these potential cumulative impacts are based on the implementation of the measures prescribed in Table 8.28. Consultation with potentially affected landowners and other stakeholders, including proponents of non-Inland Rail projects that interface with this Project, may result in additional mitigation measures of relevance being identified during the detail design process. In such instances, additional mitigation measures will be incorporated into relevant components of the CEMP, if appropriate to do so.

TABLE 8.31 ASSESSMENT OF LAND RESOURCE CUMULATIVE IMPACTS

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
InterLinkSQ	Leaks or spills leading to migration of contaminants through surface water/ soil/groundwater or increased human health risk through ingestion/ dermal contact	Probability of the impact	Medium (2)	5	Low	Will be managed through: ▶ Development and implementation of a Hazardous Materials Management Sub-plan and Contaminated Land Management Sub-plan, as a component of the CEMP for the Project ▶ Consultation with InterLinkSQ regarding scheduling of construction activities ▶ Development and implementation of emergency response procedures, compatible with InterLinkSQ's adjoining activities.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
InterLinkSQ	Permanent loss of soil resources within the permanent footprint	Probability of the impact	Medium (2)	7	Medium	Will be managed through: ▶ The Project design will be refined during detail design to minimise the Project footprint to the extent required for the construction works and safe operation of the Project in proximity to the InterLinkSQ site ▶ Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner ▶ Development and implementation of a Rehabilitation and Landscaping Management Sub-plan, as a component of the CEMP for the Project that is compatible with InterLinkSQ's adjoining activities and addresses cumulative impacts to agricultural land.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
InterLinkSQ	ASS, including the potential to disturb ASS	Probability of the impact	Low (1)	4	Low	The likelihood of encountering ASS in proximity to the InterLinkSQ site is considered to be low. If detailed geotechnical and soil investigations identify a potential for ASS to occur in this location, an ASS Management Plan will be prepared and implemented, in accordance with the requirements of *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* (Dear et al., 2014)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
InterLinkSQ (continued)	Change to landform and topography	Probability of the impact	Medium (2)	7	Medium	The design levels of the Project will need to be assessed for compatibility with landform modifications and land management practices within the InterLinkSQ site. Cross-drainage and longitudinal drainage provided as part of the Project will need to be developed to accommodate for overland flows that move into the Project footprint from the adjoining InterLinkSQ site.
		Duration of the impact	High (3)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Secondary salinity	Probability of the impact	Medium (2)	6	Low	The potential for the Project to contribute to secondary salinity will be managed through the development and implementation a Soil Management Sub-plan. Site levels within the Project footprint will be established to prevent the inadvertent ponding of water.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Erosion	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to exacerbated erosion will be managed through: ▸ The implementation of location-specific erosion and sediment control measures, developed by a certified practitioner in erosion and sediment control in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008) ▸ ARTC will consult with InterLinkSQ regarding the scheduling of construction activities and the compatibility of proposed erosion control measures with activities and land management measures on the adjoining site ▸ The effectiveness of erosion controls that are within the Project footprint will be monitored by the Principal Contractor during construction ▸ Permanent erosion control measures will be monitored for ongoing effectiveness as part of ARTC's rail corridor maintenance program.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
InterLinkSQ (continued)	Weed management	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to the degradation of land and soil due to weed infestation will be managed through the development and implementation of a Biosecurity Management Sub-plan, as a component of the CEMP for the Project.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
Commodore Mine and Millmerran Power Station	Leaks or spills leading to migration of contaminants through surface water/ soil/groundwater or increased human health risk through ingestion/ dermal contact	Probability of the impact	Medium (2)	5	Low	Will be managed through: ▸ Development and implementation of a Hazardous Materials Management Sub-plan and Contaminated Land Management Sub-plan, as a component of the CEMP for the Project ▸ Consultation with Intergen regarding scheduling of mine expansion activities, which may interface with construction activities for the Project ▸ Development and implementation of emergency response procedures, compatible with Intergen's adjoining activities.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Permanent loss of soil resources within the permanent footprint	Probability of the impact	Medium (2)	7	Medium	Will be managed through: ▸ The Project design will be refined during detail design to minimise the Project footprint to the extent required for the construction works and safe operation of the Project in proximity to the Commodore Mine site ▸ Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner ▸ Development and implementation of a Rehabilitation and Landscaping Management Sub-plan, as a component of the CEMP for the Project that is compatible with Intergen's adjoining activities and addresses cumulative impacts to agricultural land.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	ASS, including the potential to disturb ASS	Probability of the impact	Low (1)	4	Low	The likelihood of encountering ASS in proximity to Commodore Mine site is considered to be low. If detailed geotechnical and soil investigations identify a potential for ASS to occur in this location, an ASS Management Plan will be prepared and implemented, in accordance with the requirements of *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* (Dear et al., 2014)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Commodore Mine and Millmerran Power Station (continued)	Change to landform and topography	Probability of the impact	Medium (2)	7	Medium	The design levels of the Project will need to be assessed for compatibility with landform modifications and land management practices within the Commodore Mine site. Cross-drainage and longitudinal drainage provided as part of the Project will need to be developed to accommodate for overland flows that move into the Project footprint from the adjoining Commodore Mine site.
		Duration of the impact	High (3)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Secondary salinity	Probability of the impact	Medium (2)	6	Low	The potential for the Project to contribute to secondary salinity will be managed through the development and implementation a Soil Management Sub-plan. Site levels within the Project footprint will be established to prevent the inadvertent ponding of water.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Erosion	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to exacerbated erosion will be managed through: ▶ The implementation of location-specific erosion and sediment control measures, developed by a certified practitioner in erosion and sediment control in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008) ▶ ARTC will consult with Intergen regarding the scheduling of construction activities and the compatibility of proposed erosion control measures with activities and land management measures on the adjoining site ▶ The effectiveness of erosion controls that are within the Project footprint will be monitored by the Principal Contractor during construction ▶ Permanent erosion control measures will be monitored for ongoing effectiveness as part of ARTC's rail corridor maintenance program.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	Weed management	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to the degradation of land and soil due to weed infestation will be managed through the development and implementation of a Biosecurity Management Sub-plan, as a component of the CEMP for the Project.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
North Star to NSW/QLD Border (Inland Rail)	Leaks or spills leading to migration of contaminants through surface water/ soil/groundwater or increased human health risk through ingestion/ dermal contact	Probability of the impact	Medium (2)	5	Low	Will be managed through: ▶ Development and implementation of a Hazardous Materials Management Sub-plan and Contaminated Land Management Sub-plan, as a component of the CEMP for the Project ▶ ARTC will facilitate discussions between principal contractors for adjoining Inland Rail projects regarding the scheduling of construction activities and the development and implementation of compatible emergency response procedures.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Permanent loss of soil resources within the permanent footprint	Probability of the impact	Medium (2)	7	Medium	Will be managed through: ▶ The Project design will be refined during detail design to minimise the Project footprint to the extent required for the construction works and safe operation of the Project ▶ Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner ▶ Development and implementation of a Rehabilitation and Landscaping Management Sub-plan, as a component of the CEMP for the Project that addresses cumulative impacts to agricultural land.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	ASS, including the potential to disturb ASS	Probability of the impact	Low (1)	4	Low	There is potential of ASS to be encountered in the Macintyre River. However, if presented, the cumulative impacts from ASS are expected to be low, as disturbance of ASS material will be undertaken under a single construction package. If detailed geotechnical and soil investigations identify a potential for ASS to occur in this location, an ASS Management Plan will be prepared and implemented, in accordance with the requirements of *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* (Dear et al., 2014)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
North Star to NSW/QLD Border (Inland Rail) (continued)	Change to landform and topography	Probability of the impact	Medium (2)	6	Low	These two adjoining projects are part of the same Inland Rail program; therefore, they will not be viewed as separable contributors to modifications in landform and topography.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Secondary salinity	Probability of the impact	Medium (2)	6	Low	The potential for the Project to contribute to secondary salinity will be managed through the development and implementation a Soil Management Sub-plan. Site levels within the Project footprint will be established to prevent the inadvertent ponding of water.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Erosion	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to exacerbated erosion will be managed through: ▸ The implementation of location-specific erosion and sediment control measures, developed by a Certified Practitioner in Erosion and Sediment Control in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008) ▸ ARTC will facilitate discussions between principal contractors for the adjoining packages regarding the scheduling of construction activities and the compatibility of proposed erosion control measures ▸ The effectiveness of erosion controls that are within the Project footprint will be monitored by the Principal Contractor during construction ▸ Permanent erosion control measures will be monitored for ongoing effectiveness as part of ARTC's rail corridor maintenance program.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	Weed management	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to the degradation of land and soil due to weed infestation will be managed through the development and implementation of a Biosecurity Management Sub-plan, as a component of the CEMP for the Project.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Gowrie to Helidon (Inland Rail)	Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or increased human health risk through ingestion/dermal contact	Probability of the impact	Medium (2)	5	Low	Will be managed through: ▸ Development and implementation of a Hazardous Materials Management Sub-plan and Contaminated Land Management Sub-plan, as a component of the CEMP for the Project ▸ ARTC will facilitate discussions between principal contractors for adjoining Inland Rail projects regarding the scheduling of construction activities and the development and implementation of compatible emergency response procedures.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Permanent loss of soil resources within the permanent footprint	Probability of the impact	Medium (2)	7	Medium	Will be managed through: ▸ The Project design will be refined during detail design to minimise the Project footprint to the extent required for the construction works and safe operation of the Project ▸ Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner ▸ Development and implementation of a Rehabilitation and Landscaping Management Sub-plan, as a component of the CEMP for the Project that addresses cumulative impacts to agricultural land.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	ASS, including the potential to disturb ASS	Probability of the impact	Low (1)	4	Low	If detailed geotechnical and soil investigations identify a potential for ASS to occur in this location, an ASS Management Plan will be prepared and implemented, in accordance with the requirements of *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* (Dear et al., 2014)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Change to landform and topography	Probability of the impact	Medium (2)	6	Low	These two adjoining projects are part of the same Inland Rail program; therefore, they will not be viewed as separable contributors to modifications in landform and topography. The design levels of the Project will need to be assessed for compatibility with landform modifications and land management practices on surrounding land. Cross-drainage and longitudinal drainage provided as part of the Project will need to be developed to accommodate for overland flows that move into the Project footprint.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Gowrie to Helidon (Inland Rail) (continued)	Secondary salinity	Probability of the impact	Medium (2)	6	Low	The potential for the Project to contribute to secondary salinity will be managed through the development and implementation a Soil Management Sub-plan. Site levels within the Project footprint will be established to prevent the inadvertent ponding of water.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Erosion	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to exacerbated erosion will be managed through: - The implementation of location-specific erosion and sediment control measures, developed by a Certified Practitioner in Erosion and Sediment Control in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008) - ARTC will facilitate discussions between principal contractors for the adjoining packages regarding the scheduling of construction activities and the compatibility of proposed erosion control measures - The effectiveness of erosion controls that are within the Project footprint will be monitored by the principal contractor during construction - Permanent erosion control measures will be monitored for ongoing effectiveness as part of ARTC's rail corridor maintenance program.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	Weed management	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to the degradation of land and soil due to weed infestation will be managed through the development and implementation of a Biosecurity Management Sub-plan, as a component of the CEMP for the Project.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
Asterion Medicinal Cannabis Project	Leaks or spills leading to migration of contaminants through surface water/ soil/groundwater or increased human health risk through ingestion/ dermal contact	Probability of the impact	Medium (2)	5	Low	Will be managed through: - Development and implementation of a Hazardous Materials Management Sub-plan and Contaminated Land Management Sub-plan, as a component of the CEMP for the Project - Consultation with Asterion regarding scheduling of construction activities - Development and implementation of emergency response procedures, compatible with Asterion's adjoining activities.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Asterion Medicinal Cannabis Project (continued)	Permanent loss of soil resources within the permanent footprint	Probability of the impact	Low (1)	6	Low	Will be managed through: ▶ The Project design will be refined during detail design to minimise the Project footprint to the extent required for the construction works and safe operation of the Project in proximity to the Asterion site ▶ Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner ▶ Development and implementation of a Rehabilitation and Landscaping Management Sub-plan, as a component of the CEMP for the Project that is compatible with Asterion's adjoining activities and addresses cumulative impacts to agricultural land
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	ASS, including the potential to disturb ASS	Probability of the impact	Low (1)	4	Low	The likelihood of encountering ASS in proximity to the Asterion site is considered to be low. If detailed geotechnical and soil investigations identify a potential for ASS to occur in this location, an ASS Management Plan will be prepared and implemented, in accordance with the requirements of *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* (Dear et al., 2014)
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Change to landform and topography	Probability of the impact	Medium (2)	7	Medium	The design levels of the Project will need to be assessed for compatibility with landform modifications and land management practices within the Asterion site. Cross-drainage and longitudinal drainage provided as part of the Project will need to be developed to accommodate for overland flows that move into the Project footprint from the adjoining Asterion site.
		Duration of the impact	High (3)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
	Secondary salinity	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to secondary salinity will be managed through the development and implementation a Soil Management Sub-plan. Site levels within the Project footprint will be established to prevent the inadvertent ponding of water.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Asterion Medicinal Cannabis Project (continued)	Erosion	Probability of the impact	Medium (2)	7	Medium	The potential for the Project to contribute to exacerbated erosion will be managed through: ▶ The implementation of location-specific erosion and sediment control measures, developed by a certified practitioner in erosion and sediment control in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008). ▶ ARTC will consult with Asterion regarding the scheduling of construction activities and the compatibility of proposed erosion control measures with activities and land management measures on the adjoining site ▶ The effectiveness of erosion controls that are within the Project footprint will be monitored by the principal contractor during construction ▶ Permanent erosion control measures will be monitored for ongoing effectiveness as part of ARTC's rail corridor maintenance program.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
	Weed management	Probability of the impact	Low (1)	5	Low	The potential for the Project to contribute to the degradation of land and soil due to weed infestation will be managed through the development and implementation of a Biosecurity Management Sub-plan, as a component of the CEMP for the Project.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Table notes:

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 measure 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.

8.10 Conclusions

This chapter has been prepared to evaluate potential impacts of the Project on land resources and addresses sections 11.88 to 11.93 and sections 11.150 to 11.154 of the ToR.

This chapter has identified and discussed existing conditions within the impact assessment area in relation to geology and topography, soils, agricultural land and contamination.

Following the establishment of existing conditions, Project impacts with the potential to adversely impact land resources have been identified. The potential impacts identified were as follows:

- Permanent alteration to landform and/or topography
- The loss of soil resources on agricultural and other economically valuable land
- The accelerated loss of topsoil through erosional processes, as a result of landform and hydrological modifications as a result of the Project
- Potential exposure of ASS and acid rock to oxidising conditions during excavation and earthworks
- Exacerbation of existing soil salinity and sodicity
- Contribution to the creation of new areas of salinity expression
- Disturbance to existing contaminated land
- Contribution to the creation of contaminated land.

The reference design has been developed in parallel with the draft EIS to avoid the occurrence of impacts to or from land resources. Where avoidance has not been possible, design development has sought to minimise the likelihood and/or consequence of these impacts, as far as possible. Responses of the reference design to land resources issues has been detailed in Section 8.7.1.

Where potential impacts to land resources have not been fully avoided or mitigated through the reference design, additional mitigation measures have been nominated for implementation in future phases of the Project. These proposed mitigation measures have been detailed in Section 8.7.2.

A risk assessment of potential impacts both without (initial risk) and with the application of proposed mitigation measures (residual risk) has been undertaken (refer Section 8.8). This assessment concluded that the majority of potential impacts to land resources through Project activities are expected to have a low residual risk rating. Permanent alteration to landform and topography, loss of soil resources, erosion and disturbance of existing contaminated land during the construction phase of the Project all remain a medium residual risk. All potential impacts to land resources will be managed through adherence to the Outline EMP (Chapter 22: Outline Environmental Management Plan).

The development of a reference design is an interactive process and the Project footprint remains subject to confirmation through the detail design process; consequently, it was considered to be of limited value to undertake soil sampling and analysis at a more intensive scale during the reference design stage for a Project of this nature. In acknowledging the preliminary nature of geotechnical and soil investigations undertaken to date, ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 8.7.2). Additional soil data will be incorporated into the Final EIS and will enable identification of potential/actual problematic soils, including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants.

The methodology for the detailed soil investigation will be developed in consultation with DNRME and will be in accordance with the *Guidelines for surveying soil and land resources* (McKenzie et al., 2008), the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015). Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner. Weather permitting, these additional investigations will commence in the first quarter of 2021.