APPENDIX R

Groundwater Technical Report

Part 1 of 2

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.

IR_1534

Inland Rail Border to Gowrie

Appendix R – Groundwater Technical Report

Australian Rail Track Corporation

Reference: 3100

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Contents

Appendices

Figures

Tables

1 Introduction

1.1 Project overview and objectives

The Australian Rail Track Corporation (ARTC), the proponent, proposes to construct and operate the Border to Gowrie section of the Inland Rail program ('the Project') which would be approximately 216.2 km of single track railway, built to accommodate double stack freight trains initially up to 1,800 m long. The Project will utilise a combination of existing rail corridors (brownfield) and new rail corridor (greenfield).

The objectives of the Project are to:

- Provide rail infrastructure that meets the Inland Rail specifications, to enable trains using the Inland Rail route to travel from the New South Wales (NSW) and Queensland (QLD) border to Gowrie, connecting with other sections of Inland Rail to the north and south
- Minimise the potential for adverse environmental, social and economic impacts.

The objectives of Inland Rail as a whole are to:

- Provide a rail link between Melbourne and Brisbane that is interoperable with train operations to Perth, Adelaide and other locations on the standard gauge rail network. This will serve future rail freight demand and stimulate growth for inter-capital and bulk rail freight
- Provide an increase in productivity that will benefit consumers through lower freight transport costs
- Provide a step-change improvement in rail service quality in the Melbourne to Brisbane corridor and deliver a freight rail service that is competitive with road
- Improve safety, congestion and reduce environmental impacts by moving freight from road to rail
- Bypass bottlenecks within the existing metropolitan rail networks and free up train paths for other services along the coastal routes
- Act as an enabler for regional economic developments along the Inland Rail corridor.

1.2 Project location and existing land use

The Project is located within the Toowoomba Regional Council and Goondiwindi Regional Council Local Government Areas (LGA) in south-east Queensland. The Project commences at the NSW/QLD border, the median line of the Macintyre River, approximately 18 km to the south east of Goondiwindi near Kurumbul. The Project then extends for 216.2 km in a north-northeast direction where it finishes between Leeson Road and Draper Road, on the southeastern outskirts of Kingsthorpe. The Project in its local context is shown in Figure 1.1.

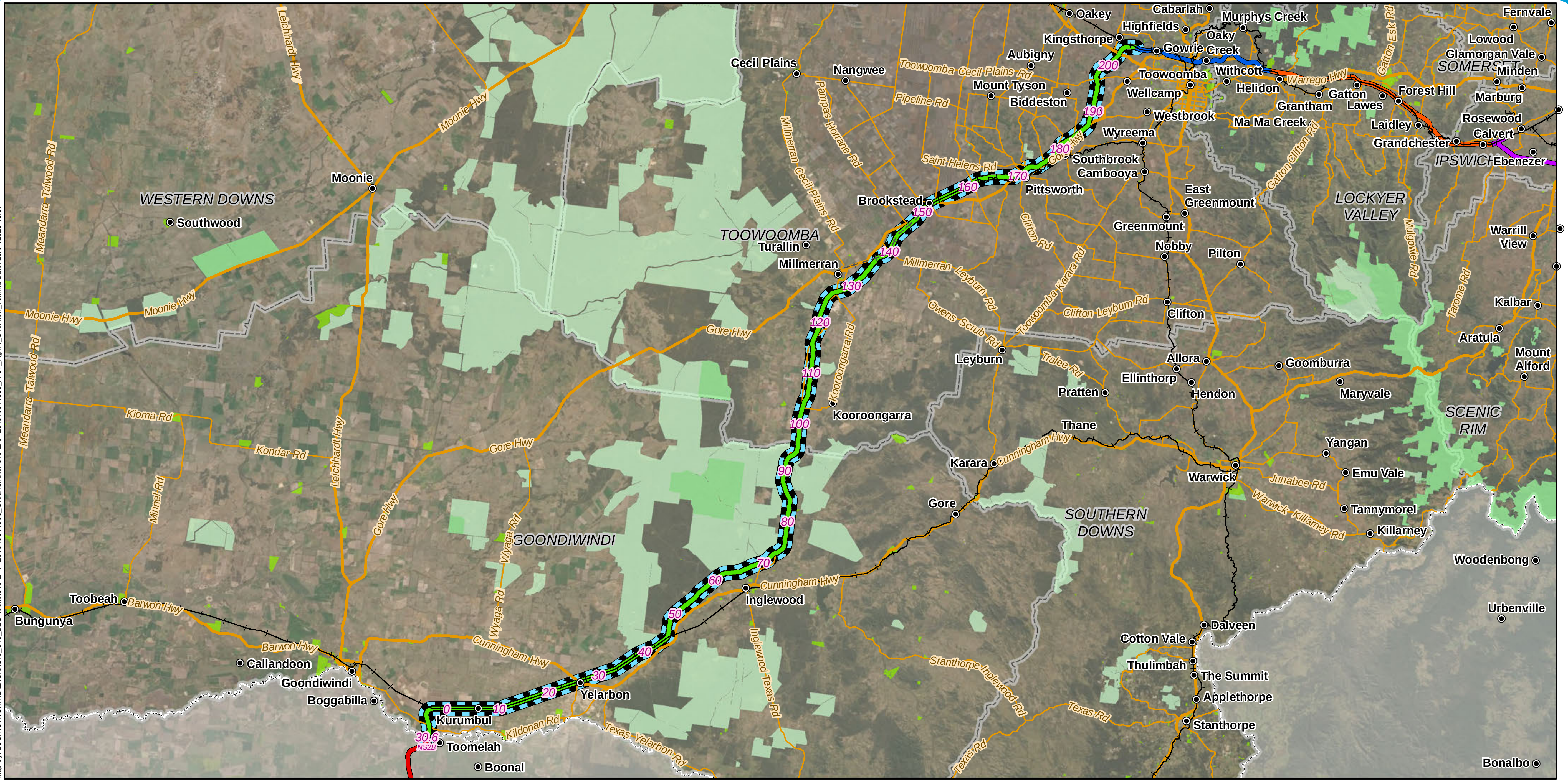
At each end, the Project connects into adjoining Inland Rail projects, being the North Star to NSW/QLD Border project at the southern end and the Gowrie to Helidon project at the northern end.

The impact assessment area for the Project is primarily characterised by rural and rural-residential land uses on a variety of property sizes. The diversity in rural land use is reflected through the various rural allotment sizes.

The Project passes through, or within proximity to, several townships such as Yelarbon, Inglewood, Millmerran, Pampas, Brookstead, Pittsworth, Southbrook, Athol, Gowrie Mountain and Kingsthorpe. It is also aligned in proximity to numerous existing agricultural, industrial and commercial operations, such as feedlots, the Commodore Mine and the Toowoomba Wellcamp Airport.

The Project traverses approximately 46 km of floodplain as mapped on the Queensland Reconstruction Authority Indicative Flood Assessment Overlay. Floodplains crossed by the Project are those associated with the Macintyre River, Macintyre Brook, Pariagara Creek, Cattle Creek, Native Dog Creek, Bringalily Creek, Nicol Creek, Back Creek, Condamine River, Westbrook Creek and Gowrie Creek.

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



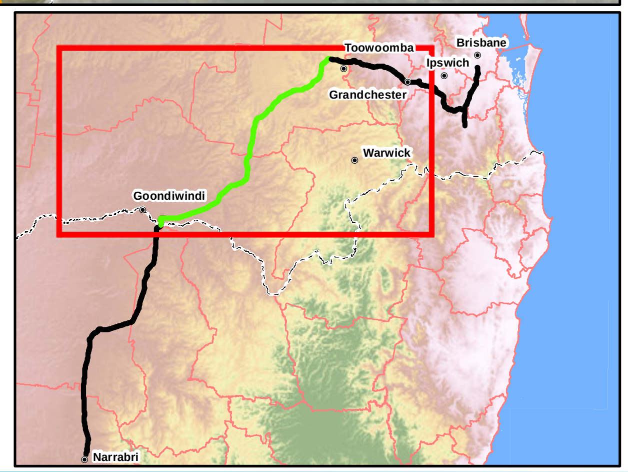
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig1.1_Overview_v3.mxd Date: 23/04/2020 16:37

Legend

5 Chainage (km)
Localities
North Star to NSW/QLD border alignment
Border to Gowrie alignment
Gowrie to Helidon alignment
Helidon to Calvert alignment
Calvert to Kagaru alignment
Existing rail (operational)
Existing rail (non-operational)
Major roads
Minor roads
NSW/QLD border
Groundwater impact assessment area
Local Government Areas

Tenure, other than freehold

National Park
Reserve
State Forest



A3 scale: 1:800,000

0 6 12 18 24 30 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 23/04/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Figure 1.1: Project location overview

1.3 Project description

The Project consists of the key permanent and temporary features listed in Table 1.1.

Table 1.1 Key features of the Project

Aspect	Description
Permanent features	
New track	▪ Approximately 216.2 km of new single track railway, consisting of: – 7.0 km of standard gauge rail (1,435 millimetres (mm)) – 209.2 km of dual gauge rail (standard (1,435 mm) and narrow (1,067 mm) gauge). ▪ Railway infrastructure and the corridor will initially be constructed for 1,800 m long trains, and future- proofed for operation of 3,600 m trains.
Rail corridor	▪ Establishment of approximately 145.0 km of new rail corridor and use of approximately 71.2 km of existing rail corridor. ▪ The rail corridor is generally a minimum width of 40 m. There is one exception to this where the Project utilises 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. ▪ The rail corridor will be of sufficient width to accommodate all proposed railway infrastructure, including the crossing loops, as well as future expansion to accommodate the potential for 3,600 m long trains.
Crossing loops and turnouts	▪ Crossing loops are places on a single-line track where trains in opposing directions can pass each other. Five crossing loops will be constructed as part of the Project, at a minimum of 2,200 m in length for each loop. ▪ Turnouts allow the train to be guided from one section of track to another. Turnouts that connect in to crossing loops and QR's existing South Western Line, Millmerran Branch Line and sidings have been incorporated into the reference design.
Bridges	▪ Bridges to accommodate topographical variation, crossings of waterways or other infrastructure.
Drainage	▪ Cross-drainage is provided by reinforced concrete pipe culverts and reinforced concrete-box culverts. ▪ Scour protection measures will be installed around culverts and abutments to prevent erosion.
Rail crossings	▪ Rail crossings, including level crossings, grade separated crossings (rail or road overbridges) and occupational/private crossings.
Ancillary works	▪ The construction of associated railway infrastructure, including maintenance sidings and signalling infrastructure to support Advanced Train Management Systems (ATMS). ▪ Ancillary works, including works to level crossings, signalling and communications, signage and fencing, drainage works, and installation or modification of services and utilities within the rail corridor.
Construction features (temporary	
Land	▪ Temporary access tracks will be used to access construction sites. Where possible, access tracks will be retained to serve as RMAR during the operation of the Project. ▪ Land requirements for construction will include temporary workspaces, site offices and laydown facilities. These requirements are encompassed within the nominated temporary footprint for the Project. ▪ Laydown areas will be located approximately every 5 km (avoiding one per cent annual exceedance probability (AEP) floodplains, where possible). Larger sites will be located approximately every 2 km.
Embankments and cuttings	▪ Embankments and cuttings will be required along the length of the rail alignment.
Borrow pits	▪ Identification, establishment and lawful use of borrow pits for the sourcing of construction materials for the Project. This does not include existing borrow pits owned by third parties. Borrow pits are not included in the Project footprint as approval to establish and use borrow pits will be sought separately to the EIS approval process.

Aspect	Description
Accommodation camps	■ Construction, use and decommissioning of up to three temporary non-resident workforce accommodation camps. These camps are not included in the Project footprint as approval to establish and operate non-resident workforce accommodation camps will be sought separately to the EIS approval process.

1.4 Timing and operation

Early works for the Project are planned to start in 2021, with construction scheduled to be completed by the beginning of 2026. Inland Rail, and the Project, are scheduled to be operational in 2026.

The Project will be operational when all 13 sections of Inland Rail are complete, which is estimated to be in 2026. The Project will be managed and maintained by the ARTC; however, train services will be provided by a variety of operators. The trains will be a mix of grain, intermodal (freight) and other general transport trains.

1.5 Scope and purpose

The objective of this report is to support the EIS submission by addressing all groundwater related requirements of the *Terms of reference* [ToR] *for an environmental impact statement: Inland Rail – Border to Gowrie project November 2018* (DSDMIP, 2018). This groundwater assessment includes a description of the existing groundwater resources, an assessment of environmental values (EVs) and conceptualisation of the groundwater resources.

The key objectives of this groundwater assessment are to:

- Establish existing groundwater resources, values and conditions within the impact assessment area (defined in Section 1.7), using a combination of published information and data collected from groundwater investigations conducted to inform the reference design and EIS
- Identify key Project impacts on groundwater environmental values within the impact assessment area
- Identify mitigation measures and controls that have been factored into the design, or otherwise implemented during the reference design phase for the Project
- Identify mitigation measures and controls that will be implemented during future phases of the Project to further reduce the magnitude of potential impacts
- Evaluate the significance of the impacts of the Project on groundwater environmental values within the impact assessment area, with and without the application of mitigation measures during future phases of the Project
- Provide an assessment of the potential for cumulative impacts to groundwater resources as a consequence of the Project, in combination with other projects

1.6 Terms of reference requirements

This report has been prepared to address sections of the ToR of relevance to groundwater. A compliance check of this report against each of the relevant components of the ToR is presented in Table 1.2.

Table 1.2 Compliance against relevant sections of the terms of reference

Groundwater terms of reference requirements		Section where addressed
Existing environment		
11.36	Identify the water related environmental values and describe the existing surface water and groundwater regime within the impact assessment area and the adjoining waterways in terms of water levels, discharges and freshwater flows.	Section 4 Section 5

Groundwater terms of reference requirements		Section where addressed
11.37.	Identify the environmental values of groundwater within the Project area and immediately downstream that may be affected by the Project, including any human uses of the water and any cultural values.	Section 5 Section 6
11.38.	At an appropriate scale, detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the Project. Include a description of the natural water quality variability within the impact assessment area associated with climatic and seasonal factors, and flows.	Groundwater characteristics are discussed in Section 4.7 Chemical, physical and biological characteristics of surface waters are addressed in Appendix P: Surface Water Quality Technical Report of the Border to Gowrie EIS.
11.39.	Describe any existing and/or constructed waterbodies adjacent to the proposed alignment.	Section 4.3
11.40	Undertake a landowner bore survey to identify the location and source aquifer of licensed groundwater extraction in areas potentially impacted by the Project (e.g. near cuttings and bridges).	Section 4.7.5 and Appendix A
Water quality: impact assessment		
11.41.	The assessment of impacts on water will be in accordance with the DES Information guideline for an environmental impact statement – ToR Guideline – Water, where relevant, located on the DES website	Section 2.3.4 Section 3
11.44.	Where significant cuttings are proposed, identify the presence of any sulphide minerals in rocks with potential to create acidic, metalliferous and saline drainage. If present, describe the practicality of avoiding their disturbance. If avoidance is not practicable, characterise the potential of the minerals to generate contaminated drainage and describe abatement measures that will be applied to avoid adverse impacts to groundwater quality.	Section 4.6.2 Section 8.1.2.2 Section 9.2
Water quality: mitigation measures		
11.47	Describe how the water quality objectives (WQOs) identified above would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Section 9.2 and Section 9.3
11.48	Describe appropriate management and mitigation strategies and provide contingency plans for: a) potential accidental discharges of contaminants and sediments during construction and operation a) management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Section 9.2
Water resources: impact assessment		
11.52	Provide details of any proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the Water Act, *Water Supply (Safety and Reliability) Act 2008* or Planning Act.	Sections 7.2, Section 7.3, Section 8.1.1 and Section 9.2 Full discussion on approval requirements for the Project is provided in Chapter 3: Legislation and project approvals process of the Border to Gowrie EIS. Discussion on proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water is presented in Appendix P: Surface Water Quality Technical Report of the Border to Gowrie EIS.

Groundwater terms of reference requirements		Section where addressed
11.54	Develop hydrological models as necessary to describe the inputs, movements, exchanges and outputs of all significant quantities and resources of surface water and groundwater that may be affected by the Project. The models should address the range of climatic conditions that may be experienced at the site, and adequately assess the potential impacts of the Project on water resources. This should enable a description of the Project's impacts at the local scale and in a regional context including proposed: (a) changes in flow regimes from structures and water take (c) direct and indirect impacts arising from the Project (d) impacts to aquatic ecosystems, including groundwater dependent ecosystems and environmental flows.	Groundwater modelling: Section 7 Discussion of impacts: Section 8
11.55	Provide information on the proposed water usage by the Project including details about: (a) the estimated supply required to meet the demand for construction and full operation of the Project, including timing of demands (b) the quality and quantity of all water supplied to the site during the construction and operational phases based on minimum yield scenarios for water reuse, rainwater reuse and any bore water volumes (d) sufficient hydrogeological information to support the assessment of any temporary water permit applications.	Sections 7 and 8.1.1.7 Full discussion on construction water requirements for the Project is provided in Chapter 5: Project description of the Border to Gowrie EIS.
11.56.	Describe proposed sources of water supply given the implication of any approvals required under the Water Act. Estimated rates of supply from each source (average and maximum rates) must be given and proposed water conservation and management measures must be described.	Section 8.1.1.7 Full discussion on construction water requirements for the Project is provided in Chapter 5: Project description of the Border to Gowrie EIS.
11.57	Determination of potable water demand must be made for the Project, including the temporary demands during the construction period. Include details of any existing town water supply to meet such requirements. Detail should also be provided to describe any proposed on-site water storage and treatment for use by the site workforce.	Section 8.1.1.7 Full discussion on potable water requirements and treatment of waste water, for the Project is provided in Chapter 5: Project description of the Border to Gowrie EIS.
11.58	Identify relevant Water Plans and Resources Operations Plans under the Water Act. Describe how the Project will impact or alter these plans. The assessment should consider, in consultation with Department of Natural Resources, Mines and Energy (DNRME), any need for: (a) a resource operations licence (b) an operations manual (c) a distribution operations licence (d) a water licence (e) a water management protocol.	Sections 2.2 and 8.1.1 Full discussion on approval requirements for the Project is provided in Chapter 3: Legislation and project approvals process of the Border to Gowrie EIS.
11.59	Identify other water users that may be affected by the proposal and assess the Project's potential impacts on other water users.	Section 4.7.5, Section 4.7.6 Section 7.3.4, Section 8.1.1.2 and Section 8.2.1.1
Water resources: mitigation measures		
11.62	Describe measures to minimise impacts on surface water and ground water resources.	Section 9.2 and Section 9.3
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	Section 8.1.2, Section 8.2.1.1 and Section 9.2

1.7 Impact assessment area

An impact assessment area has been established to delineate the spatial extent for the groundwater assessment. The impact assessment area is generally defined as the area within a one-kilometre (1 km) distance from the centre line of the proposed Project alignment.

In some instances, due to a paucity of available groundwater data, the impact assessment area has been increased to appropriately characterise certain EVs (i.e. 5 km distance for groundwater dependant ecosystems (GDEs), Section 4.7.7). Where an extension of the impact assessment area was warranted to sufficiently address the ToR, the impact assessment area has been defined within that section of the report.

The Project footprint is wholly within the impact assessment area. The Project footprint has been established to encompass all permanent infrastructure required for the Project. Permanent infrastructure features include the new rail track, bridges and drainage structures, level crossings, road realignments, possible upgrades to adjacent roads and infrastructure, a rail maintenance access road, fencing and signage.

The Project footprint also 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 access track(s).

Horizontal distances and locations along a rail corridor are typically defined by chainage measured in kilometres along the centreline of the alignment. For this Project chainages start at chainage (Ch) 30.60 km at the southern-most point on the Macintyre River. Chainages increase in a northerly direction along the alignment to Ch 39.86 km within the South Western Line rail corridor, which is the northern limit of standard gauge rail for the Project. At this point chainages are reset and revert to zero. From this zero-point, chainages continue to increase in a northern direction along the dual gauge rail alignment to Ch 206.95 km at the northernmost point of the Project.

For clarity in this report, chainages south of the zero-point within the South Western Line rail corridor are presented with suffix '(NS2B)'. Chainages north of this point are presented without the suffix. For example, Ch 38.00 km (NS2B) and Ch 38.00 km relate to two different locations along the Project alignment.

2 Legislation, policy, standards and guidelines

The subsections below summarise the relevant Commonwealth and Queensland legislation, policies, and plans that apply to the Project with respect to groundwater resources. These have been considered during preparation of this groundwater technical report.

2.1 Legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) provides that any action (i.e. a project, development, undertaking, activity or series or activities) that has, will have or is likely to have a significant impact on matters of national environmental significance (MNES), or other matters protected under the EPBC Act such as the environment of Commonwealth land, requires approval from the Australian Government Minister for the Environment. Groundwater can provide habitat conditions for, or provide linkage to habitat for threatened species and ecological communities that are MNES. Groundwater may also be considered an MNES itself, in relation to coal seam gas development and large coal mining developments.

On 9 April 2018, the Australian Government Minister for the Environment determined the Project to be a 'controlled action' under the EPBC Act, due to the likely potential impacts on MNES (reference number EPBC 2018/8165). It was established through the Project referral and subsequent determination that the Project does not have the potential for significant impacts on water resources.

2.1.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (QLD) (EP Act) aims 'to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends' (EP Act, Part 2). Under the EP Act, environmental protection policies are developed to cover specific aspects of the environment.

The EP Act identifies EVs of Queensland waters, including those located within the impact assessment area, which are protected under the EP Act and the subordinate legislation. The EP Act defines an EV as:

- A quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety or
- Another quality of the environment identified and declared to be an EV under an environmental protection policy or regulation.

Further information regarding EVs is included in Section 2.2.1.

2.1.3 Water Act 2000

The *Water Act 2000* (QLD) (Water Act) provides for the sustainable management of water and the management of impacts on underground water amongst other purposes. The main objective of the Water Act is to provide a framework for:

- Sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water
- Sustainable and secure water supply and demand management for the southeast Queensland region and other designated regions

- Management of impacts on underground water caused by the exercise of underground water rights by the resource sector
- Effective operation of water authorities.

The Water Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam.

The Project involves works which may intersect shallow groundwater units and as such the provisions of the Water Act apply.

2.1.4 Water Regulation 2016

The *Water Regulation 2016* is a subordinate legislation made under the *Water Act 2000* and details administrative and operational matters for the Act. Matters governed by the *Water Regulation 2016,* with relevance to the Project include, but are not limited to:

- Provide matters for the Minister's report on water plans
- Prescribe the purpose and conditions for which a constructing authority may take water
- Prescribes activities for which the taking of, or interfering with, water is authorised without an entitlement
- Provide for matters relating to water licences
- Provide matters for water supply and demand management
- Allow for seasonal water assignments and prescribe associated rules
- Provide criteria for establishing water allocations and prescribe water allocation dealing rules
- Prescribe requirements for decommissioning water bores
- Provide for works that are self-assessable and assessable development for the *Planning Act 2016* and prescribe the associated codes
- Make declarations about underground water taken to be water in a watercourse
- Provide rules for managing underground water that is not managed through a water plan.

2.2 Policies and plans

2.2.1 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

Under the EP Act, the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP (Water and Wetland Biodiversity)) achieves the objectives of the Act in relation to Queensland waters. The purpose of the EPP (Water and Wetland Biodiversity) is achieved by:

- Identify EVs and management goals for Queensland waters
- Providing state water quality guidelines and water quality objectives (WQOs) to enhance or protect the EVs
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters.

Groundwater resources within the impact assessment area occur within two river basins with identified EVs and WQOs under the EPP (Water and Wetland Biodiversity). These basins are:

- Queensland Border Rivers catchment from Ch 30.6 km (NS2B) to Ch 117.0 km
- Condamine River Basin from Ch 117.0 km to Ch 206.9 km.

EVs relevant to the Project are presented in detail in Section 5.

2.2.2 Healthy Waters Management Plans

Healthy Waters Management Plans (HWMPs) are a key planning mechanism to improve the quality of Queensland waters under the EPP (Water and Wetland Biodiversity). HWMPs provide an ecosystem-based approach to integrated water management and include:

- Identification and mapping of EVs, desired levels of aquatic ecosystem protection and management goals for Queensland waters
- WQOs under the National Water Quality Management Strategy (NWQMS) to protect the EVs
- Management responses, which address point and diffuse emission sources, and may include market-based instruments, best management practice and adaptive management.

The relevant HWMPs for the Project include:

- Ch 30.6 km (NS2B) to Ch 117.0 km: within the boundaries of the Border Rivers catchment. The relevant EVs for the impact assessment area are described in the Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins (DES 2019c).
- Ch 117.0 km to Ch 206.9 km: within the boundaries of the Condamine-Balonne River catchment. The relevant EVs for the impact assessment area are described in the Healthy Waters Management Plan: Condamine River Basin (DES 2019b).

EVs relevant to the Project are presented in detail in Section 5 of this report.

2.2.3 Basin Plan 2012 (Basin Plan)

The Basin Plan is a Commonwealth instrument, made under subparagraph 44(3)(b)(i) of the *Water Act 2007* (Cth), that provides a framework to manage the water resources of the Murray-Darling Basin and sets out limits for sustainable use of surface water and groundwater in each water resource plan area.

The impact assessment area is located within the Condamine and Balonne (groundwater unit GW21) and the Border Rivers and Moonie (groundwater unit GW19) water resource plan area, which are covered by the Basin Plan. Both of these water resource areas have water plans, which are discussed further in Section 2.2.4.

2.2.4 Water plans

Water sharing plans were developed under the *Water Act 2000* to sustainably manage and allocate water resources in Queensland. The plans apply to water in watercourses and lakes, water in springs, overland flow water, and groundwater and allow for identification of availability of water options for project uses.

Three water sharing plans, and associated groundwater units, are relevant to the Project. Each of these are described below.

Each of the groundwater units identified as relevant for the groundwater impact assessment are described in detail in Section 4.7. Water entitlements under each of the water sharing plans are discussed in Section 4.7.6

2.2.4.1 Water Plan (Border Rivers and Moonie) 2019

The Water Plan (Border Rivers and Moonie) is applicable to the Border Rivers catchment, south of Millmerran. The Border Rivers Alluvium, as defined in this plan, is relevant to the Project.

2.2.4.2 Water Plan (Condamine and Balonne) 2019

This plan is applicable to the Project north of Millmerran, where the following groundwater units occur, as defined in this plan:

- Condamine Alluvium
- Upper Condamine Basalts (i.e. Main Range Volcanics).

2.2.4.3 Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017

This plan is applicable to the following groundwater units within the impact assessment area:

- Kumbarilla Beds
- Walloon Coal Measures (WCM).

2.3 Guidelines

2.3.1 Australia and New Zealand Guidelines for Fresh and Marine Water Quality

The objective of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (ANZECC and ARMCANZ, 2018) is to provide authoritative guidance on the management of water quality in Australia and New Zealand. The guidelines include setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources.

The Water Quality Guidelines provide:

- A platform for consistent water quality management and planning
- Technical support for Australia's National Water Quality Management Strategy and New Zealand's National Policy Statement for Freshwater Management
- Sound tools for governments and the community to assess and manage ambient water and sediment quality.

The ANZG have been used to assess groundwater quality in the impact assessment area.

2.3.2 National Health and Medical Research Council Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines (ADWG) (NHMRC & NRMMC, 2011) provide guidance to water regulators and suppliers on monitoring and managing drinking water quality. The ADWG provides details on the framework for Management of Drinking Water Quality, which is a preventive management approach that encompasses all steps in water production from catchment to consumer, and aims to assure safe, good quality drinking water. The ADWG is used by state and territory health departments, local health authorities and water utilities.

The ADWG were used to assess groundwater quality in the impact assessment area.

2.3.3 Application requirements for activities with impacts to water guideline

The Department of Environment and Science (DES) *Guideline: Application requirements for activities with impacts to wate*r (DES, 2017) focuses on the types of impacts that environmentally relevant activities (ERAs) can have on water, and outlines the information to be provided to the department as part of the ERA application process. This guideline is applicable to the following ERAs:

- Controlled/planned releases to water
- Uncontrolled/unplanned releases to water
- Changes to the quantity and quality of stormwater runoff from the site of the ERA
- Indirect impacts
  - Disturbance to the bed or banks of waters
  - Turbidity due to disturbance or clearing of riparian vegetation during construction
  - Changes to groundwater formation characteristics
  - Changes to groundwater ecology (and surface water ecology).

Based on the proposed works associated with the Project, this guideline is not considered relevant to groundwater in the impact assessment area.

2.3.4 EIS information guideline – Water 2016

The DES *EIS information guideline – Water* (DES, 2016) has been developed to assist in the assessment of water resources for EISs. This intent of this guideline has been considered in developing the methodology, approach, and data sources for this groundwater impact assessment. The guideline is complimentary to the Project-defined ToR, established in November 2018 by the Coordinator-General.

2.3.5 Queensland Water Quality Guidelines 2009

The Queensland Water Quality Guidelines (DEHP, 2009) provide the approach to determine guideline values for physical and chemical stressors. The guidelines indicate the ANZG (2018) includes default guidelines values however local water quality information is the first reference point and the water quality guideline values for physical and chemical stressors follows the hierarchy defined below:

1. EPP (Water and Wetland Biodiversity) scheduled EVs and WQOs
2. End of catchment anthropogenic pollutant reduction targets in Great Barrier Reef catchments
3. Queensland water quality guidelines (in the absence of EPP (Water and Wetland Biodiversity) scheduled EVs and WQOs
4. Water monitoring protocols contained in the Queensland Monitoring and Sampling Manual (2018).

This assessment includes EVs and WQOs provided in the EPP (Water and Wetland Biodiversity), which is the priority source for water quality guideline values as they are developed based on local water quality conditions (refer Section 2.2.1).

3 Methodology

3.1 Approach

A staged approach has been adopted for the groundwater assessment for the Project. This methodology allows for the compilation and assessment of sufficient data to address the groundwater requirements of the ToR and the provision of recommendations for impact avoidance and mitigation through the reference design and future Project phases. Stages adopted for the groundwater study include:

- Stage 1 – Desktop study
- Stage 2 – Reference design phase investigations
- Stage 3 – Groundwater impact assessment
- Stage 4 – Significance assessment.

3.1.1 Stage 1 – Desktop study

Available geological and hydrogeological literature and data were reviewed to establish a detailed description of the existing hydrogeological regime and identification of groundwater EVs. Interrogation of publicly available databases, including the DNRME Groundwater Database, was undertaken to identify registered groundwater bores within the impact assessment area and corresponding groundwater level and quality data. In addition, published studies and reports of relevance to the impact assessment area were reviewed to further inform the understanding of regional geological and hydrogeological characteristics. Data sources accessed for this assessment are specified in Section 3.4.

3.1.2 Stage 2 – Reference design phase investigations

Groundwater investigations were undertaken between May 2018 and February 2019, concurrent with geotechnical investigations that were completed to inform development of the reference design.

Direct impacts by new freight rail infrastructure on groundwater resources are typically associated with locations of deep cuts and bridge piling works. Project monitoring bores were primarily located near proposed bridge structures and deep cuttings (> 10 m) to reflect this risk and to provide site-specific groundwater data within areas considered most likely to be affected by the Project. The site-specific groundwater data collected was used to further refine and describe the existing hydrogeological regime.

The scope and findings of the groundwater investigations are discussed in Section 6.

3.1.3 Stage 3 – Groundwater impact assessment

Potential impacts on the existing groundwater regime, at local and regional scales, were identified and assessed based on review of planned construction and rail operation activities with respect to the current geological and hydrogeological environment.

Groundwater numerical modelling was performed for the Project in the form of two-dimensional (2-D) cross sectional models in locations where deep cuttings (> 10 m) are proposed as part of the reference design. The predictive modelling was used to inform development of the reference design for the Project in terms of potential drawdown and seepage rates in locations where deep cuttings may be required. Modelling results were reviewed and interpreted to assess potential impacts on groundwater resources from the Project.

A detailed discussion of the modelling results is provided in Section 7.3.

3.1.4 Stage 4 – Significance assessment

Potential impacts on groundwater resources have been assessed using a qualitative significance assessment method. For groundwater, the significance of an impact is dependent upon the sensitivity of the groundwater EVs (i.e. the quality of the environment to be impacted) and the magnitude (i.e. intensity, duration and potential spatial extent) of the identified potential impact. Determination of the sensitivity of the groundwater EVs and the magnitude of the potential impact enables the assessment of the significance of potential groundwater impacts.

This approach has allowed for the evaluation of significance classifications, with and without mitigation. These mitigation measures have been used as a basis for developing an outline for a Groundwater Monitoring and Management Program (GMMP) for the Project, as discussed in Section 9.3.

3.2 Impact assessment methodology

A qualitative impact assessment for groundwater has been applied in the form of a significance-based impact assessment framework to identify and assess Project-related impacts in relation to environmental receptors.

For the purpose of this assessment, a 'significant impact' is dependent upon the sensitivity of the groundwater EV, the quality of the environment to be impacted, and the intensity, duration, magnitude, and potential spatial extent of the identified potential impact. Determination of the sensitivity/vulnerability of the groundwater EVs and the magnitude of the potential impact facilitate the assessment of the significance of potential groundwater impacts. The following sections discuss and define impact magnitudes, receptor sensitivity, and impact significance.

3.2.1 Magnitude of impacts

The magnitude of a potential impact is essential to the determination of its level of significance on EVs/receptors. For the purposes of the groundwater assessment, impact magnitude is defined as being comprised of the nature and extent of the potential impacts, including direct and indirect impacts.

The impact magnitude is divided into five classifications, as included in Table 3.1. The magnitude of a potential impact is determined with techniques and tools that facilitate an estimation of the extent, duration, and frequency of the potential impacts.

Table 3.1 Magnitude classifications of potential impacts

Magnitude	Description
Major	An impact that is widespread, permanent and results in substantial irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of environmental management controls are required to address the impact.
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the Project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.
Negligible	An extremely localised impact that is barely discernible and is effectively mitigated through standard environmental management controls.

Table 3.2 presents the timeframes for impact duration terms utilised to inform the magnitude of a potential impact.

Table 3.2 Timeframes for duration terms

Duration term	Timeframe – to be defined for each receptor type if required
Temporary	Days to months (e.g. 1 to 2 seasons; 3 to 12 months)
Short term	Up to 2 years (i.e. 12 to 24 months)
Medium term	From 2 to 10 years[1]
Long term/long lasting	From 11 to 20 years[2]
Permanent or irreversible	More than 21 years[3]

Table notes:

1 Derived from the term 'moderate' EAM Risk Management Framework 2009 (GBRMPA 2009)
2 Derived from the term 'major' EAM Risk Management Framework 2009 (GBRMPA 2009)
3 Derived from the term 'catastrophic' EAM Risk Management Framework 2009 (GBRMPA 2009).

Potential impacts identified for the Project are presented in Section 8; the impact assessment performed for the Project with respect to groundwater resources is presented in Section 10.

3.2.2 Sensitivity of impacts

To assess the significance of potential impacts on groundwater resources, sensitivity categories are applied to each of the identified groundwater EVs. The sensitivity categories are split into five discrete groups as described in Table 3.3. These groupings are based on qualitative assessments utilising information related to the sensitivity or vulnerability of the EV and the magnitude of the potential impact (refer Table 3.1).

Through the determination of sensitivity categories for each of the identified groundwater EVs, the potential impacts are then able to be assessed through a matrix against the magnitude of the potential project impact to indicate the level of significance for each of the impact types on the groundwater EVs.

Table 3.3 Sensitivity criteria

Sensitivity	Description
Major	▪ The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance and/or ▪ The environmental value is entirely intact and wholly retains its intrinsic value and/or ▪ The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area, which is poorly represented in the region, state, country or the world and/or ▪ It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the environmental value. ▪ Project activities would have an adverse effect on the value.
High	▪ The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance and/or ▪ The environmental value is intact and retains its intrinsic value and/or ▪ The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area, which is poorly represented in the region and/or ▪ The environmental value has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the sensitive value. ▪ Project activities would have an adverse effect on the value.
Moderate	▪ The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers and/or ▪ The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements and/or ▪ It is relatively well represented in the systems/areas in which it occurs, but its abundance and distribution are exposed to threatening processes and/or ▪ Threatening processes have reduced its resilience to change. Consequently, changes resulting from Project activities may lead to degradation of the prescribed value and/or ▪ Replacement of unavoidable losses is possible due to its abundance and distribution.

Sensitivity	Description
Low	▪ The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations e.g. historical societies and/or ▪ The environmental value is in a poor to moderate condition as a result of threatening processes, which have degraded its intrinsic value and/or ▪ It is not unique or rare and numerous representative examples exist throughout the system/area and/or ▪ It is abundant and widely distributed throughout the host systems/areas and/or ▪ There is no detectable response to change or change does not result in further degradation of the environmental value and/or ▪ The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is achievable.
Negligible	▪ The environmental value is not listed on any recognised or statutory register and is not recognised locally by relevant suitably qualified experts or organisations and/or ▪ It is not unique or rare and numerous representative examples exist throughout the system/area and/or ▪ There is no detectable response to change or change does not result in further degradation of the environmental value.

3.2.3 Significance of impact

The significance of a potential impact is a function of the sensitivity of the EV and the magnitude of the potential impact. Although the sensitivity of the EV will not change (i.e. is generally determined qualitatively by the interaction of the receptor's condition, adaptive capacity, and resilience), the magnitude of the potential impact is variable and may be categorised quantitatively to facilitate the prediction of the significance of the potential impact.

Once the EV has been identified, and the sensitivity of the value and the magnitude of the potential impact have been determined, a significance assessment of the potential impact can be conducted via application of a five by five matrix as detailed in Table 3.4.

Table 3.4 Significance assessment matrix

Magnitude of impact	Sensitivity				
	Major	**High**	**Moderate**	**Low**	**Negligible**
Major	Major	Major	High	Moderate	Low
High	Major	Major	High	Moderate	Low
Moderate	High	High	Moderate	Low	Low
Low	Moderate	Moderate	Low	Negligible	Negligible
Negligible	Moderate	Low	Low	Negligible	Negligible

Definitions for each of the significance classifications are provided in Table 3.5.

Table 3.5 Significance classifications

Significance rating	Description
Major	Arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
High	Occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
Moderate	Results in degradation of the environmental value due to the scale of the impact or its susceptibility to further change even though it may be reasonably resilient to change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.

Significance rating	Description
Low	Occurs where an environmental value is of local importance and temporary or transient changes will not adversely affect its viability provided standard environmental management controls are implemented.
Negligible	Does not result in any noticeable change and hence the proposed activities will have negligible effect on environmental values. This typically occurs where the activities are located in already disturbed areas.

Upon identification of the level of significance of a potential impact, mitigation measures can then be applied to the potential (unmitigated) impact to identify the residual (mitigated) impact.

The identified potential impacts on groundwater resources, because of the Project, are presented in Section 8. Section 9 includes mitigation measures for the identified potential impacts and Section 10 presents a significance impact assessment for the Project (refer Table 10.1).

3.3 Cumulative impact assessment

It is a requirement of the ToR for this Project that the potential for cumulative impacts be considered. 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.

A groundwater cumulative impact assessment is presented in Section 11.

3.4 Data sources

The groundwater impact assessment has been developed in reference to information obtained from publicly available, published datasets and reports and from site-specific geotechnical and hydrogeological investigations. The information sources listed in Table 3.6. have been referenced in establishing an understanding of the existing hydrogeological regime within the impact assessment area and in the assessment of potential impacts on groundwater resources.

Table 3.6 Primary data sources for the groundwater technical report

Data	Source
Hydrology/climate	▪ Historical Climate Database - BoM (http://www.bom.gov.au/climate/data/) ▪ EIS Appendix P: Surface Water Technical Report ▪ Queensland Globe datasets (https://qldglobe.information.qld.gov.au/)
Soil types	▪ Inland Rail: Phase 2 - Border to Gowrie - Geotechnical Interpretive Report (October 2019) (FFJV, 2019b) ▪ Queensland Globe datasets (https://qldglobe.information.qld.gov.au/)
Geology/ hydrostratigraphy	▪ Inland Rail: Phase 2 - Border to Gowrie - Geotechnical Interpretive Report (FFJV, 2019b) ▪ Inland Rail: Phase 2 - Border to Gowrie - Geotechnical Factual Report (Golder, 2019a ▪ Inland Rail Condamine River Valley Geotechnical Investigation – Factual Report, Inland Rail Project – Border to Gowrie Section (Golder, 2019b) ▪ Inland Rail: Border to Gowrie – 100% Feasibility Design Scope of Works – Hydrogeology (Golder, 2019c) ▪ Goondiwindi 1:250,000 Geological Sheet – 1972 (NSW Planning and Environment-Resources and Geosciences) ▪ DNRME groundwater database ▪ Queensland Globe geological map datasets (https://qldglobe.information.qld.gov.au/)

Data	Source
Groundwater Levels and Quality	■ DNRME groundwater database (online) ■ Queensland Globe datasets (https://qldglobe.information.qld.gov.au/) ■ Inland Rail: Border to Gowrie – 100% Feasibility Design Scope of Works – Hydrogeology (Golder, 2019c)
Groundwater Dependent Ecosystems (GDEs)	■ GDE Groundwater Dependent Ecosystem Atlas - Bureau of Meteorology (BoM): (http://www.bom.gov.au/water/groundwater/gde/map.shtml) ■ Queensland Globe datasets (https://qldglobe.information.qld.gov.au/)
Groundwater Use and Management	■ DNRME groundwater database ■ Water Plan (Border Rivers and Moonie) 2019 ■ Water Plan (Condamine and Balonne) 2019 ■ Water Plan (Great Artesian Basin and Other Regional Aquifers [GABORA]) 2017

4 Existing environment

4.1 Land use

Land use within the impact assessment area is predominately grazing land (refer Figure 1.1). The next most common land uses are also predominately of an agricultural nature including cropping and irrigated cropping. Other land uses which exceed one per cent of the Project footprint include land classified as other minimal use (consisting of areas of land that are largely unused, for example, residual native cover or land reserved for stock routes), production forestry and transport and communication (which includes transportation infrastructure and commercial services).

Grazing, cropping and resource extraction land uses are particularly of relevance to the profile of existing groundwater usage and impacts within the impact assessment area.

Stock grazing on native and modified pasture is distributed throughout most of the impact assessment area whilst cropping occurs across floodplain areas. Irrigated cropping (cotton and grain) is focused on the river floodplains of the Macintyre and Dumaresq rivers, Macintyre Brook, Condamine River and Gowrie Creek.

The Commodore Mine is located south of Millmerran. At its closest point, the Project is situated approximately 600 m to the west of the current mining operations.

Coal seam gas (CSG) production is a major regional activity; however, the nearest CSG production bores are located over 40 km from the Project, near Cecil Plains (refer location overview for proximity of Cecil Plains to the Project alignment in Figure 1.1).

4.2 Watercourses

Under the *Water Act 2000* a watercourse is defined as a river, creek or other stream, which includes a stream in the form of an anabranch or a tributary, where water flows either permanently or intermittently regardless of flow frequency. A watercourse, however, does not include any section of a feature that has a tidal influence or is upstream or downstream from a defined limit (State of Queensland 2018).

The Project intersects the full width of 15 major waterways (stream order ≥ 3) and 66 minor waterways (stream order < 3). The major waterways that are crossed by the Project are as follows:

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

The Project does not include a full width crossing of the Macintyre River. Therefore, it is not included in this summary.

In addition to the natural watercourses summarised above, there are several artificial/constructed waterbodies located within the impact assessment area and that are intersected by the Project alignment. These twelve (12) artificial/constructed waterbodies are predominantly rural farm dams used for agricultural purposes and typically occur along unnamed drainage watercourses. The artificial waterbodies are located at various chainages from approximately Ch 75.4 km to Ch 161.4 km.

The primary watercourses which the Project intersects are presented on Figure 4.1a-d

4.3 Catchments

The Project is located across two surface water catchment areas, the Condamine River basin and the Border Rivers basin (refer Figure 4.1a-d). The Project alignment extends through the Borders Rivers basin from the NSW/QLD border to approximately 15 km southwest of Millmerran (Ch 117.0 km). From this point, the Project alignment is located in the Condamine River basin until its northern end point at Ch 206.9 km.

The Border Rivers basin covers approximately 23,800 km^2 and, in combination with the Moonie River basin, comprises approximately 12 per cent of the Queensland portion of the Murray-Darling basin (DES, 2019b). 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, 2019b). 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. 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, 2019b).

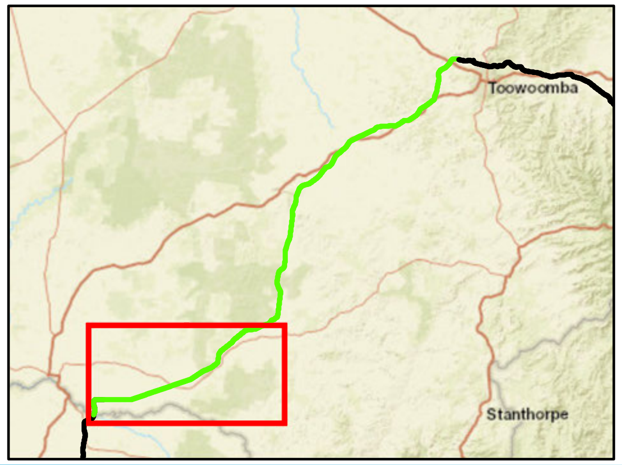
The Condamine River basin covers approximately 25,440 km^2 and comprises approximately 9 per cent of the Queensland Murray-Darling basin (DES, 2019a). The Condamine River basin forms part of the headwaters of the Murray-Darling basin river system that flows through the southern states.

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

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

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

Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.1_Hydrology_Topography_v6.mxd Date: 25/05/2020 13:38



Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border
- 20m Contour
- Border Rivers catchment
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5 km

Future Freight
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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Figure 4.1a:
Topography and surface water features

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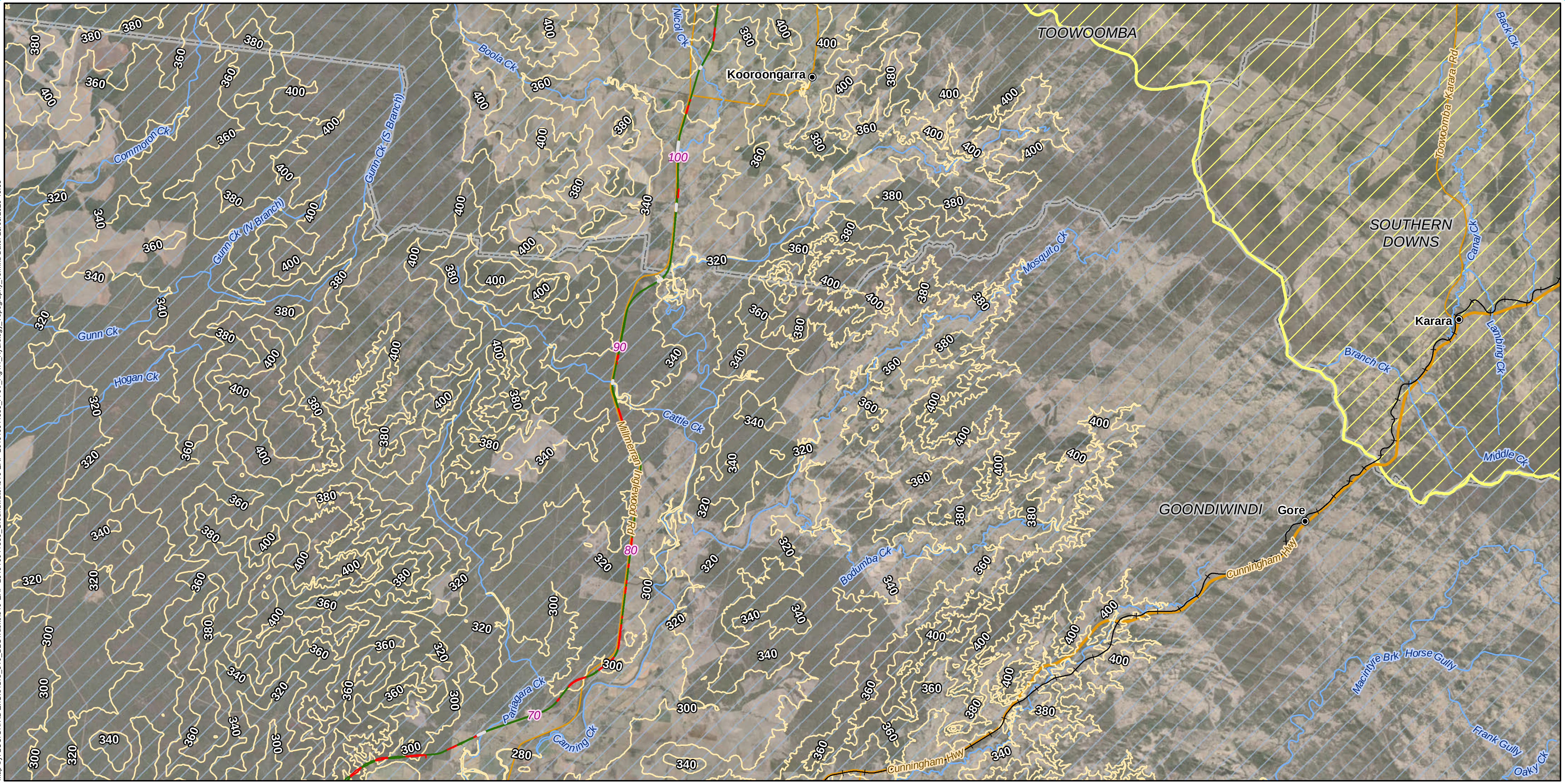

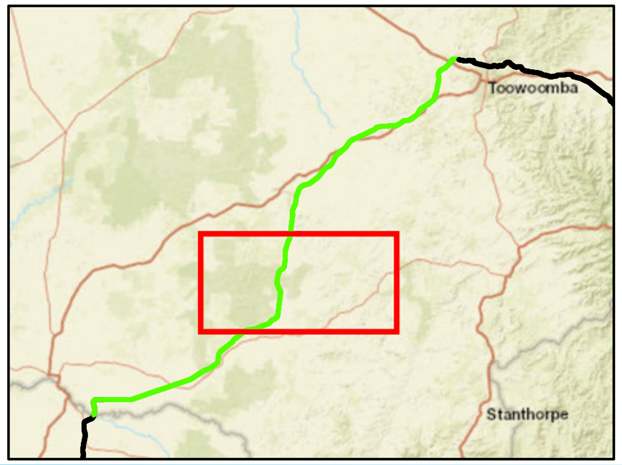

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Major roads
- Minor roads
- Watercourses
- 20m Contour
- Border Rivers catchment
- Condamine and Balonne catchment
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5 km

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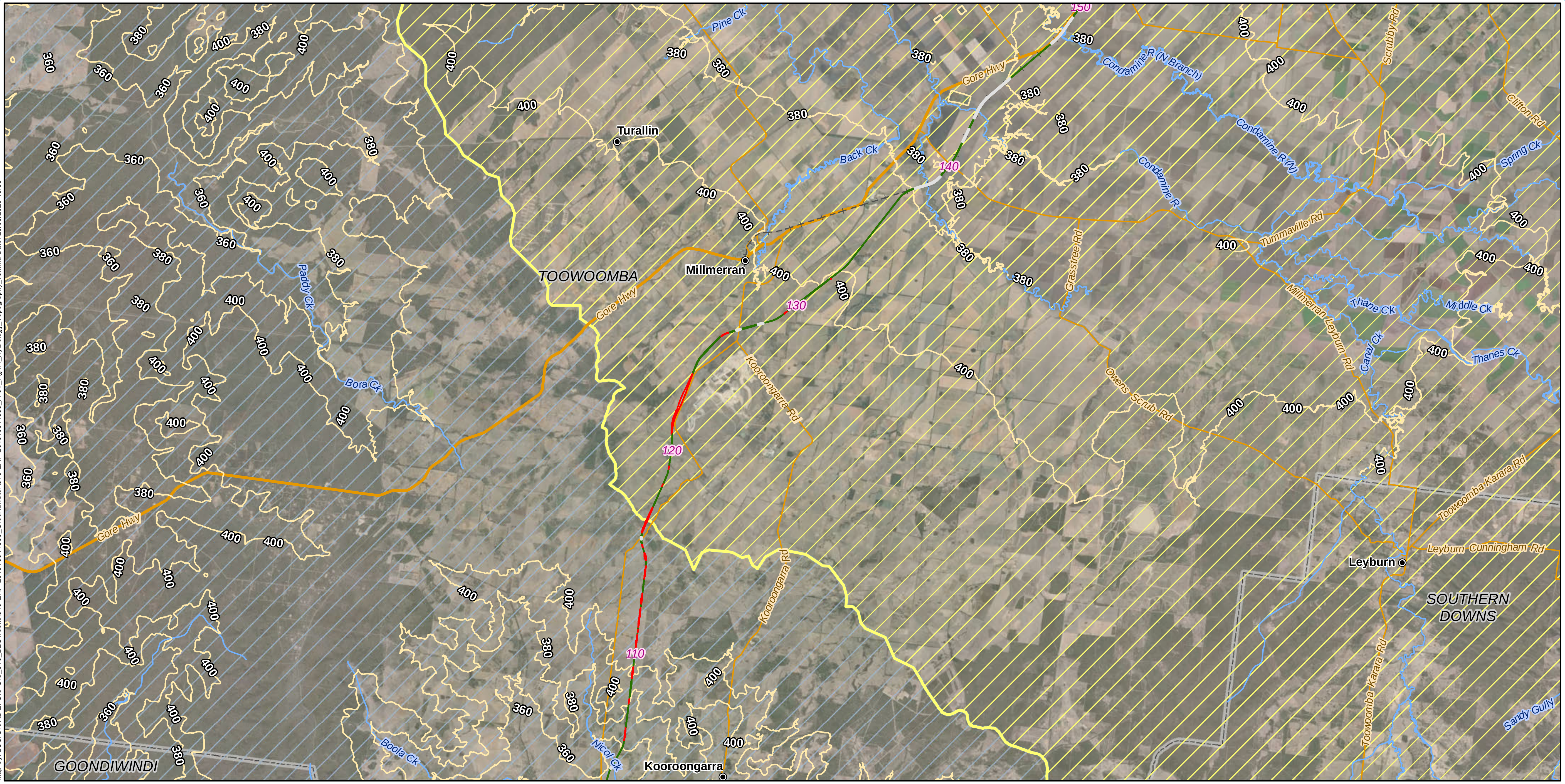
Coordinate System: GDA 1994 MGA Zone 56

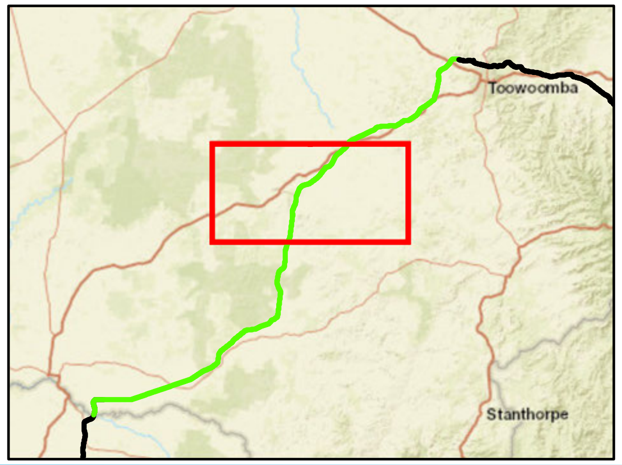
Border to Gowrie

Figure 4.1b:
Topography and surface water features

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



Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.1_Hydrology_Topography_v6.mxd Date: 25/05/2020 13:38



Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Bridges
- Major roads
- Minor roads
- Watercourses
- 20m Contour
- Border Rivers catchment
- Condamine and Balonne catchment
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5 km

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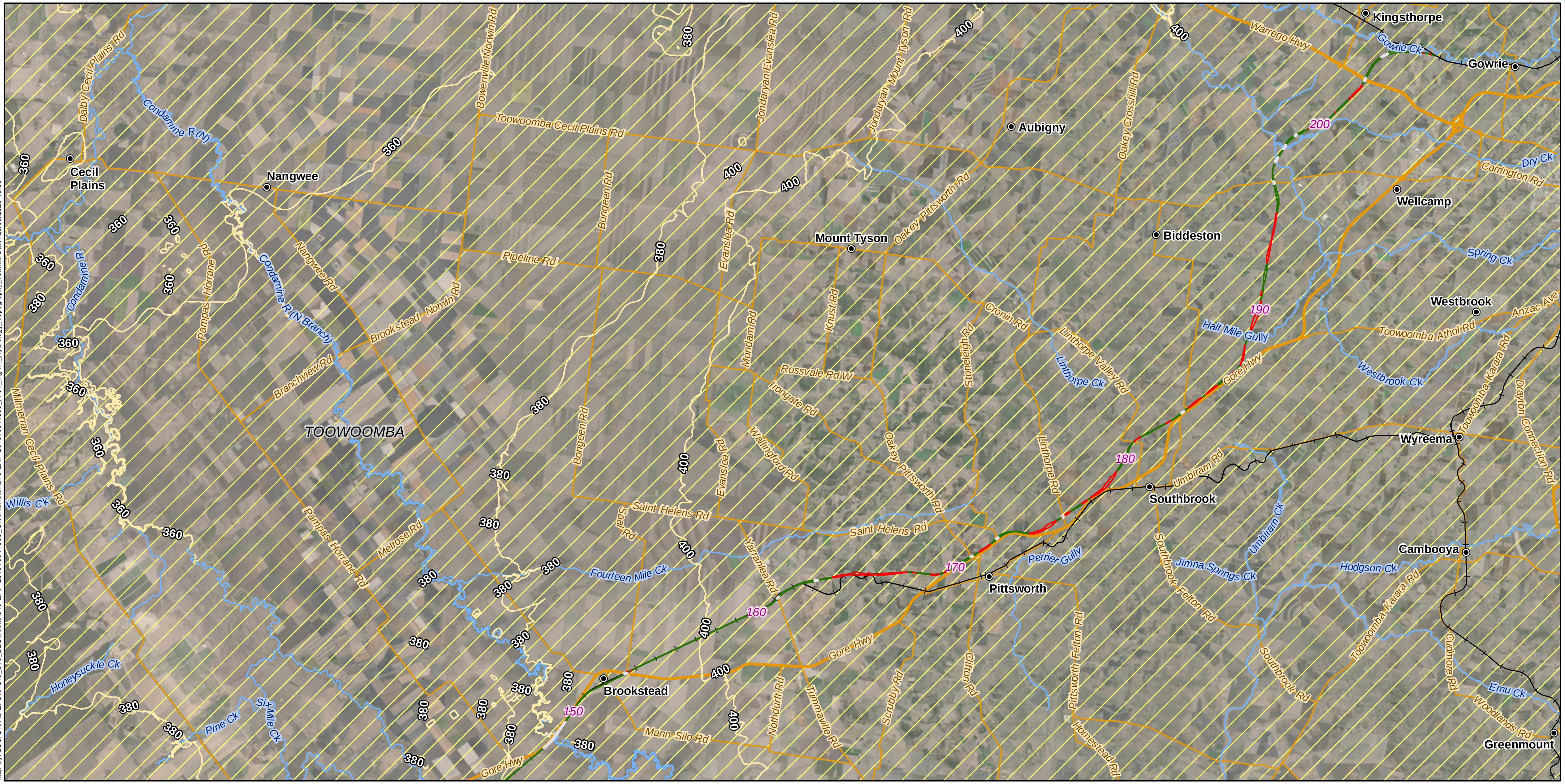
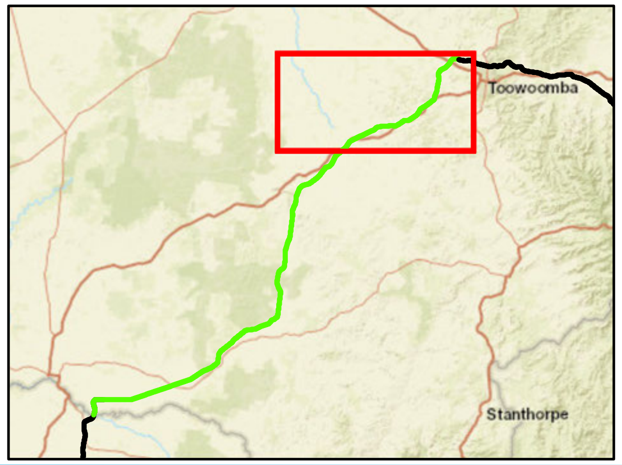
Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.1c:
Topography and surface water features

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





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Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Bridges
- Major roads
- Minor roads
- Watercourses
- 20m Contour
- Condamine and Balonne catchment
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.1d:
Topography and surface water features

4.4 Climate

A review of the BoM climate data was undertaken and information was sourced from the monitoring station proximal to Inglewood, Woodspring (041391) (BoM 2018). The region has a typical hot and dry climate and typically experiences warm to hot summers and mild to cool winters. Rainfall is seasonally distributed with a distinct wet season occurring during the summer months of December through February and an extended dry season during the months of April through September. Mean maximum monthly temperatures typically range from 26.9°C in the summer to 11.5°C in the winter.

4.4.1 Rainfall

Rainfall data was collected from six weather stations across the impact assessment area to assess rainfall and evaporation rates from 1883 to 2018. Both currently active and inactive stations indicated that the area receives an average of between 600 mm and 700 mm of annual rainfall (BoM 2018).

Table 4.1 identifies the recorded rainfall data for the six weather stations across the impact assessment area. The region receives its heaviest rainfall in summer, with the highest recorded single rainfall event occurring in January 2010 with 433.6 mm. During the winter months, the area predominantly receives low to no rainfall (BoM 2018).

Table 4.1 Weather stations within proximity of the Project and rainfall data

Station number	Name	Approximate distance from Project (km)	Operation date	Annual rainfall average (mm)	Month of highest rainfall/ record amount (mm)	Month of lowest rainfall/ record amount (mm)
041391	Woodspring	5	1954-2018	636.5	Dec (330.7)	Aug (0.0)
041047	Inglewood Post Office	2	1883-2018	656.5	Jan (400.4)	Jul (0.0)
41069	Millmerran Post Office	2	1900-2018	662.6	Jan (343.6)	Aug (0.0)
041110	Turallin	10	1909-2018	678.5	Dec (333.5)	Jul (0.0)
41314	Brookstead Post Office	<1	1958-2018	647.7	Dec (370.2)	Jun (0.0)
41082	Pittsworth	<1	1886-2018	695.0	Dec (433.6)	Aug (0.0)

Source: BoM (2018)

To inform the groundwater existing environment shallow aquifer characteristics, Section 4.7, climate data from the three weather stations below were assessed to characterise hydrogeologic conditions along the rail alignment:

- Inglewood Bridge (Station 041123) - located 2.5 km south of Ch 66 km – Rainfall data only
- Glen Royal (Station 041504) – located 4km north west of Ch 151 km - Rainfall data only
- Warwick (Station 041525) – located 78km south west of Ch 157 km - Rainfall and evaporation data.

Rainfall data and evaporation data (Warwick only) is summarised in Table 4.2 and presented on Figure 4.2. A seasonal rainfall pattern exists along the alignment is proposed with stable dry winters and warm to hot summers. Moderate to high rainfall is typical during summer storm activity. Monthly mean rainfall at Inglewood Bridge is typically 10 - 30mm less than Glen Royal and Warwick stations indicating the western portion of the alignment (i.e. Ch 36.6 km [NS2B] to Ch 100 km) is likely to experience lower monthly rainfall.

Evaporation data from Warwick indicates a net water deficit throughout the year (refer Table 4.2). The closest BoM weather station that records evaporation is the Oakey Aero station (041359), which is located approximately 13 km northwest of Gowrie and 11 km from the impact assessment area. From 1973 to 2018 evaporation data for the impact assessment area generally consisted of higher evaporation in the summer months where the mean average evaporation rate was 7.7 mm compared to the winter months where the mean evaporation rate was 3.2 mm (BoM 2019).

Modelling of future aquifer recharge trends due to global warming suggests much of Eastern Australia, including the Border Rivers and Condamine catchments, could experience a decrease in recharge (CSIRO 2011). This decrease is projected for the period 2030 to 2050, which may have impacts on the land use, watercourses, and shallow aquifers in the region.

Table 4.2 Summary of rainfall and evaporation data for Inglewood Bridge (041123), Glen Royal (041504) and Warwick (041525)

Month	Mean rainfall (mm)			Minimum rainfall (mm)			Maximum rainfall (mm)			Warwick mean evaporation (mm)
	Inglewood Bridge	Glen Royal	Warwick	Inglewood Bridge	Glen Royal	Warwick	Inglewood Bridge	Glen Royal	Warwick	
January	58.1	85.8	84.0	2.0	0.0	3.6	178.8	285.7	176.2	210.8
February	47.0	75.3	63.4	0.0	0.0	8.8	96.0	194.0	171.6	173.6
March	57.1	59.2	68.6	0.0	0.0	0.0	204.8	329.4	214.2	158.1
April	21.5	36.1	28.6	0.0	0.0	0.0	63.0	253.0	74.6	120.0
May	25.1	41.4	38.2	0.0	0.0	0.0	99.0	289.6	187.6	86.8
June	32.3	32.0	38.0	0.0	0.0	3.0	94.0	121.5	109.8	66.0
July	20.3	34.8	25.3	0.0	0.0	0.0	71.0	140.5	101.6	74.4
August	27.2	30.1	26.4	0.2	0.0	0.0	88.0	104.7	108.6	108.5
September	27.3	30.7	35.4	0.0	0.0	0.6	108.0	109.4	125.6	144.0
October	46.3	62.4	71.6	1.0	0.0	0.6	103.0	210.9	183.5	186.0
November	47.0	69.8	85.3	7.0	0.6	22.5	129.0	240.7	198.6	198.0
December	70.6	101.1	106.0	0.0	2.0	12.4	181.0	385.6	282.4	210.8

Table note:

Rainfall statistics sourced from BoM and are representative for the following periods: Inglewood Bridge – 2001 to 2018; Glen Royal – 1928 to 2018; Warwick – 1994 to 2018.

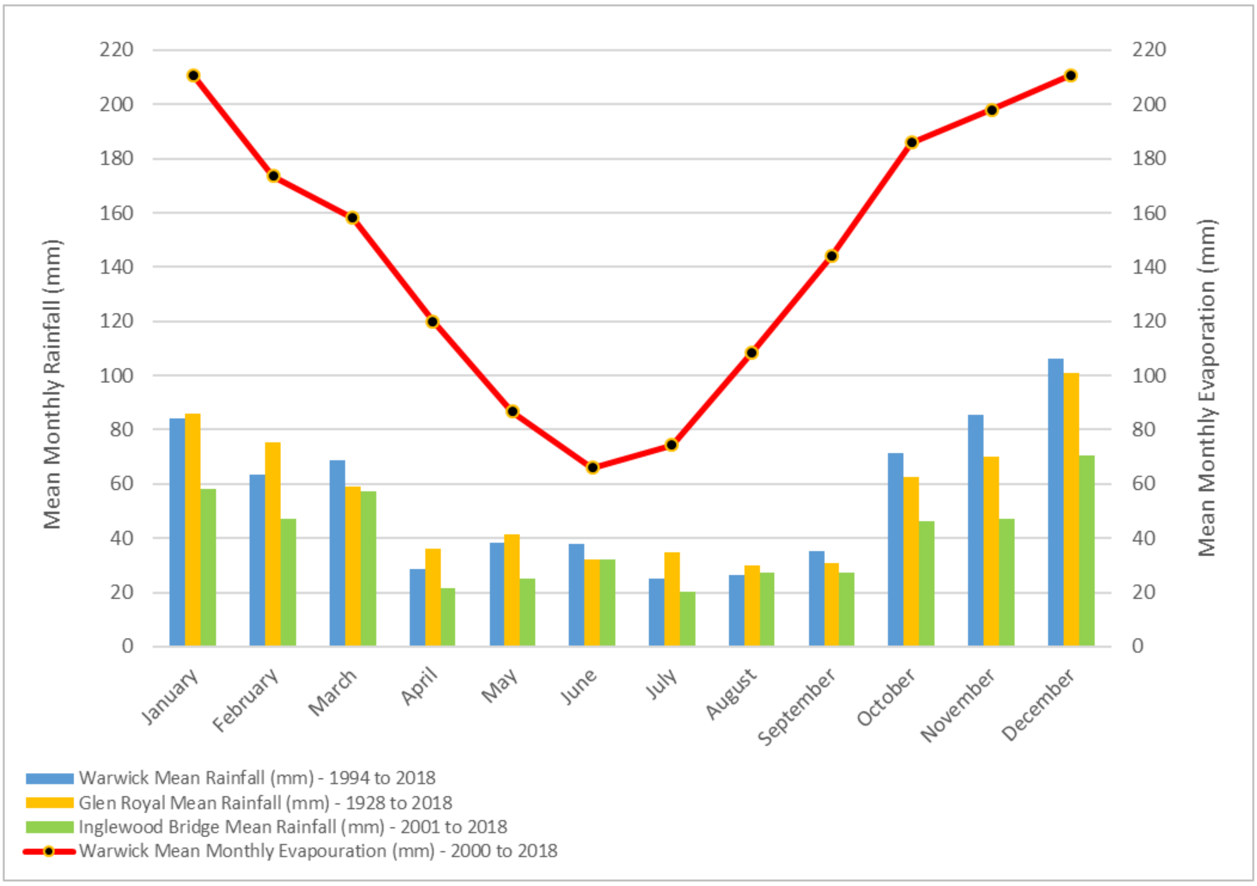


Figure 4.2 Representative mean monthly rainfall and evaporation data along the Project

Cumulative rainfall deviation from long-term monthly rainfall records at Glen Royal are presented in Figure 4.3. Under steady state conditions (i.e. no groundwater abstraction taking place), the trends in this plot may provide an indication of water level response in unconfined aquifers which receive direct rainfall recharge. A positive trend indicates periods of above average rainfall where increased groundwater recharge can occur in unconfined aquifers. A negative slope indicates periods of below average rainfall where decreased groundwater recharge may occur in unconfined aquifers.

The period 1950 to 2018 at Glen Royal (Station 041504) presented in Figure 4.3 is considered representative of conditions along the Project. The graph indicates:

- An increasing trend from 1975 to 1990 characterised by above average rainfall
- A decreasing trend from 1990 to 1995 characterised by below average rainfall
- A brief increasing trend followed by a prolonged decreasing trend from 1995 to 2010, characterised by below average rainfall
- A general increasing trend from 2010 to 2017 characterised by below average rainfall.

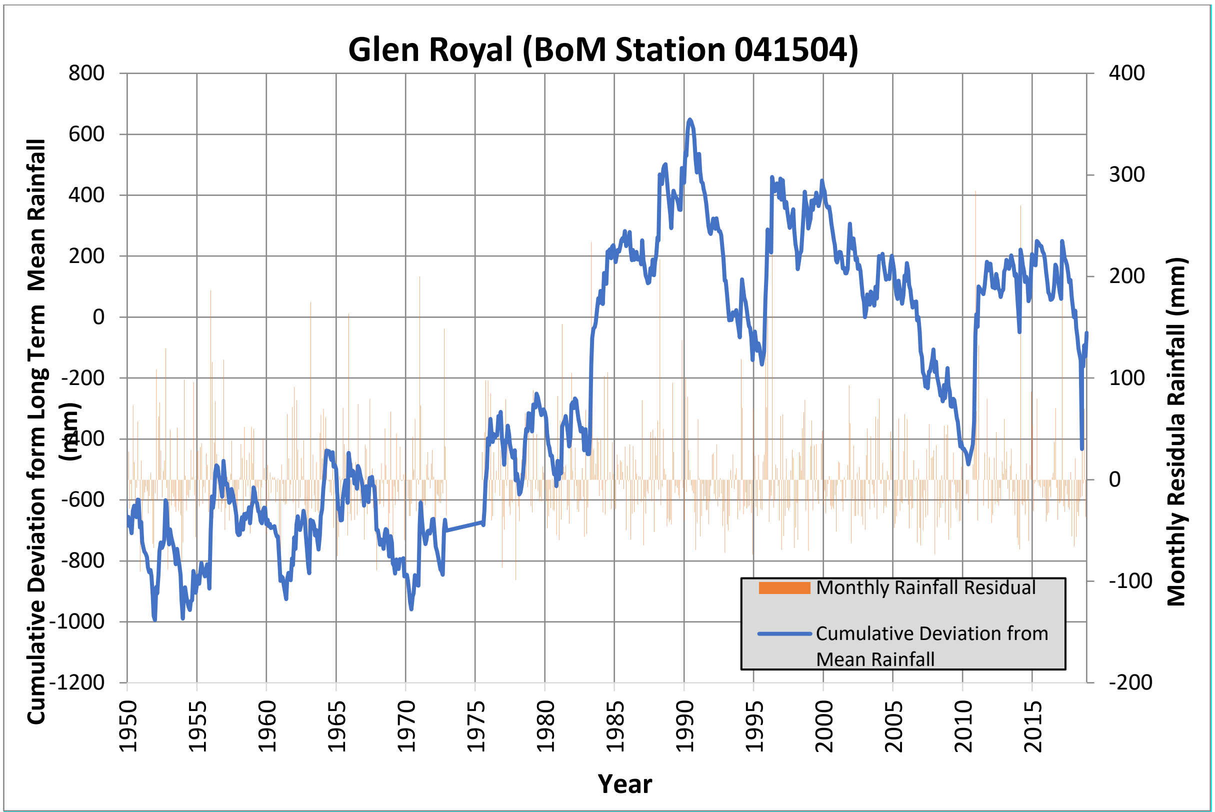


Figure 4.3 **Cumulative deviation for monthly rainfall at Glen Royal (BoM station 041504) from 1950 to 2015**

4.4.2 Temperature

The climate of the impact assessment area remains relatively warm all year round with cooler temperatures occurring during winter nights and early mornings (BoM 2018). Data was collected from the Texas Post Office (041100) weather station which is located approximately 46 km south east of Yelarbon and the Project. Between 1969 and 2019 the impact assessment area recorded an average maximum temperature of 33.1°C during summer and an average minimum temperature of 4.3°C during winter. The hottest day recorded for the impact assessment area occurred in December 1979 where it reached 37.5°C, whilst the coldest ever day record reached by the area was -1.1°C in July 1972. Figure 4.4 provides the mean maximum and minimum temperature recorded at the Texas Post Office (041100).

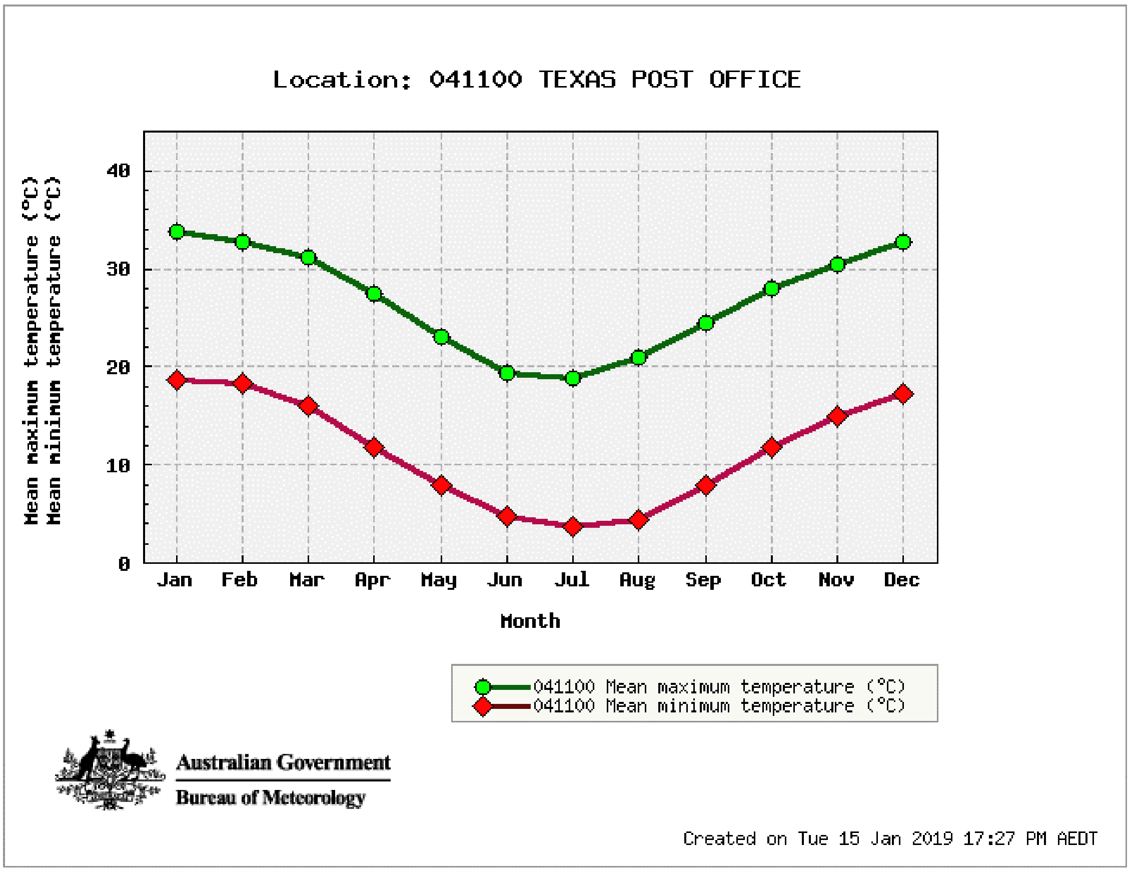


Figure 4.4 Summary of the maximum and minimum temperature recorded at Texas Post Office (041100)

Source: BoM (2019c)

4.5 Topography

The impact assessment area features two distinct areas of high elevation along flat to undulating terrain as the Project alignment passes through the floodplains of the Border Rivers and Condamine River basins (BoM, 2017a). The Project's lowest point of elevation occurs at the southern end of the Project alignment at the Macintyre River with an approximate elevation of 227 m. From this point, elevation along the Project alignment generally increases steadily in a northward direction towards Mount Domville and Commodore Peak, south of Millmerran. The Project alignment peaks at 482 m at Ch 122.2 km as it passes through the Clontarf and Millmerran area before dropping into the Condamine River floodplain, a shallow topographical parabola between Millmerran and Yarranlea with a low point of 377 m. From Yarranlea, the Project alignment increases in elevation until Ch 178.5 km near Southbrook, where a maximum elevation of 595 m is reached. From this high point, elevation of the Project alignment decreases to an end point at Ch 206.9 km of 458 m.

Topographical contours across the impact assessment area are shown on Figure 4.1a-d.

4.6 Geology

4.6.1 Regional geology

4.6.1.1 Depositional basins

The Project is underlain at depth by the depositional Permo-Triassic aged Bowen Basin. Overlying the Bowen Basin are the Jurassic to Cretaceous aged Surat and Clarence-Moreton basins which are separated by the north - south trending Kumbarilla Ridge. This ridge forms a subsurface bedrock high which the Project alignment encounters at Ch 117.0 km, as depicted in Figure 4.5.

The Bowen Basin, due to its position below the Surat and Clarence – Moreton basins, is not discussed further; however, the relevant geology for the groundwater impact assessment is presented in the subsections below.

4.6.1.2 Surat Basin

The Surat Basin is the sedimentary basin underling the rail alignment between Ch 30.60 km (NS2B) to Ch 117.0 km. Here, the basin generally consists of southwest dipping clastic Jurassic and Cretaceous aged marine sediments (Exon 1976). The basin began forming during a new phase of thermal subsidence after the Hunter-Bowen orogeny (Fielding et. al. 1993). The base of the Surat Basin is an unconformable contact over the Triassic Precipice Sandstone and underlying units, including the Moolayember Formation of the Bowen Basin.

4.6.1.3 Clarence-Moreton Basin

The Clarence - Moreton Basin is an extensive intracratonic basin which extends from the Kumbarilla Ridge in the west to the east coast of Australia (O'Brian et al. 1993). This basin underlies the eastern portion of the Project, approximately between Ch 117.0 km to Ch 206.9 km and is dominated by non-marine clastic sedimentary units.

Understanding of the tectonic setting and structural elements in the basin is still evolving (Rassam et al 2014). It is suggested that a strike-slip fault regime was initiated during major tectonic activity in the Late Carboniferous period, some 300 million years ago (Mya). Strike-slip movement occurred along several major faults which are inferred to control the magnitude of extension during evolution of the basin. As a result, the basin comprises three sub-basins: Cecil Plains sub-basin, Laidley sub-basin, and Logan sub-basin.

Structural features with a major influence on the development of depositional centres include:

- West Ipswich Fault: forms part of the Great Moreton Fault System and forms the eastern limit of the Laidley sub-basin
- Gatton Arch: a broad basement ridge over which sedimentary rocks of the Clarence - Moreton Basin are folded over and become relatively thin; the Gatton arch separates the Cecil Plains and Laidley sub-basins
- South Moreton Anticline: a broad structural high over which the basin strata are folded and thin. This structure is bounded to the west by the West Ipswich Fault and to the east by the East Richmond Fault.

The Project traverses the Cecil Plains sub-basin of the Clarence - Moreton Basin which extends from the Kumbarilla Ridge to the Toowoomba Straight (OGIA 2016b). The Cecil Plains sub-basin forms a broad undeformed depression overlying the Horrane trough and reaches a maximum thickness of 1.3 km. Further discussion with respect to structural elements is presented in Section 4.6.1.5.

4.6.1.4 Regional stratigraphy

The key stratigraphic units traversed by the Project and the equivalent nomenclature between the Surat and Clarence - Moreton basins are summarised in Table 4.3.

Table 4.3 Summary stratigraphic column of the Project

<table>
<tr><th>Age</th><th colspan="2">Surat Basin</th><th>Clarence-Moreton Basin</th><th>Lithology</th><th>Thickness</th><th>Extent and comments</th></tr>
<tr><td>Quaternary to Tertiary</td><td colspan="3">Alluvium and Colluvium (includes the Border Rivers and Condamine alluvial units)</td><td>Clays, silts, sands and gravels.
Clays in upper portions of both the Border Rivers and Condamine Alluvium is common. This is likely to reduce recharge via rainfall (Hillier 2010)</td><td>Border Rivers Alluvium: up to 100 m
Condamine Alluvium: up to 150 m</td><td>Aquifer (water table) associated with modern river sediments, paleochannels and old alluvial fans.</td></tr>
<tr><td>Tertiary</td><td colspan="3">Main Range Volcanics</td><td>Basalts, tuff and agglomerate.</td><td>Typically, 30 to 150 m, highly variable (OGIA 2016b)</td><td>Aquifer (fractured)
Outcrop and sub-crop at higher elevations along the eastern portion of the rail alignment between Ch 163.0 km and Ch 206.9 km.</td></tr>
<tr><td rowspan="4">Cretaceous</td><td colspan="2">Wallumbilla Formation</td><td rowspan="5">Kumbarilla Beds</td><td>Mudstone and siltstone</td><td>~ 100 m</td><td>Aquitard</td></tr>
<tr><td rowspan="4">Kumbarilla Beds</td><td>Bungil Formation</td><td>Mudstone, siltstone, and carbonaceous sandstone.</td><td>< 200 m</td><td>Aquitard</td></tr>
<tr><td>Mooga Formation</td><td>Clayey sandstone, siltstone and mudstones.</td><td>< 100 m</td><td>Aquifer</td></tr>
<tr><td>Orallo Formation</td><td>Interbedded siltstone and mudstone</td><td>~ 150 to 250 m</td><td>Aquitard</td></tr>
<tr><td rowspan="4">Jurassic</td><td>Pilliga Sandstone/Springbok Sandstone</td><td>Porous, fine to coarse massive sandstone and conglomerate</td><td>~100 to 300 m</td><td>Major aquifer for GAB & the Gwydir subregion</td></tr>
<tr><td colspan="3">Walloon Coal Measures</td><td>Claystone, shales, sandstones and major coal seams</td><td>~ 200 to 400 m</td><td>Leaky aquitard.</td></tr>
<tr><td colspan="2">Hutton Sandstone</td><td rowspan="2">Marburg Subgroup</td><td>Porous quartz rich sandstone.</td><td>120 to 180 m</td><td>Major Aquifer Unit</td></tr>
<tr><td colspan="2">Evergreen Formation</td><td>Mainly siltstone and mudstone</td><td>Average thickness is ~150 m</td><td>Confining Bed</td></tr>
<tr><td>Jurassic to Triassic</td><td colspan="2">Precipice Sandstone</td><td>Helidon Sandstone</td><td>Medium to coarse sandstone</td><td>Up to 110 m</td><td>Aquifer</td></tr>
<tr><td>Triassic to Permian</td><td colspan="2">Bowen Basin (Rewan Group)</td><td>Basement</td><td>Sandstone, siltstone, claystone, tuff and coal.</td><td>Up to 1,200 m</td><td>Bowen Basin underlies the Surat Basin.</td></tr>
</table>

Source: GABCC 1998 and OGIA 2016b

4.6.1.5 Structural geology

Key structural features for the region are displayed on Figure 4.5 and mapped faults of the Surat and Clarence - Moreton basins are presented on Figure 4.6.

The majority of structures identified in the Surat Basin are spatially controlled by deep faults within the underlying Bowen Basin and basement units. The primary structural feature of the Surat Basin is the Mimosa Syncline which formed the main depocenter of the basin. A major north-south trending fault, the Goondiwindi-Moonie Fault, bounds the eastern edge of the Mimosa Syncline (refer Figure 4.5). The Texas Block lies to the east of the impact assessment area.

A key structural element which separates the Surat and Clarence - Moreton basins is the north-south trending Kumbarilla Ridge (OGIA 2016b). Sedimentary units of the two basins lap over the Kumbarilla Ridge and some are hydraulically connected in this area. The Surat Basin strata between the Goondiwindi Fault and the Kumbarilla Ridge dip gently to the west (OGIA 2016b).

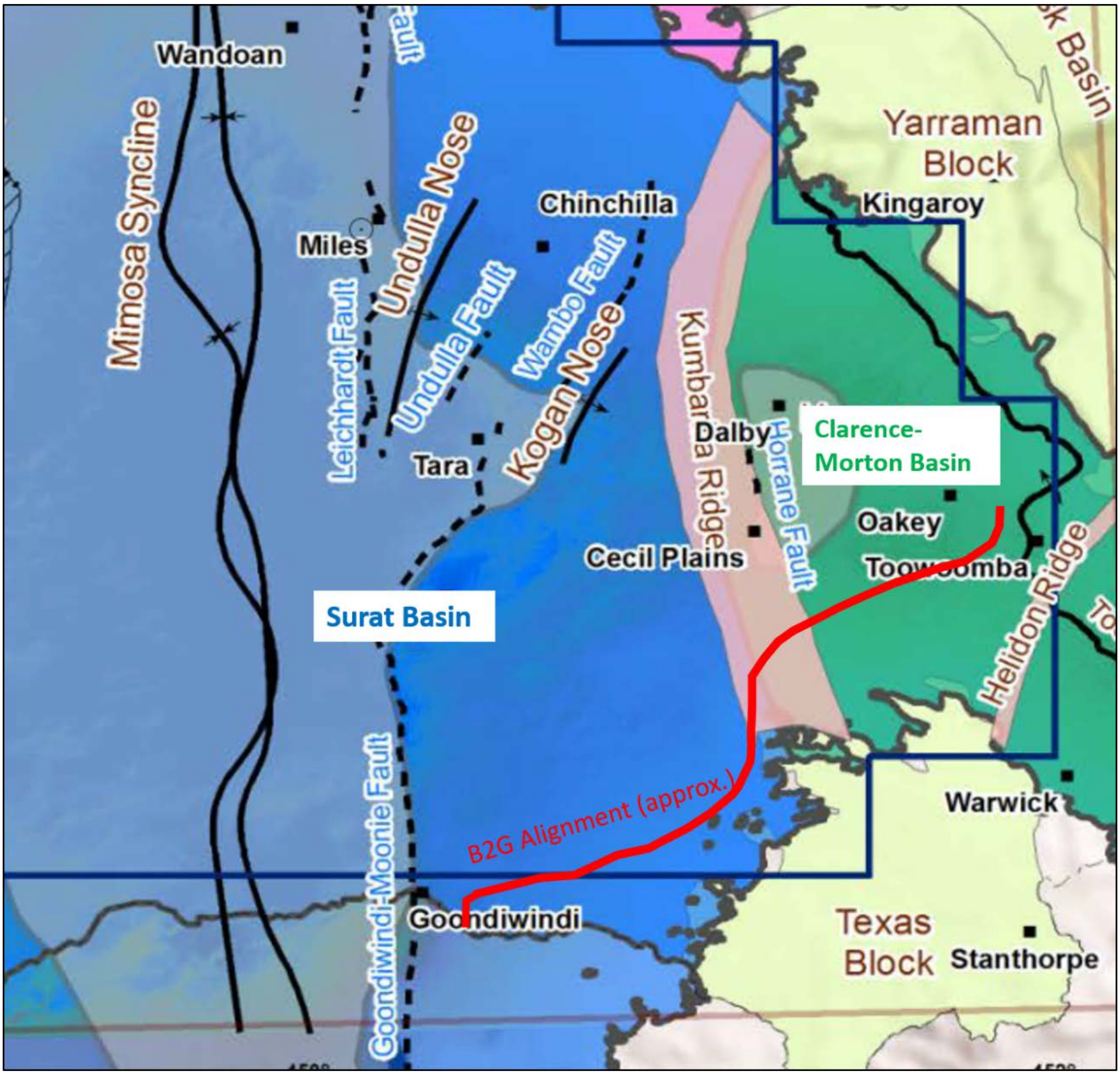


Figure 4.5 Regional structural features

Figure note: Modified from OGIA 2016b

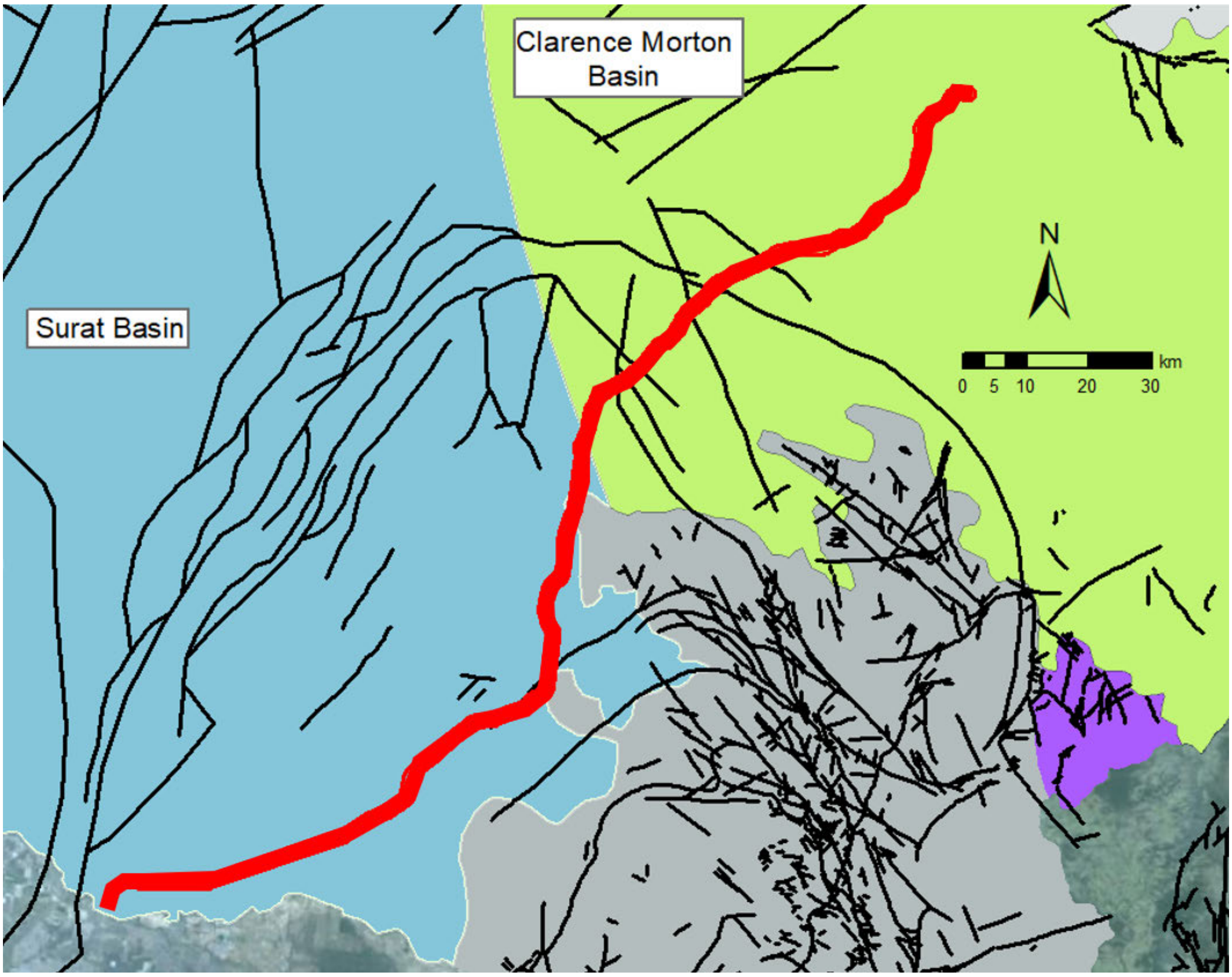


Figure 4.6 **Mapped faults in proximity to the Project**

Figure note: Fault traces sourced from the DNRME detailed structural geology spatial dataset published May 2018

The Peel Fault is a major north trending thrust system located approximately 30 km west of Yelarbon. A large dryland salinity scald near Yelarbon has been associated with an offset fault from the Peel Fault (Knight et al. 1989). Here, the Peel Fault offset is postulated to act as a conduit for saline groundwater to infiltrate the soil profile and exacerbated erosion in this area. The Salinity Management Handbook suggests geological faulting can provide a preferential flow path for groundwater to the surface, resulting in springs (Department of Environment and Resource Management (DERM), 2019).

This salinity scald occurs along the Project alignment between Ch 23 km to Ch 27 km.

Other mapped faults traversed by the Project include:

- Ch 64.0 km and Ch 78.0 km: An inferred fault trending northeast-southwest of unknown displacement direction
- Ch 128.0 km: north-south trending fault inferred from geophysics of unknown displacement direction
- Ch 150.0 km: northwest-southeast trending fault through the Condamine River floodplain inferred from geophysics of unknown displacement direction
- Ch 159.5 km: northwest-southeast trending fault inferred from geophysics of unknown displacement direction.

Figure 4.7 presents a conceptualisation of the Peel Fault depicting the inferred mechanism for the salinity scald.

Section 4.7.3 discusses groundwater quality and hydrochemical classification for the main aquifers considered to be of relevance to the Project. The alluvial aquifers hydrochemical classifications are consistent with those in Figure 4.7.

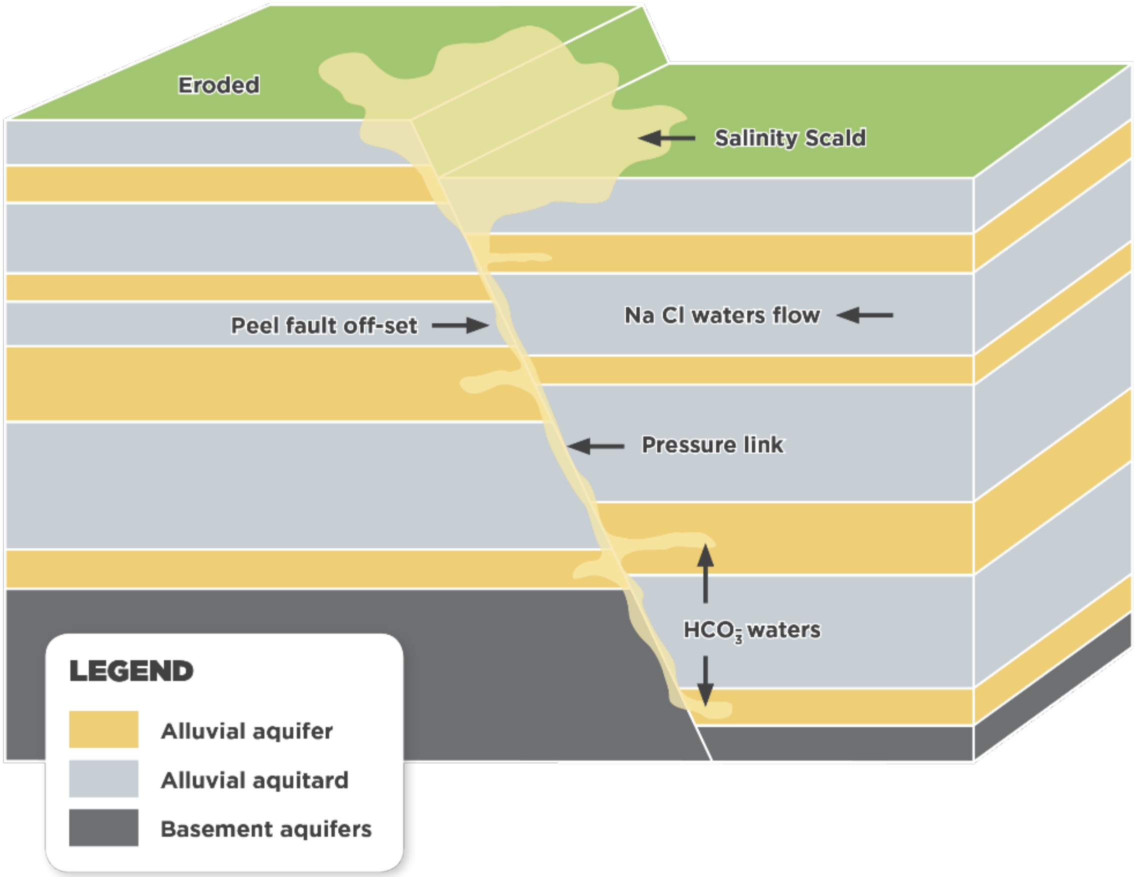


Figure 4.7 Conceptualisation of the Peel Fault

4.6.2 Project geology

The geological units within the impact assessment area, inclusive of those which outcrop and sub-crop, are described below, from youngest to oldest (based on Rassam et al 2014 and Golder 2019a).

Where provided, borehole references (BH) relate to boreholes installed during the reference design phase investigations. Refer to Section 6 for borehole details.

4.6.2.1 Alluvium/colluvium (Cainozoic)

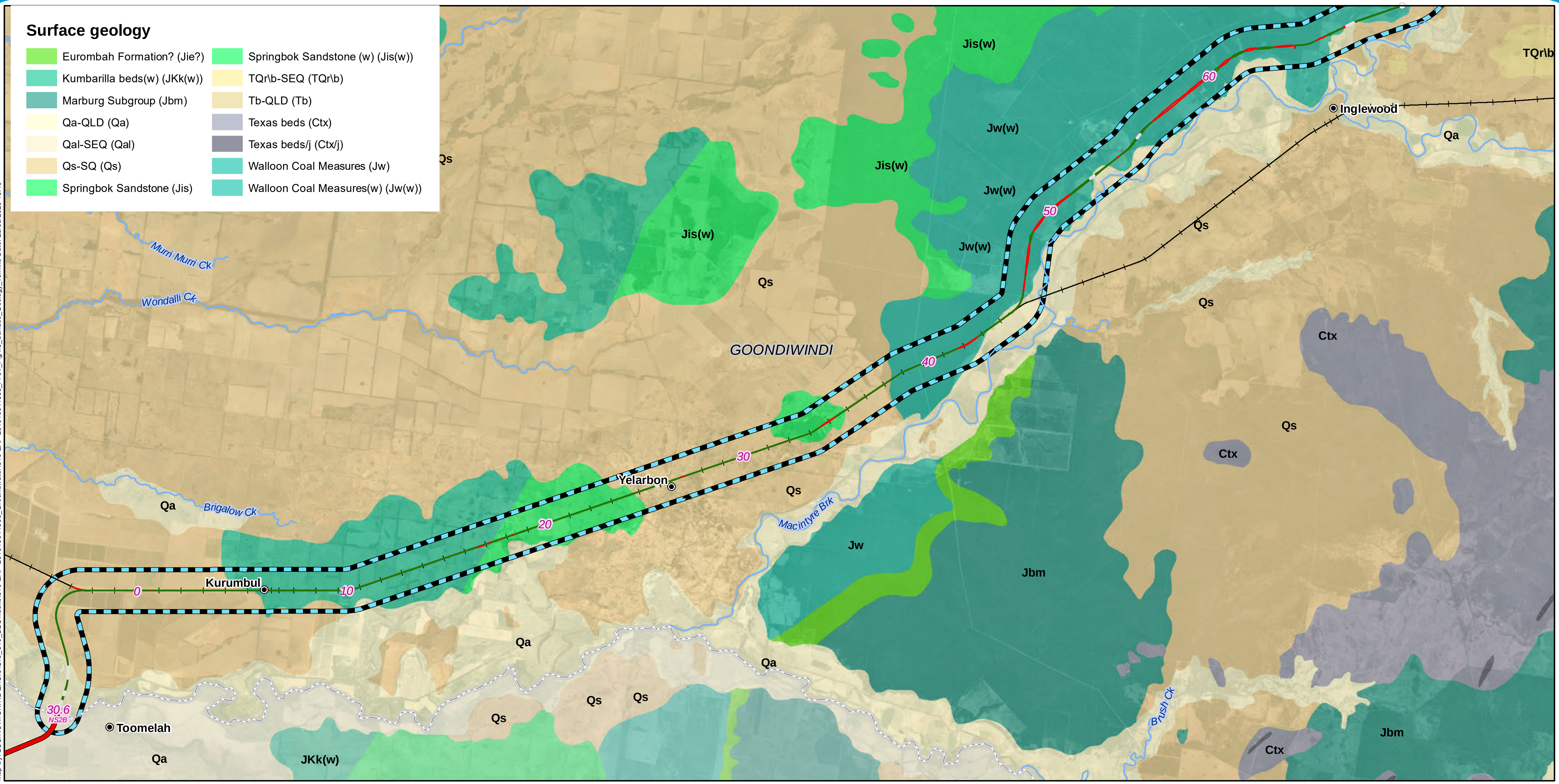
Two primary alluvial units of relevance are present at surface along the impact assessment area and include the:

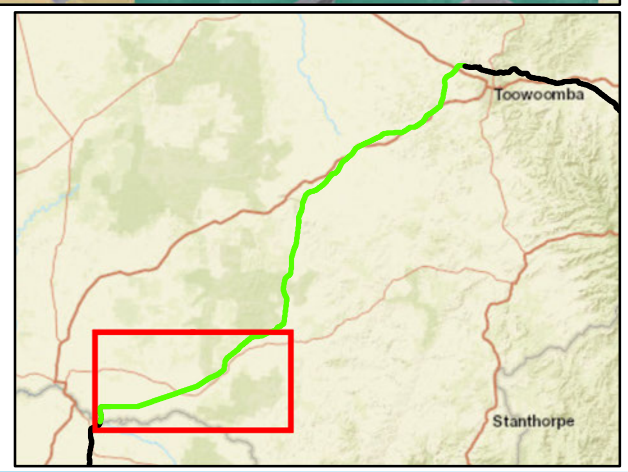
- Border Rivers Alluvium (Queensland)
- Condamine Alluvium (Central Condamine and tributary alluvium).

These Cainozoic sedimentary units comprise alluvial and colluvial sediments. Colluvium/colluvial sediments consist of sands and soils derived from slope wash deposition are distributed throughout the impact assessment area. Particularly near the edge of valleys, colluvium may become interfingered with the alluvium and becomes difficult to distinguish. This colluvium is likely to comprise significant portions of the geological unit mapped as abandoned river terraces (Qs) in Figure 4.8.

Each of the alluvial units are discussed in the subsections below. Figure 4.8 depicts the mapped surface geology within and adjacent to the impact assessment area.

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





Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.8_Surface_Geology_v6.mxd Date: 25/05/2020 13:43

Legend

- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- NSW/QLD border
- Groundwater impact assessment area
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5km

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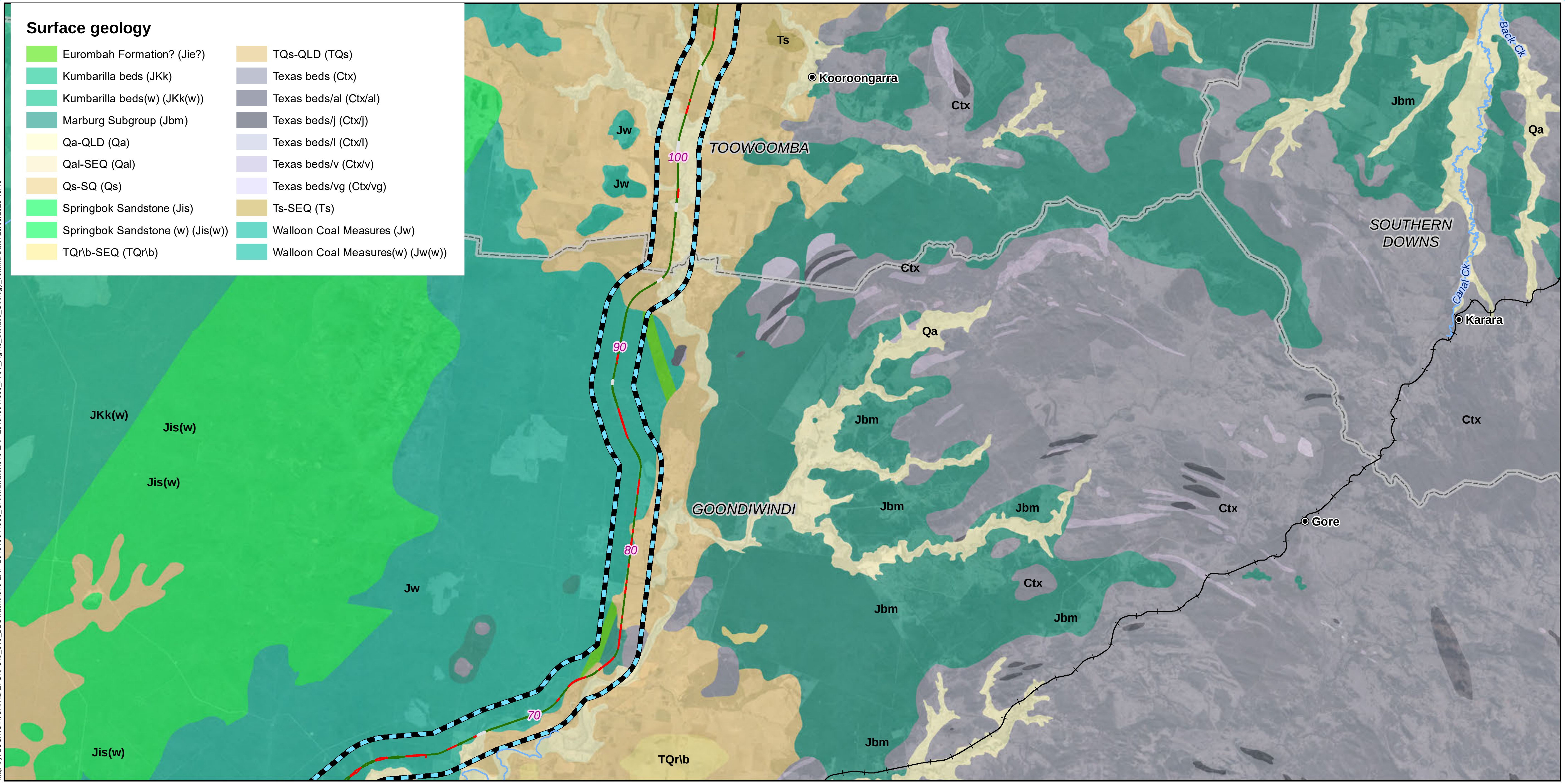
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

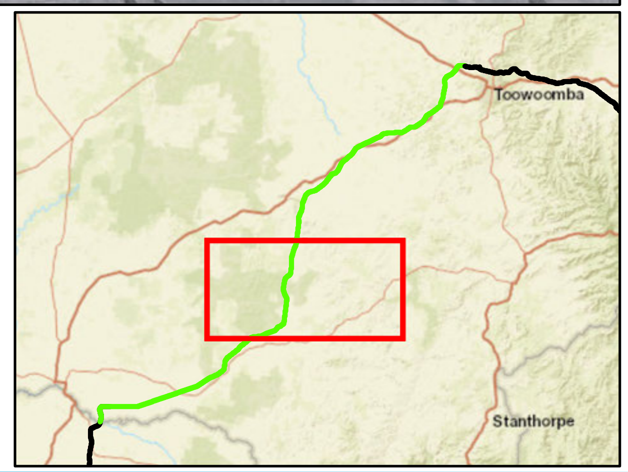
**Figure 4.8a:
Surface geology**

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



Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas



A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5km

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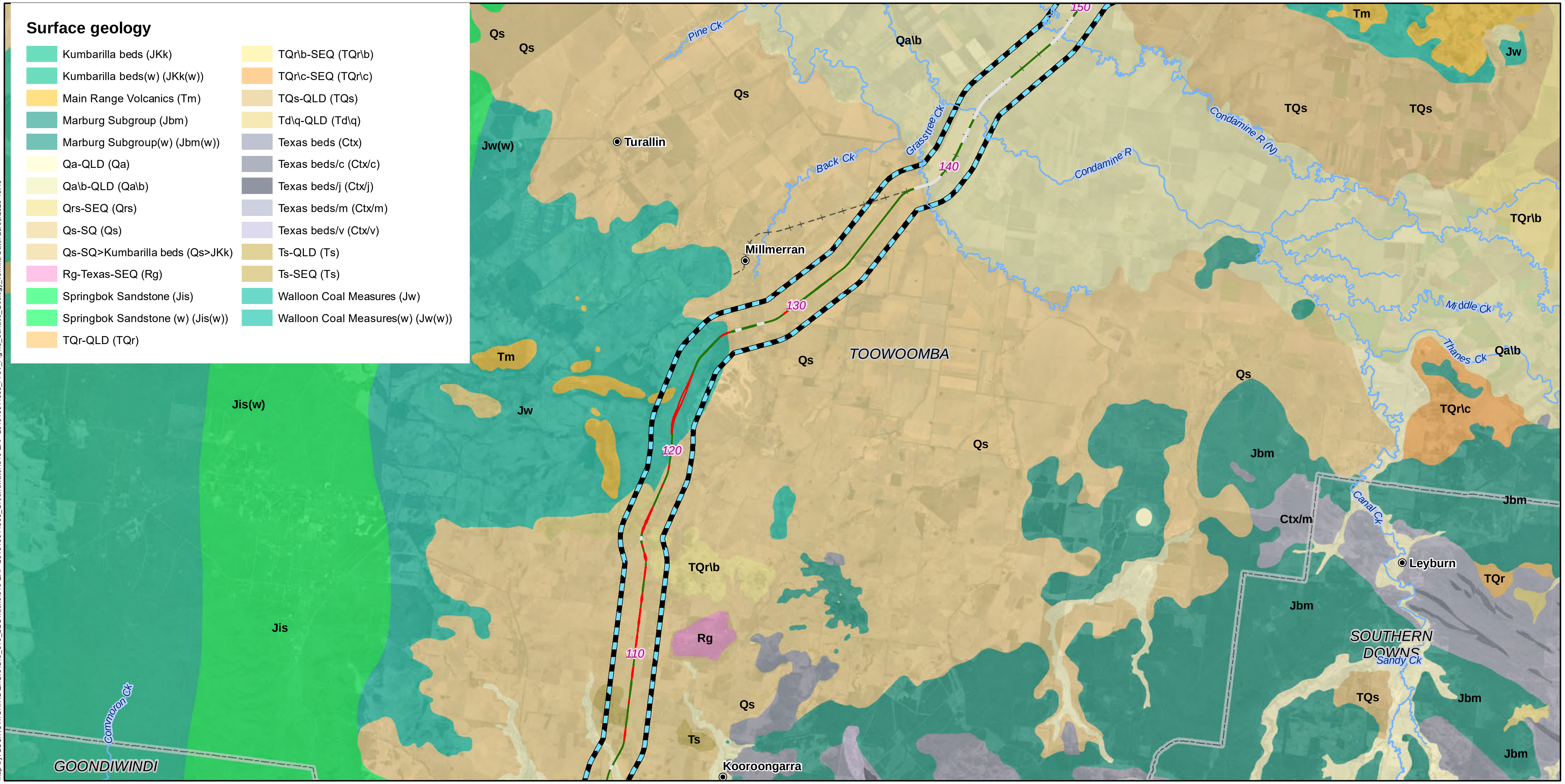
Coordinate System: GDA 1994 MGA Zone 56

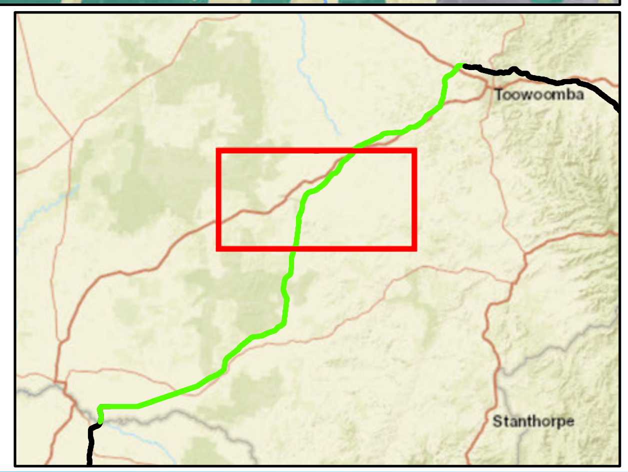
Border to Gowrie

Figure 4.8b: Surface geology

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.8_Surface_Geology_v6.mxd Date: 25/05/2020 13:43





Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5km

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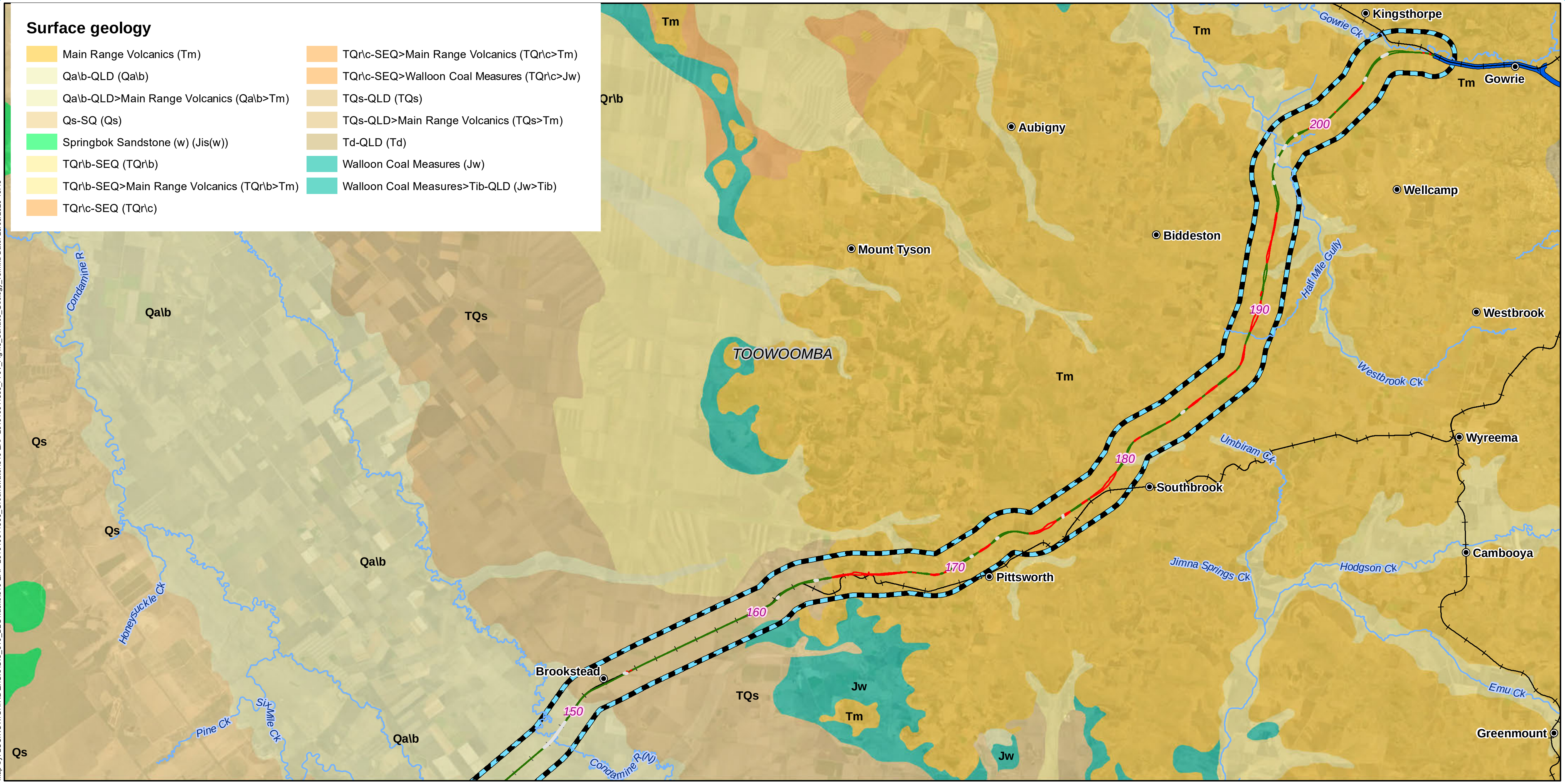
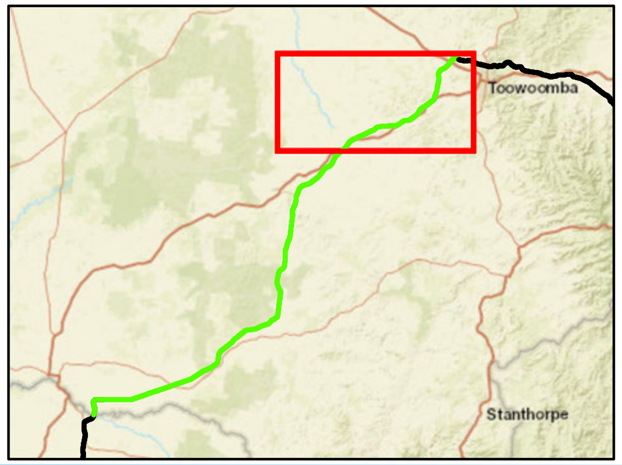
Border to Gowrie

Figure 4.8c: Surface geology

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



Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.8_Surface_Geology_v6.mxd Date: 25/05/2020 13:43



Legend

- 5 Chainage (km)
- Localities
- Gowrie to Helidon alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5km

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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.8d: Surface geology

4.6.2.2 Border Rivers Alluvium

The Border Rivers Alluvium is associated with the Dumaresq and Macintyre rivers, Macintyre Brook and associated tributaries (i.e. Canning Creek). The Project intermittently crosses sections of this alluvium between Ch 30.6 km (NS2B) and Ch 117.0 km and is represented in Figure 4.8 above as Qs and Holocene alluvium (Qa). This alluvial unit typically comprises clays, sands, and gravelly sands deposited on weathered Kumbarilla Beds (KB) and WCM of the Surat Basin.

Distribution of the Border Rivers Alluvium is generally restricted to tributary systems such as Canning Creek and Macintyre Brook with a more extensive presence on the flood plains of the Dumaresq and Macintyre rivers. The Border Rivers Alluvium thickness ranges from less than five (5) m thick overlying the Kumbarilla Beds and WCM (boreholes BH2304 at Ch 53.0 km and BH2210 at Ch 65.0 km, refer Figure 4.30) to thick, generally fining upwards successions over 60 m in the paleochannels of the larger Macintyre and Dumaresq rivers (i.e. RN12095).

The alluvial sediments of the Dumaresq and Macintyre rivers, Macintyre Brook and associated tributaries (i.e. Canning Creek) is referred to collectively as the Border Rivers Alluvium to distinguish from the Condamine Alluvium in the sections below.

4.6.2.3 Condamine Alluvium

The Condamine Alluvium comprises a broad alluvial plain composed primarily of Quaternary unconsolidated clay, silt, sand, and gravel, depicted as Qa in Figure 4.8 and a conceptualisation depicted on Figure 4.9. Alluvium within tributaries of the Condamine River, such as Westbrook Creek, are considered part of the Condamine Alluvium stratigraphic unit. Based on a review of DNRME registered bores and reference design phase investigation bores within the impact assessment area, the indicative total thickness of the Condamine Alluvium is at least 60 m. Outside the impact assessment area, bores indicate the thickness may reach up to 130 m further north towards Dalby (OGIA 2016b).

The stratigraphy of the Condamine Alluvium consists of an upper clay sheetwash unit which thins towards the west and is underlain by a coarser sand and gravel unit. Within the impact assessment area, the thickness of the upper clay unit was observed to be 7.8 m (in borehole BH2234 [Ch 142.7 km]) and 6.8 m thick (borehole BH2235 [Ch 148.0 km]), respectively. Below the coarser sand/gravel unit is a basal clay which separates the alluvial sediments from the underlying WCM.

Within the Condamine Alluvium footprint, the Surat Basin sediments have been eroded down (not present) to the WCM where a basal clay separates the main Condamine Alluvium sequence from highly weathered WCM, as depicted in Figure 4.9 (OGIA 2016). This basal clay is commonly referred to as a ‘transition zone’ and is understood to be discontinuous across the Condamine Alluvium footprint.

Due to the complex nature of the alluvial sediments within the impact assessment area, a summary of the various components of the alluvium, stratification details and borehole data utilised to characterise these strata are presented in Figure 4.9.

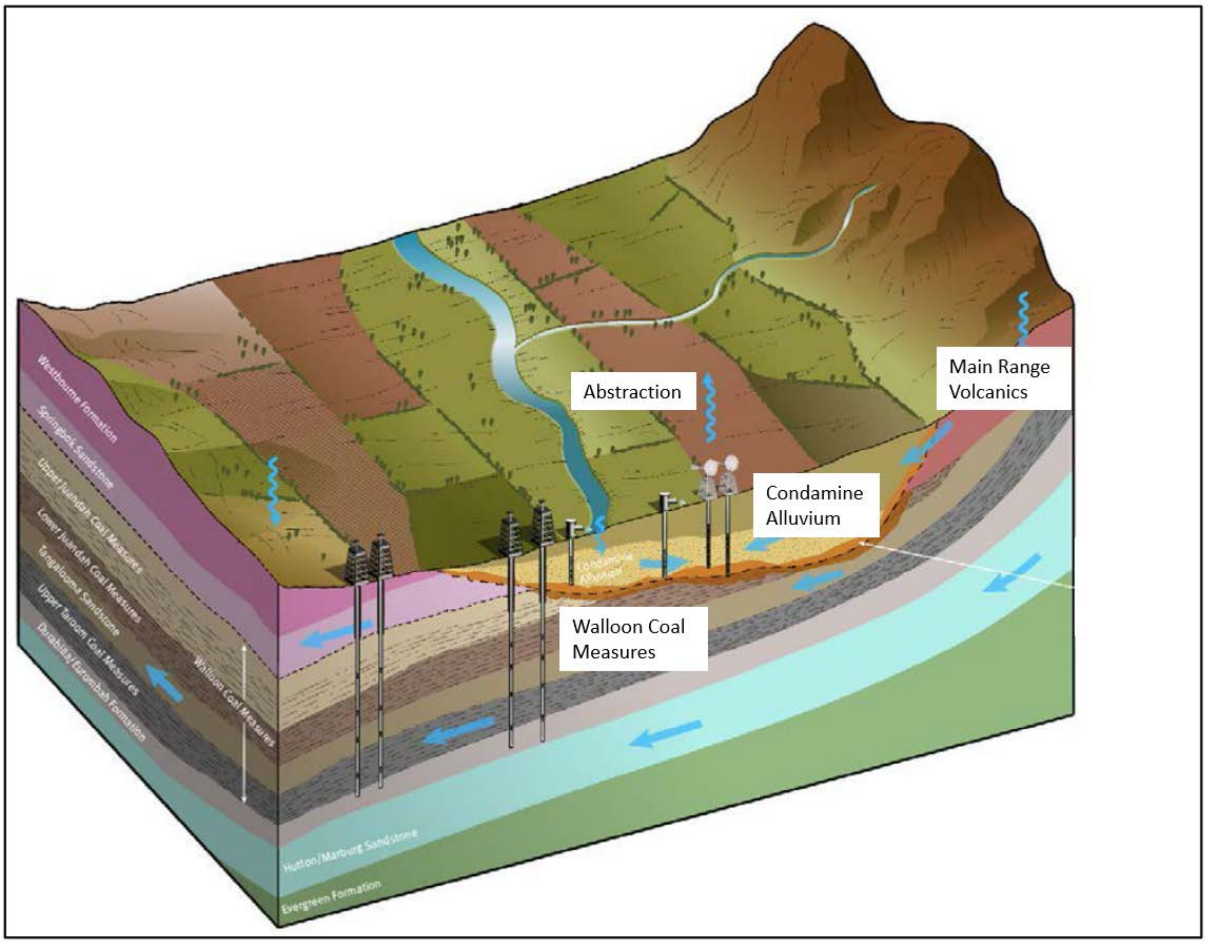


Figure 4.9 Geological conceptualisation of the Condamine Alluvium

Source: OGIA (2016)

Table 4.4 Stratigraphic summary of alluvium within the impact assessment area

Chainage range	Unit	Thickness (m)	Description	Reference boreholes
Ch30.6 km (NS2B) - Ch 38.0 km (Border Rivers Alluvium)	Topsoil	0 – 1.5 m	Sandy clay and clays	RN77068 RN71611 RN12095 RN77347 BH2213 BH2217 BH2218
	Clay (with minor Silt)	5.0 – 9.0 m	Yellow to brown clays	
	Clayey Sand/Sand/Gravels	5.0 – 60 m	Sand/sandy gravels/clays	
	Basal Contact	**Kumbarilla Beds:** Mudstone and siltstone - extremely weathered siltstone and mudstone.		
Ch 92.0 – Ch 117.0 km (Border Rivers Alluvium including Macintyre Brook and Canning Creek)	Topsoil	0.1 – 0.3 m	Sand/silt	BH2309 BH2210 BH2311 BH2216 BH2201 RN48791 RN77025
	Clay/Sands/minor gravels	3 - 28 m	Clays/clayey sands/minor sandy gravels	
	Basal Contact	**Kumbarilla Beds & WCM:** Extremely weathered sandstone and mudstone.		
Ch 138.0 – Ch 151.0 km (Condamine Alluvium and tributaries)	Topsoil	0.3 m	Clay, dark grey, high plasticity.	BH2231 BH2234 BH2235 RN147510
	Clay and Clayey Sand	6 – 8 m	Clay and sandy clay, grey – dark brown, med-high plasticity, stiff to very stiff.	
	Sand and Gravel	5 - 10 m	Well graded sands and gravels	
	Clay/Sands	10 – 30m	Brown clays and sandy clays	
	Basal Contact	**WCM**		

4.6.2.4 Main Range Volcanics (Tertiary)

The Main Range Volcanics (MRV) 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 MRV is depicted as Tm in Figure 4.8.

The MRV formation consists mainly of Oligocene-Miocene age alkaline olivine basalts which erupted from fissures that have since become extensively eroded (OGIA 2016). 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 MRV is up to 150 m; however, thinner portions of the formation underly some areas of the Condamine Alluvium.

4.6.2.5 Kumbarilla Beds (Jurassic to Cretaceous)

The Kumbarilla Beds (KB) represent a succession of fluvial, lacustrine, and marginal marine facies deposited during the middle Jurassic to middle Cretaceous period (Ransley et al. 2015). This unit includes, from youngest to oldest:

- *Bungil Formation (Mid-Cretaceous):* This formation consists of siltstones, mudstones, and carbonaceous sandstones associated with a lacustrine to marginal marine depositional environment (Ransley et al. 2015)
- *Mooga Formation (Late Jurassic – Cretaceous):* The Mooga Formation is considered fluvial facies characterised by clayey sandstones interbedded with siltstones and mudstones with a typical thickness of less than 100 m
- *Orallo Formation (Late Jurassic):* Flood plain facies comprised predominantly of interbedded siltstone and mudstone
- *Pilliga Sandstone (Mid-Late Jurassic):* The Pilliga Sandstone is comprised of quartzose sandstone and conglomerate with minor mudstone, siltstone, and shales. The unit is representative of a high energy braided fluvial depositional environment and regionally forms an important aquifer (Ransley et al. 2015).

During reference design phase investigations in 2018, the Kumbarilla Beds were interpreted to have been intersected in BH2201 located at Ch 35.1 km. The top of the Kumbarilla Beds were encountered at between 5 to 10 metres below ground level (mbgl) and were characterised by extremely weathered siltstone and mudstone (Golder 2019b). Due to the western dip of the Surat Basin strata, the Kumbarilla Beds do not outcrop east of approximately Ch 38.0 km.

4.6.2.6 Walloon Coal Measures (Jurassic)

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; OIGA 2016b). The WCM are contiguous between the Surat and Clarence-Moreton Basin 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 2016a).

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 4.8.

A review of data from the 30 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).

4.6.2.7 Hutton Sandstone (Jurassic)

The Hutton Sandstone is fluvial in origin and composed of quartzose sandstone with interbeds of siltstone, shale, and minor mudstone with a typical thickness of 150 to 200 m (OIGA 2016b). The Hutton Sandstone underlies the WCM and is intersected by over ten registered bores within the impact assessment area between Ch 60 km and Ch 115 km (i.e. RN108444 and RN71656) and near Gowrie at Ch 206.9 km (i.e. RN94161 and RN147439). The Hutton Sandstone is a lateral equivalent of the upper Marburg Subgroup in the Clarence - Moreton Basin and encountered at depths ranging from 50 to 100 mbgl (DNRME 2018).

4.7 Hydrogeology

This section provides a description of the existing hydrogeological regime and is based on a review of available hydrogeological reports, reference design phase investigations between May 2018 and February 2019 (refer Section 6), and State Government data sets described in Table 3.6.

There are three main aquifer systems present within the impact assessment areas which are of relevance to the Project:

- Cainozoic to recent alluvial/colluvial sediments (Quaternary/Tertiary): of shallow alluvial systems along river valleys (Border Rivers and Condamine River alluvial units) and volcanic basalt aquifers in the eastern portion of the Project
- Tertiary MRV, fractured basalt aquifers in the eastern portion of the Project; and
- Jurassic WCM, interbedded sandstone, claystone, shale, and major coal seams.

These aquifer systems are part of the larger GAB 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 (refer Table 4.3). Therefore, the Hutton Sandstone aquifer is not considered further in this assessment.

The subsections below describe the physical and chemical aspects of the three aquifers that are susceptible to impacts in the context of their respective hydrogeological regime.

4.7.1 Existing hydrogeological regime

4.7.1.1 Alluvium/Colluvium (Quaternary/Tertiary)

The impact assessment area is underlain by two alluvium/colluvium units distinguished by their respective catchments, namely the:

- Border Rivers Alluvium (Queensland) – within the Border Rivers catchment between approximately Ch 30.60 km (NS2B) to Ch 117.0 km
- Condamine Alluvium (Central Condamine and tributary alluvium) – within the Condamine-Balonne catchment between approximately Ch 117.0 km to Ch 206.9 km.

Due to the nature of the alluvial and colluvial sediments, these units are not distinguishable and hence discussed as one (alluvial/alluvium) unit. The characteristics of these two units are discussed below. Groundwater quality within these two units is summarised in Section 4.7.3 and groundwater users that are reliant on these units are discussed in Section 4.7.6.

Occurrence

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 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 WCM of the Surat Basin and forms the primary bedrock to the alluvium (OGIA 2016b). The MRV underlies the alluvium further to the east.

As discussed in Section 4.6.2.3, an upper low permeability unit of sheetwash clays up to 10 m thick overlies a lower granular unit. This lower granular unit is mainly sand and gravels separated by clay lenses. The granular alluvium is the most transmissive part of the alluvium and is, therefore, the main source of groundwater (DNRM 2016). Due to the heterogeneity of the alluvial sediments, localised perched aquifers have been observed in the Condamine Alluvium along the eastern rim of the river valley (E. Dafny., D.M. Silburn 2013). Perched aquifers result from a lens of more permeable sediments between two less permeable matrices where the hydraulic gradients of the over-and under-lying units recharge the more permeable lens. These perched aquifers are considered to be limited in both space and time; that is, the storage and yield are not considered sustainable for long durations.

Groundwater has been used extensively from the Condamine Alluvium for irrigation, industrial, and stock and domestic purposes since the 1960s (OGIA 2016a). The most productive groundwater resource is present in the central portion of the mapped alluvium.

Recharge and discharge mechanisms

In general, recharge to alluvial aquifers is anticipated to occur from both rainfall and by seepage from ephemeral watercourses. Sub-cropping rock below permeable alluvium may also act as a source of recharge due to upward discharge of groundwater (Golder, 2019c).

Recharge to the Condamine Alluvium is complex and there are differing views on the relative significance of different recharge pathways. The most common and prevalent view is that the alluvium is mainly recharged from river and stream flow leakage (39 to 115 mm/year, OGIA 2016a). Diffuse rainfall recharge is expected to be limited by the high clay content of near-surface soils and fine-grained sheetwash deposits. On average, recharge to the Condamine Alluvium is exceeded by outflows, the largest outflow being extraction from groundwater bores. As a result, groundwater levels in the Condamine Alluvium have declined in many areas, by up to 25 m, over the past 60 years (OGIA, 2016a).

Black soils characterised by a large shrink-swell potential and very high plasticity are developed on the Condamine Alluvium. The physical properties of the black soils are likely to retard direct infiltration of rainfall to the alluvium aquifer.

The primary discharge mechanisms from these units are extraction, as baseflow to the adjacent surface water features, and local leakage into the underlying units. Evapotranspiration, from vegetation growing along the bed and banks of water features, and seepage to the underlying units from the alluvial/colluvial sediments are also considered to be primary discharge mechanisms from these unit.

Hydraulic parameters and yields

Interrogation of the DNRME Groundwater Database reported groundwater yield results from 26 bores within the impact assessment area for alluvial aquifers. The yields reported for the 26 registered bores ranged from 0.38 litres per second (L/s) to 25.00 L/s, which results in an average yield of 5.67 L/s. This large variation is attributed to the complex nature of the alluvial sediments, as discussed in the previous sections.

Results from aquifer pump tests performed within the impact assessment area, from registered bores RN86616 and RN83477 (refer Figure 4.30), are included in the DNRME database; transmissivity was estimated to be 451 and 500 m^2/day, respectively. Indicative horizontal hydraulic conductivity values, based on the typical alluvium thickness of 50m and these transmissivity values, are 9 m/day and 10 m/day, respectively.

A total of 108 regional horizontal hydraulic conductivity records were accessed and analysed, the majority of which were bores located in the Condamine Alluvium aquifer. From these records, horizontal hydraulic conductivity values were reported to range between 0.089 metres per day (m/d) and 1,728 m/d (Golder, 2019c). Of these 108 records, 88 (81 per cent) were above 8.64 m/d and 39 (36 per cent) were above 86.40 m/d. These records are often biased towards the upper end of the hydraulic conductivity range as tested bores are predominantly drilled for irrigation purposes, for which high yielding alluvial gravels and sand aquifers are targeted.

4.7.1.2 Main Range Volcanics

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

Occurrence

The impact assessment area traverses the MRV between approximately Ch 163.0 km and Ch 206.9 km; located east and southeast of the Condamine Alluvium, the main (southern) body of basalt trends almost parallel with the Condamine Alluvium to the southeast, near Killarney. The MRV are commonly greater than 150 metres thick except where the Condamine Alluvium overlies the MRV where they were incised by surface water features and reduced in thickness as a result (OGIA 2016b).

The MRV forms a significant productive aquifer used for irrigation, stock, and town water supplies. A total of 149 of the 298 bores registered on the DNRME Groundwater Database and located within the impact assessment area are reported to be screened within the MRV (refer Section 4.7.5). A review of registered bores indicates this is the primary aquifer screened by registered bores in the impact assessment area between Ch 163.0 km and Ch 206.9 km near Gowrie (refer Figure 4.30).

Recharge and discharge mechanisms

Based on available data, recharge to the MRV is considered to primarily be via direct rainfall infiltration, local vertical leakage from the underlying units and adjacent flow through from the Condamine Alluvium where they are co-located, particularly after large rainfall events (OGIA, 2016b).

Regionally, recharge to the MRV ranges widely from 1.3 to 105 mm/year (UQ 2014). Within the impact assessment area, estimated recharge is 25.8 mm/yr (Golder, 2019c).

The primary discharge mechanisms are considered to include bore extraction and local vertical leakage to deeper units.

Hydraulic parameters and yields

A review of regional literature data and results from the Project hydrogeological investigations identified 69 aquifer tests which provided hydraulic conductivity values ranging from 8.64×10^{-5} to 2,590 m/day. Literature values for transmissivity in the MRV typically range from 200 square metres per day (m^2/day) to 300 m^2/day (OGIA, 2016b). These transmissivity values correspond to horizontal hydraulic conductivity values of 2 m/day to 3 m/day for a typical MRV thickness of 100 m. The literature and Project hydrogeological investigation data indicate the hydraulic conductivity of the MRV is highly variable, reflecting the fractured and anisotropic nature of the aquifer.

The specific yield for the MRV is estimated at 0.1 while a hydraulic conductivity value of 0.061 m/day has been adopted as a typical value for modelling inflow assessments (Golder, 2019c). The average bore yield within the MRV is approximately 4 L/s based on registered bores within the impact assessment area (refer Table 4.11).

4.7.1.3 Kumbarilla Beds

Occurrence

The lithology of the Kumbarilla Beds comprises sandstone, siltstone, mudstone, and some conglomerate (refer Table 4.3).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 2016a).

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 2016a).

The Project alignment traverses intermittent outcrop and subcrop 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 (NS2B) to Ch 38.0 km are recognised to be screened across the Kumbarilla Beds.

Recharge and discharge mechanisms

The outcrops of the Kumbarilla Beds are believed to be recharged by direct infiltration of rainfall, and by seepage from ephemeral streams during periods of flow following rainfall. Locally, upward leakage from sub-cropping rock below permeable alluvium may also act as a source of recharge (OGIA, 2016b).

Discharge mechanisms from the Kumbarilla Beds are believed to occur via seepage/through flow into the underlying and/or adjacent aquifers, evapotranspiration (primarily in subcrop/outcrop areas), and groundwater extraction.

Hydraulic parameters and yields

The DNRME Groundwater Database has record of one pump test of a registered bore within the impact assessment area and located in the Kumbarilla Beds. Transmissivity was estimated from this single pump test at 404 m^2/d (RN43148). The reported yields ranged from 0.18 L/s to 5.5 L/s.

One slug test near Ch 35.0 km (BH2201) was conducted within the Springbok Sandstone sub-unit of the Kumbarilla Beds during the Project hydrogeological investigations. Hydraulic conductivity was reported from this slug test as 0.3 m/day based on the results of this falling head test.

The site-specific aquifer test results (based on various interpretations) and regional (literature) hydraulic conductivity data indicate the various units of the Kumbarilla Beds range from 3.7×10^{-9} m/s (0.0003 m/day) to 8.2×10^{-6} m/s (0.7 /day) (Golder, 2019c).

4.7.1.4 Walloon Coal Measures

Occurrence

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; OIGA 2016b). 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, 2016a).

The Project alignment traverses the WCM intermittently, in the form of outcrop and subcrop along the rail alignment, between approximately Ch 38.0 km and Ch 126.0 km, as depicted as Jw in Figure 4.8.

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 (OGIA, 2016b). 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 depth (DNRME, 2016a).

Recharge and discharge mechanisms

Recharge of the WCM is considered to primarily be through seepage from the overlying and underlying units and via direct rainfall infiltration in areas of subcrop (OGIA, 2016b).

Estimates of the long-term recharge have been derived using a modified Chloride Mass Balance (CMB) method. Estimated long-term mean recharge rate in the WCM is 3.6 mm/yr, with a maximum of 5 mm/yr (OGIA 2016a).

The primary discharge mechanisms from the WCM are considered to include bore extraction, where the WCM locally acts as an aquifer, and vertical seepage into the under and overlying units.

Hydraulic parameters and yields

A total of seven bores were installed and screened in the WCM during the Project hydrogeological investigation. Aquifer tests, in the form of slug and variable head tests, were completed in for each of these bores. Hydraulic conductivity values from these tests ranged from 0.0001 m/day to 0.05 m/day. Typical literature values for the hydraulic conductivity in the WCM range from 0.00016 m/day to 0.045 m/day (OGIA 2016b) which is consistent with the results obtained from testing during the Project hydrogeological investigation.

4.7.2 Groundwater levels and flow

4.7.2.1 Cainozoic Alluvium

Border Rivers Alluvium

Interrogation of the DNRME database yielded five bores which had static water levels for the Border Rivers Alluvium. These water levels range between approximately 5.8 and 9.0 mbgl. Recent water levels from regularly monitored bores include RN41640003 (4.5 km south of Yelarbon) in May 2018 (9.0 mbgl) and February 2018 (5.8 mbgl), which correspond to the dry season and wet season, respectively.

Representative groundwater elevations for the Border Rivers Alluvium are displayed in Figure 4.10 as elevation (mAHD). The data shows a general decreasing trend between 1985 and 2009 in nested bores RN41640003A (deep) and RN41640003B (shallow), located near Ch 23.0 km. The water level reported for the deep bore, when compared to the shallow bore, indicates an upward gradient under semi-confined aquifer conditions.

Bore RN41640038, near Ch 44.0 km, has published data records from 2011 to 2018. This data shows a general decrease in water level over time. The water level ranges between 8 to 9 mbgl (+/- 1 m) over the course the seven years.

The water levels reported for bore RN41640009 are fairly consistent, with levels remaining around 13 mbgl from 2005 to 2018 with no obvious trends (refer Figure 4.11).

Four Project investigation bores were installed during the 2018 geotechnical and hydrogeological investigations for the Project. A summary of Project bores within the Border Rivers Alluvium is presented in Table 4.5 and depicted on Figure 4.30.

Table 4.5 Summary of Project bores constructed within Border Rivers Alluvium

Borehole ID	Chainage	SWL (mbgl)	Alluvium being monitored
BH2213	Ch 30.7 km (NS2B)	11.9	Border Rivers Alluvium
BH2217	Ch 32.8 km (NS2B)	12.3	Border Rivers Alluvium
BH2218	Ch 34.8 km (NS2B)	12.0	Border Rivers Alluvium
BH2617	Ch 95.8 km	4.8	Canning Creek Alluvium

Groundwater flow within the Border Rivers Alluvium is inferred towards the southwest, as depicted on Figure 4.12. Groundwater contours crossing the Dumaresq River and Macintyre River suggest that these rivers are losing in these reaches.

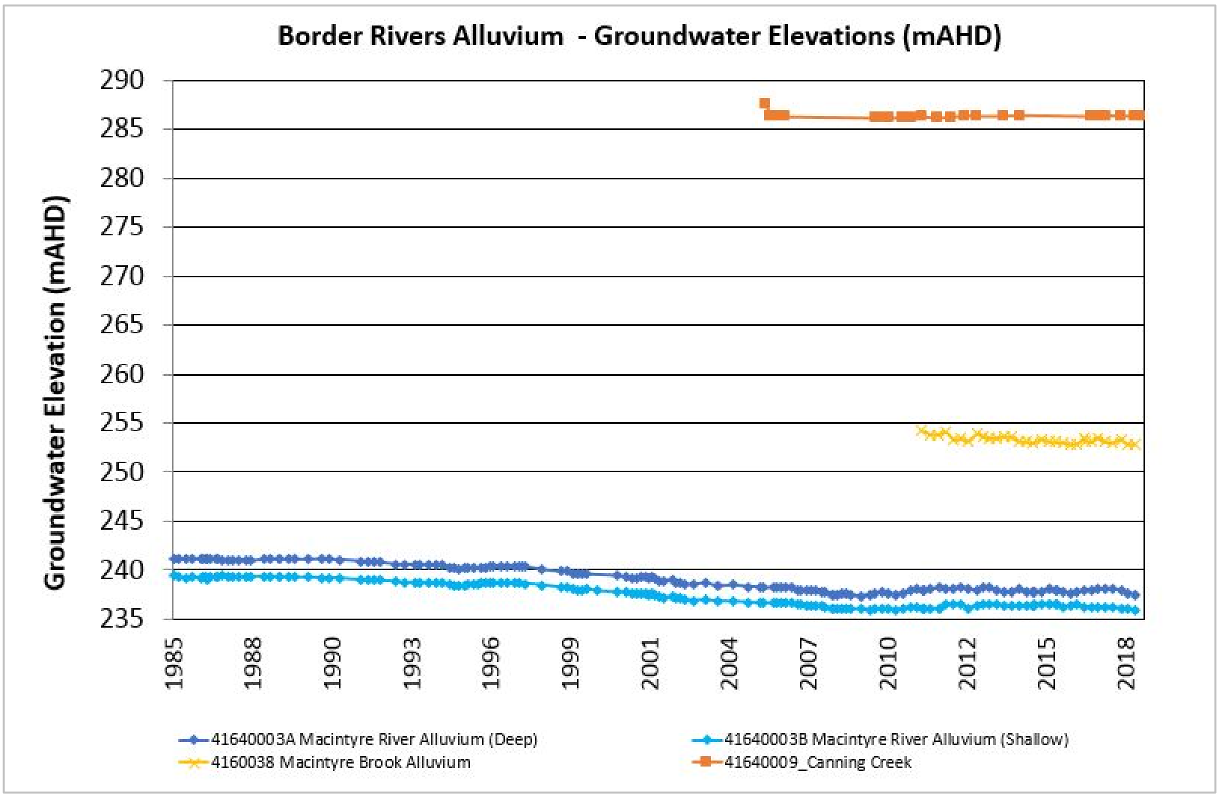


Figure 4.10 Groundwater elevation within the Border Rivers Alluvium

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

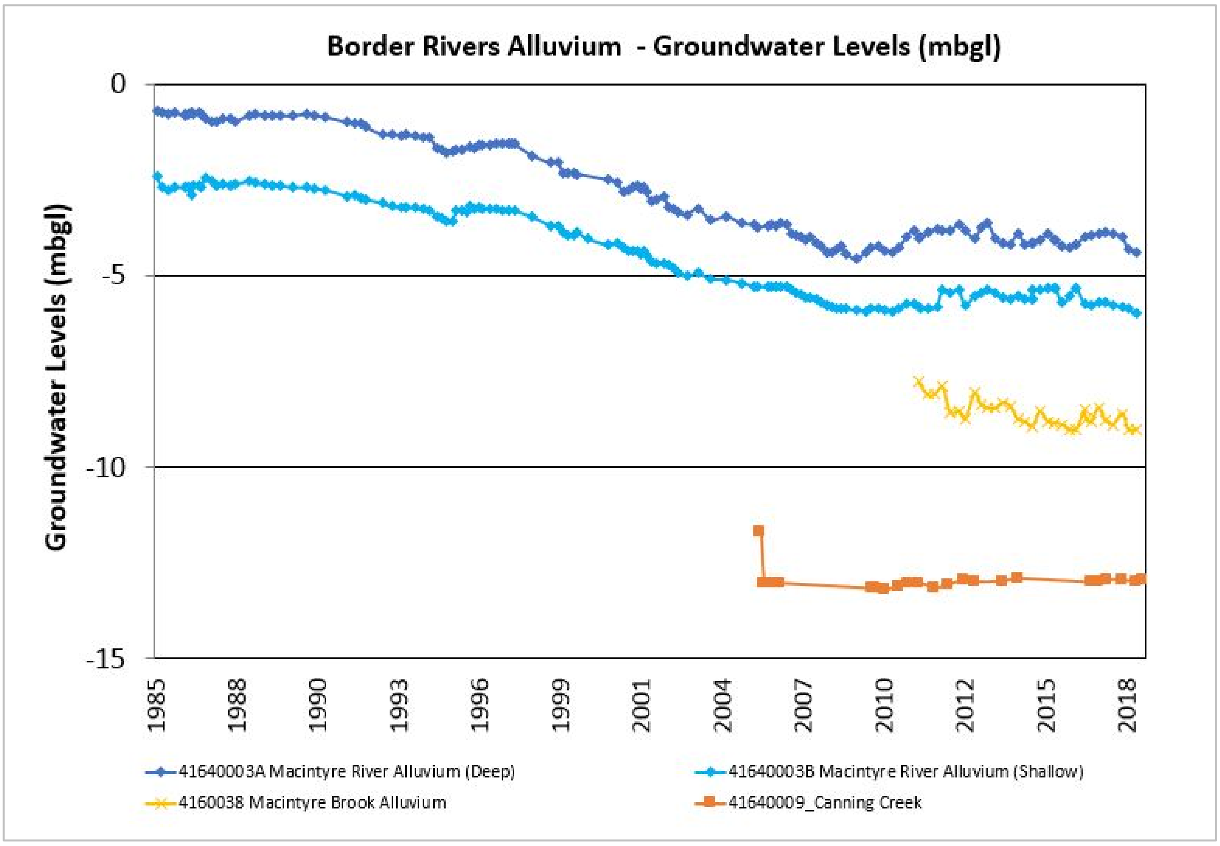


Figure 4.11 **Groundwater levels within the Border Rivers Alluvium**

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

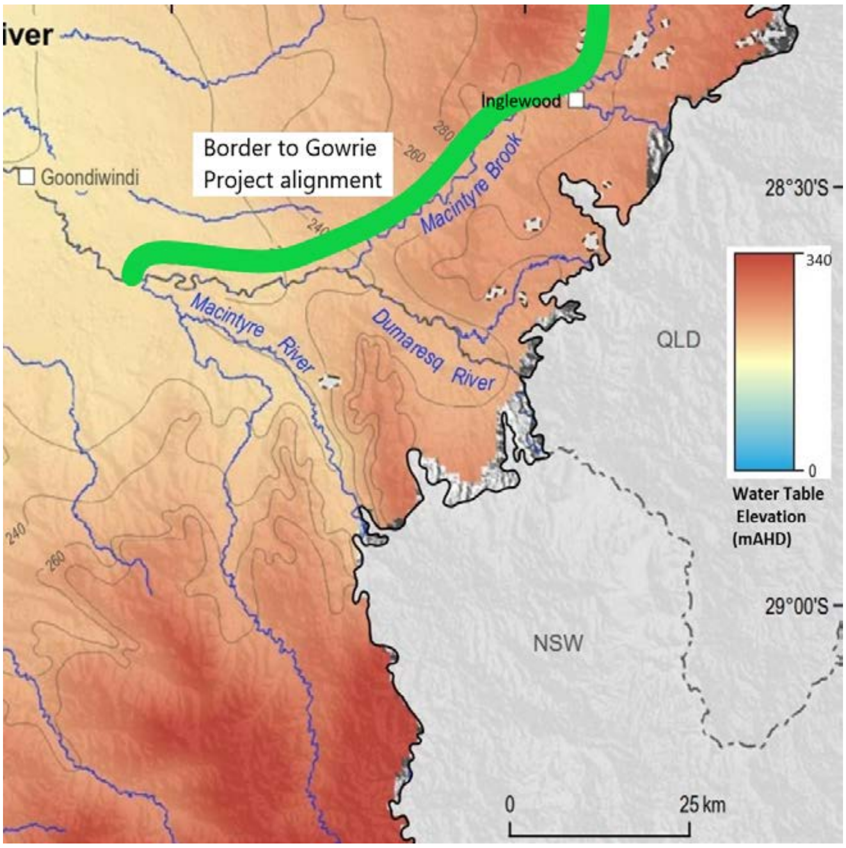


Figure 4.12 **Approximate location of the Project in relation to the inferred groundwater flow direction of the Border Rivers Alluvium**

Source: Modified from Ransley, et al. 2015

Condamine Alluvium

Records from the DNRME Groundwater Database indicate that 81 registered bores within the impact assessment area are screened in the Condamine Alluvium aquifer. Screened intervals typically occur above 50 mbgl with the deepest bore screened between 107 mbgl to 119 mbgl. A total of 54 static water levels are recorded from these registered bores. These levels range from 6.9 mbgl to 36.2 mbgl, with a mean static water level of 20 mbgl. Representative groundwater levels for bores with available long-term data within the Condamine Alluvium are displayed in mAHD on Figure 4.13 and in mbgl on Figure 4.14.

Two of the water level data sets for the Condamine Alluvium cover approximately 40 years while the third set covers 27 years. The three data sets reflect similar trends over time with a general decreasing trend between 1976 and 2007. This decreasing trend is generally associated with abstraction from bores over the past 60 years (OGIA 2016a).

Bores reported to be screened in the middle and deeper sections of the Condamine Alluvium display water levels that show similar trends. However, in all cases, water levels in the deep bores are approximately 2 m higher than those measured in the mid-aquifer zone (Golder, 2019c). This suggests an upward hydraulic gradient into the overlying sheetwash, where present.

Four bores were installed into the Condamine Alluvium during the 2018 geotechnical and hydrogeological investigations for the Project. Recorded water levels in these bores have a median range of between 358.8 mAHD (BH2235) and 364.8 mAHD (BH2233) where the corresponding static water levels are 22.3 mbgl and 14.1 mbgl, respectively. This range is consistent with historical water level ranges observed in registered bores within the same unit.

Table 4.6 presents a summary of the alluvial characteristics with respect to water levels.

Groundwater flow of the Condamine Alluvium with respect to the Project, is inferred to be north-northwest with a local depression centred in Norwin (18 km east of Cecil Plains) inferred to be resultant from groundwater extraction (pumping) (DNRME, 2016a). This inferred direction of flow is depicted on Figure 4.15.

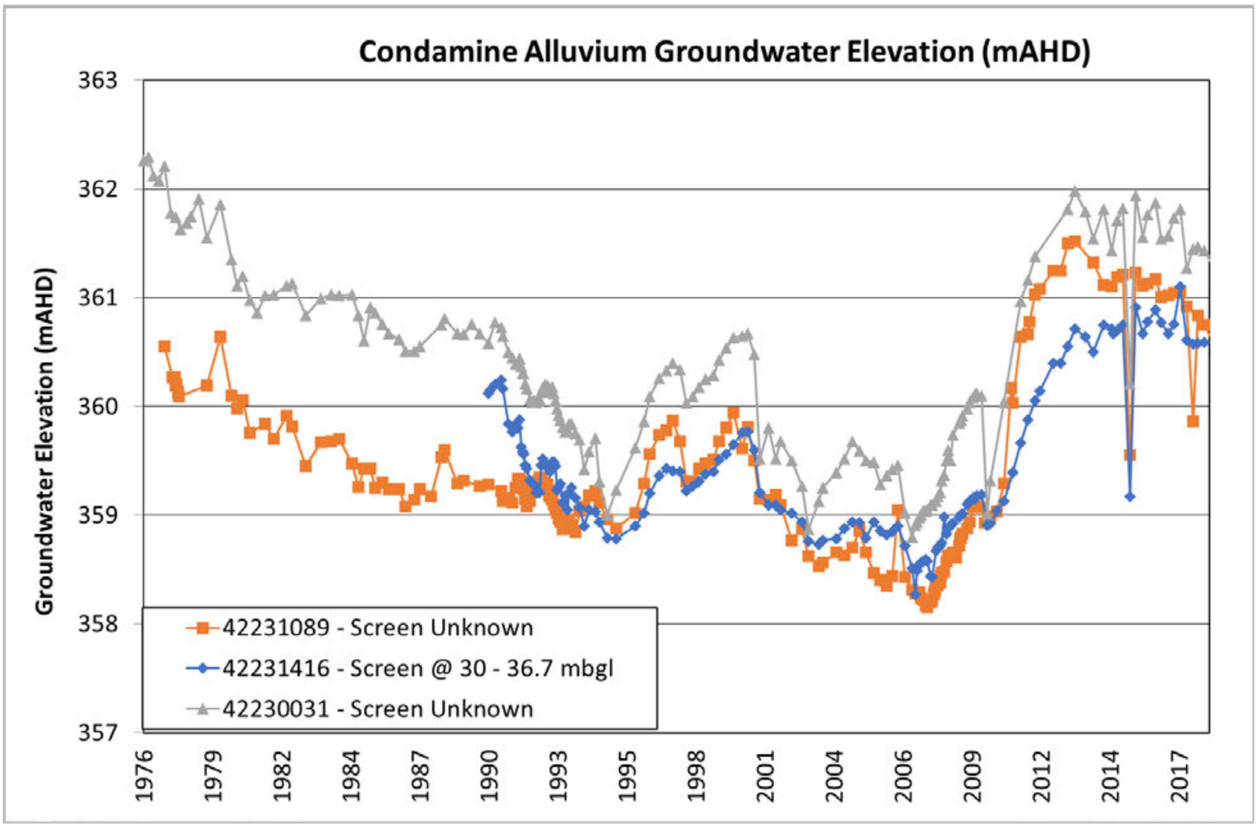


Figure 4.13 **Groundwater elevation within the Condamine Alluvium**

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

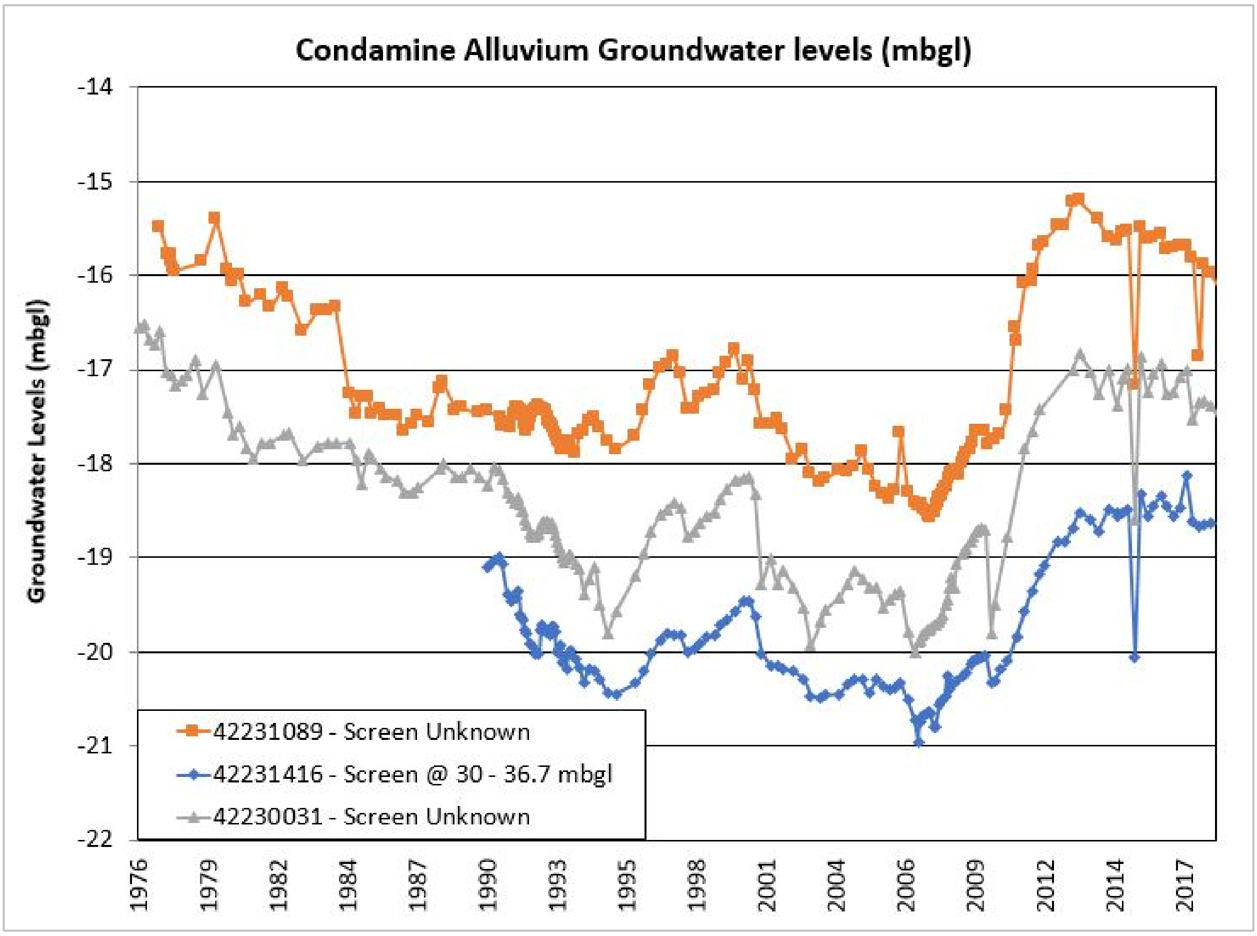


Figure 4.14 **Groundwater levels within the Condamine Alluvium**

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

Table 4.6 **Summary of alluvium characteristics and depth to the water bearing zone along the rail alignment**

Location along the rail alignment	Description	Inferred depth to top of water bearing zone	Comments
Ch 30.6 km (NS2B) – Ch 6.1 km	Brown/grey sandy clay and clayey sand (minor gravel lenses) to 6.6 to 11 mbgl	N/A – no water bearing zone identified in alluvium or residual soils in registered bores. Possible shallow perched groundwater in soils overlying clay.	Macintyre River Alluvium (Border Rivers Alluvium) inferred from RN 41640005 (Macintyre River Alluvium 0 – 73 mbgl, Kumbarilla Beds 73 - 75 mbgl), BH2213, BH2217, BH2218.
Ch 25.3 – Ch 39.0 km	Brown clayey very fine sand to 10.5 mbgl	0 to 5 mbgl but no water observed during drilling.	Macintyre Brook (Border Rivers Alluvium) Alluvium from 0 – 10.5 mbgl. Seepage water static water level (SWL) 9.91 mbgl measured on 19 Feb 2019. Inferred from RN 41640040.
Ch 92.0 – Ch 119.0 km	Brown/grey clayey fine to very fine sand. Gravel base at 5 mbgl. Medium to coarse grained sand and gravels below 5 m depth.	Screen at 23 to 24 mbgl. Bentonite seal at 15.5 to 16.5 mbgl.	Border Rivers Alluvium as observed in RN 41640009. Water level at 12.99 mbgl measured on 19 Feb 2019. This is the closest registered bore to this section of the corridor that covers alluvium.
Ch 125.0 to Ch 163.0 km	Alternating brown clay and sand/gravel from 0 to 38.2 mbgl	Perforated casing 30 to 36.7 mbgl. Depth to saturated zone is 18.88 mbgl measured on 23 Jan 2019.	Condamine Alluvium. Information from RN 42231416.

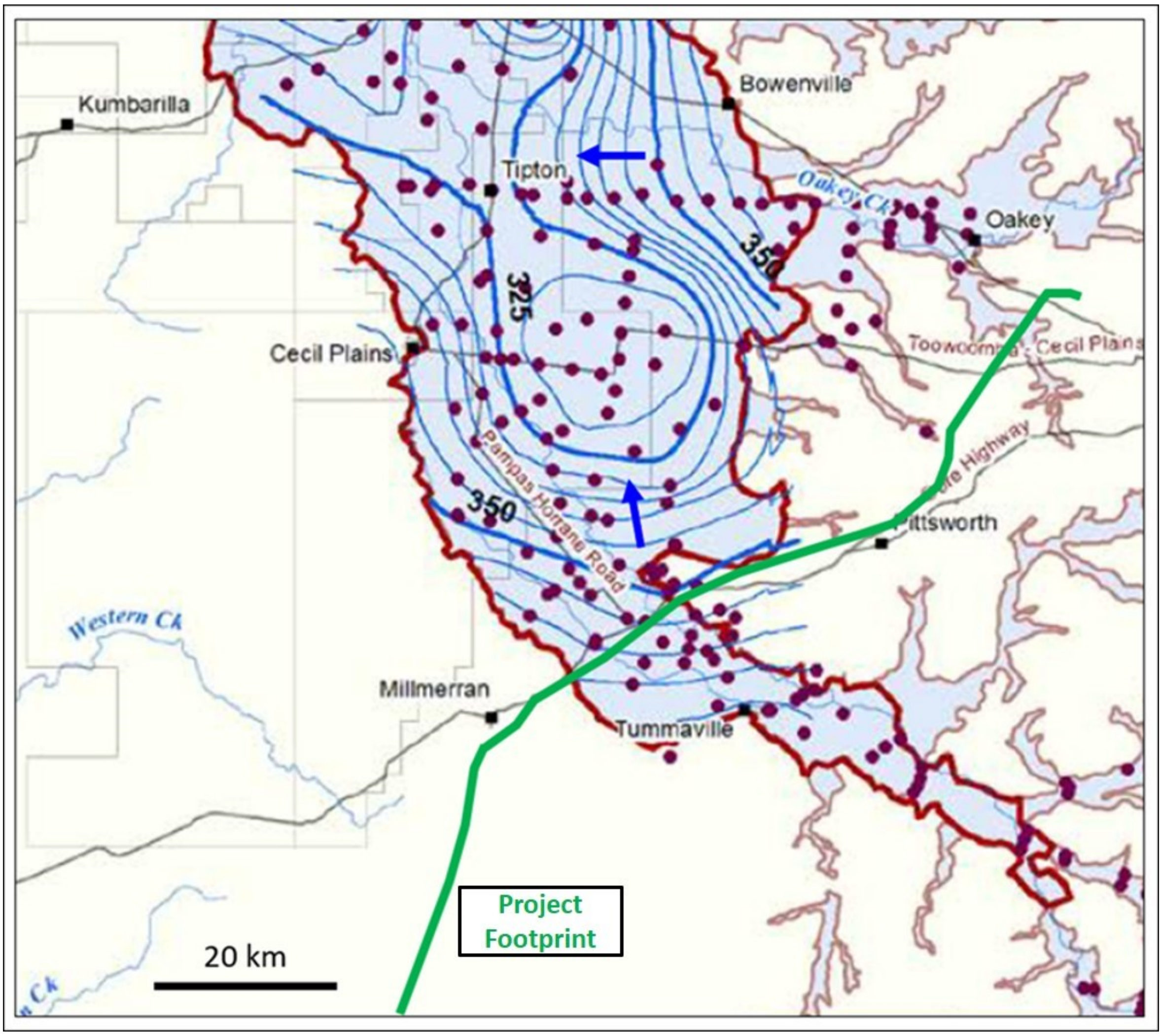


Figure 4.15 **Approximate location of the Project in relation to regional groundwater contours for the Condamine Alluvium indicating predominant flow directions**

Source: Modified from DNRM (2016)

4.7.2.2 Main Range Volcanics

There is an abundance of publicly available groundwater level information for bores screened in the MRV within the impact assessment area. Of the 149 registered bores identified, 55 have records of static water levels. These levels range between 1.8 and 60.1 mbgl, with an average of approximately 18.7 mbgl. Representative groundwater levels from bores with long-term data within the MRV are displayed on Figure 4.16 (mAHD), and on Figure 4.17 (mbgl). The presented data covers the period from 1976 to 2017 and shows different patterns suggesting variable aquifer responses to recharge and/or discharge over time and space.

Site specific monitoring wells were installed in the MRV at Ch 188.0 km (BH2344) and Ch 194.0 km (BH2347) in 2018. The median water levels recorded for these bores were 516.5 and 453.8 mAHD (8.3 and 9.2 mbgl), respectively. Given the broad range of water levels in the database, these levels fit within the upper level of the general range for the MRV.

Aquifers associated with the MRV generally exhibit dynamic and rapid water level variations in response to rainfall recharge, pumping events, and natural depletion. Barnett et al. (2004) assessed water level changes for the period 1990 to 2000 as well as seasonal variations, concluding that the trend of water levels in the MRV has a close correlation with rainfall and in general does not indicate either a rising or falling trend. The dynamic nature of this groundwater system is evident in bores with seasonal water level variations of one to greater than three metres and (in some cases) water level variations in the order of 11 m between periods of high rainfall and drought (AFG, 2018).

Groundwater flow of the MRV, with respect to the Project, is inferred to be towards the west and northwest as depicted on Figure 4.18.

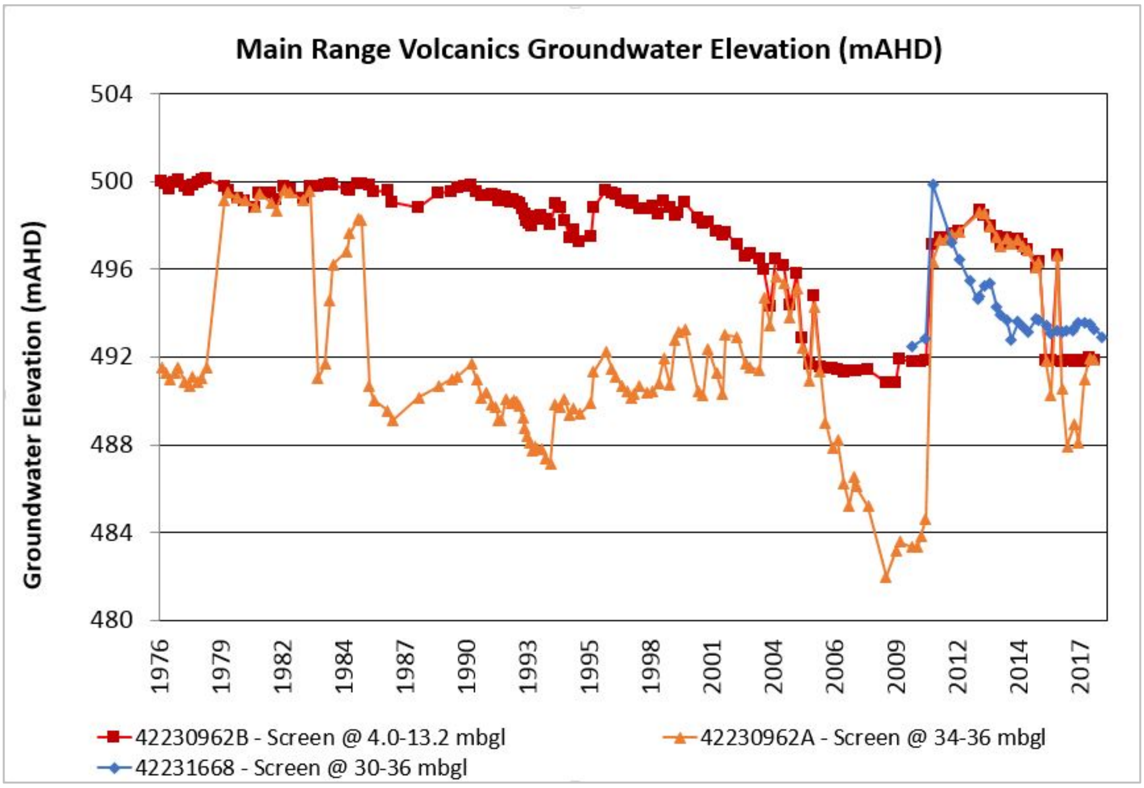


Figure 4.16 **Groundwater elevation within the Main Range Volcanics**

Figure notes:
Water level data sourced from the DNRME groundwater database on 31 January 2019
Nested wells RN42230962 is located 2km east of Ch 188 km. Well RN42231668 is located 4.7km east of Ch 197 km

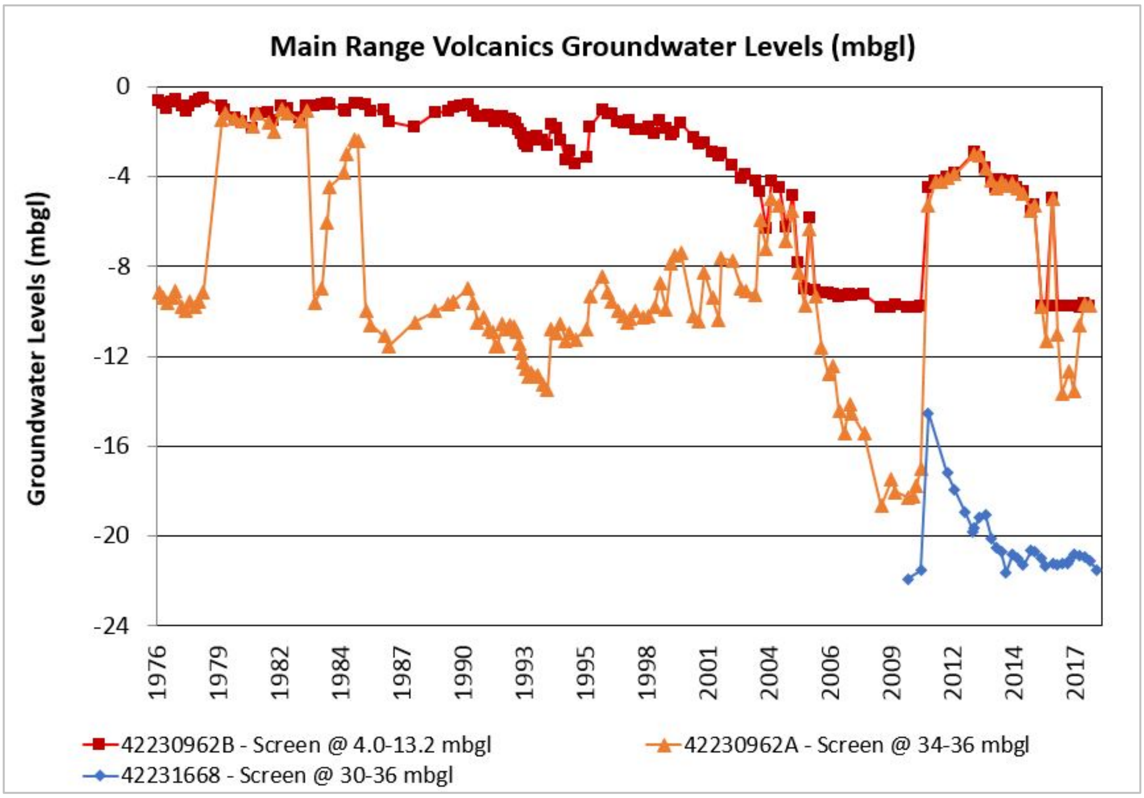


Figure 4.17 **Groundwater levels within the Main Range Volcanics**

Figure note:
Water level data sourced from the DNRME groundwater database on 31 January 2019
Nested wells RN42230962 is located 2km east of Ch 188 km. Well RN42231668 is located 4.7km east of Ch 197 km

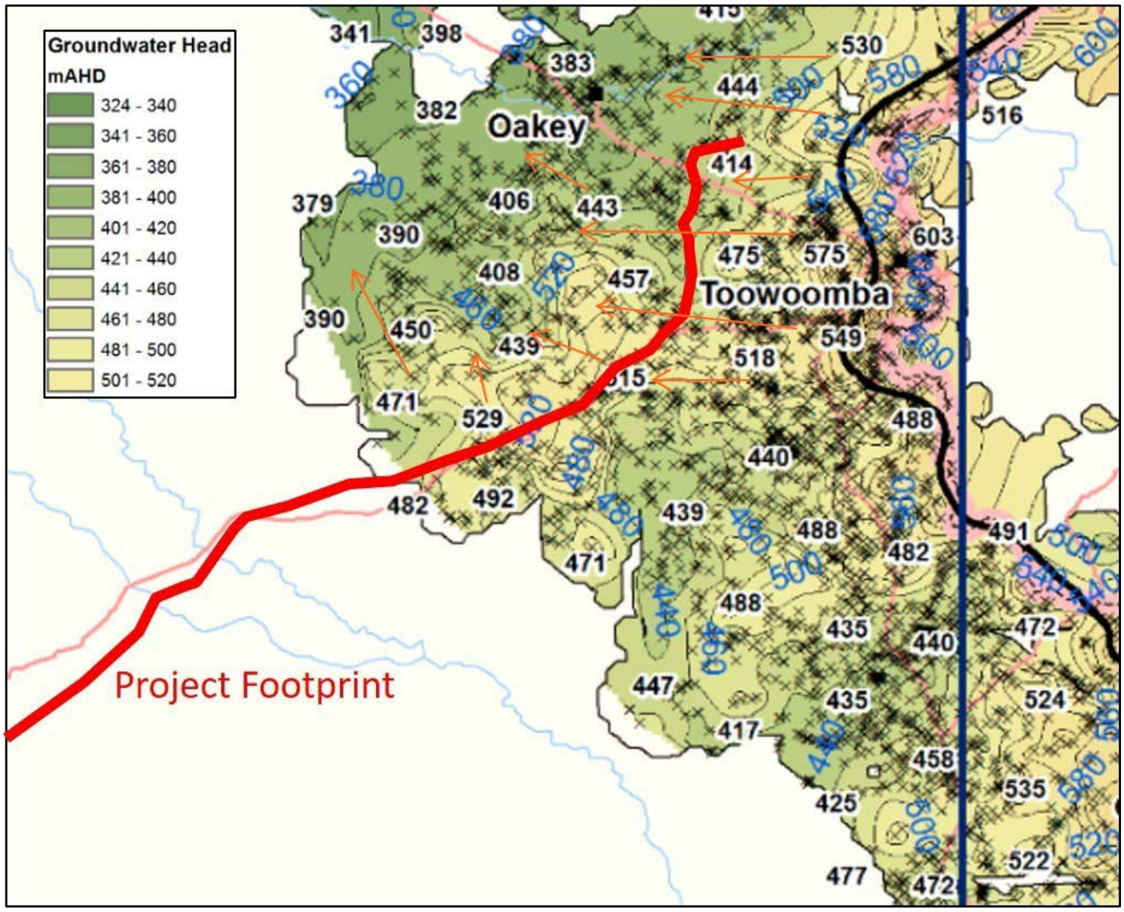


Figure 4.18 **Approximate location of the Project in relation to inferred groundwater flow direction of the Main Range Volcanics**

Figure note: Red line is the Project footprint

Source: Modified from OGIA (2016b)

4.7.2.3 Kumbarilla Beds

There are 21 registered bores within the impact assessment area with reported water levels for the Kumbarilla Beds (refer Table 4.11). Several bores were reported to display artesian conditions while others had water levels at depths to 133 mbgl; however, the mean water level for this unit is approximately 25 mbgl.

Representative groundwater levels for the Kumbarilla Beds are displayed on Figure 4.19 and Figure 4.20 for bore RN41640003 for the period of 1985 to 2017. A long gradual declining trend is apparent to 2009. This trend may relate to drought conditions and/or bore extraction, the impact of which would be compounded during drought. After 2009, groundwater levels increased slightly then remain largely static. This suggests this bore has not recovered since the Millennium drought broke in 2011 and/or has been unable to recover from extraction.

One monitoring well (BH2201) was installed within the impact assessment area at Ch 35.1 km; the screened interval is from 20.2 to 29.15 mbgl. The median water level at this bore is 7.9 mbgl (248.6 mAHD) which is significantly less than the mean water level calculated for the entire formation but still falls within the general range of water levels which may be attributed to the various depositional nature of the unit (refer Section 4.6.2.5).

The data for bore RN41640003, as shown in Figure 4.19 and Figure 4.20, demonstrates a relatively small degree of seasonal variance in water levels which may reflect confinement of the aquifer.

Groundwater flow in the Kumbarilla Beds near the Project is inferred towards the west, which follows the general topographic trends in the region (UQ, 2014).

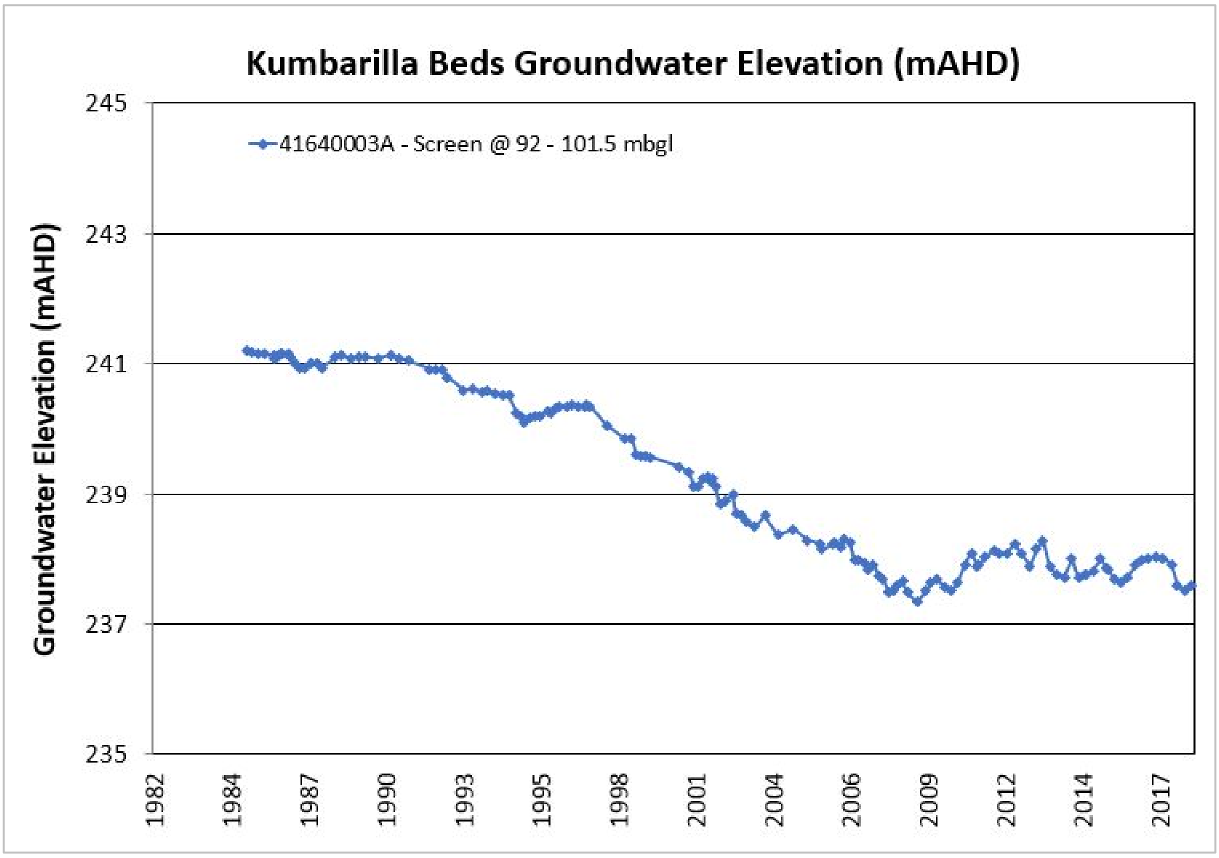


Figure 4.19 **Groundwater elevation within the Kumbarilla Beds**

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

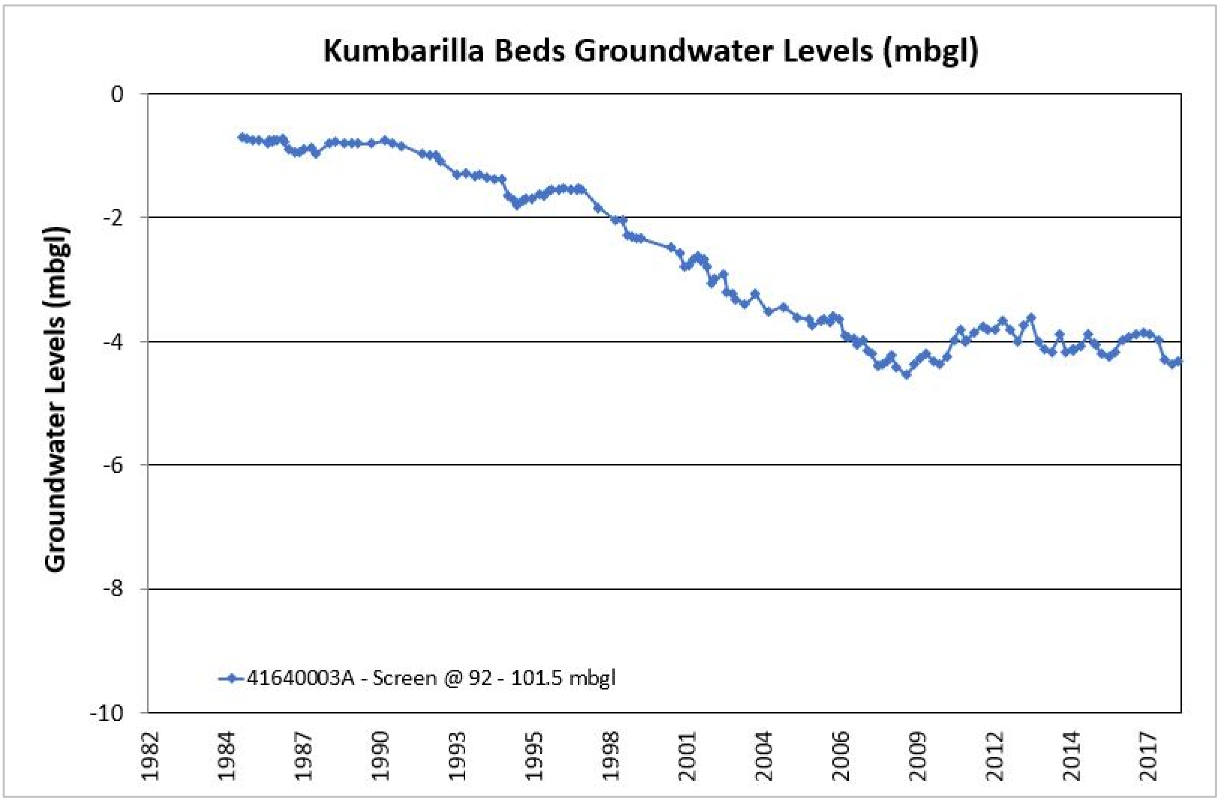


Figure 4.20 **Groundwater levels within the Kumbarilla Beds**

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

4.7.2.4 Walloon Coal Measures

The DNRME Groundwater Database includes 22 water levels records from registered bores located in the WCM. These recorded levels range between zero (artesian) and 102 mbgl, with a mean level of 35 mbgl. Time-series data for three representative bores with long-term data is presented on Figure 4.21, in mAHD, and Figure 4.22, in mbgl, over the period from 1977 to 2017.

Bore RN42231135 shows significant variation and a strong downtrend in levels, particularly after the drought broke in early 2011 but during an increase in CSG development projects in the region.

The other two bores (RN42231358 and RN42231340) show less dramatic changes in water level over time, where, conversely, bore RN42231340 shows an increasing trend between 1988 and 2017. Water level variation in the WCM reveals the complex hydrogeological setting of this geological formation coupled with the pressures of resource development and landowner extraction.

Groundwater flow in the WCM in the Condamine to Gowrie area (i.e. Ch 115.0 km to Ch 206.9 km) is generally towards the northwest. However, between Millmerran and Yelarbon, the flow direction is inferred towards the west-southwest (OGIA, 2016a). Available groundwater level data suggests that there is potential for groundwater flow from the basalts to the WCM (UQ, 2014). This flow is likely exacerbated by depressurisation of the coal seams which can induce flow from the adjacent units.

Ten site specific bores were drilled in 2018 and details are summarised in Table 4.7. The median water level in proximity to the rail alignment is approximately 270 mAHD, which is the equivalent of approximately 12 mbgl. Review of data captured at these bores via automated groundwater level loggers shows there can be significant variation in water level at individual bores. Most logger results display variations within a 10 m range; the greatest variability was observed at BH2210 (19 m). Similar seasonal water level variation was observed in the last 5 years of data from bore RN42231135 which varied by approximately 18 m.

Table 4.7 Site specific bore data for the Walloon Coal Measures

Bore ID	Chainage (km)	Surface elevation (mAHD)	Median SWL (mAHD)	Median SWL (mbgl)
BH2203	52.9	278.7	258.9	19.8
BH2304	53.0	289.8	-	-
BH2305	53.4	287.2	-	-
BH2206	55.0	272.4	263.5	8.9
BH2308	59.0	301.6	288.3	13.3
BH2309	63.8	277.1	266.1	11.0
BH2210	65.8	283.4	274.3	9.1
BH2214	87.4	-	-	-
BH2215	88.3	-	-	-
BH2216	94.0	320.8	307.6	13.2
Median of all boreholes:			270.2	12.1

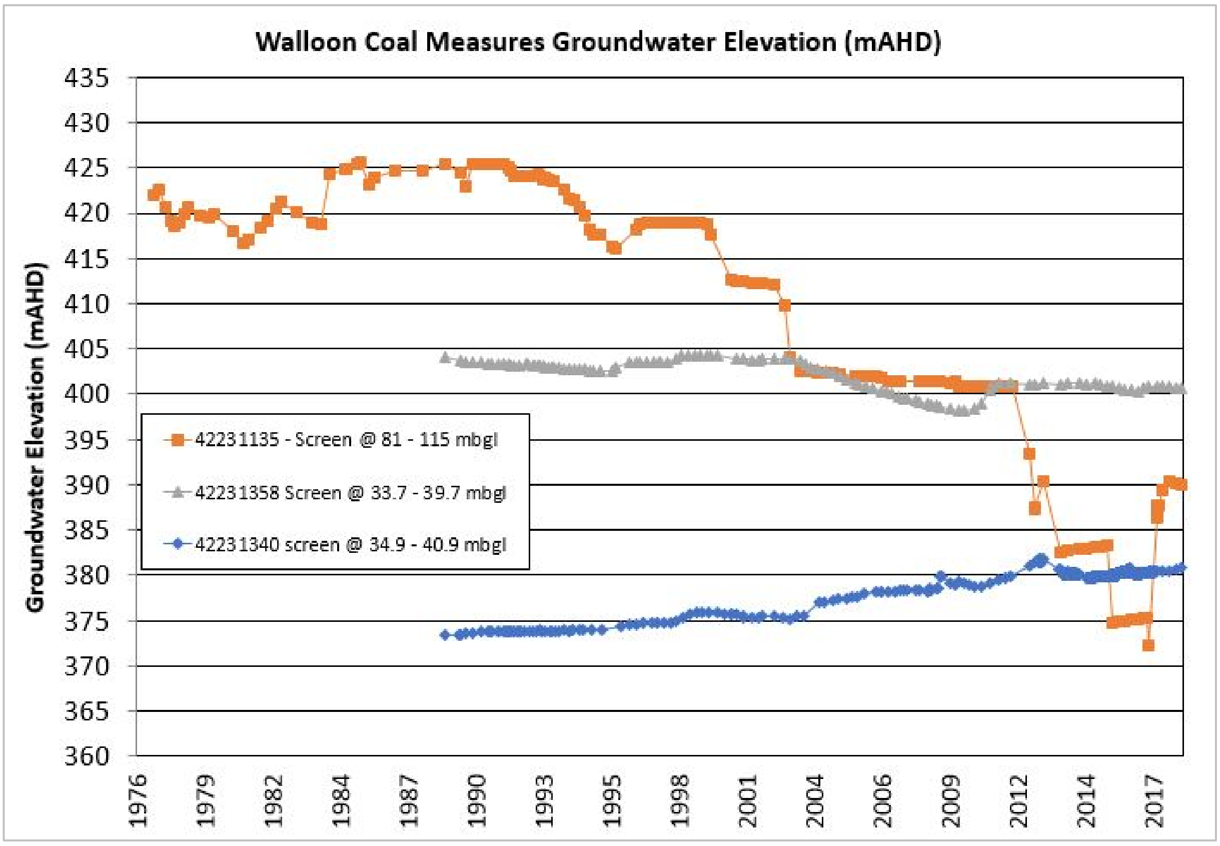


Figure 4.21 Representative groundwater elevation within the Walloon Coal Measures

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

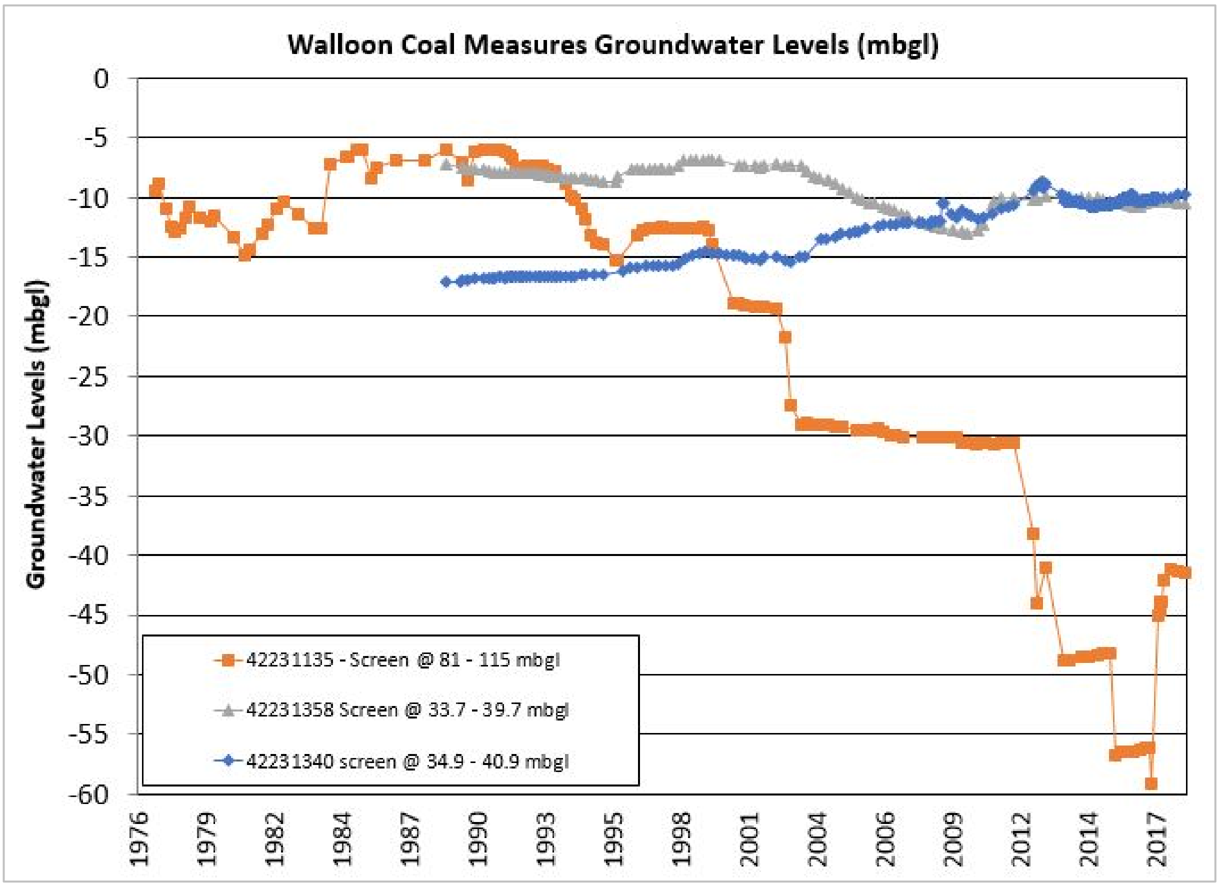


Figure 4.22 Representative groundwater levels within the Walloon Coal Measures

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

4.7.2.5 Vertical hydraulic gradients

Recent groundwater measurements from nested bores near the Project within the alluvium, and sedimentary units of the Surat Basin and Clarence-Moreton Basin, were evaluated to interpret vertical groundwater gradients.

Representative nested bores and groundwater level data are summarised in Table 4.8 and presented on the figures in the relevant subsection above. Due to a lack of nested bore locations close to the Project, bores up to 4.5 km from the impact assessment area were reviewed to characterise vertical gradients.

Table 4.8 Vertical groundwater evaluation form nested bore data from the Border Rivers region

Bore	Monitoring Point	Screened Interval (mbgl)	Aquifer	Water Level (mAHD)	Location relative to the Project	Comment
41640003	Pipe B	42 - 47.5	Border Rivers Alluvium	235.92	4.5 km to south of Ch 24 km	Upward gradient. Kumbarilla Beds water level 1.6m above alluvium water level. Levels gauged on 6/11/2018.
	Pipe A	92 - 101.5	Kumbarilla Beds	237.58		
42231378	Pipe B	56 - 67	Upper Condamine Alluvium	356.05	250 m south of Ch 153 km	Slight downward gradient. Levels gauged on 3/10/2018.
	Pipe A	107 - 119	Lower Condamine Alluvium	355.71		
42230962	Pipe B	4.0 – 13	Upper MRV	491.87	2 km east of Ch 188 km	Negligible vertical gradient in most recent water levels on 23/05/2018. Groundwater levels in Figure 4.17 indicate the upper and lower portions of the MRV have been hydraulically connected since 2010. Prior to 2010 an upward hydraulic gradient persisted.
	Pipe A	34 - 36	Lower MRV	491.86		
42231209	Pipe A	21 - 150	WCM	351.32	Ch 25.56 km NNW	No nested bores located to compare these two aquifers. Both water levels measured on 23 Jan 2019. Downward gradient. WCM water level 2.34m below that of Condamine Alluvium.
42230060	Pipe A	14 – 28.4	Condamine Alluvium	353.66	Ch 20.33 km NNW	

The static water level data indicates the following with respect to groundwater hydraulic gradients:

- The upward gradient from the KB and into the overlying Border Rivers Alluvium shows that the Kumbarilla Beds aquifer is confined and therefore there is limited hydraulic connection between the two
- The slight downward gradient between the upper and lower Condamine Alluvium shows hydraulic connectivity exists through the aquifer profile
- Negligible vertical gradient between the upper and lower MRV shows well established hydraulic connectivity through the aquifer. This is a well-connected fractured hard rock aquifer which acts as a single unit.
- The downward gradient that exists between the Condamine Alluvium and the deeper WCM shows limited hydraulic connectivity probably due to semi-confined conditions. Groundwater has potential to flow from the alluvium to the WCM.

Given the above observations, there does not seem to be significant hydraulic connectivity between the shallow alluvial and deeper fractured hard rock aquifers of the Border Rivers Alluvium. However, exceptions may occur where paleochannels are deeply incised, such as in the Macintyre River area of the Border Rivers Alluvium, where upward leakage from the Kumbarilla Beds could take place. Another potential mechanism for aquifer interaction is via faults that act as conduits for downward or upward migration of groundwater between aquifer systems.

Groundwater flow in the underlying GAB system is to the northwest and is understood to be locally recharged through the MRV and outcrop areas along the eastern and southeastern margins. A significant upward gradient in groundwater levels from the GAB to the Condamine Alluvium in the central area has developed because of water extraction from the alluvium (DNRME 2016).

The dataset included in the hydraulic connectivity assessment is somewhat limited when compared to the geographical size of the assessment area. As such, there is potential for connectivity between the alluvial sediments and underlying bedrock in localised areas; however, these are likely to impact negligibly on the overall inferred hydraulic connectivity of the alluvial units and underlying bedrock presented above.

4.7.3 Groundwater quality

The DNRME groundwater database was interrogated for groundwater quality data which yielded a total of 157 bores with available data. The water quality data was then sorted according to each aquifer type and used to derive minimum, maximum, and median values for select hydrochemical parameters to gain an understanding of the current conditions of the identified aquifers with potential to be impacted by the Project.

In 2016, DNRME undertook a hydrochemical assessment for the Condamine Alluvium, MRV, WCM, and the Hutton/Marburg (DNRME, 2016a). The results from that report have been referenced for this assessment, specifically those that focus on the interrelationship between the Condamine Alluvium, the MRV and the WCM. These three formations are important for understanding groundwater connectivity within the impact assessment area. Quality data obtained from the DNRME assessment was compared to the ADWG (NHMRC & NRMMC, 2011) and the ANZG (ANZECC & ARMCANZ, 2018) to identify the existing water quality of each aquifer.

Water samples can be analysed for, and characterised by, their hydrochemical composition. Such analysis enables a hydrochemical type to be assigned to a water source, or in this case an aquifer. A hydrochemical type is a sequence of a water sample's three major ions, listed in order of increasing concentration. A summary of major ion concentrations for the Condamine Alluvium, the MRV and the WCM is shown in Table 4.9. This data shows that water from the Condamine Alluvium and the MRV has a sodium-bicarbonate-chloride (Na-HCO_3-Cl) dominant hydrochemical type, whilst water from the WCM is sodium-chloride-bicarbonate (Na-Cl-HCO_3) dominant.

The data also shows that the WCM has much higher concentrations of Na+, HCO_3-, Cl-, SAR (sodium adsorption ratio) and total dissolved solids (TDS) than the Condamine Alluvium and the MRV. In particular, SAR and the percentage of Ca^{2+} and Mg^{2+}, as contributed from the weathering of rock minerals, differs greatly between the Condamine Alluvium and the WCM (DNRME, 2016a).

Table 4.9 Hydrochemical composition of water in three main aquifers

Aquifer	Hydrochemical type	Major ions	Mean (mg/L)	Median (mg/L)	Range (mg/L)	No. of observations
Condamine Alluvium	(Na-HCO_3-Cl)	Na^+	347	195	27-900	1,133
		HCO_3^-	408	390	6-973	
		Cl^-	585	235	8-900	
		SAR	7 (no unit)	5	1-56	
		TDS	1,371	827	200-16,700	
Main Range Volcanics	(Na-HCO_3-Cl)	Na^+	128	100	15-1,340	980
		HCO_3^-	357	345	6-1,150	
		Cl^-	272	180	10-3,300	
		SAR	4 (no unit)	2	1-35	
		TDS	778	651	75-5,4760	

Aquifer	Hydrochemical type	Major ions	Mean (mg/L)	Median (mg/L)	Range (mg/L)	No. of observations
Walloon Coal Measures	(Na-Cl-HCO_3)	Na^+	1,062	730	63-6,331	367
		HCO_3^-	614	508	12-1,650	
		Cl^-	1,537	940	35-11,058	
		SAR	51 (no unit)	22	1-219	
		TDS	3,209	2,283	326-18,999	

Source: DNRME (2016)

4.7.3.1 Hydrochemical classification

The Piper diagram is one of the most commonly used techniques to interpret water chemistry data, such as that presented in Figure 4.23. Piper diagrams plot relative abundances of major cations and anions on adjacent tri-linear fields, with these points then being extrapolated to a central diamond field. Here the chemical character of water, in relation to its environment, can be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents per million for the main diagnostic cations of Ca^{2+}, Mg^{2+}, and Na+/K+, and anions Cl^-, $SO4^{2-}$, and CO_3^{2-}/HCO_3^-.

Waters from different environments typically plot in diagnostic areas or 'hydrochemical facies'. The upper half of the diamond normally contains water of static environments, while the middle area normally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and co-ordinated environments. Sodium chloride brines (old water) normally plot in the right corner of the diamond shape while recently recharged water plots on the left corner of the diamond plot. The top corner normally indicates water contaminated with gypsum (sulphate impact).

Water quality, including Piper diagrams and determination of corresponding hydrochemical characteristics, is presented in the following subsections for each of the relevant aquifer units.

Alluvium (Condamine River)

Water chemistry data from water samples obtained from the Condamine Alluvium (DNRME, 2016a) have been compared to the Australian Drinking Water Guidelines (NHMRC & NRMMC, 2011). An assessment of median parameter values indicates that none of the criteria established in the Australian Drinking Water Guidelines are exceeded by water samples from the Condamine Alluvium. However, when maximum values are considered there are exceedances such as TDS (990 mg/L), pH (8.9), chloride (750 mg/L), sodium (297 mg/L).

Salinity is highly variable in this aquifer with TDS ranging between 227 and 990 mg/L, which is considered to be fresh (< 1,000 mg/L). This suggests that the aquifer is regularly recharged and that there is no extended residence time to facilitate water-sediment interaction (i.e. this is a typical dynamic primary aquifer system).

Water chemistry data from water samples obtained from the Condamine Alluvium have been plotted onto a Piper diagram to determine the hydrochemical character of the aquifer (refer Figure 4.23). The data points plot in a well-defined area where the dominant ions are Na-HCO_3-Cl which is consistent with the Na-HCO_3-Cl hydrochemical classification previously documented by DNRME (DNRME, 2016a).

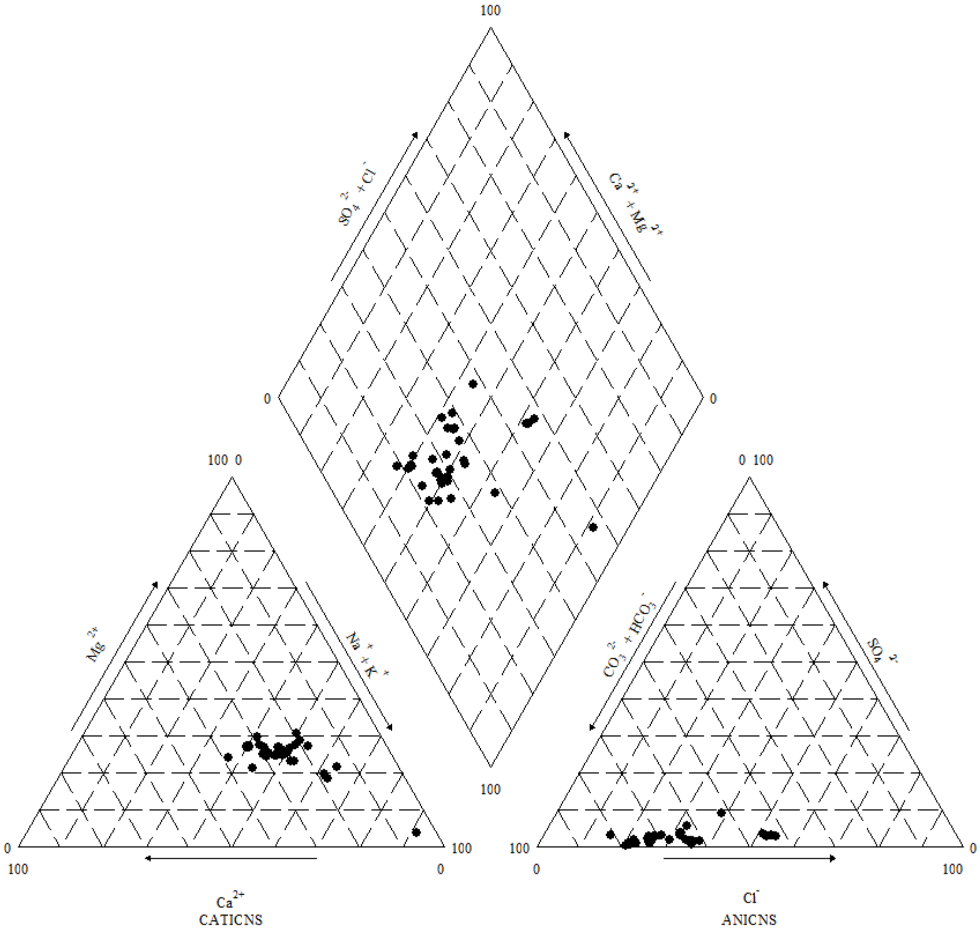


Figure 4.23 **Piper diagram of results for groundwater samples collected from the Condamine Alluvium**

Alluvium (Border Rivers)

Water chemistry data from water samples obtained from the Border Rivers Alluvium (DNRME, 2016a) have been plotted onto a Piper diagram to determine the hydrochemical character of the aquifer (refer Figure 4.24). The data points plot in two well-defined groups. The orange group is dominated by Cl-Ca-HCO_3 ions whereas the blue group is dominated by Na-K-HCO_3 ions.

These two groups clearly originate from different zones within the aquifer and acquire their character from the hosting alluvial sediments. The blue group suggests possible mixing of waters from two different regimes.

When comparing the water quality to the ADWG, only the median value of TDS exceeds the parameter standard of 600 mg/L. However, when taking maximum values into account, there are exceedances such as TDS (1,448 mg/L), pH (8.6), chloride (565 mg/L), sodium (542 mg/L), iron (0.62 mg/L) and nitrate (36 mg/L).

Salinity is highly variable in this aquifer with electrical conductivity (EC) ranging between 563 µS/cm and 2,600 µS/cm which is considered fresh to brackish groundwater. This suggests that certain parts of the aquifer can yield moderately saline water and that such areas are probably further from recharge zones which typically reflects longer residence time in the aquifer.

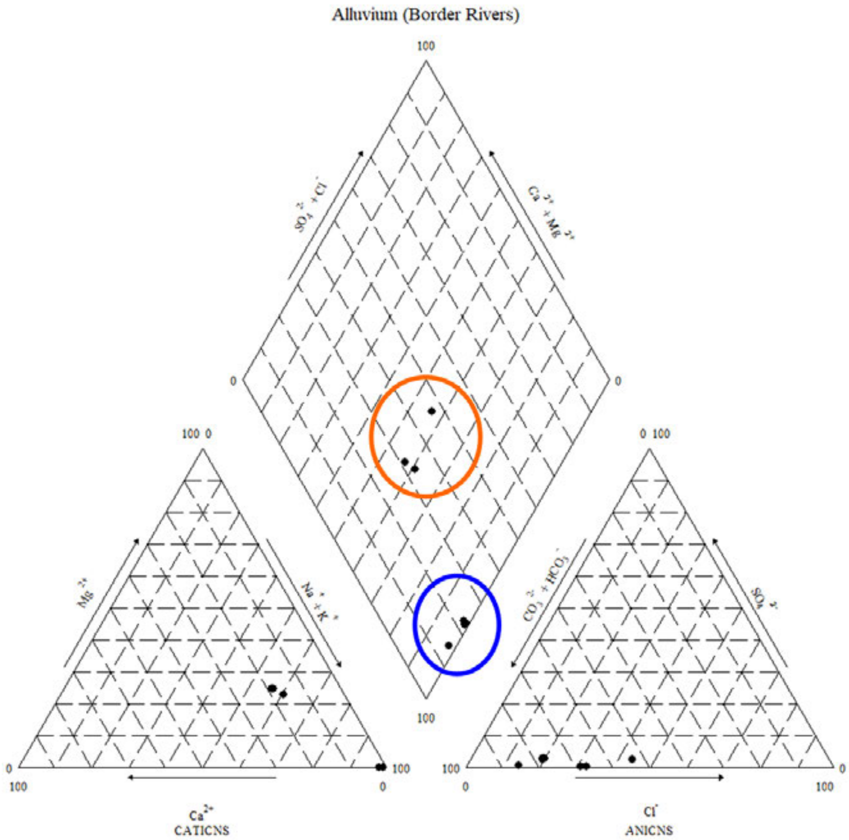


Figure 4.24 Piper diagram of results for groundwater samples collected from the Border Rivers Alluvium

Main Range Volcanics

The MRV consist of basalt that underlies the Condamine Alluvium tributaries in the eastern portion of the impact assessment area and overlies the WCM.

Data from the MRV is plotted in Figure 4.25 and presents available data from the DNRME groundwater database (black circles) and data from the site investigations for the Project (BH2344 and BH2347) (Golder, 2019c). The DNRME have previously reported groundwater from the MRV as being Na-HCO_3-Cl dominant and ranging from fresh to brackish in salinity (DNRME 2016a). However, when plotted onto a Piper diagram, water chemistry data shows that water within this aquifer does not have a specific hydrochemical signature, with individual samples plotting across the diagram (rather than plotting in a cluster). The dominant cation in the majority of samples is shown to be magnesium and the dominant anion is shown to be bicarbonate. The scattered nature of the samples indicates that there are multiple processes occurring in this aquifer. These processes are likely to involve recent recharge, mixing environments and cation exchange of magnesium and calcium for sodium (refer Figure 4.25).

When compared to the ADWG, only the median value of TDS and chloride exceeds the parameter standards of 600 mg/L and 254 mg/L respectively. When taking maximum values into consideration, there are exceedances such as TDS (5,510 mg/L), chloride (1,770 mg/L), fluoride (2.5 mg/L), sodium (517 mg/L), iron (0.52 mg/L) and nitrate (160 mg/L). Nitrate concentrations are significantly elevated in some samples and this could be related to local agricultural land use such as feedlots or use of fertilizer on cultivated land.

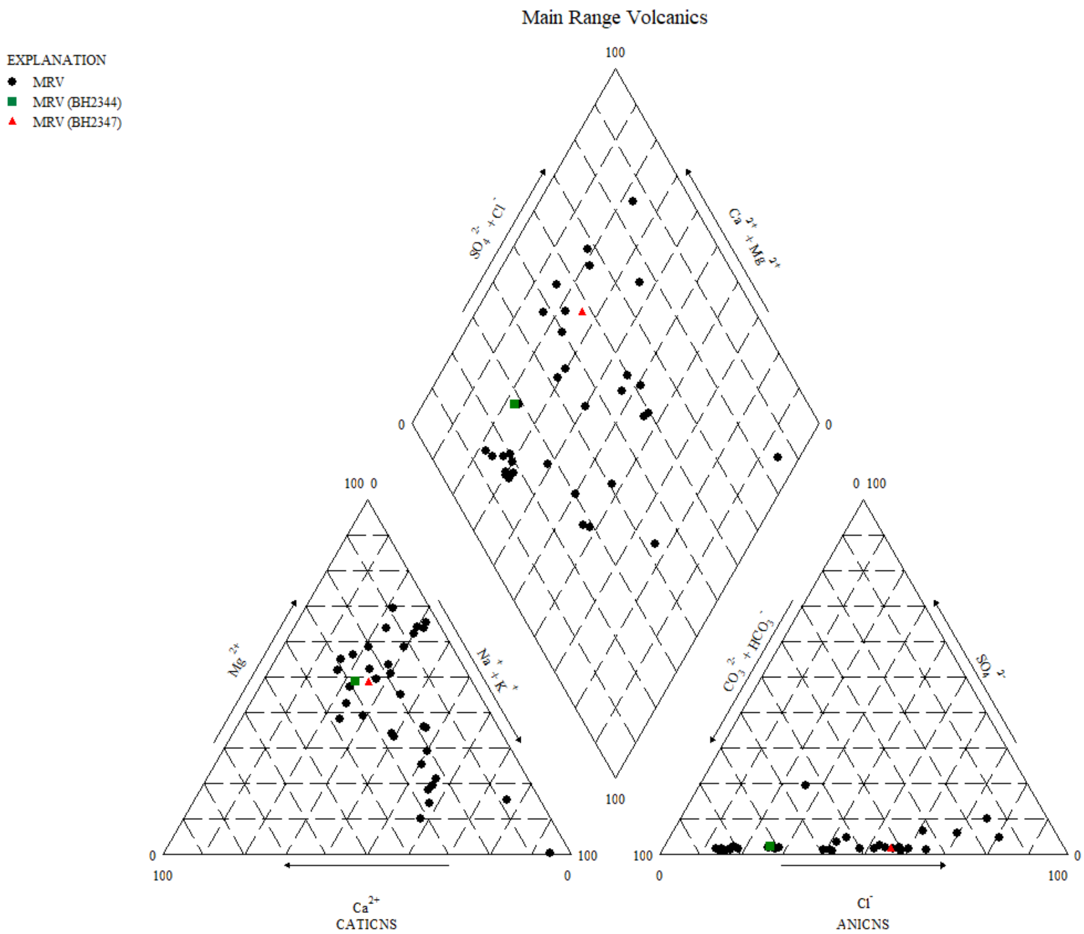


Figure 4.25 Piper diagram of results for groundwater samples collected from the Main Range Volcanics

Walloon Coal Measures

The quality of the groundwater within the WCM is highly variable due to the structure of the unit and the hydraulic connectivity (leakage) with the overlying units, which are known to be of fresher quality. Water chemistry data from water samples obtained from the WCM indicate TDS values ranging from 374 mg/L up to 5,741 mg/L, which is considered fresh to saline. The high variability in the dissolved salt load is also evident in the scattered nature of samples when plotted into a Piper diagram, as depicted in Figure 4.26.

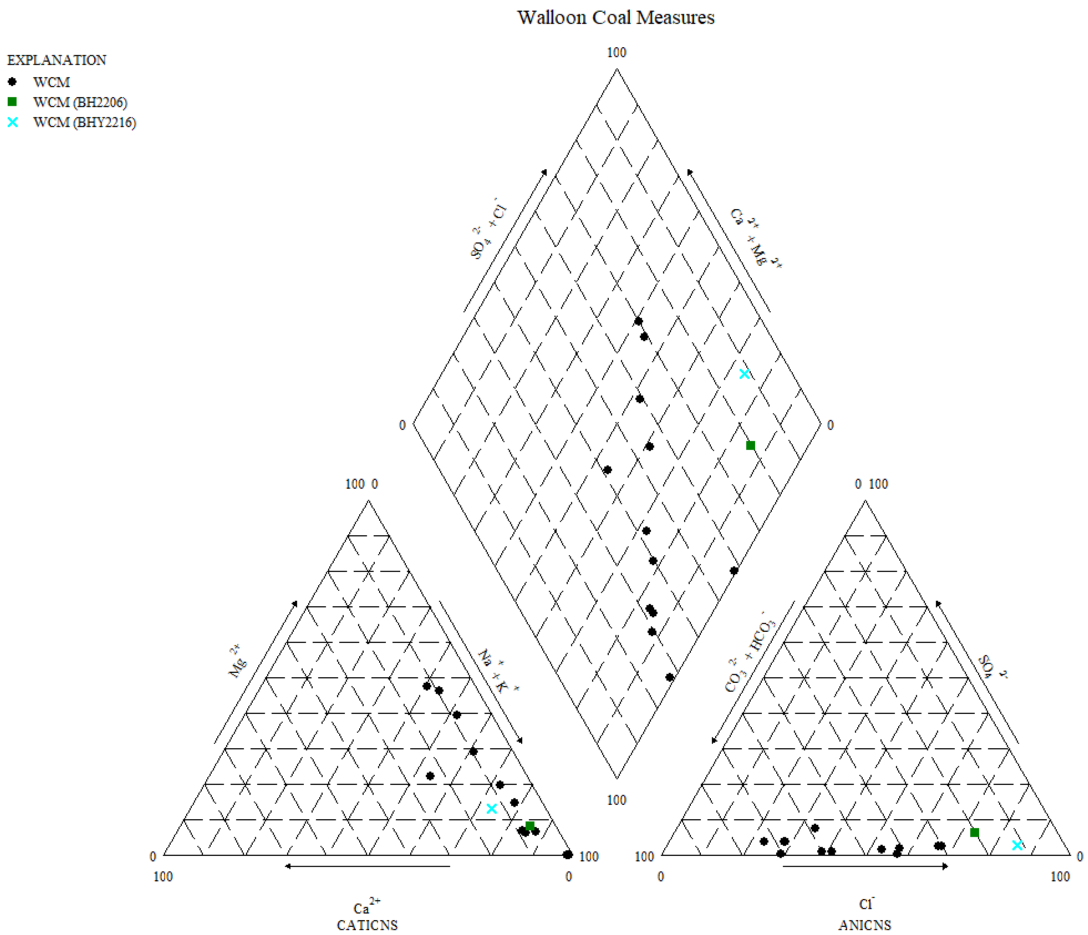


Figure 4.26 **Piper diagram of results for groundwater samples collected from the Walloon Coal Measures**

Groundwater quality summary

The available quality data was tabulated into Table 4.10 to compare the quality of the aquifers described above. As a general overview of water quality in each aquifer zone, chloride and sodium are the main ions that exceed the water quality standards. Iron exceeds the drinking water standard limit in the alluvium (Border Rivers) and in the MRV.

Table 4.10 Comparison of groundwater quality to guideline values

Parameter	Guidelines		Alluvium (Condamine & Westbrook Creek) (n=56)			Alluvium (Border Rivers) (n=10)			Main Range Volcanics (n=46)			Walloon Coal Measures (n=27)		
	ANZG Stock (2018)	NHMRC Drinking Water (2018)	*Min*	*Max*	*Median*	*Min*	*Max*	*Median*	*Min*	*Max*	*Median*	*Min*	*Max*	*Median*
Physiochemical														
Electrical Conductivity (µs/cm)			480	2750	952	563	2600	1255	420	5510	1497	*660*	*9710*	1965
Total Dissolved Solids (mg/L)			227	990	505	351	1448	740	258	3064	833	*374*	*5741*	1041
pH			6.6	8.9	8.0	7.2	8.6	8.0	7.0	8.4	7.8	*7.4*	*8.7*	8.3
Na Adsorption Ratio			-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (mg/L)	4000	6000	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (mg/L)			20	651	321	202	600	436	69	870	383	215	620	373
Dissolved Anions														
Bicarbonate (mg/L)			24	794	370	245	705	501	83	1061	458	259	757	434
Carbonate (mg/L)			0.3	276.0	49.0	0.3	19.5	10.0	0.6	362.0	13.8	1.3	303	42.0
Chloride (mg/L)		250	45	750	137	64	565	137	32	1770	254	68	3300	390
Flouride (mg/L)			0.1	0.6	0.2	0.4	1.0	0.6	0.1	2.5	0.3	0.2	1.69	0.5
Sulphate as SO4 (mg/L)	1000	500	2	44	11	1	19	12	2	108	23	2	58	18
Dissolved Cations														
Sodium (mg/L)		180	49	297	111	74	542	269	24	517	117	84	2157	319
Potassium (mg/L)			1	18	4	1	5	2	1	5	2	0.8	9.8	3
Iron (mg/L)		0.3	0.01	0.07	0.02	0.01	0.62	0.20	0.01	0.52	0.10	0.01	0.03	0.02
Calcium (mg/L)	1000		1	112	48	2	36	11	2	196	62	1.4	130	35
Magnesium (mg/L)			2	152	33	0	29	8	1	487	90	0.1	160	35
Nutrients														
Nitrate (mg/L)			0.2	3.5	1	0.5	36	4.01	0.6	160	22.21	1	16	4.5

Table notes:

Ground water quality data is sourced from the DNRME groundwater database. Data presented is for registered bores within a 1 km radius of the rail alignment centre line (impact assessment area).
N = total data points but in many cases the dataset is incomplete thus making “n” variable for each parameter.

4.7.3.2 Regional salinity

Salinity is a major land degradation issue that can impact on land productivity, in-stream salt loads and concentrations. Two salinity risk assessments have previously been undertaken within the impact assessment area. The Murray Darling region salinity risk assessment intersects the impact assessment area between the Macintyre River and east of Millmerran State Forest (Biggs et al. 2010b). The Condamine Catchment salinity risk assessment intersects 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. The Yelarbon area (approximately from Ch 20 km to Ch 30 km) is known for its extremely alkaline, sodic sodosol soils strongly attributed to upwelling of sodium bicarbonate rich groundwater (Biggs et al. 2010a). This upwelling is primarily attributed to an offset fault from the Peel Fault which allows saline groundwater to infiltrate the soil zone (Knight et al., 1989). The Peel Fault is discussed in further detail in Appendix R: Groundwater Technical Report.

Within the Border Rivers catchment, the salinity risk assessment identified the use of saline groundwater, leaking dams and dissolution of salts as the most common salinity types upon assessment of the existing landscape. Despite the need for greater research regarding secondary salinity formation and the impact of salinity on infrastructure assets, the risk assessment concluded salinity in the region will have a low risk to rail infrastructure (Biggs et al. 2010b).

The Condamine Catchment salinity risk assessment identified more than 170 salinity expression sites with most influenced by climatic conditions. The assessment identified return to typical long-term weather patterns will likely increase the size and number of dryland salinity expressions in the region and increase salt load exported from the catchment. The impact assessment area intersected sub-catchments considered to contain a very low to high overall salinity risk. The Millmerran area was considered to have a very low to low risk of secondary salinity, whilst the Pittsworth and Gowrie area considered to have moderate risk. An area of high salinity risk intersects the impact assessment area near Southbrook and presents a ‘Current’ threat, through salinity, to infrastructure assets in the area (Searle et al. 2007).

An assessment of the salinity hazard risk along the Project alignment has been undertaken and documented in Chapter 8: Land resources of the Border to Gowrie EIS.

4.7.4 Surface water - groundwater interactions

4.7.4.1 Condamine Alluvium

The Condamine Alluvial system has been traditionally conceptualised as a single connected groundwater system with little or no interaction with underlying bedrocks. Recharge to the Condamine Alluvium is complex and there are differing views on the relative significance of different recharge pathways. The most common and prevalent view is that the alluvium is mainly recharged from river and stream flow leakage, as discussed in Section 4.7.1.1. This relationship is demonstrated by the hydrograph in Figure 4.27 produced from the groundwater bore database that spans a time period between June 1995 and January 2019.

Data for stream flow were taken from the Lemon Tree Weir on the Condamine River, station number 422349A, and groundwater level data were taken from registered bore RN42231089 which is approximately eight kilometres downstream adjacent to the Gore Highway (refer Figure 4.30). Rainfall data has been obtained from the Glen Royal BoM weather station (Station 041504).

There is an approximate 10 m difference in elevation between the groundwater level and Condamine River water level with the latter being most elevated. This difference in water level elevation suggests that the Condamine River is a losing river by virtue of aquifer recharge. Diffuse rainfall recharge is expected to be limited by the high clay content of near-surface soils and fine-grained sheetwash deposits. Discharge is mostly through extraction and downstream lateral flow (DNRME 2016).

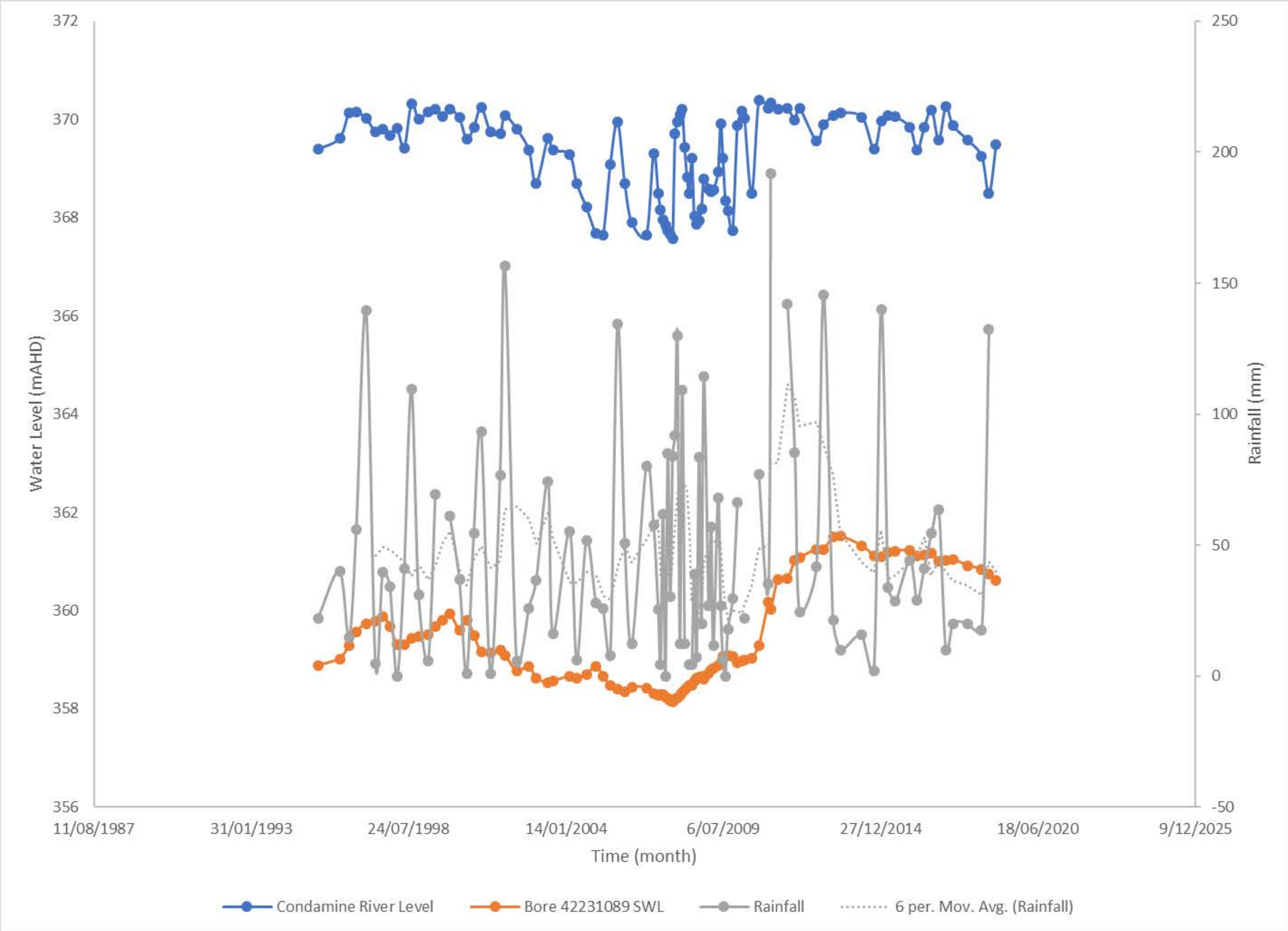


Figure 4.27 Representative hydrograph of the Condamine River area

4.7.4.2 Border Rivers Alluvium

Regional assessments of surface water - groundwater interactions have identified the Macintyre River and other watercourses in the region to be in a losing condition (Parson et al. 2008). This means that surface water typically infiltrates vertically to recharge local groundwater within the alluvium. This relationship is demonstrated by a hydrograph produced from data that spans a time period between April 2011 and August 2018 (refer Figure 4.28). Data for stream flow were taken from the Ben Dor Weir on the McIntyre River (Station Number 416406A) and groundwater level data were taken from registered bore RN41640038 which is approximately 7 km upstream adjacent to the Cunningham Highway (refer Figure 4.30). There is an approximate 6 m difference in elevation between the groundwater level and McIntyre River water level with the latter being most elevated. This difference in water level elevation confirms that the McIntyre River is a losing river by virtue of aquifer recharge.

The Glenlyon and Pindari Dams in the upper reaches of the Border Rivers catchment result in regulated flows to the Severn and Macintyre Rivers (DPI 2012). Consequently, there is likely to be an artificial influence on recharge to alluvial aquifers during low flow periods (periods of dam discharge to the rivers).

4.7.4.3 Main Range Volcanics

There are no perennial streams/rivers crossing outcrops of MRV in proximity to the Project but there is potential recharge from local ephemeral streams/creeks. To identify surface-groundwater interaction, rainfall data has been compared to groundwater level response. A hydrograph was produced using time-series groundwater data from registered bore RN42230962 and rainfall data from the Glen Royal weather station (refer Figure 4.29).

The hydrograph shows that there is a rapid response in groundwater level to rainfall which illustrates a typical attribute of a highly fractured aquifer. Seasonal streams will readily recharge the aquifer because of the high degree of hydraulic connection.

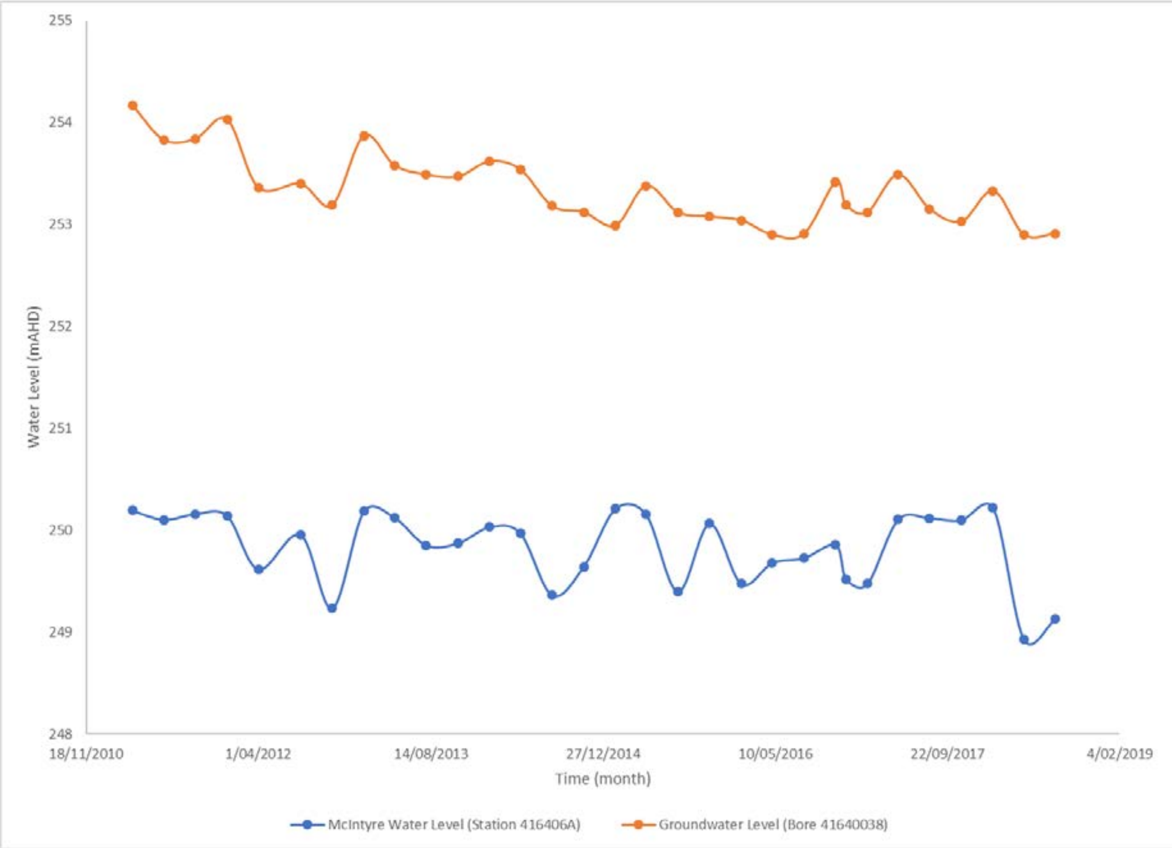


Figure 4.28 Representative hydrograph of the McIntyre River area

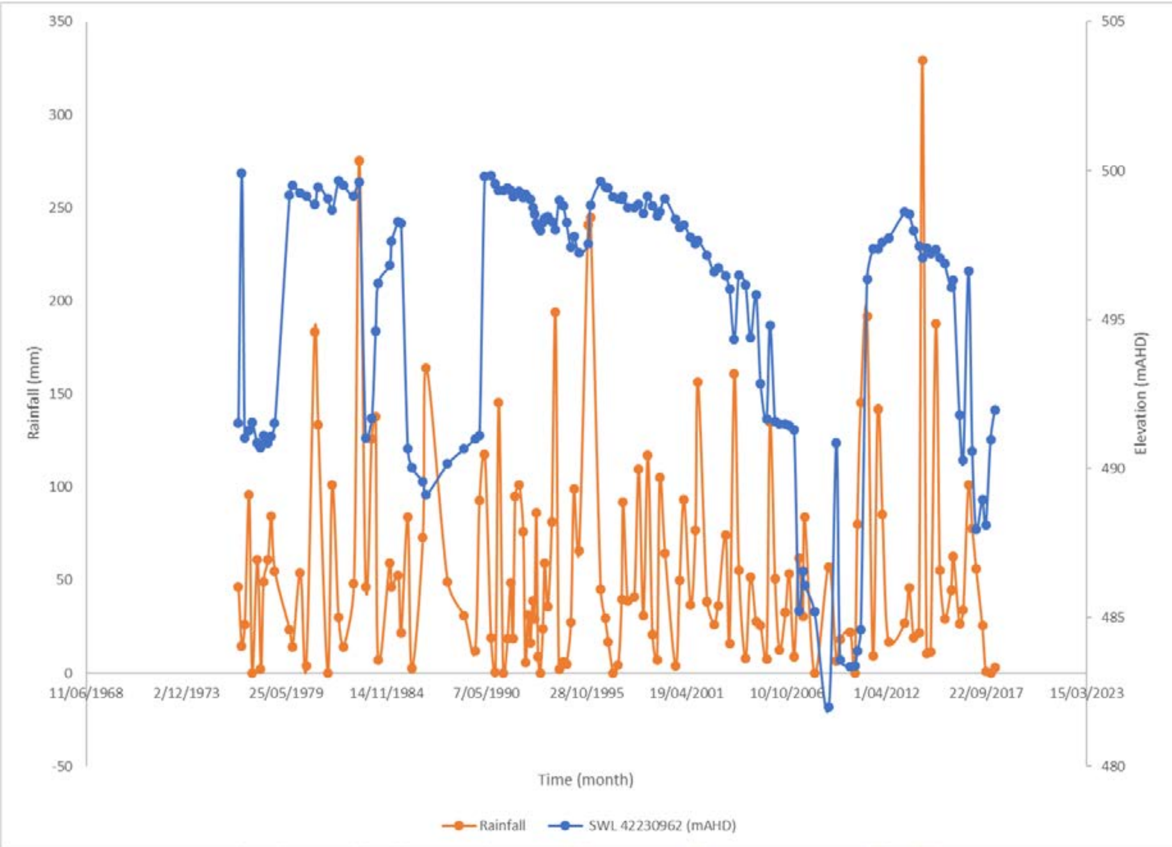


Figure 4.29 Representative hydrograph of static water level and rainfall in the Main Range Volcanics

4.7.5 Registered groundwater bores

A search of registered groundwater bores within the impact assessment area was completed in March 2019 using the DNRME Groundwater Database and Queensland Globe. The search identified a total of 439 registered bores within the impact assessment area of which 156 were excluded from further evaluation due to an absence of data on aquifer lithology, bore construction details or water levels. The remaining 283 registered bores within the impact assessment area are depicted in Figure 4.30 and summarised in Table 4.11. The database was utilised to develop an appreciation for existing groundwater usage within the impact assessment area.

Many of the registered bores screened within fractured-rock aquifers are within Surat Basin strata and are primarily screened in the Kumbarilla Beds, WCM and the Hutton Sandstone.

Box and whisker plots for reported static water levels are presented on Figure 4.31 and reported yields for registered bores on Figure 4.32. A comprehensive table of the registered bores within the Project footprint is provided in Appendix A.

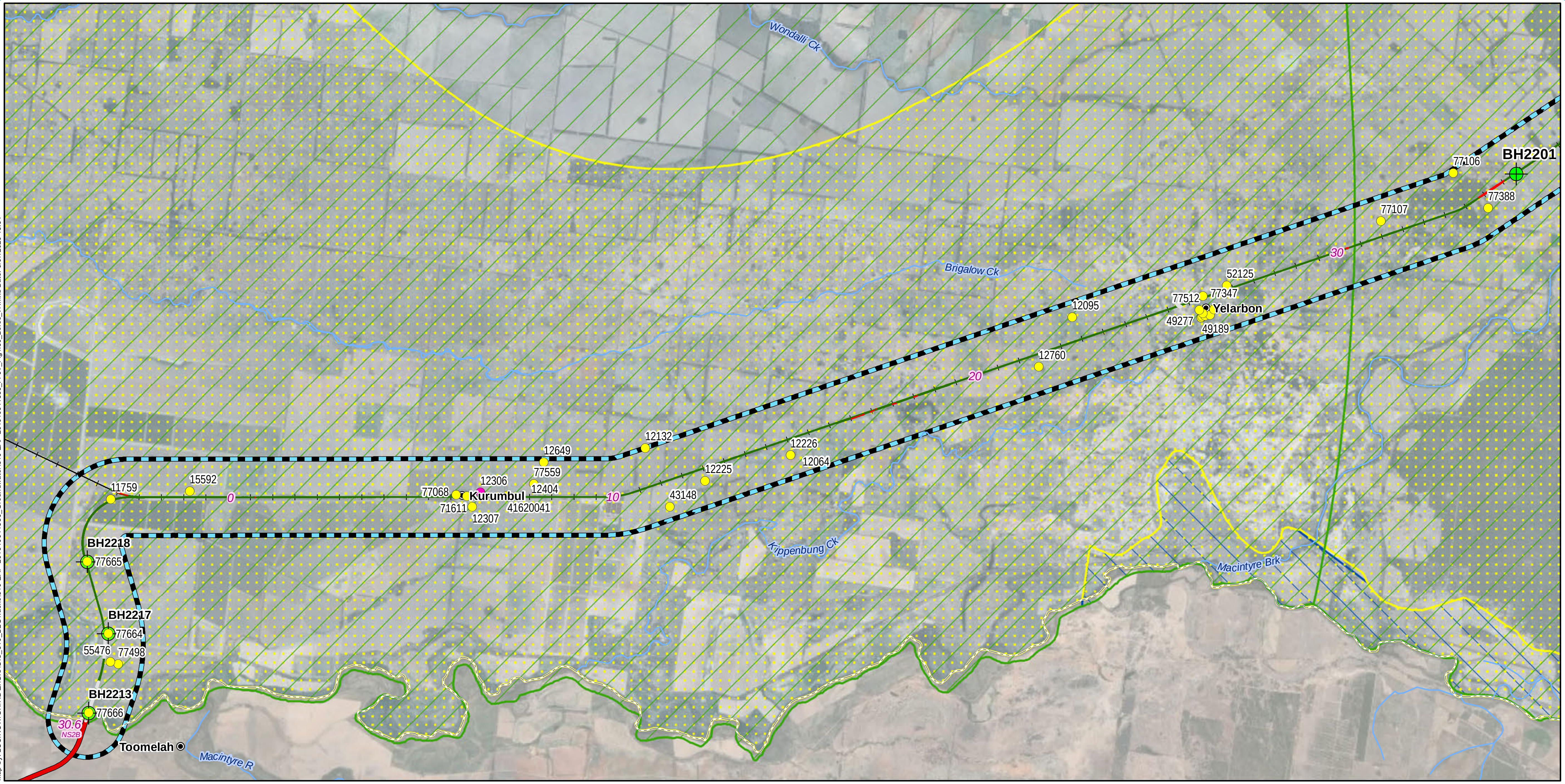
Table 4.11 Summary of Department of Natural Resources, Mines and Energy registered bores within the impact assessment area

Aquifer	Number of bores	Standing water level (mbgl)				Yield (L/s)			
		Min	Max	Mean	Count	Min	Max	Mean	Count
Border Rivers Alluvium	6	7.6	9.0	7.4	5	0.5	1.8	1.1	4
Condamine Alluvium	81	6.9	36.2	20.0	55	0.4	25	6.2	26
MRV	148	1.8	60.1	18.7	55	0.06	18.9	3.9	63
Kumbarilla Beds	21	0*	133	24.8	19	0.2	5.5	1.7	17
WC	27	0*	102	35	22	0.12	22.9	4.12	21
Total	**283**								

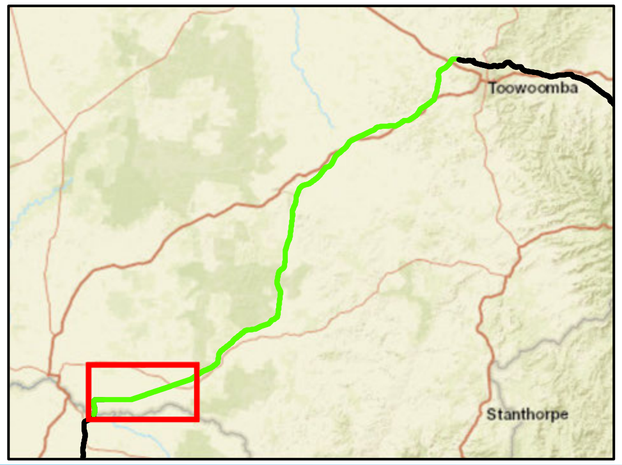
Table note:

* Free flowing bores encountered.

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



Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34



Legend

- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Cut
- Fill
- Watercourses
- NSW/QLD border
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Border Rivers and Moonie) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Regulation 2016

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

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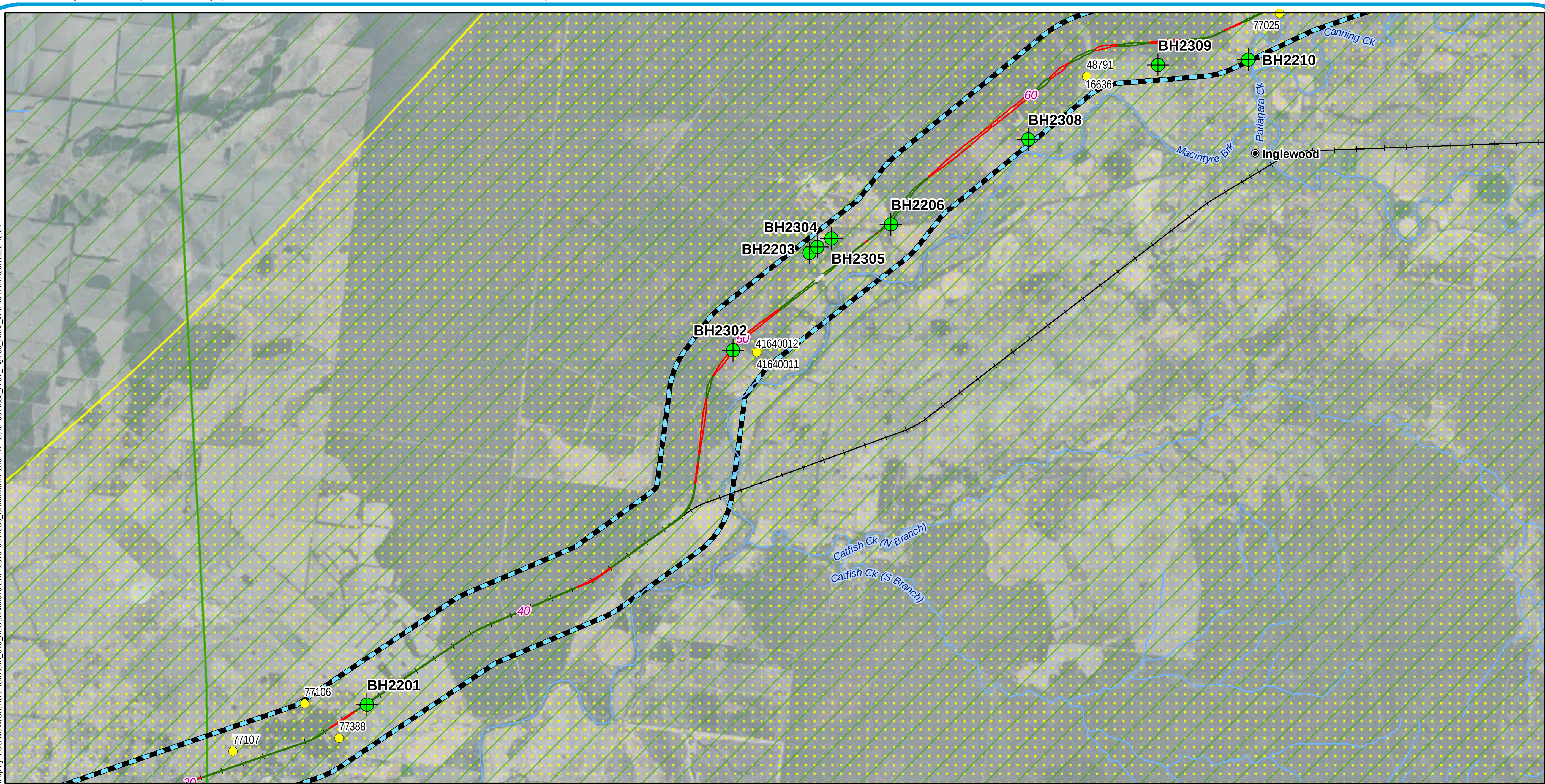
Border to Gowrie

Figure 4.30a: Registered and design phase bores within the impact assessment area

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



Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

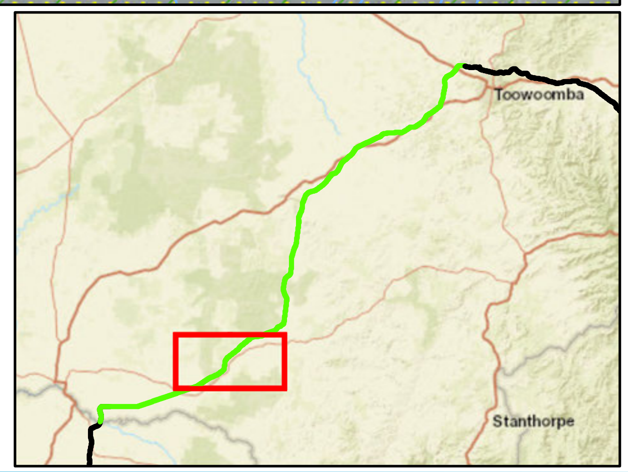
Groundwater management areas

- Water Act 2000
- Water Plan (Border Rivers and Moonie) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)



A3 scale: 1:110,000

0 1 2 3 4 5km

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Issue date: 09/07/2020 Version: 7
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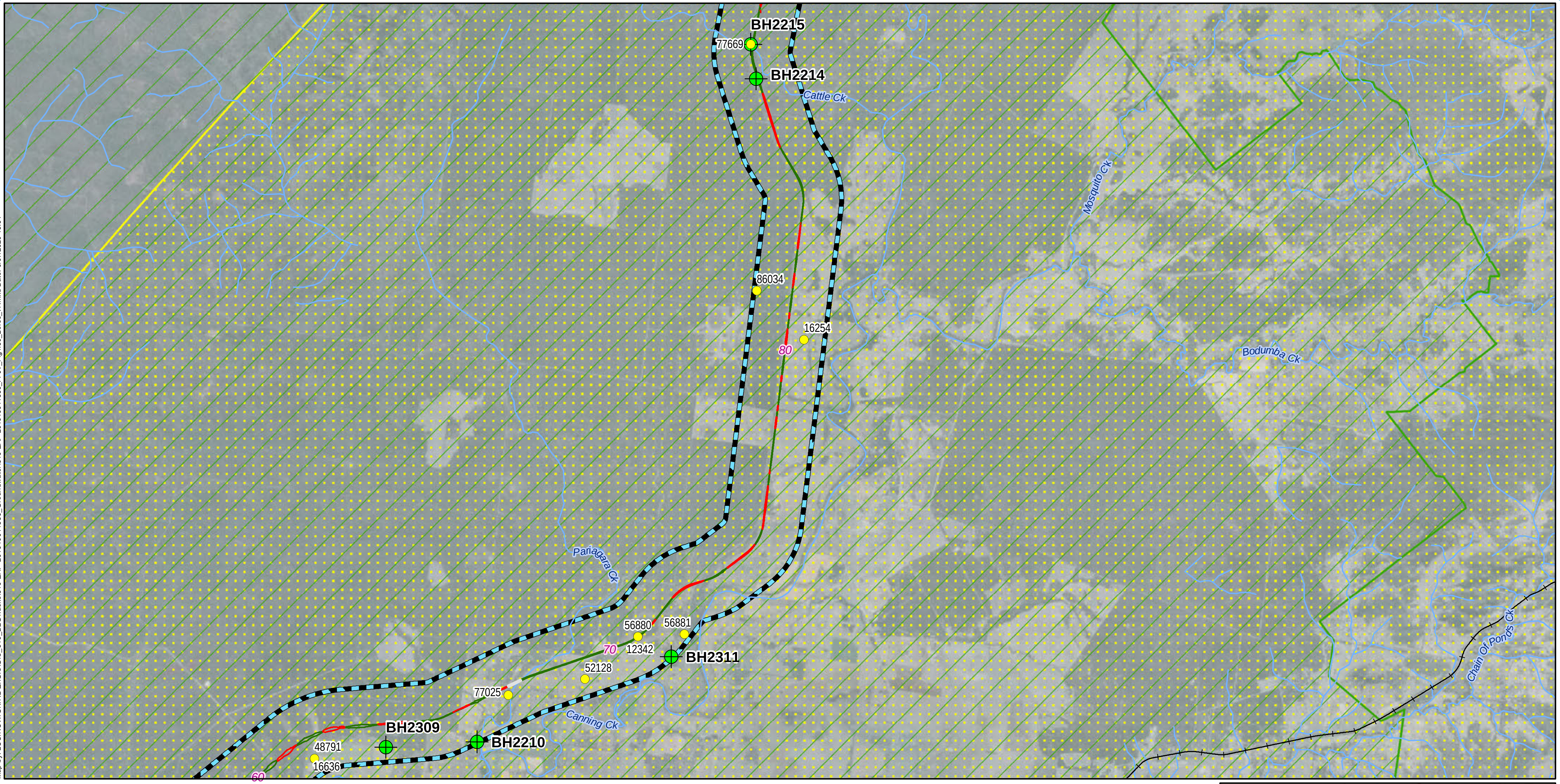
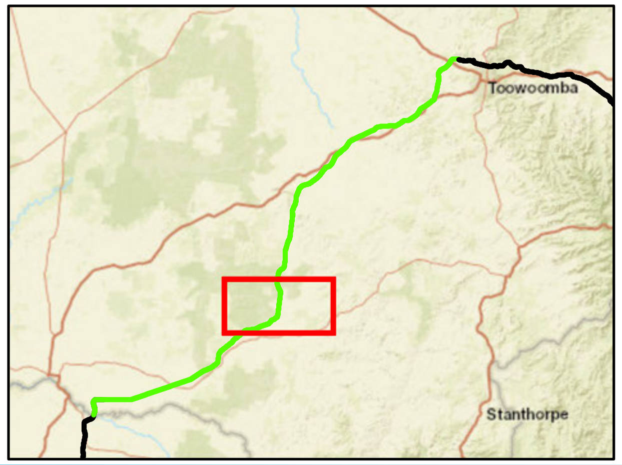
Border to Gowrie

Figure 4.30b: Registered and design phase bores within the impact assessment area

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34





Legend

- 5 Chainage (km)
- Existing rail (operational)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Border Rivers and Moonie) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

Future Freight
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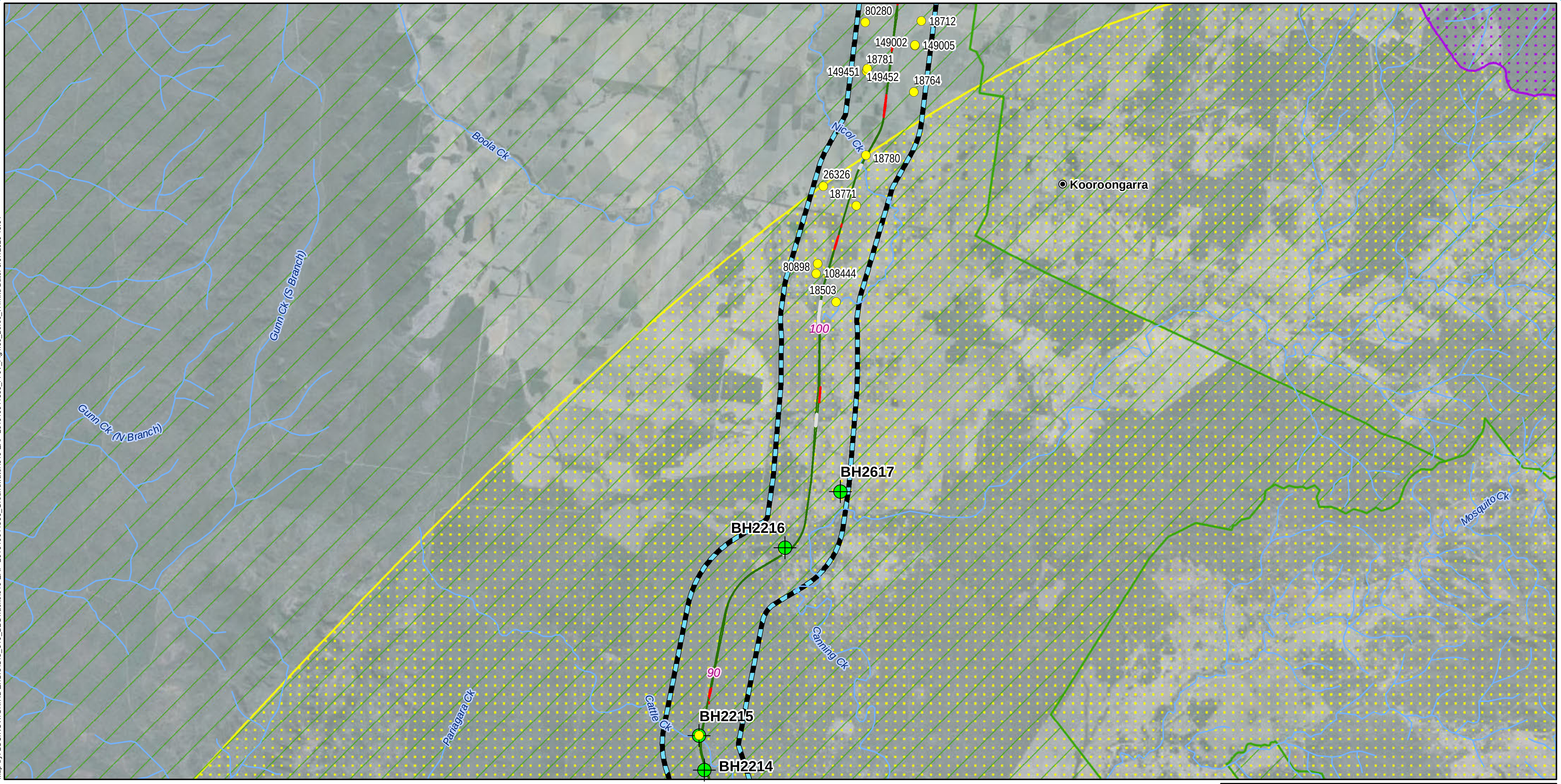
Issue date: 09/07/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

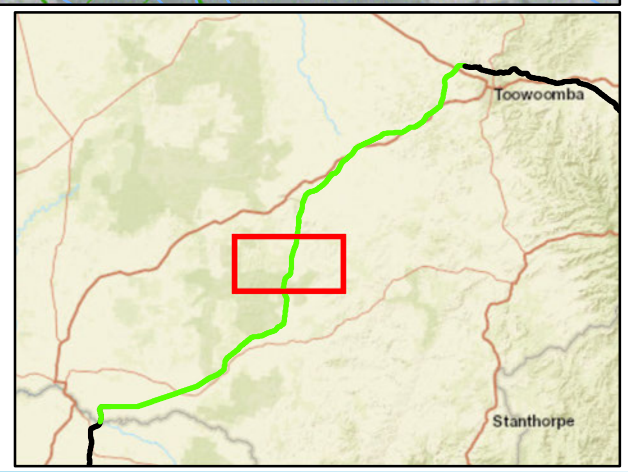
Border to Gowrie

Figure 4.30c: Registered and design phase bores within the impact assessment area

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34





Legend

- 5 Chainage (km)
- Localities
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Border Rivers and Moonie) 2019
- Water Plan (Condamine and Balonne) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

Future Freight
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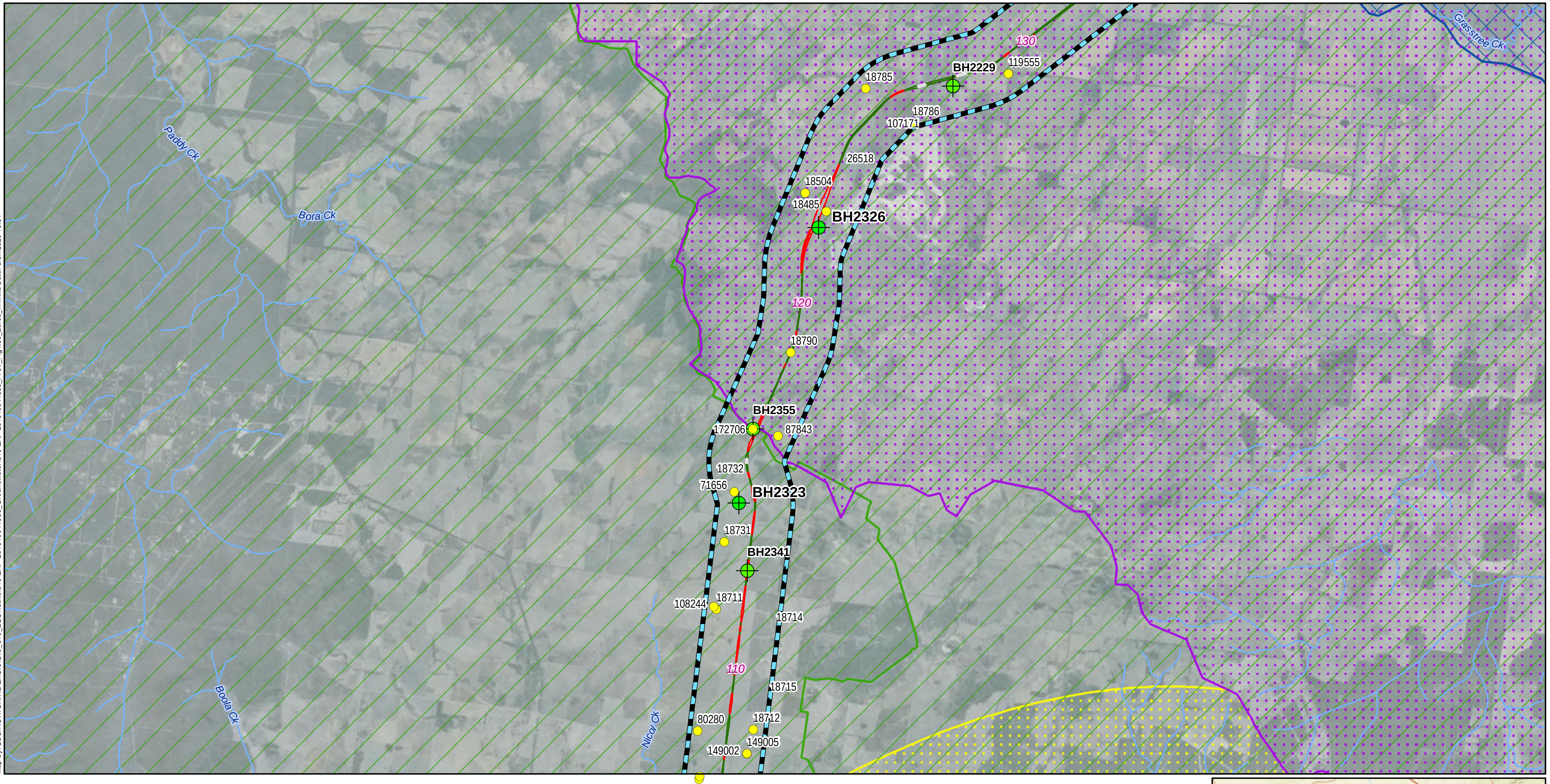
Issue date: 09/07/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.30d: Registered and design phase bores within the impact assessment area

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



Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34

Legend

- 5 Chainage (km)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

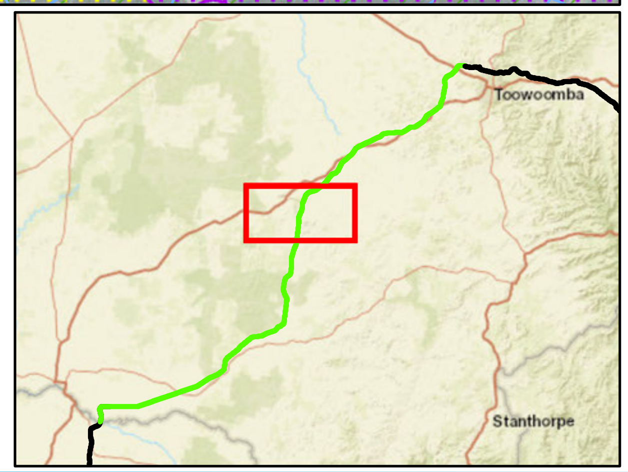
Groundwater management areas

- Water Act 2000
- Water Plan (Border Rivers and Moonie) 2019
- Water Plan (Condamine and Balonne) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Regulation 2016

Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)



A3 scale: 1:110,000

0 1 2 3 4 5km

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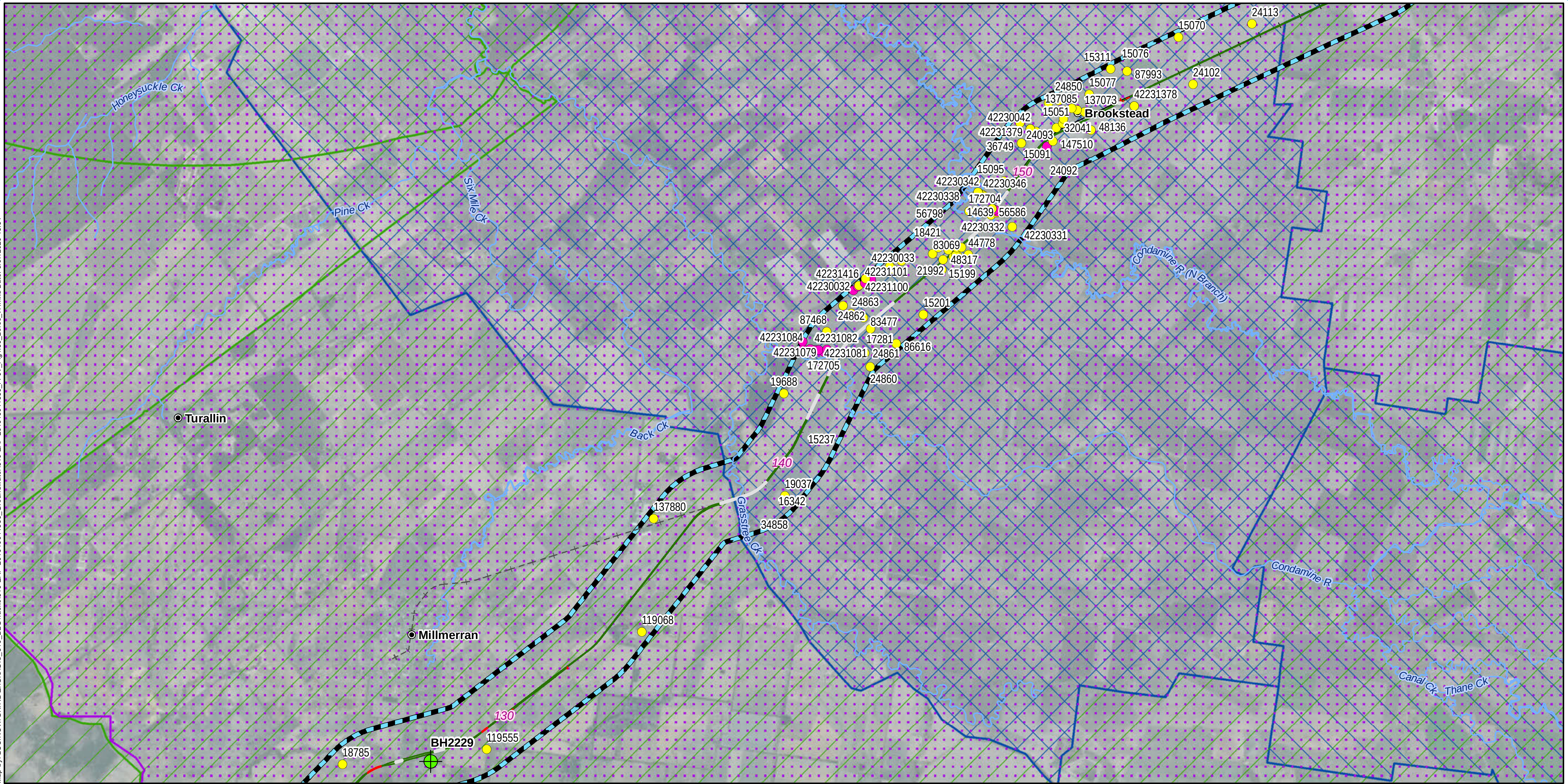
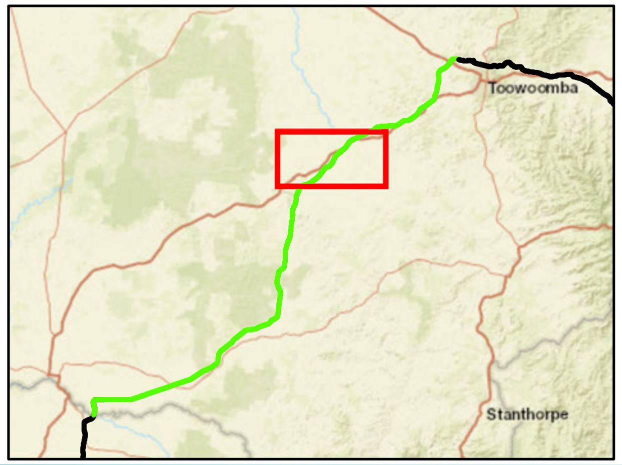
Border to Gowrie

Figure 4.30e: Registered and design phase bores within the impact assessment area

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34





Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Condamine and Balonne) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Regulation 2016

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

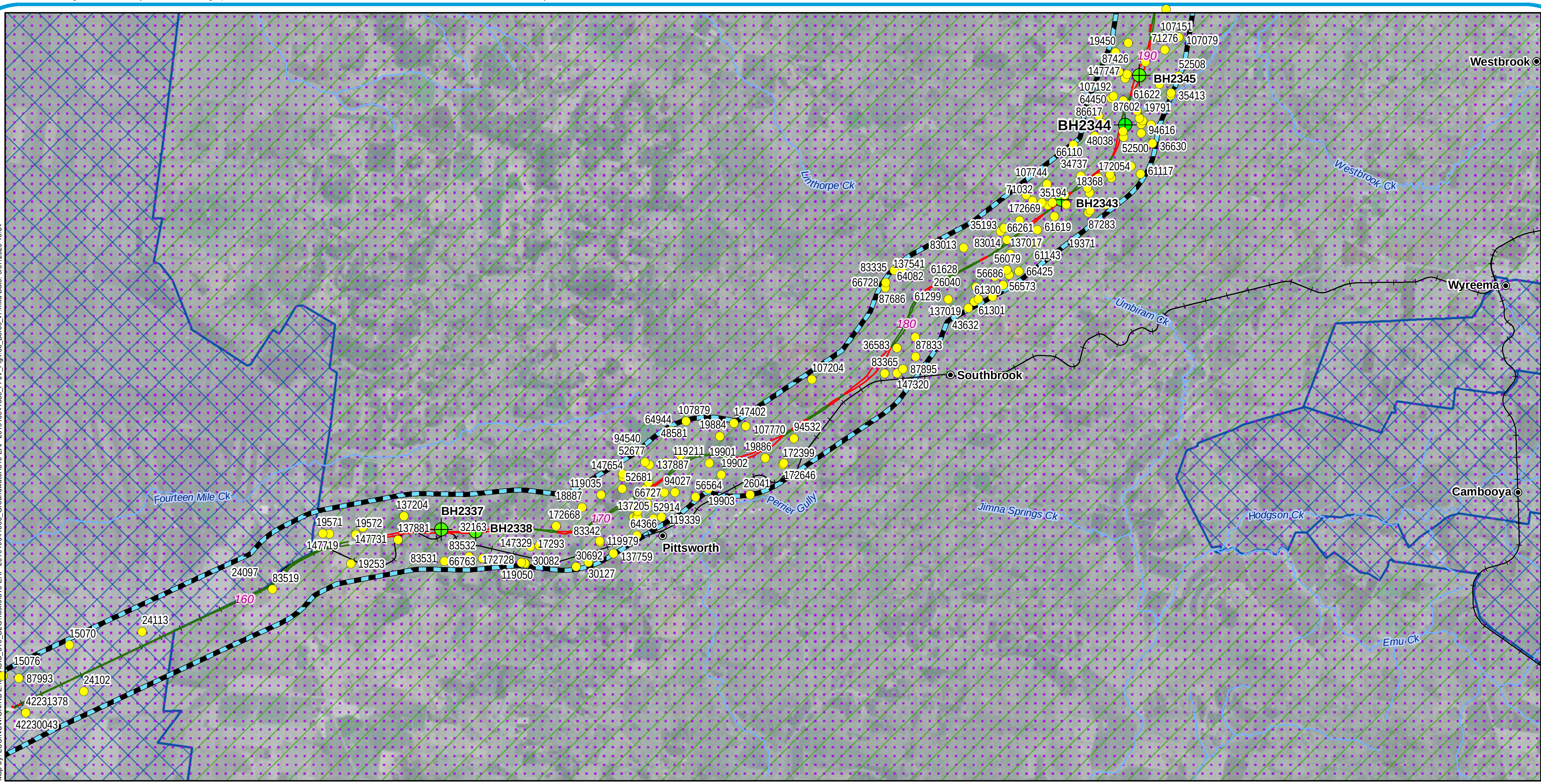
Future Freight
Integrating Community, Environment and Engineering

Issue date: 09/07/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

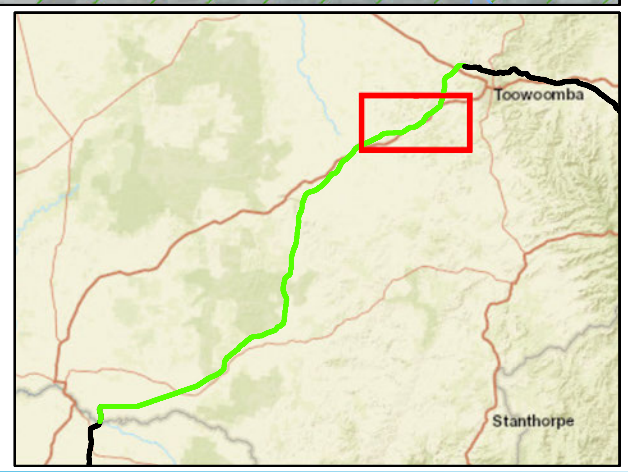
Border to Gowrie

Figure 4.30f: Registered and design phase bores within the impact assessment area

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



Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34



Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Condamine and Balonne) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Regulation 2016

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

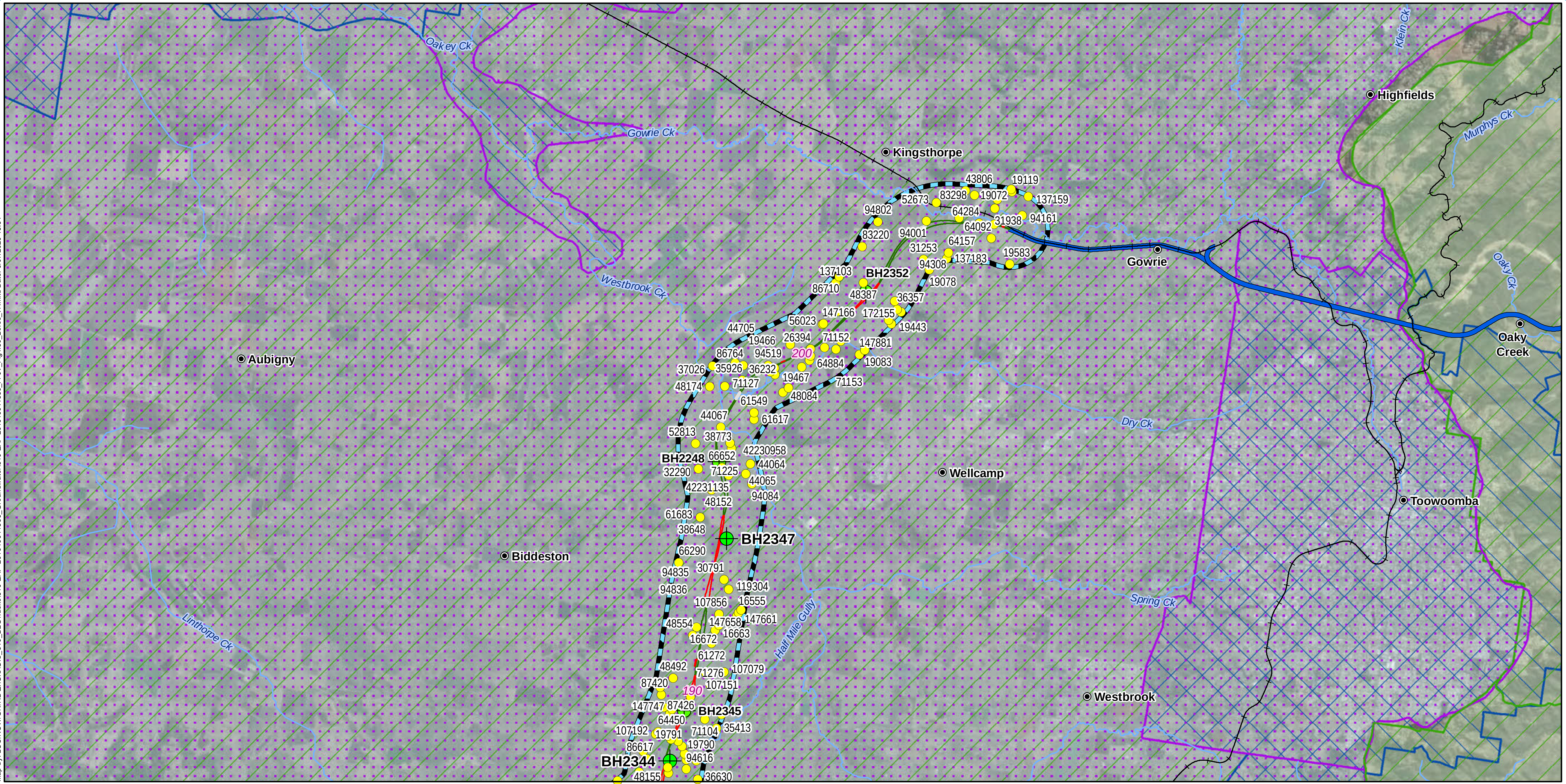
Future Freight
Integrating Community, Environment and Engineering

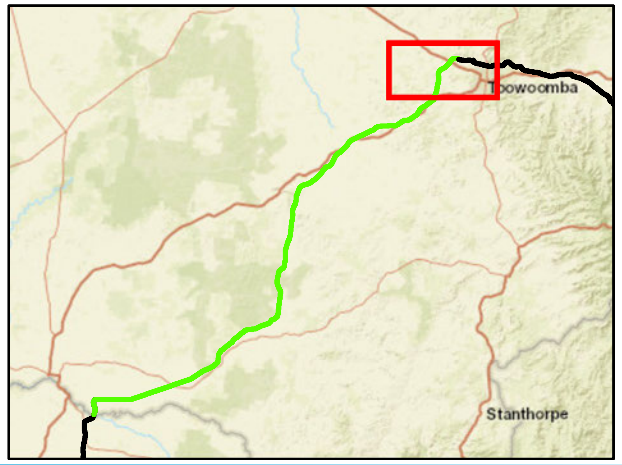
Issue date: 09/07/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.30g: Registered and design phase bores within the impact assessment area

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





Legend

- 5 Chainage (km)
- Localities
- Gowrie to Helidon alignment
- Existing rail (operational)
- Cut
- Fill
- Watercourses
- Bridges
- Groundwater impact assessment area

Groundwater management areas

- Water Act 2000
- Water Plan (Moreton) 2007
- Water Plan (Condamine and Balonne) 2019
- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Regulation 2016

- Site investigation bore

Registered bores

- AU (abandoned but stil usable)
- EX (existing)

A3 scale: 1:110,000

0 1 2 3 4 5km

Future Freight
Integrating Community, Environment and Engineering

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Border to Gowrie

Figure 4.30h: Registered and design phase bores within the impact assessment area

Map by: LUC/NCWGN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.30_Bores_v7.mxd Date: 9/07/2020 13:34

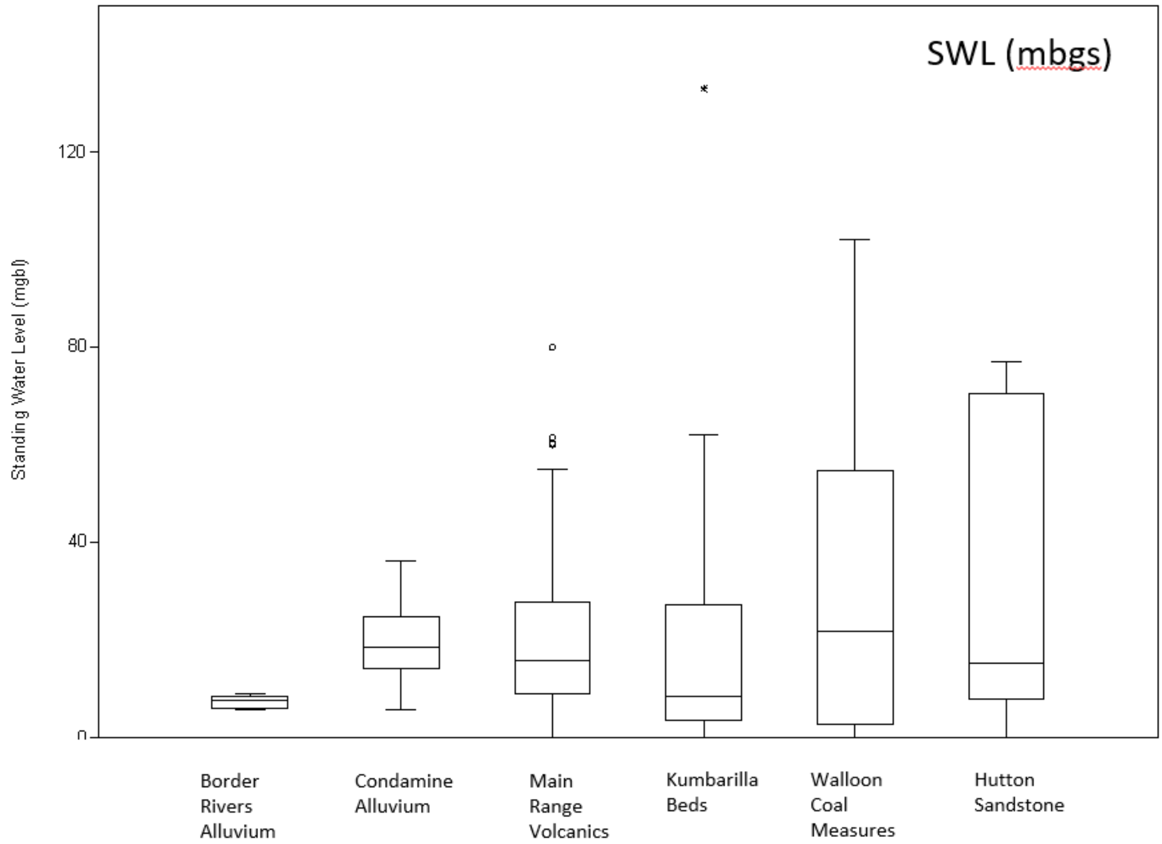


Figure 4.31 Box and whisker plot of SWLs for registered bores within the impact assessment area

Figure note: The horizontal line in each box is the median SWL.

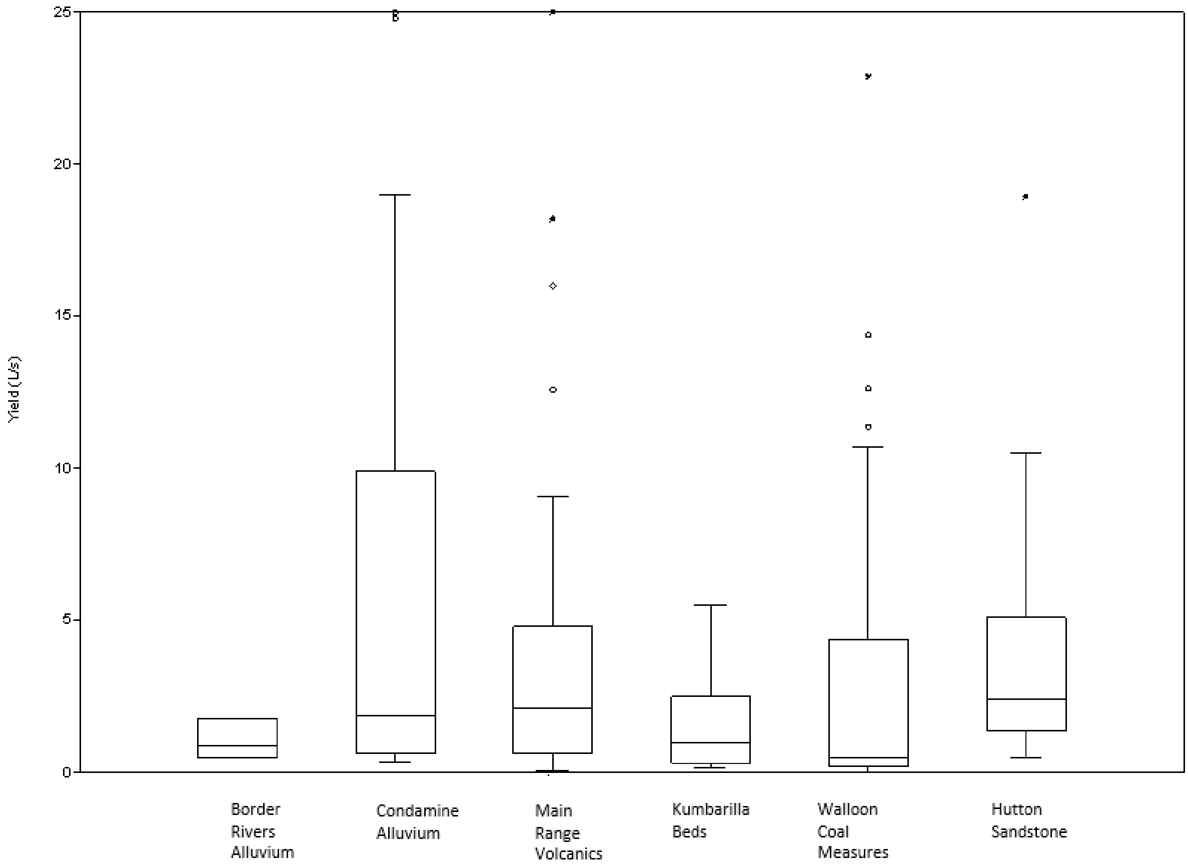


Figure 4.32 Box and whisker plot of yields (L/sec) for registered bores within the impact assessment area

Figure note: The horizontal line in each box is the median SWL.

4.7.6 Groundwater use

A review of reported groundwater uses from relevant aquifers surrounding the Project footprint has been completed to assist with the evaluation of EVs (discussed in Section 5). This review is based on the Queensland water entitlements database (DNRME, 2018c) which details the licence type and source aquifer for all water entitlements in Queensland. An annual water volume is typically assigned to each licence (refer Table 4.12) and is summarised for each of the three water sharing plans identified for the Project.

Analysis of water entitlements within the impact assessment area indicates that irrigation is the primary groundwater entitlement licence type for the key aquifers near the Project footprint. For the shallow aquifers (being Border Rivers Alluvium, the Condamine Alluvium, and the MRV) irrigation comprises 70 to 85 per cent of the annual assigned groundwater take. This is followed by stock, industrial and urban takes from these shallow aquifers. In the Border Rivers Alluvium, the majority of the assigned entitlements are for supplementing surface water supplies during drought periods, this often results in only a small proportion of the groundwater allocation being used (OGIA, 2016b).

Under the Water Plan (GABORA) 2017, GAB sedimentary rock aquifers from the Surat and Clarence Moreton Basins have almost 2,500 entitlements assigned to stock and domestic purposes compared to irrigation use, which has 286 entitlements. This discrepancy is likely reflective of the less suitable groundwater chemistry for irrigation (i.e. high sodium adsorption ratios) from formations such as the Kumbarilla Beds and WCM (refer Table 4.12).

Intensive stock and town water supply entitlements comprise most of the remaining entitlements for groundwater takes from sedimentary rock aquifers in the area.

Table 4.12 Summary of groundwater entitlements and availability for the impact assessment area

Queensland Water Plan	Water source	Licensed purpose	Number of entitlements	Water made available (ML/yr)	Per cent of assigned water volume
Queensland Border Rivers-Moonie Water Resource Plan 2019	Border Rivers Alluvium	Irrigation	76	13,749	72.6
		Industrial and commercial	7	44	0.2
		Irrigation and stock	6	3,917	20.7
		Town water and urban supply	4	547	2.9
		Domestic supply and stock	3	30	0.2
		Any	3	664	3.5
Total per cent of assigned water volume					**100.1**
Total per cent available for new entitlements under Queensland Border Rivers-Moonie Water Resource Plan 2019					**0.0**
Water Plan (Condamine and Balonne) 2019	Condamine River Alluvium and tributaries	Irrigation and minor stock	742	96,387	83.2
		Stock intensive	37	749	0.6
		Any	35	11,634	10.0
		Commercial and industrial	17	1,430	1.2
		Town water and urban supply	13	4,204	3.6
		Aquaculture	7	683	0.6
		Environmental	5	716	0.6
		Productive base	3	106	0.1
	Total per cent of assigned water volume				99.9

Queensland Water Plan	Water source	Licensed purpose	Number of entitlements	Water made available (ML/yr)	Per cent of assigned water volume
	Main Range Volcanics	Irrigation and minor stock	1,019	48,712	80.9
		Commercial and industrial	82	3,076	5.1
		Stock intensive	60	959	1.6
		Any	41	1,761	2.9
		Town water and urban supply	11	5,483	9.1
		Agriculture and aquaculture	10	254	0.4
	Total per cent of assigned water volume				**100.0**
Total per cent of assigned water volume					**100.0**
Total per cent available for new entitlements under Water Plan (Condamine and Balonne) 2019					**0.0**
Water Plan (GABORA) 2017	Balonne-Condamine and Border Rivers Basin Regions	Stock and domestic	2,447	Not assigned	N/A
		Irrigation and minor stock	286	10,945	20.1
		Stock intensive	174	11,319	20.8
		Town water and urban supply	70	17,967	33.0
		Commercial and industrial	55	8,497	15.6
		Any	53	4,918	9.0
		Aquaculture	6	696	1.3
		Dairying	4	62	0.1
Total per cent of assigned water volume					**99.9**
Total per cent available for new entitlements under Water Plan (GABORA) 2017					**0.01**

4.7.7 Groundwater dependent ecosystems

Groundwater plays an important role in sustaining aquatic and terrestrial ecosystems, such as springs, wetlands, rivers and vegetation. Understanding these groundwater-dependent ecosystems (GDEs) is essential for groundwater management and planning.

The BoM has developed a Groundwater Dependent Ecosystems Atlas (GDE Atlas) as a national dataset of Australian GDEs and potential GDEs (BoM, 2019d). The GDE Atlas contains information about three types of ecosystems:

- **Aquatic** ecosystems that rely on the surface expression of groundwater–this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs. Marine and estuarine ecosystems can also be groundwater dependent, but these are not mapped in the Atlas.
- **Terrestrial** ecosystems that rely on the subsurface presence of groundwater–this includes all vegetation ecosystems
- **Subterranean** ecosystems – this includes cave and aquifer ecosystems.

It is important to note that the GDE Atlas mapping is from two broad sources:

- National assessment – national scale assessment based on a set of rules that describe potential for groundwater/ecosystem interaction and available GIS data

- Regional studies – more detailed assessment by States and/or regional agencies using approaches included field work, analysis of satellite imagery and application of rules/conceptual models.

The identification of potential GDEs in the Atlas therefore does not confirm that a particular ecosystem is groundwater dependent.

The Atlas was accessed on 17 January 2019 to assess potential GDEs within or in proximity to the impact assessment area. An approximate 5 km radius around the alignment was evaluated for potential GDEs. An overview of potential aquatic GDEs is provided on Figure 4.33a-d and potential terrestrial GDEs are presented on Figure 4.34a-d.

4.7.7.1 Aquatic groundwater dependent ecosystems

The GDE Atlas indicates that there are no high potential aquatic GDEs located within 5 km of the Project footprint. Areas where potential aquatic GDEs are identified within 5 km of the Project are as follows:

- Between Ch 40.0 km and Ch 95.0 km the Project crosses numerous unnamed tributaries associated with Macintyre Brook and Canning Creek. These drainage features have a moderate aquatic GDE potential
- Unnamed creeks with moderate potential for aquatic GDEs occur to the southwest of Millmerran within and surrounding the Project footprint between Ch 115.0 km to Ch 125.0 km
- The Condamine River, which the Project alignment crosses near Ch 142.9 km, is considered to have a low potential for aquatic GDEs
- Low to moderate potential for aquatic GDEs is associated with narrow, unnamed creeks underlain by the MRV subcrop between Ch 160.0 km to Ch 206.9 km.

The location of potential aquatic GDEs in relation to the Project footprint are shown on Figure 4.33.

4.7.7.2 Terrestrial groundwater dependent ecosystems

Areas where terrestrial GDEs are identified by the GDE Atlas as occurring within 5 km of the Project footprint are as follows:

- One high potential terrestrial GDE is crossed by the Project alignment between Ch 25.0 km and Ch 28.0 km, near Yelarbon. This GDE is associated with the alkaline landscape of the Yelarbon Desert sandy plains (DSITI, 2017). Here, permeable sediments of the Border Rivers Alluvium store and readily transmit groundwater from the underlying GAB to provide a permanent connection to this GDE. This GDE is recognised under Water Plan (GABORA) 2017 as a GDE Area.
- Broad areas of moderate potential for terrestrial GDEs occur between Ch 55.0 km and Ch 95.0 km. These areas are characterised to have intermittent connection to brackish aquifers associated with shallow alluvium (DSITI, 2017).
- Irregular areas of moderate potential for terrestrial GDEs are crossed by and surround the Project footprint between Ch 165.0 km to Ch 200.0 km. These GDEs are associated with fractured-rock aquifers of the MRV which may provide an intermittent connection to these ecosystems.

The location of terrestrial GDEs in relation to the Project footprint are shown on Figure 4.34.

4.7.7.3 Subterranean groundwater dependent ecosystems

No potential subterranean GDEs have been identified within the BoM GDE Atlas within 5 km of the impact assessment area.

4.7.7.4 Springs

A spring is a hydrogeological feature which occurs due to natural groundwater discharge and may be classed as having a permanent or non-permanent (ephemeral) saturation regime. GDEs may in turn be associated with the expression of surface water in a spring. Springs can have a substantial environmental, cultural and economic values.

A total of ten springs are identified within a 20 km distance from the Project footprint. All of these springs are sourced from the MRV. Nine of these springs are classified as non-permanently saturated, as detailed in Table 4.13.

The closest registered spring to the Project alignment, Stone Spring, is 2 km to the northwest of Ch 173.0 km, near Pittsworth. There are no mapped GAB springs identified within a 20 km distance from the Project alignment. Locations of the mapped springs in proximity to the Project are depicted on Figure 4.33).

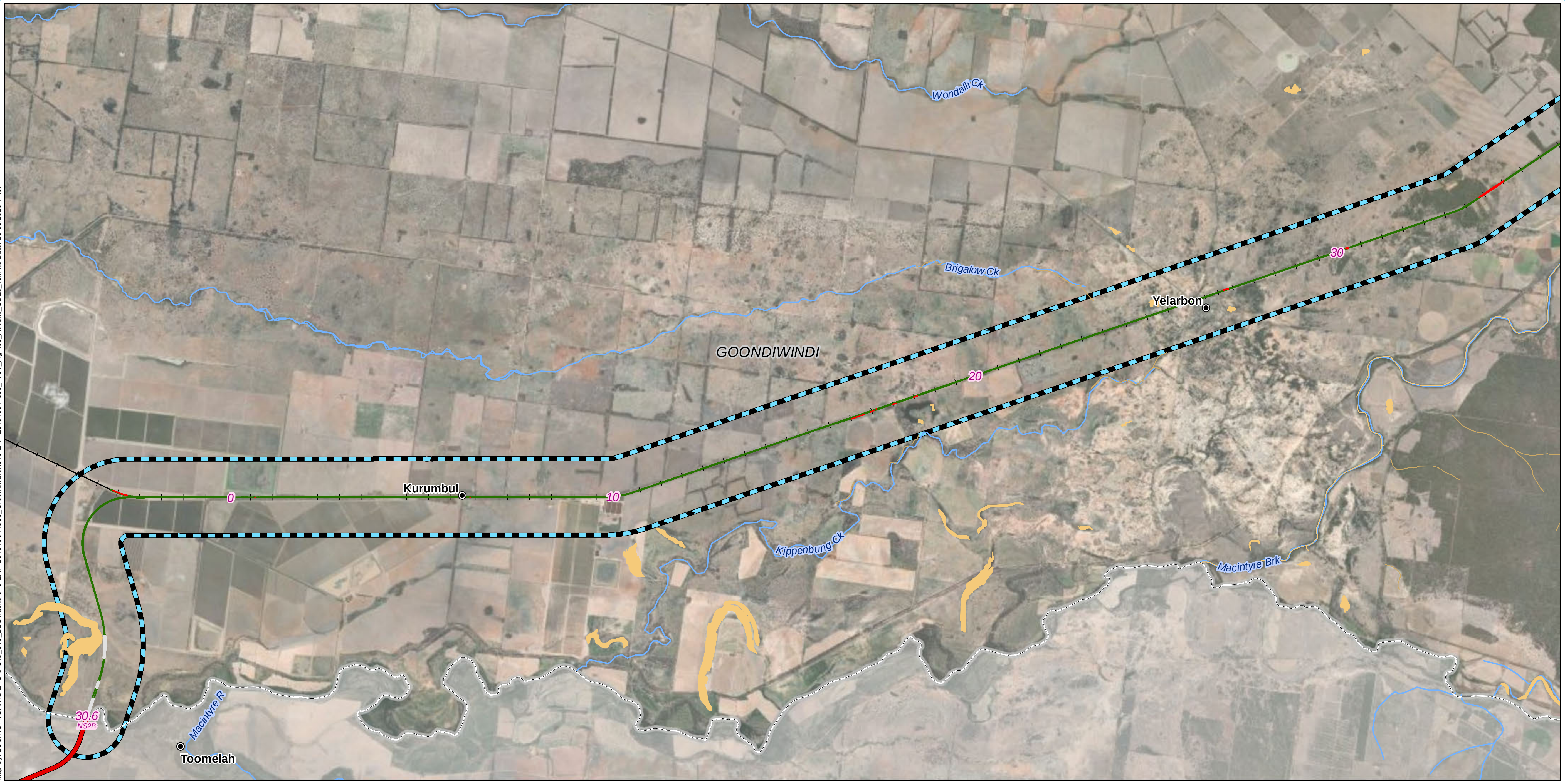
Table 4.13 Summary of springs within 20 km of the Project alignment.

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

Table notes:

Data sourced from QLD Springs Dataset (Queensland Herbarium & DSTIA, 2016).

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



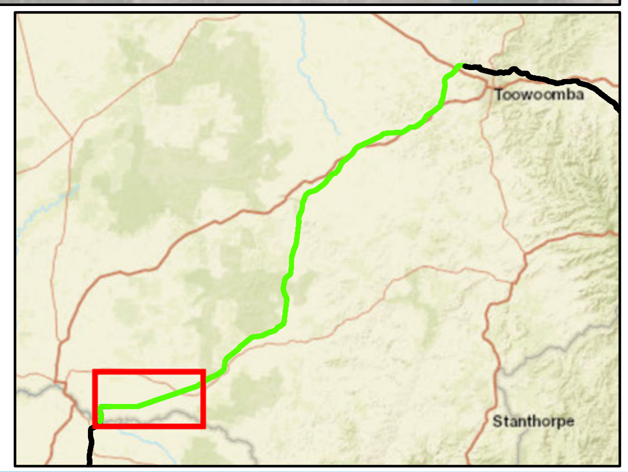
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37

Legend

5 Chainage (km)
Localities
North Star to NSW/QLD border alignment
Existing rail (operational)
Cut
Fill
Bridges

Watercourses
NSW/QLD border
Groundwater impact assessment area
Local Government Areas

Aquatic GDEs
High potential GDE
Moderate potential GDE
Low potential GDE



A3 scale: 1:110,000
0 0.85 1.7 2.55 3.4 4.25km

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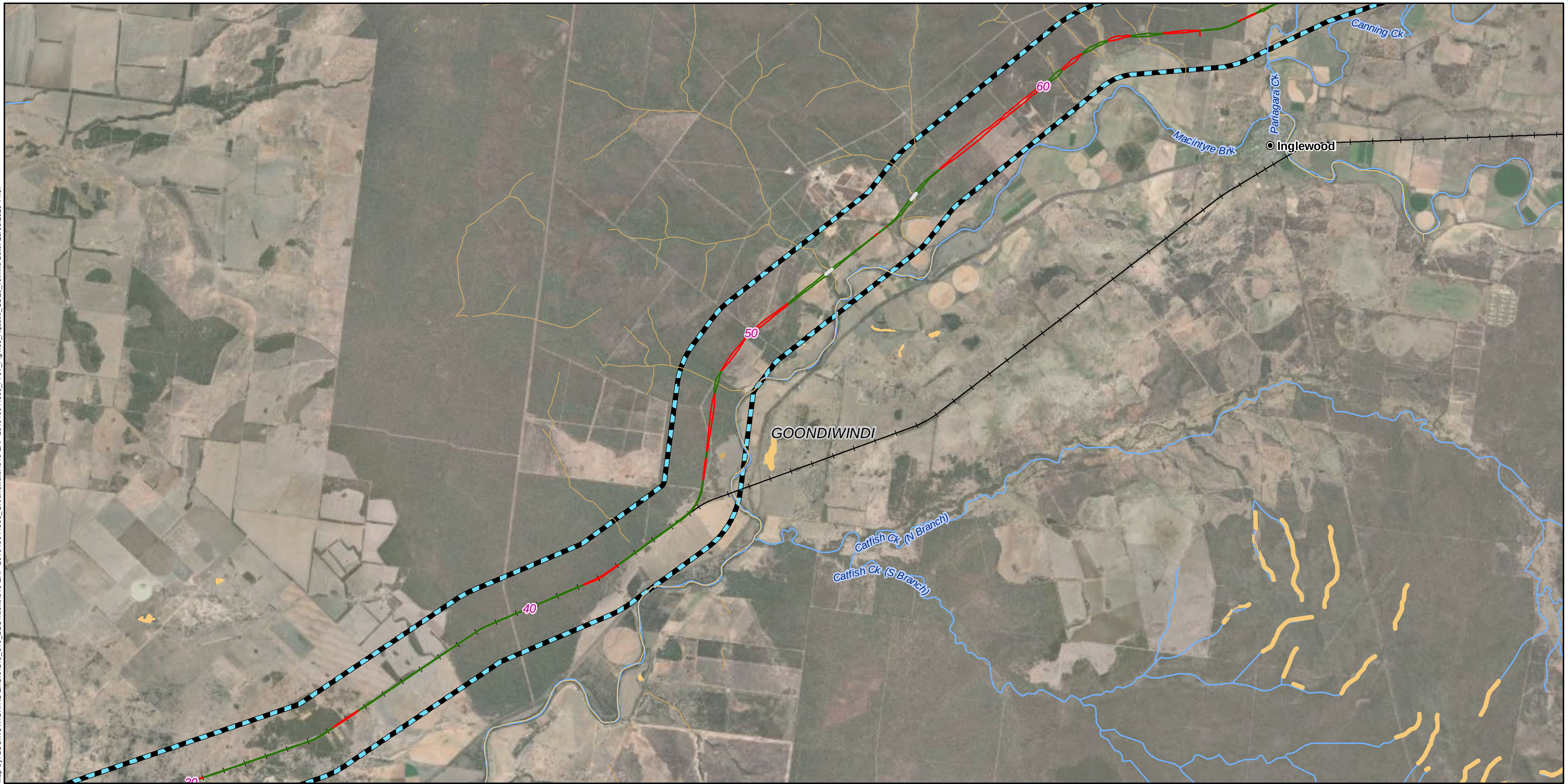
Border to Gowrie
Figure 4.33a: Aquatic GDEs

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



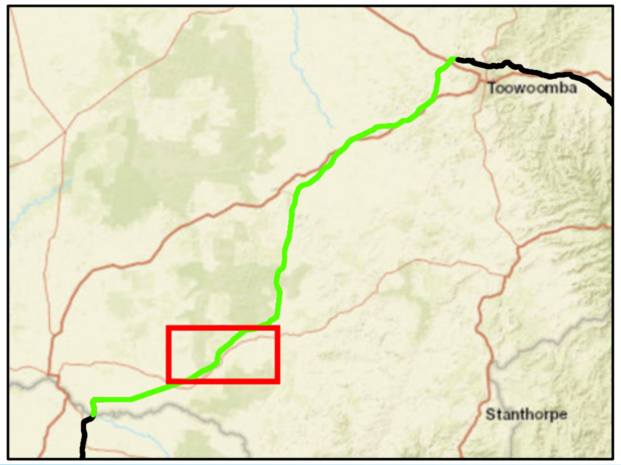
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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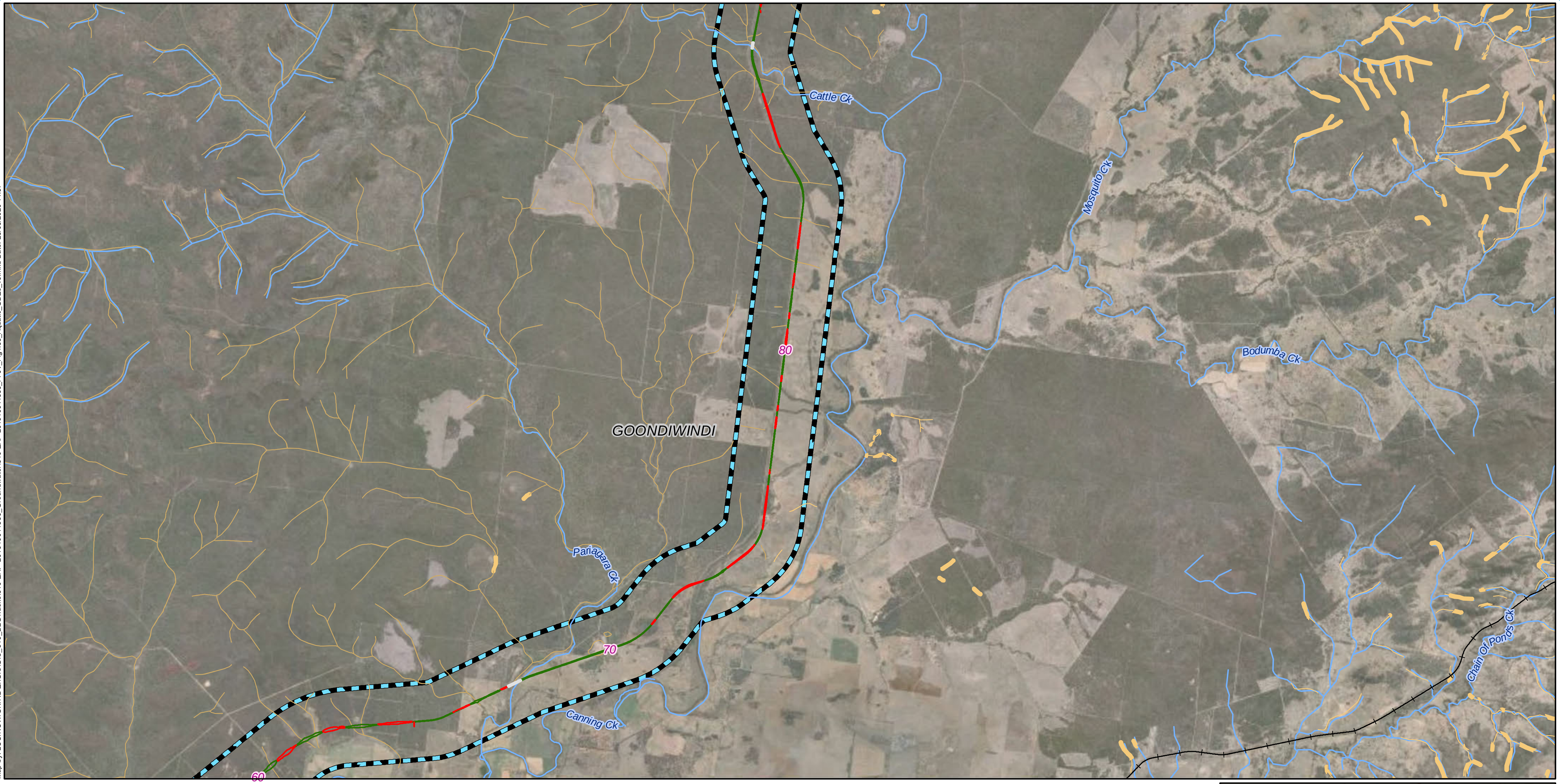
Border to Gowrie

Figure 4.33b: Aquatic GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37

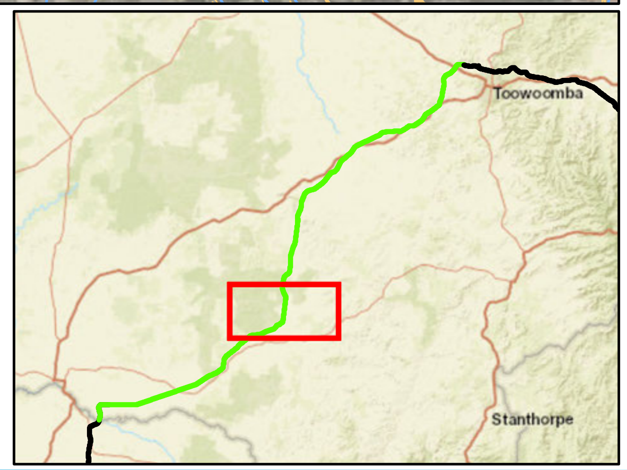


Legend

- 5 Chainage (km)
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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Issue date: 25/05/2020 Version: 6
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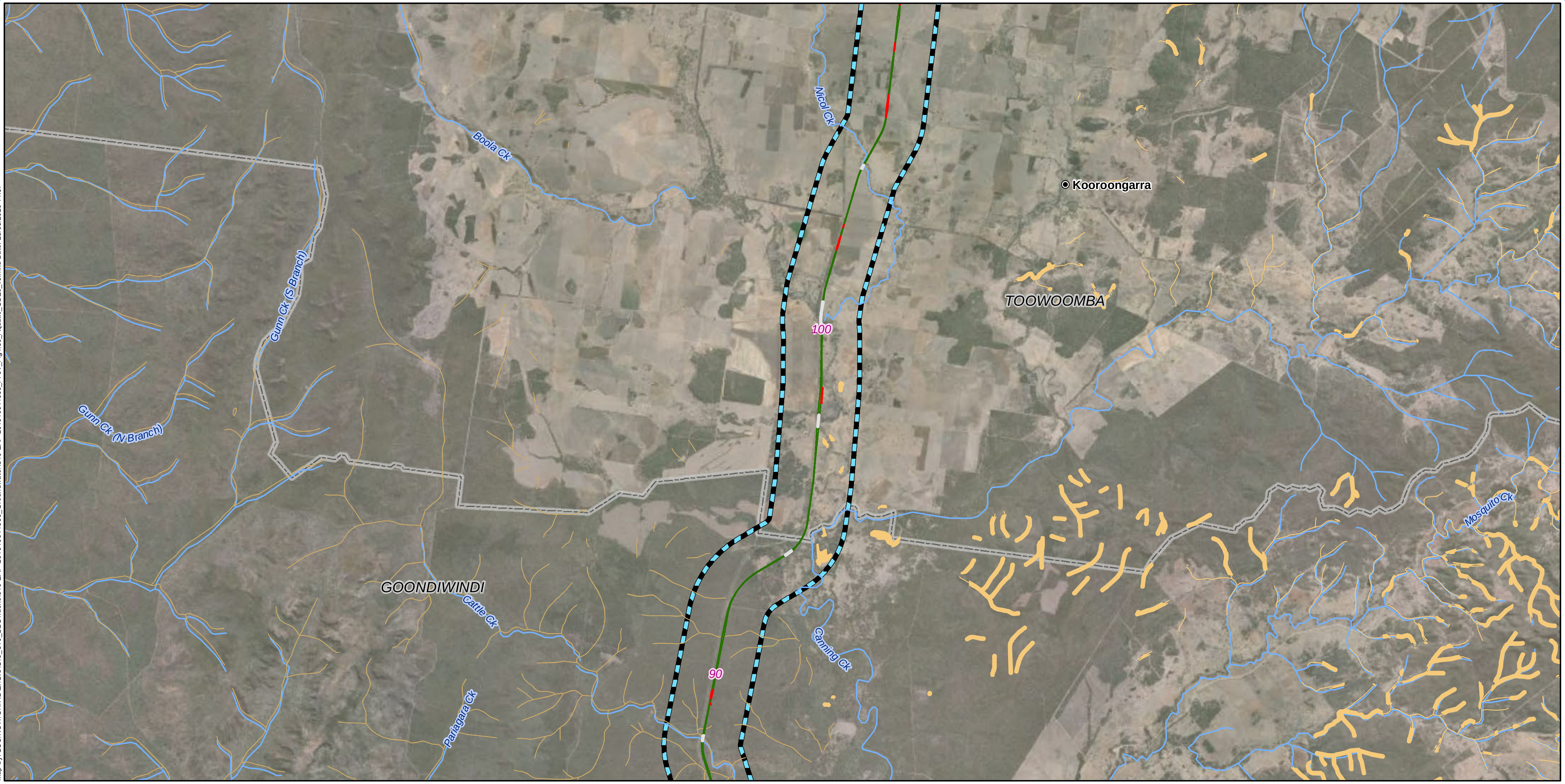
Border to Gowrie

Figure 4.33c:
Aquatic GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37

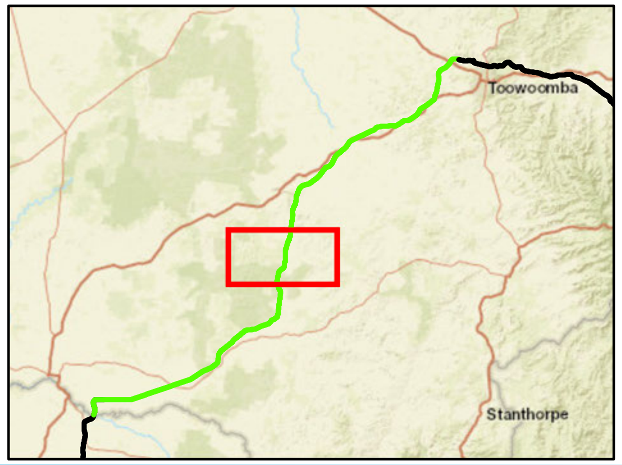


Legend

- 5 Chainage (km)
- Localities
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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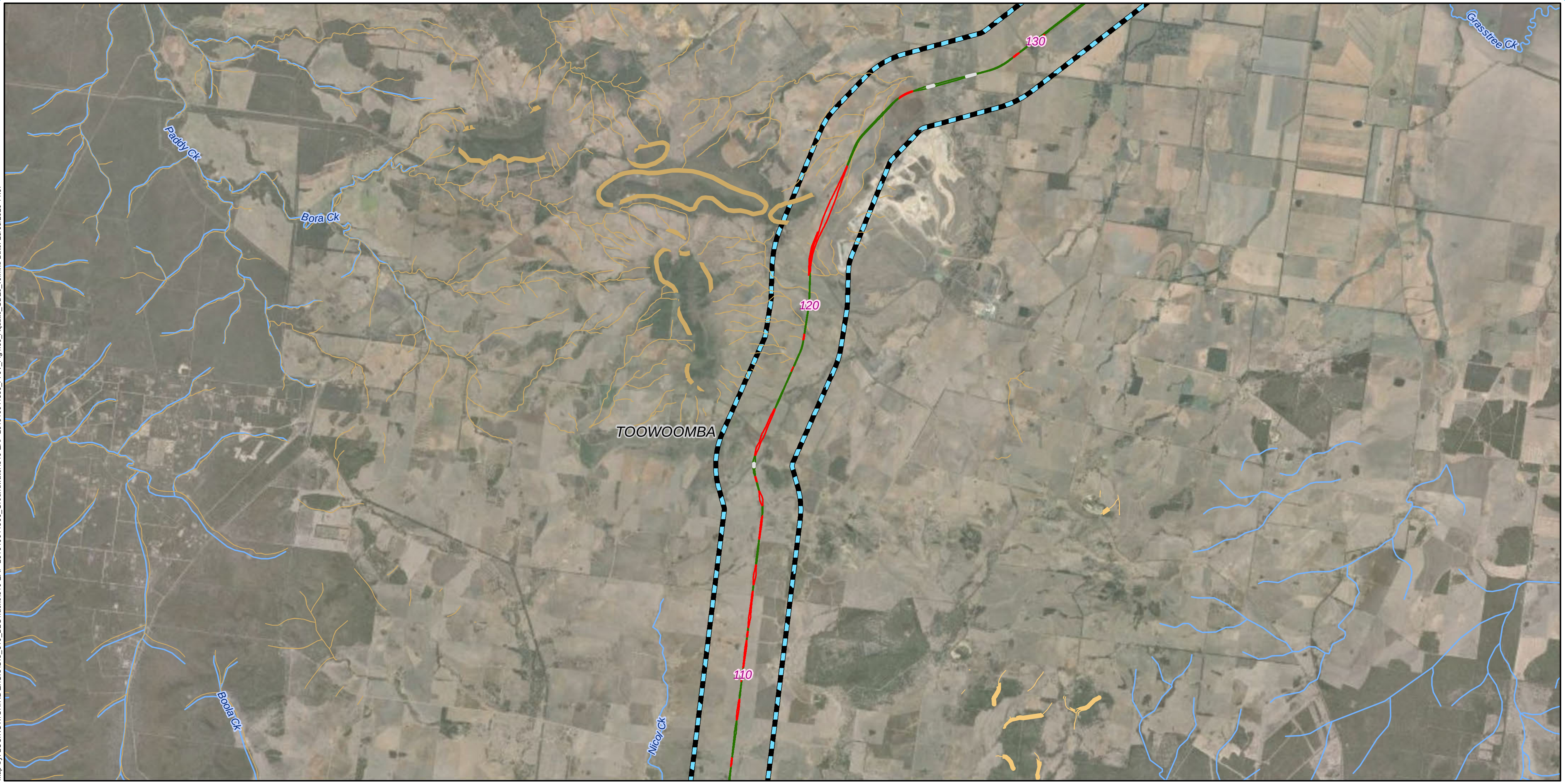
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.33d: Aquatic GDEs

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



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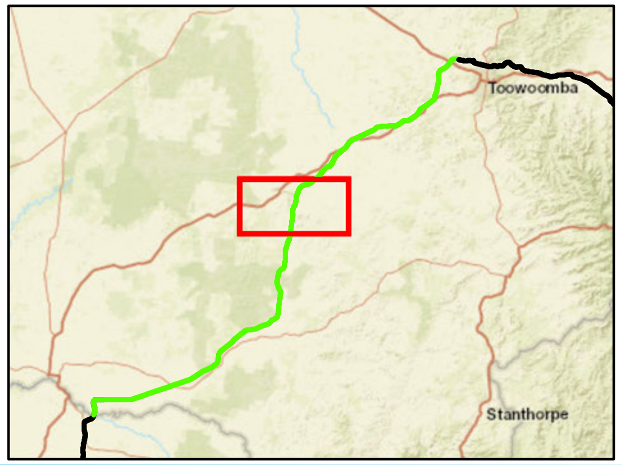
Legend

- 5 Chainage (km)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.33e: Aquatic GDEs

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

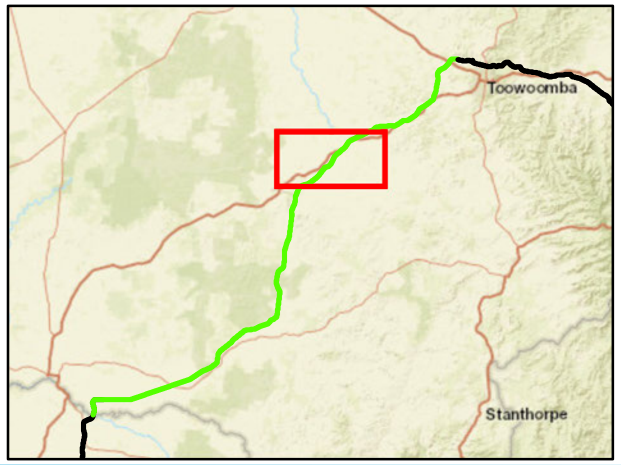
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37

Legend

5	Chainage (km)
	Localities
	Existing rail (operational)
	Existing rail (non-operational)
	Cut
	Fill
	Bridges
	Watercourses
	Groundwater impact assessment area
	Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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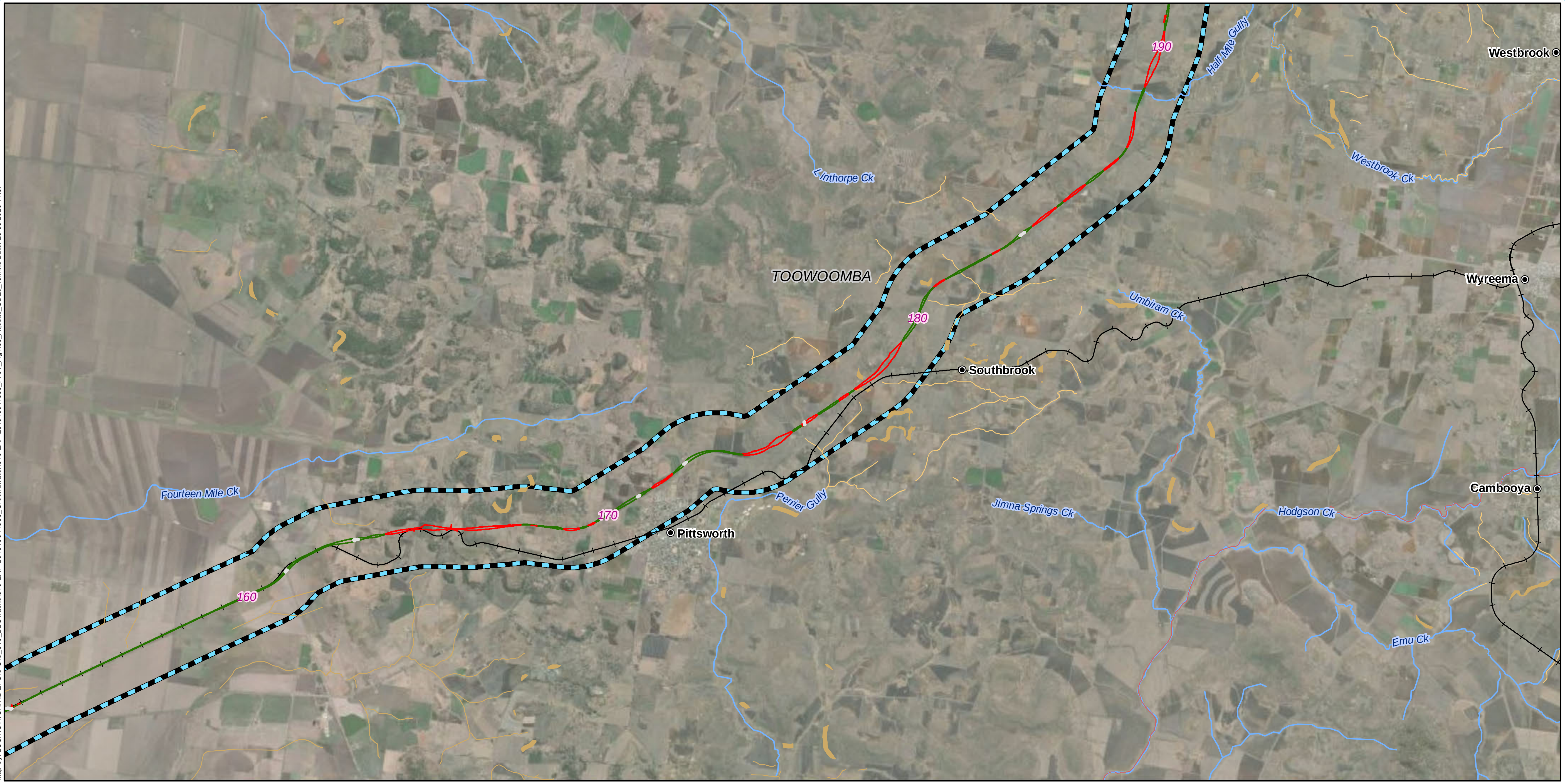
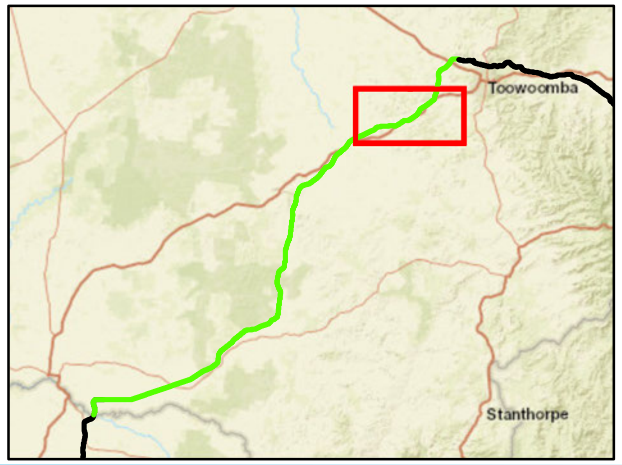
Border to Gowrie

Figure 4.33f: Aquatic GDEs

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.33_Aquatic_GDEs_v6.mxd Date: 25/05/2020 14:37





Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE

A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

Future Freight
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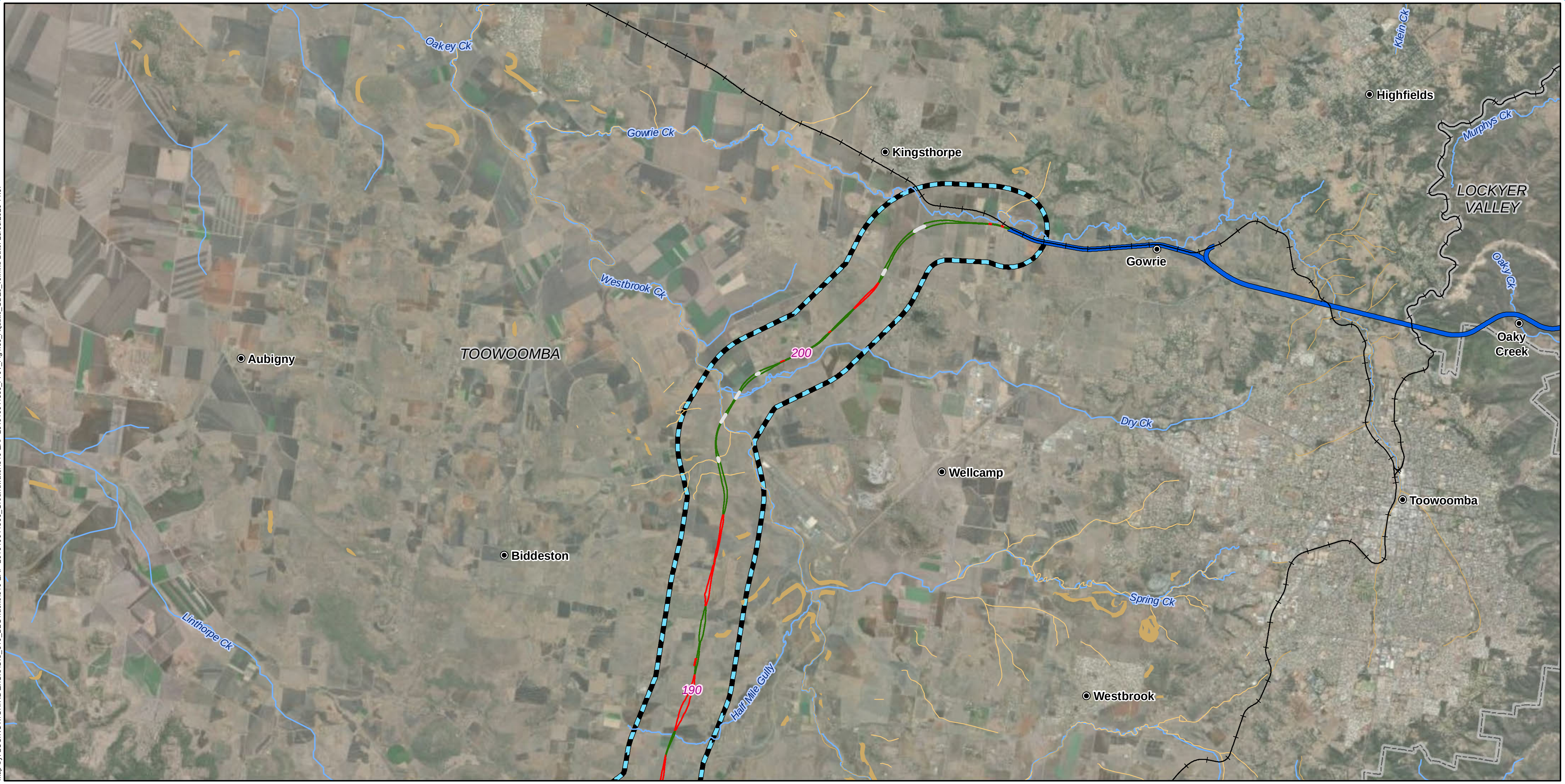
Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.33g: Aquatic GDEs

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



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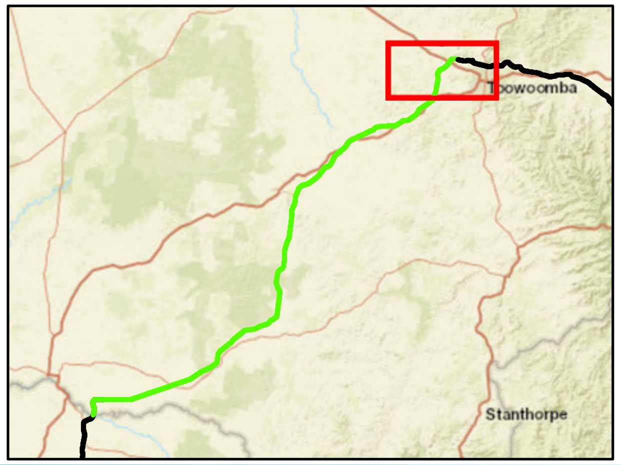
Legend

- 5 Chainage (km)
- Localities
- Gowrie to Helidon alignment
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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Issue date: 25/05/2020 Version: 6
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Border to Gowrie

Figure 4.33h: Aquatic GDEs

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

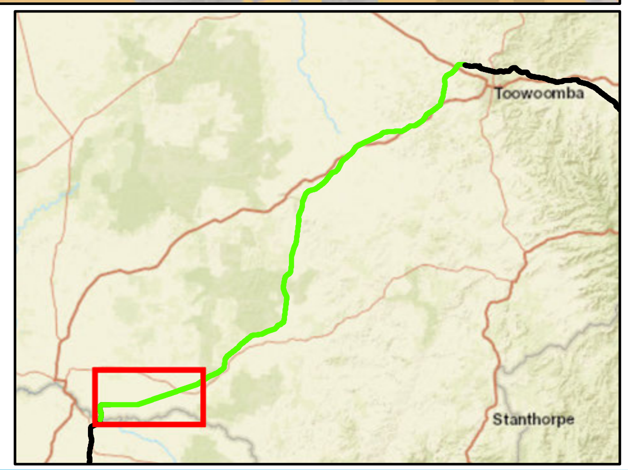
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

Legend

5 Chainage (km)
Localities
North Star to NSW/QLD border alignment
Existing rail (operational)
Cut
Fill
Bridges
Watercourses
NSW/QLD border
Groundwater impact assessment area
Local Government Areas

Terrestrial GDEs

High potential GDE
Moderate potential GDE
Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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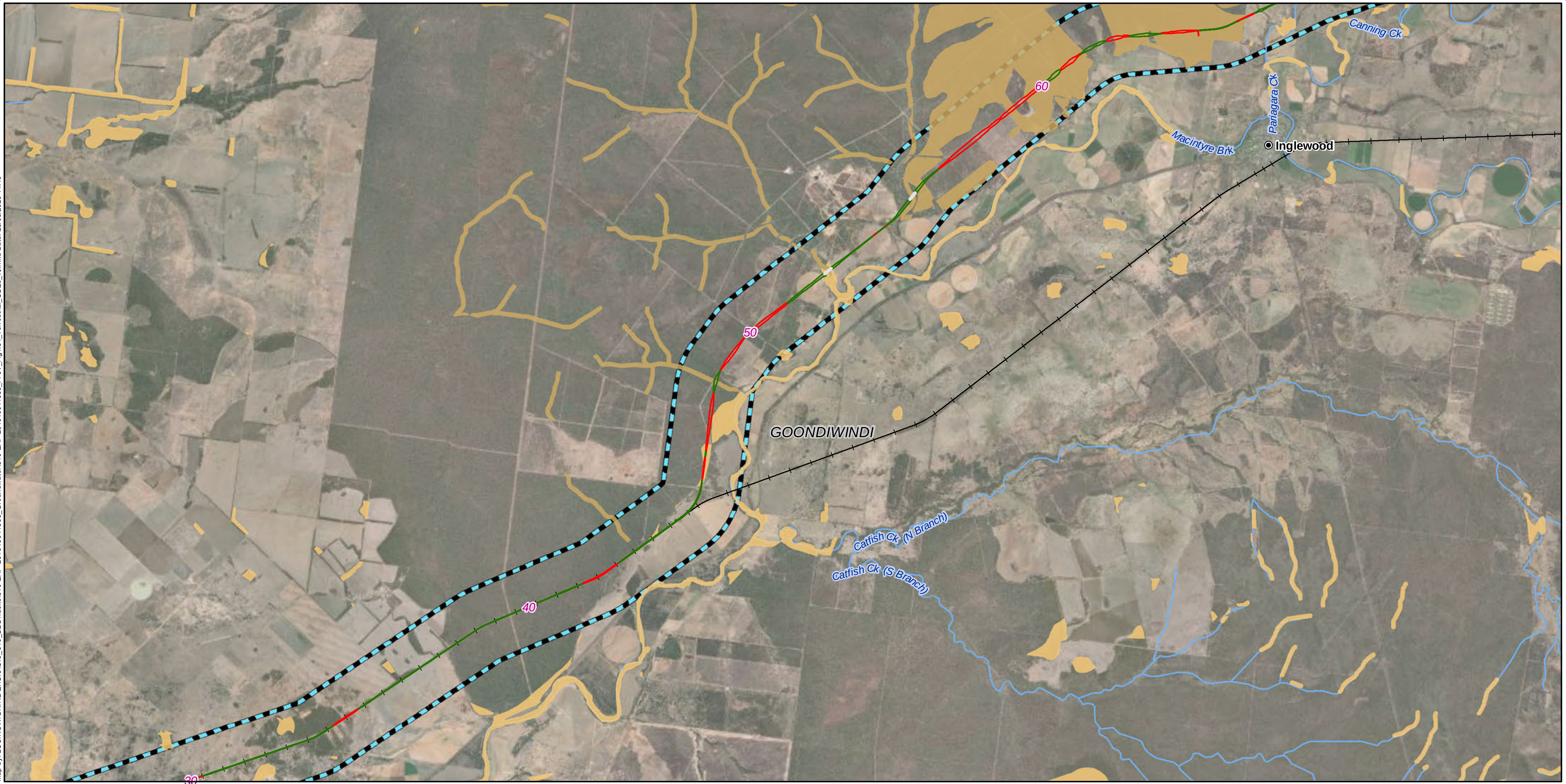
Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.34a: Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

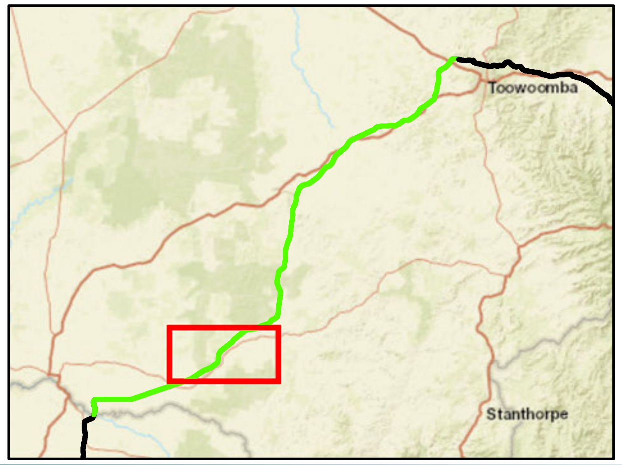


Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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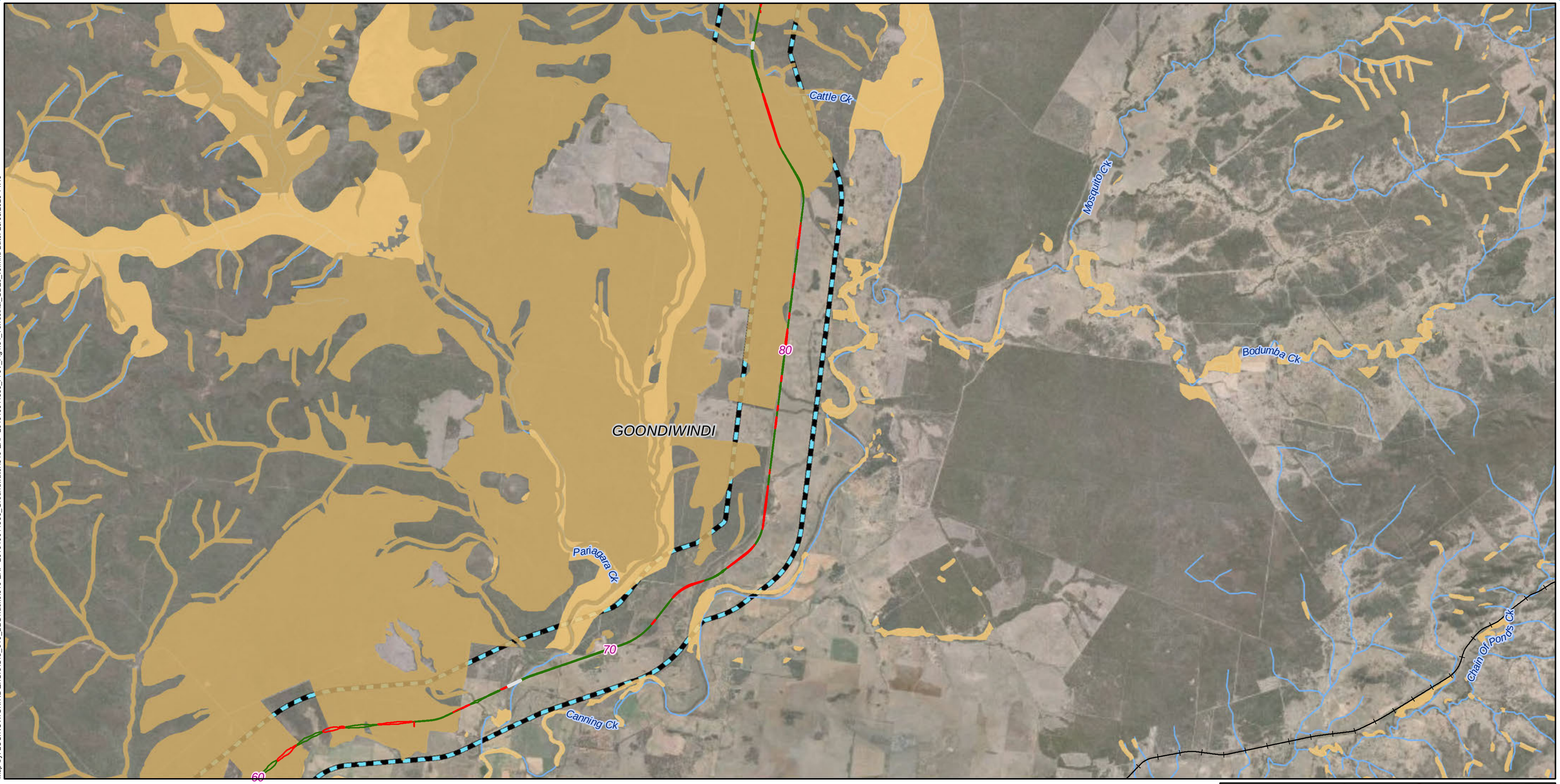
Coordinate System: GDA 1994 MGA Zone 56

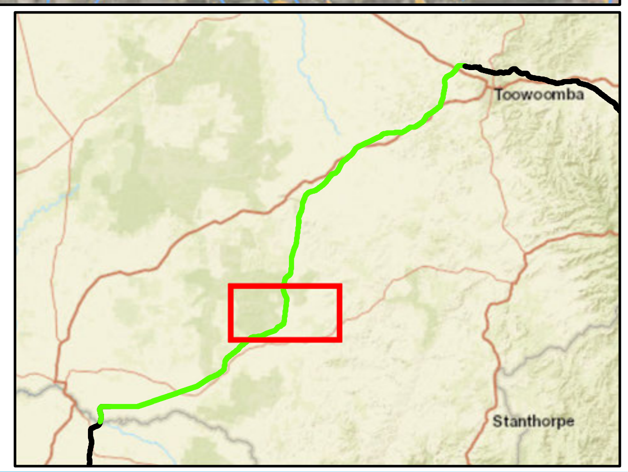
Border to Gowrie

Figure 4.34b: Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40





Legend

- 5 Chainage (km)
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE

A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

Future Freight
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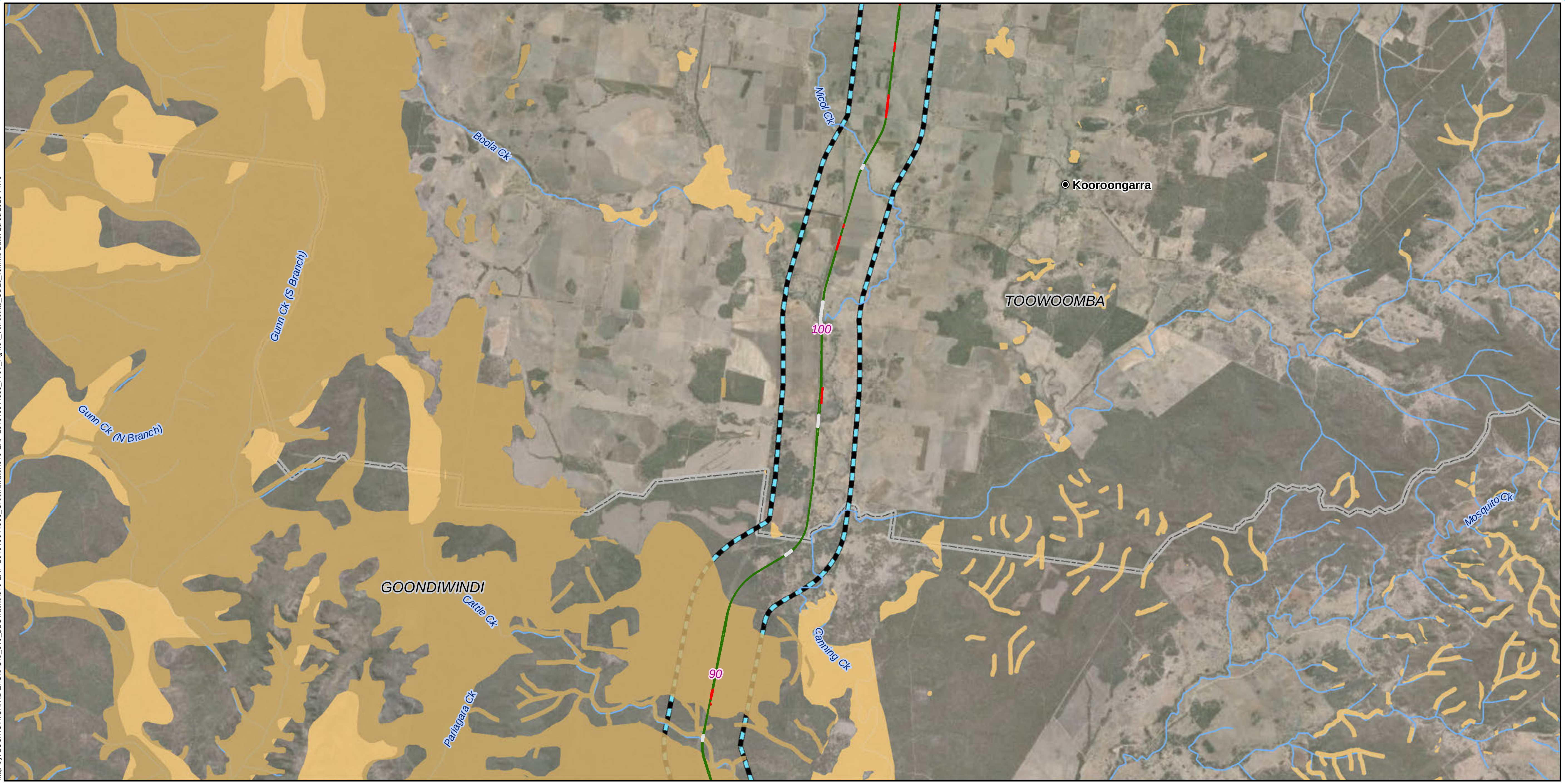
Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Figure 4.34c:
Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

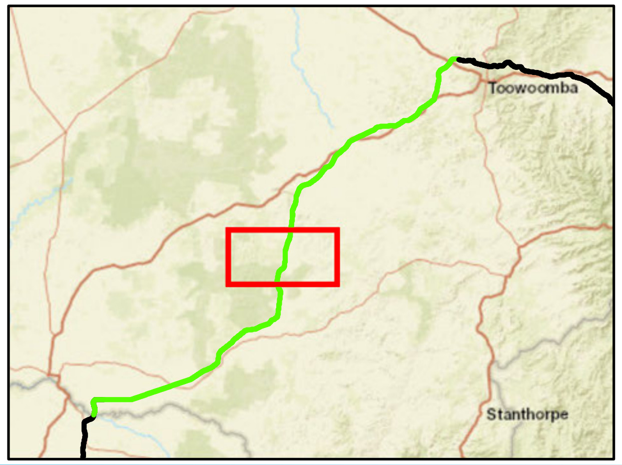


Legend

- 5 Chainage (km)
- Localities
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

Future Freight
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Issue date: 25/05/2020 Version: 6
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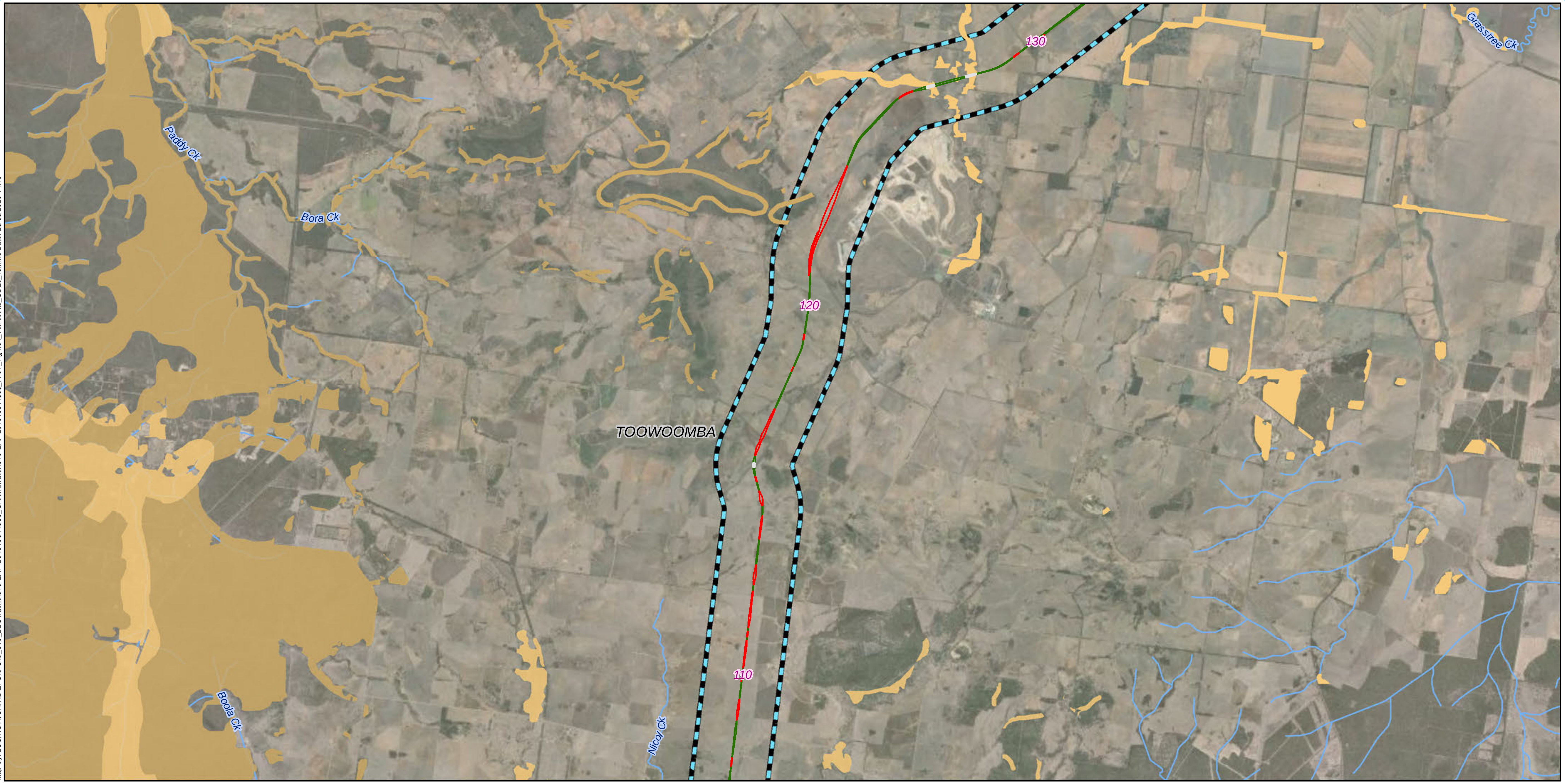
Border to Gowrie

Figure 4.34d: Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

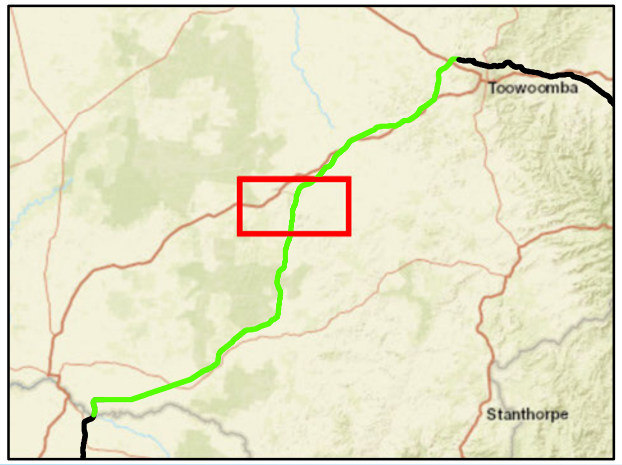


Legend

- 5 Chainage (km)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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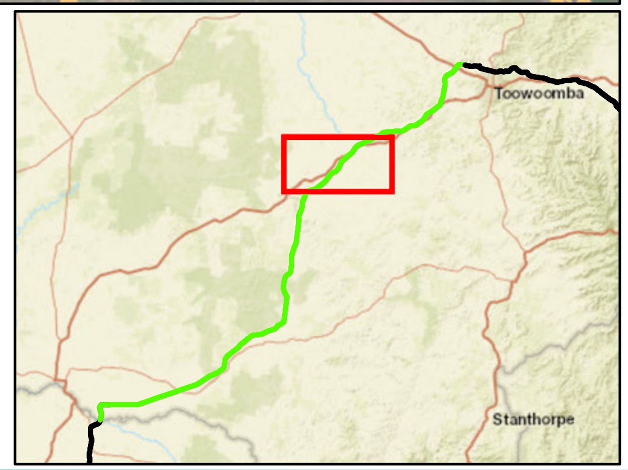
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.34e: Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40



Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE

A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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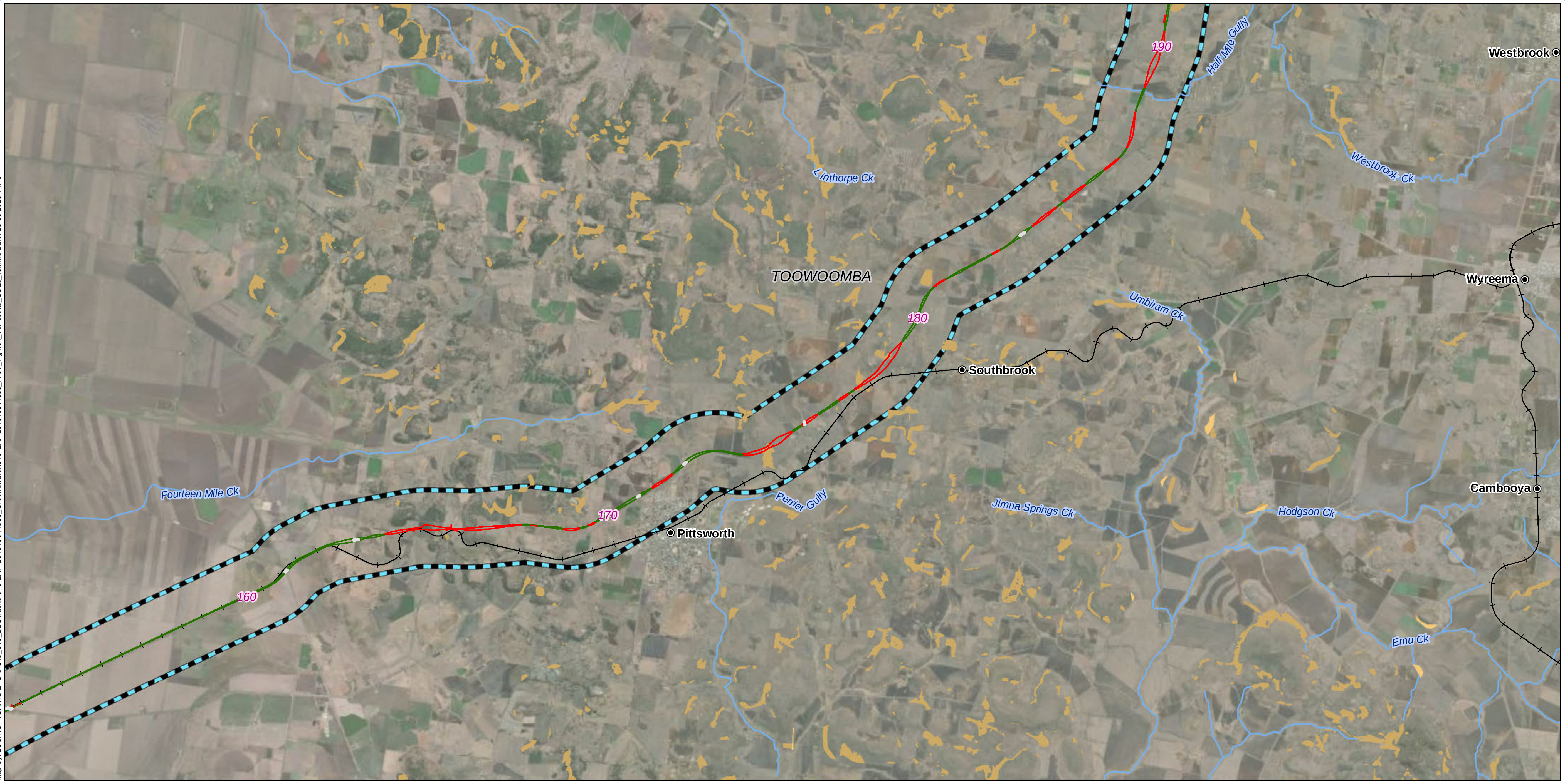
Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.34f: Terrestrial GDEs

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

Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

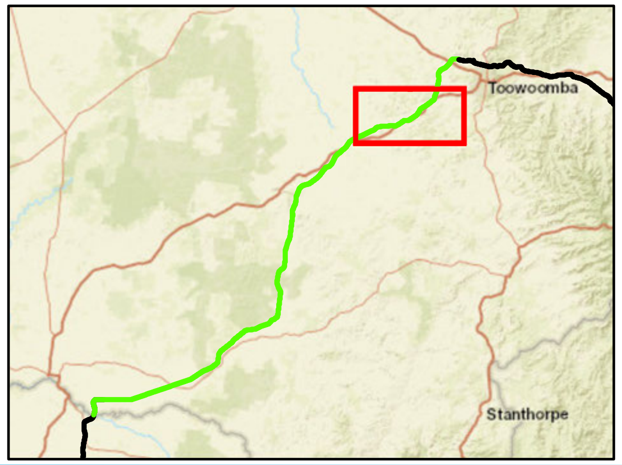


Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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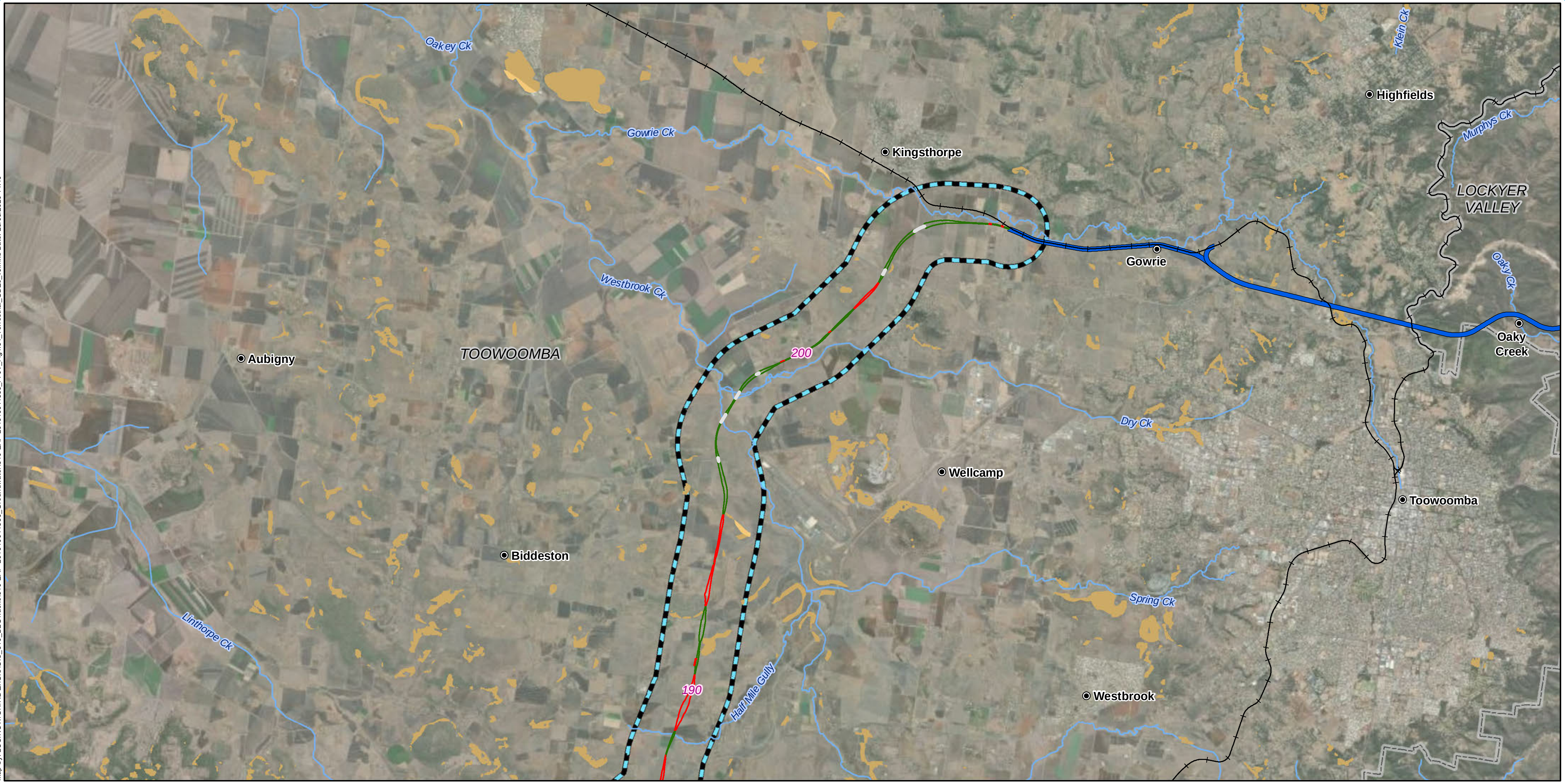
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.34g: Terrestrial GDEs



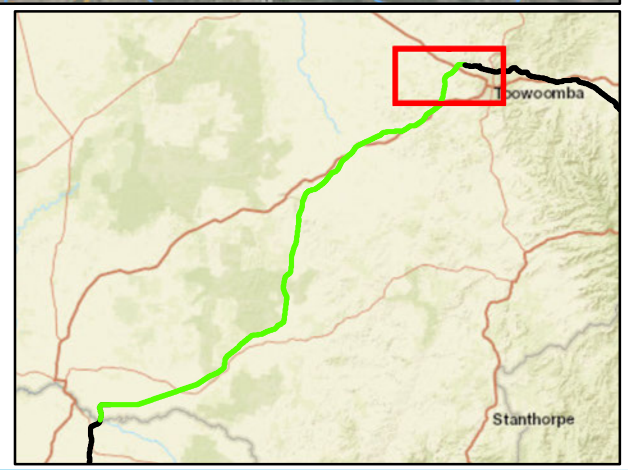
Map by: LUC/NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig4.34_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:40

Legend

- 5 Chainage (km)
- Localities
- Gowrie to Helidon alignment
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE



A3 scale: 1:110,000

0 0.85 1.7 2.55 3.4 4.25km

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Integrating Community, Environment and Engineering

Issue date: 25/05/2020 Version: 6
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.34h: Terrestrial GDEs

5 Environmental values

The Queensland Government has developed HWMPs for each river catchment and are the key planning tool for improving water quality in Queensland. For the purposes of this assessment, the 'values', as defined in the EPP (Water and Wetland Biodiversity), are those attributes of the groundwater systems within the impact assessment area that are sufficiently important to be protected or enhanced.

This section identifies and describes groundwater related EVs within the impact assessment area as defined under the following HWMPs:

- Ch 30.6 km (NS2B) to Ch 117.0 km: within the boundaries of the Border Rivers catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins* (DES 2019a).
- Ch 117.0 km to Ch 206.9 km: within the boundaries of the Condamine - Balonne River catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Queensland Condamine River Basins* (DES 2019b).

The definitions of the EVs relevant to the impact assessment area are presented in Table 5.1. Table 5.2 summarises the HWMP of relevance and WQOs for relevant aquifers are presented in Table 5.3. The WQOs are listed in full in Table 5.4.

Table 5.1 Summary of environmental value definitions

Environmental value	Definition
Aquatic ecosystems	The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways, waterholes and riparian areas, for example, biodiversity, ecological interactions, plants, animals, key species and their habitat.
Irrigation	Suitability of water supply for irrigation. For example, irrigation of crops, pastures, parks, gardens and recreational areas.
Farm supply/use	Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock water	Suitability of water supply for production of healthy livestock.
Aquaculture	Health of aquaculture species and humans consuming aquatic foods (such as fish and prawns) from commercial ventures.
Primary/secondary recreation	Health of humans during recreation which involves water, for example, swimming, diving, boating and fishing.
Drinking water	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.
Industrial use	Suitability of water supply for industrial use – for example food, beverage, paper, petroleum and power industries. Industries usually treat water supplies to meet their needs.
Cultural, spiritual and ceremonial	Cultural values of water means its aesthetic, historical, scientific, social or other significance, to the past, present or future generations.

Table 5.2 **Summary of relevant Healthy Water Management Plan environmental values by aquifer traversed by the Project**

Aquifer	HWMP Environmental Values							
	Aquatic	Irrigation	Farm supply	Stock water	Aquaculture	Drinking water	Industrial	Cultural
Border Rivers Catchment								
Border Rivers Basin (Alluvium)	✓	✓	✓	✓	✓	✓	✓	✓
Macintyre Brook Alluvium	✓	✓	✓	✓	✓	✓	✓	✓
GAB - South East Kumbarilla	✓	✓	✓	✓	✓	✓	X	✓
Condamine – Balonne River Catchment								
Central Condamine (Alluvium)	✓	✓	✓	✓	✓	✓	✓	✓
Condamine North Branch (Alluvium)	✓	✓	✓	✓	X	✓	✓	✓
Toowoomba Region Basalts	✓	✓	✓	✓	✓	✓	✓	✓
South East Walloons	✓	✓	✓	✓	✓	✓	✓	✓

Table note:

Based on the Border Rivers and Condamine – Balonne River catchment HWMPs respectively.
✓ = EV is relevant to that catchment
X = EV is not relevant to that catchment

Table 5.3 Summary of environmental values, water quality objectives and relevance to the Project

Environmental value	WQOs/Guidelines to assess WQO	Evaluation of relevance to the Project
Groundwater – aquatic and terrestrial ecosystems	**Border Rivers catchment:** WQOs defined in Tables 35 and 37 in the HWMP for aquifers in the Border Rivers catchment (DES 2019c). **Condamine – Balonne River catchment:** WQOs defined in Tables 31 and 32 in the HWMP for aquifers in Condamine-Balonne River catchment (DES 2019b).	Regional aquatic GDE data from the GDE Atlas was evaluated in Section 4.7.7. This indicated there were no high potential aquatic GDEs traversed by or in proximity to the Project footprint (refer Figure 4.33). Regional terrestrial GDE data from the GDE Atlas was evaluated in Section 4.7.7. This indicated there is one high potential terrestrial GDE traversed by the Project alignment between Ch 25.0 km to Ch 28.0 km, near Yelarbon. The nearest spring is Stone Spring, located 2 km to the northwest of Ch 173.0 km. There are numerous areas with low to moderate potential to support aquatic and terrestrial GDEs. Therefore, there is the potential for such GDEs to be impacted by dewatering or changes in groundwater quality during the construction phase of the Project. Mitigation measures to minimise such impacts are discussed further in Section 9. Based on the above, this EV is considered relevant to the Project.
Groundwater – irrigation	ANZECC/ARMCANZ Guideline 2018 The threshold salinity tolerances for plants grown in loamy to clayey soils (considered the primary soil conditions traversed by the rail alignment) are 600 µS/cm to 7,200 µS/cm as stated in Section 4.2.4 of the ANZECC/ARMCANZ Guideline 2018.	Groundwater use for irrigation is a significant EV for the region, particularly from shallow aquifers such as the Border Rivers Alluvium, Condamine Alluvium, and MRV (refer Section 4.7.6). The suitability of water from registered bores within the impact assessment area and from bores installed during the Project hydrogeological investigation is reinforced in Section 4.7.3. For example, the alluvium and MRV in the Border Rivers and Condamine Catchments generally report median salinity values of less than 2,000 µS/cm in the area. Based on the above, this EV is considered relevant to the Project.
Groundwater – farm supply/use	ANZECC/ARMCANZ Guideline 2018	Water quality results presented in Section 4.7.3 indicate that groundwater abstracted from most aquifers traversed by the rail alignment could be used for general farm purposes, although quality is noted to be highly variable. Based on the above, this EV is considered relevant to the Project.
Groundwater – stock water	ANZECC/ARMCANZ Guideline 2018 (i.e. median faecal coliforms of < 100 organisms per 100 ml) The water quality tolerances of livestock vary between livestock types (e.g. beef cattle have no adverse effects up to a TDS of 4,000 mg/L, whereas dairy cattle can only tolerate up to 2,500 mg/L TDS).	The review of entitlements, allocations and licensed uses confirmed that stock watering is a major use of groundwater in the area. This EV is the second most common use of groundwater (after irrigation) from the alluvium and MRV. Stock watering is the primary use for groundwater abstracted from the GAB aquifers (i.e. Kumbarilla Beds, WCM). Available salinity data for registered bores confirms that the alluvium, MRV and GAB aquifers are suitable for stock water (median EC values of < 1500 µS/cm). More variable water quality is evident in the WCM and may preclude some landowner bores from use for stock watering for less tolerant livestock. Based on the above, this EV is considered relevant to the Project.
Aquaculture	ANZECC/ARMCANZ Guideline 2018 HWMP (Border Rivers) – Table 59	While aquaculture is recognised as a potential EV for some aquifers within the impact assessment area (refer Table 5.2), no known aquaculture operations are located in proximity to the Project Footprint. Therefore, the scale and presence of the water use is considered limited and not a significant EV for this project.

Environmental value	WQOs/Guidelines to assess WQO	Evaluation of relevance to the Project
Groundwater – drinking water	ANZECC/ARMCANZ Guideline 2018 HWMP (Border Rivers) – Table 61	The suitability of water for human consumption is defined in the Australian Drinking Water Guidelines (NHMRC & NRMMC, 2011). The TDS threshold for fair to good water palatability is < 900 mg/L under these guidelines. Most aquifers within the impact assessment area have median TDS values below this value and are potentially suitable for drinking water use. All relevant aquifers detailed in the Condamine and Border Rivers HWMPs are recognised to have a drinking water EV. Based on the above, this EV is considered relevant to the Project.
Industrial	Applicable WQOs to protect this EV are variable between different industries and are considered on a case-by-case basis.	This EV is not considered relevant to the Project given that the majority of land use within the impact assessment area is comprised of stock grazing, dry land cropping and irrigated cropping. As summarised in Section 4.1 the remaining land uses of the Project footprint are attributed to non-industrial applications inclusive of production forestry, transportation and communications.
Cultural and spiritual	Protect or restore cultural, spiritual and ceremonial values consistent with approved policies and plans. Aboriginal waterways assessments may provide information to support the cultural, spiritual and ceremonial value.	Regionally, the Border Rivers and Condamine-Balonne River catchments have cultural and spiritual values recognised EVs for all relevant aquifers traversed by the Project, as detailed in the Border Rivers and Condamine-Balonne River catchment HWMPs (Table 5.2). Based on the above, this EV is considered relevant to the Project.
Visual amenity	Not applicable	The nearest spring is Stone Spring, located 2 km to the northwest of Ch 173.0 km. Therefore, this item is not considered to be applicable to groundwater within the impact assessment area.
Recreational	Not applicable	This EV is not considered relevant to in situ groundwater and is typically a consideration for surface water. There is a possibility of seasonal bore water use to fill swimming pools. There are no registered groundwater springs within 2 km of the Project alignment which could be considered for recreational use.

Table 5.4 Groundwater Water Quality Objectives applicable to the aquifers within the groundwater impact assessment area

Groundwater unit	Percentile	Sodium (Na)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulphate (SO_4)	Nitrate (NO_3)	EC	pH	Alkalinity	Silicon Dioxide (SiO_2)	Fluoride (F)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	SAR	Total N	Total P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	mg/L	mg/L
Border Rivers	20th	150	13	10	110	117	15.1	0.3	531	6.5	104	31	0.16	0.000	0.01	0.005	0.013	4.95	0.085	0.000
	50th	329	34	23	253	381	64.5	1.9	1,800	7.3	214	60	0.30	0.010	0.04	0.020	0.015	17.00	0.543	0.049
	80th	4,589	710	569	489	8,723	1,100.0	12.5	23,910	8.0	414	81	0.90	0.056	9.74	0.160	0.070	35.7	2.717	1.235
Macintyre Brook	20th	44	3	1	145	46	1.1	0.03	410	7.5	132	10	0.20	0.005	0.01	ID	ID	1.80	ID	ID
	50th	124	19	11	295	115	7.9	0.8	1,178	7.9	243	40	0.41	0.005	0.01	ID	ID	8.92	ID	ID
	80th	412	32	28	610	270	30.2	6.4	1,700	8.6	559	44	0.89	0.121	0.83	ID	ID	31.59	ID	ID
GAB - South East Kumbarilla	20th	315	2	0	459	72	0.0	0.0	1,173	8.0	506	13	0.55	0.005	0.00	0.000	0.000	38.10	0.000	0.000
	50th	417	3	1	720	120	2.0	0.5	1,600	8.4	660	15	1.50	0.020	0.01	0.005	0.015	56.30	0.109	0.000
	80th	530	4	2	969	260	9.1	1.3	2,050	8.6	865	19	3.20	0.130	0.01	0.017	0.015	71.65	0.283	0.033
Central Condamine	20th	85	19	12	239	70	5.0	0.2	603	7.4	200	27	0.1	0.005	0.01	0.005	0.015	3.20	0.043	0.000
	50th	213	34	16	382	170	22.0	0.5	1,160	7.9	321	33	0.16	0.010	0.010	0.005	0.015	7.30	0.109	0.033
	80th	535	61	25	465	739	84.7	2.0	2,800	8.3	390	40	0.30	0.050	0.05	0.01	0.015	12.80	0.435	0.154
Condamine North Branch	20th	83	27	17	280	54	4.0	0.0	660	7.5	240	28	0.10	0.005	0.01	0.005	0.015	2.50	0.000	0.000
	50th	105	37	26	380	80	9.6	0.5	805	7.9	320	36	0.10	0.010	0.01	0.005	0.015	3.30	0.109	0.033
	80th	158	52	34	451	136	26.0	1.0	1,050	8.3	376	40	0.20	0.030	0.01	0.010	0.015	4.90	0.217	0.098
Toowoomba Region Basalts	20th	66	16	7	180	88	3.4	0.5	660	7.5	150	20	0.10	0.000	0.00	0.005	0.010	1.30	0.087	0.000
	50th	97	52	59	350	184	10.0	5.0	1,200	7.9	291	34	0.20	0.020	0.01	0.005	0.015	2.20	1.054	0.000
	80th	147	100	116	530	356	22.0	33.0	1,750	8.2	443	47	0.30	0.050	0.02	0.025	0.015	6.20	7.391	0.000
South East Walloons	20th	121	9	4	300	101	3.4	0.0	880	7.7	251	12	0.10	0.000	0.000	0.000	0.000	2.90	0.000	0.000
	50th	225	39	27	455	236	13.0	1.0	1,500	8.0	390	17	0.27	0.010	0.01	0.010	0.010	8.10	0.217	0.000
	80th	425	89	89	662	560	46.2	6.0	2,550	8.4	562	30	0.50	0.060	0.02	0.148	0.025	17.89	1.324	0.033

Table notes:

In some instances, values have been rounded for consistent presentation of decimal places for each parameter

ID = insufficient data EC = electrical conductance SAR = sodium adsorption ratio

Total N = total nitrogen Total P = total phosphorus

Source: Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins (DES 2019c) and Healthy Waters Management Plan: Queensland Condamine River Basins (DES 2019b)

6 Field investigations

Between May 2018 and February 2019, geotechnical and hydrogeological reference design phase investigations were carried out within the Project footprint with the objective of obtaining geotechnical and hydrogeological data to inform the reference design and the EIS.

Hydrogeological investigations were conducted as part of the field investigation by qualified hydrogeologists or qualified field engineers with advice from a qualified hydrogeologist. Field investigations included:

- Standpipe piezometer installation – 30 groundwater monitoring bores
- Hydraulic aquifer testing (falling head test or rising head test) in standpipe piezometers
- Groundwater level monitoring
- Groundwater quality sampling of project monitoring bores
- Laboratory analysis.

The reference design phase investigations are detailed and discussed in depth in the following documents:

- Inland Rail: Phase 2 - Border to Gowrie - Geotechnical Interpretive Report (FFJV, 2019b).
- Inland Rail Condamine River Valley Geotechnical Factual Report (Golder, 2019b).

A summary of key hydrogeological results is provided in Table 6.1, including the screened interval depths, the screened lithology, water levels, and slug test results. The locations of monitoring bores installed during the hydrogeological reference design phase investigations are presented on Figure 4.30.

6.1 Standpipe piezometer installation

Drilling and installation of 30 standpipe piezometers (monitoring bores) were conducted according to the Minimum Construction Requirements for Water Bores in Australia (National Water Commission, 2012). Project monitoring bores were primarily located where features of the reference design, at its stage of development at the time of the investigations, had greatest potential to interface with groundwater.

In each instance, the standpipe piezometer was designed by a qualified hydrogeologist, with installation conducted by the drilling contractor under the supervision of a qualified field engineer and licensed water bore driller.

All standpipe piezometers were equipped with 50 mm diameter class 18 PVC screw jointed pipes with 0.4 mm slotted screens and blank casing. A borehole diameter of 96 mm was drilled for the installation of the standpipe piezometers. A gravel pack (1 to 3 mm washed and graded gravel) was placed in the annulus of the borehole around the screen section which was then sealed with a bentonite plug. The annular space above the bentonite plug was grouted to the surface where a protective monument or gatic cover was installed.

Each completed standpipe piezometers was developed by purging via either manual bailing or purging with a 12-volt Twister groundwater pump, as appropriate. Purging was completed prior to sampling for groundwater quality analyses. Multiple groundwater bore volumes were removed from each standpipe piezometer to stimulate flow of ambient groundwater toward the standpipe to ensure suitable development of each well.

Field parameters for groundwater quality were monitored during development to quantify when drilling influences had been removed from the piezometer and groundwater representative of the aquifer was being purged. The standpipe piezometer was considered developed when purge water was free of sediment and field parameters had stabilised over subsequent readings. Locations of the Project monitoring bores are included in Table 6.1

Table 6.1 Reference design phase investigation monitoring locations and results

Chainage (approximate)	Well ID	Screened interval (mbgl)	Screened lithology	Aquifer[1]	Surface elevation[2]	Median SWL (mAHD)	RL Range from level logger during the field investigation works (mAHD)	Average hydraulic conductivity[3], K (m/day)
Ch 30.7 km (NS2B)	270-01-BH2213	13.5 to 19.5	Sandy gravel and sand	Border Rivers Alluvium	227.0	215.1	215.1 to 215.2	0.19
Ch 32.8 km (NS2B)	270-01-BH2217	9.2 to 15.2	Clayey gravel and sandy gravel	Border Rivers Alluvium	227.6	215.3	215.3 to 215.4	0.52
Ch 34.8 km (NS2B)	270-01-BH2218	8.8 to 14.8	Clayey Gravel and gravelly sand	Border Rivers Alluvium	225.6	214.2	213.7 to 214.8	0.16
Ch 35.1 km	BH2201	20.2 to 29.2	Extremely weathered sandstone	Pilliga Sandstone/Springbok Sandstone (Kumbarilla Beds)	256.5	248.6	248.3 to 248.7	0.3
Ch 49.6 km	BH2302	9 to 15	Sandstone	WCM	300.9	Dry bore		
Ch 52.8 km	BH2203	16 to 25	Sandstone	WCM	278.7	258.9	254.5 to 264.7	$3x10^{-4}$
Ch 53.0 km	BH2304	2.6 to 8.6	Siltstone	WCM	289.8	Dry bore		
Ch 53.4 km	BH2305	9 to 15	Siltstone	WCM	287.2	Dry bore		
Ch 54.9 km	BH2206	16.5 to 25.5	Weathered mudstone/sandstone	WCM	272.4	263.5	263.4 to 263.5	$5x10^{-2}$
Ch 59.1 km	BH2308	9 to 15	Weathered clayey sandstone	WCM	301.6	291.4	287.6 to 295.2	$9x10^{-4}$
Ch 63.7 km	BH2309	9 to 15	Extremely weathered sandstone/mudstone	WCM	277.1	265.7	262.8 to 268.6	$3x10^{-3}$
Ch 65.8 km	BH2210	21 to 30	Siltstone	WCM	283.4	268	258.5 to 277.5	$1x10^{-4}$
Ch 71.1 km	BH2311	9 to 15	Extremely weathered sandstone/mudstone	Eurombah Formation (WCM)	296.7	Dry bore		
Ch 87.3 km	BH2214	14 to 20	Extremely weathered sandstone	WCM	321.6	305.1	304.2 to 306	$2x10^{-3}$
Ch 88.2 km	BH2215	21 to 30	Extremely weathered sandstone	WCM	322.5	308	306 to 310	3.3
Ch 93.8 km	BH2216	12.5 to 18.45	Extremely weathered mudstone	WCM	320.8	307	304.3 to 309.8	$8x10^{-4}$
Ch 95.6 km	BH2617	2 to 5	Sand	Border Rivers Alluvium (Canning Creek)	323.3	318.9	318.3 to 319.6	0.2

Chainage (approximate)	Well ID	Screened interval (mbgl)	Screened lithology	Aquifer[1]	Surface elevation[2]	Median SWL (mAHD)	RL Range from level logger during the field investigation works (mAHD)	Average hydraulic conductivity[3], K (m/day)
Ch 112.4 km	BH2341	9 to 15	Mudstone/sandstone	WCM	446.3	435.9	434.9 to 436.9	$9x10^{-3}$
Ch 114.3 km	BH2323	9 to 15	Extremely weathered sandstone/mudstone	Eurombah Formation (WCM)	458.6	446.2	444.5 to 450.7	0.7
Ch 116.2 km	BH2355	17 to 20	Basalt	MRV	477.5	Dry bore		
Ch 122.1 km	BH2326	9 to 15	Extremely weathered mudstone	WCM	477	468.9	465 to 472.7	$5x10^{-4}$
Ch 127.2 km	BH2229	24 to 30	Sandstone	WCM	406.6	379.5	377.2 to 381.7	$8x10^{-3}$
Ch 165.1 km	BH2337	9 to 15	Basalt	MRV	487.1	Dry bore		
Ch 166.1 km	BH2338	9 to 15	Basalt/clay	MRV	504.8	Dry bore		
Ch 184.8 km	BH2343	12 to 15	Basalt	MRV	532.8	519.9	519.6 to 520.2	4.9
Ch 187.5 km	BH2344	9 to 15	Sandy gravel/basalt	Alluvium/MRV	524.8	515.6	512.6 to 518.5	0.06
Ch 188.9 km	BH2345	21 to 30	Basalt	MRV	536.1	518.6	516.7 to 520.5	$7x10^{-3}$
Ch 193.5 km	BH2347	17 to 20	Gravelly silt	MRV	463	453.8	453.8 to 454.3	0.3
Ch 195.5 km	BH2248	19 to 25	Sandy clay/clayey sand	WCM	432.9	425.8	425.8 to 425.9	0.2
Ch 201.8 km	BH2352	12 to 15	Basalt	MRV	487.3	Dry bore		

Table notes:

RL = reduced level
SWL = standing water level
1 Refer to Section 4.7 for introduction and description for each
2 Surface elevation derived from the digital elevation model spatial data or from bore completion logs
3 Mean hydraulic conductivity value derived from falling and rising head tests completed during reference design phase investigations

6.2 Groundwater level monitoring

A dedicated automatic pressure transducer was installed in each standpipe piezometer for continuous groundwater level monitoring for durations between four and eight weeks. The pressure transducers (In-Situ Rugged Trolls) were installed at depths ranging between 9 m to 30 m. The transducers record total pressure on the sensor (water column above the sensor and atmospheric/barometric pressure) which is then converted to a groundwater level. Measurements are recorded by the pressure transducers at one-hour intervals and are calibrated by manual static water level measurements.

The groundwater level data obtained from the hydrogeological investigations are presented in Table 6.1 and discussed for each of the relevant aquifer unit in Section 4.7.

The pressure transducers will remain installed in the network of Project monitoring bores to provide a continued source of groundwater level data in proximity to the Project footprint. This data will be used in the development and finalisation of a GMMP for the Project (refer Section 9.3), as well as for the monitoring of impacts to groundwater during construction.

6.3 Permeability testing

In-situ hydraulic testing using variable head test techniques was conducted at ten Project standpipe bores. Standpipe bores that were dry at the time of visiting were not tested. Slug tests involve inducing a change in groundwater level within the bore casing by inserting (falling head) and then removing (rising head) a solid slug, or by sudden displacement of the water column in the casing using a gas slug, and then measuring the water level response over time. In each instance, water level recovery was monitored until it returned to 90 per cent of the pre-test water level. The recorded data allows for an estimation of hydraulic conductivity (k) of the screened soil or rock material. Hydraulic conductivity is reported in metres per day (m/s) and is a measurement of how easily water can move through pore spaces in a geological formation.

Slug test data were analysed using AQTESOLV Pro 4.0 which is an industry standard program widely used in the field of hydrogeology for hydraulic parameter estimation. The hydraulic test data was analysed by using the Hvorslev (1951) and KGS (Hyder et al. 1994) solution methods.

6.4 Groundwater quality sampling

One round of groundwater sampling was conducted in accordance with AS/NZ 5667.1:1998 and AS/NZ 5667.11:1998 after completion of all 30 monitoring bores. Groundwater sampling involved:

- Manual measurement of groundwater levels of each monitoring bore
- Purging of monitoring bores prior to sampling. As part of the purging, a minimum of three bore volumes were removed from each bore and field physicochemical measurements (i.e. pH, EC, redox, dissolved oxygen and temperature) were collected during purging to ensure parameters have stabilised
- Sampling of groundwater for laboratory analyses. Duplicate and triplicate samples were collected to meet adopted quality assurance and quality control (QA/QC) requirements. Quality control samples provide information that clarifies potential data errors attributable to cross contamination, inconsistencies in sampling and analytical issues.
- All samples were collected in appropriate sampling containers for the required analytical parameters, chilled and dispatched under chain of custody documentation to ALS Laboratory in Brisbane (a National Association of Testing Authorities [NATA] - accredited laboratory for analyses).

The analysed chemical parameters for each sample were as follows:

- Major anions and cations (i.e. calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), fluoride (F^{-}), sulfate (SO_4^{2-}), carbonate and bicarbonate alkalinity and hardness)
- pH
- Conductivity
- TDS
- Total and dissolved metals (i.e. arsenic, boron, barium, berylium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc, and mercury)
- Nutrients (nitrate, nitrite, ammonia, reactive phosphorous [P], total nitrogen [TN], total Kjeldahl nitrogen [TKN] and total phosphorous [TP])
- Sodium adsorption ratio (SAR).

7 Groundwater modelling

7.1 Construction methodology

Construction of the Project will involve a combination of earthworks for cuts and embankments to ensure required grade for the rail alignment, bridges, and borrow pits to supply fill and aggregate. The proposed construction activities for the Project with potential to interface with groundwater and the key assumptions for each activity are provided in Table 7.1.

A profile of the rail alignment which presents the surface geology, locations of cuts, bridges, fill, and bore locations is depicted on Figure 7.1.

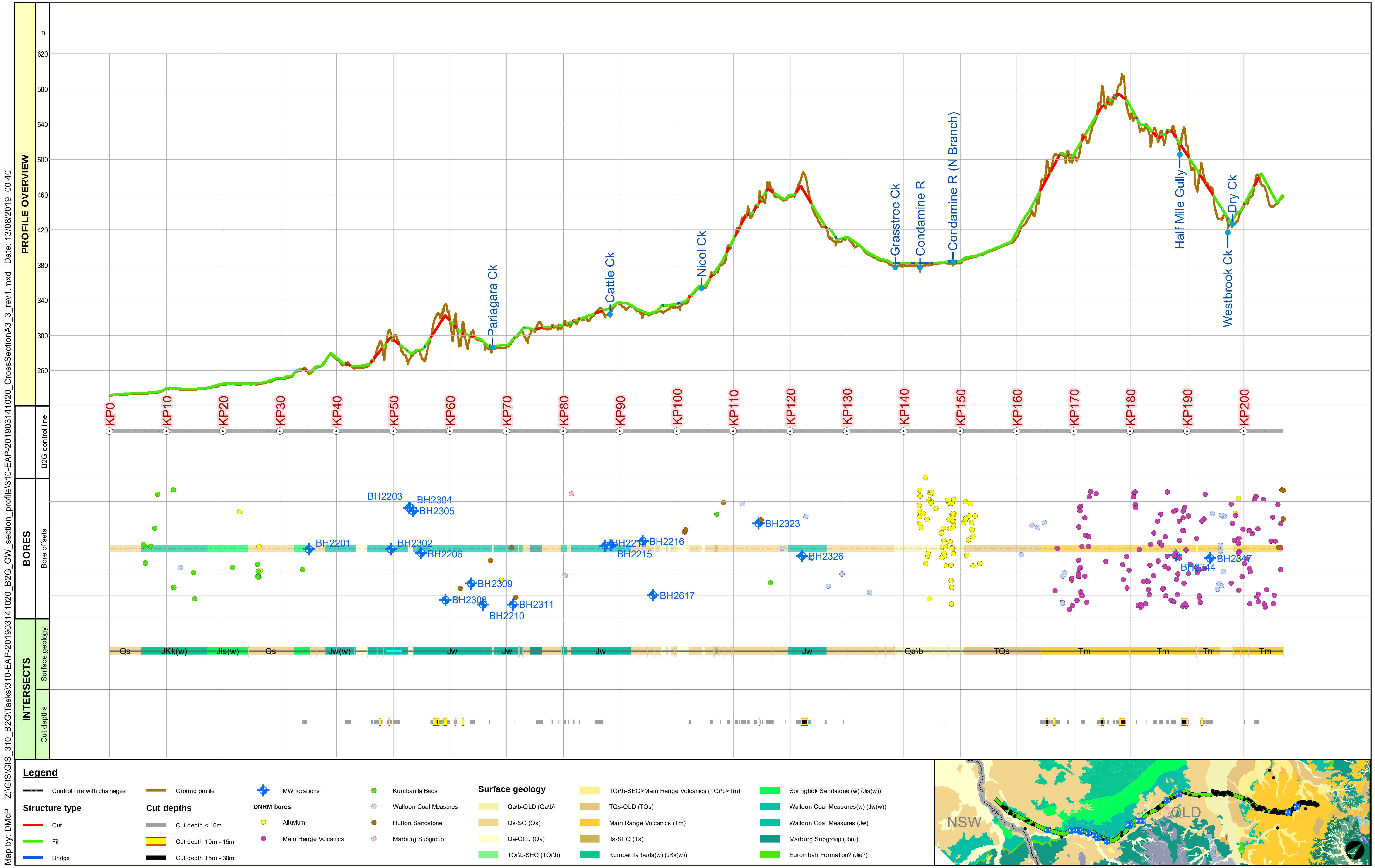
Table 7.1 Summary of construction activities and assumptions for the Project

Activity	Description	Assumptions
Embankments	Volumes of material emplaced and compacted to raise the profile of the railway alignment to meet design specifications. A total of 77 embankments are proposed.	No dewatering, which may alter shallow groundwater levels, is anticipated. Compaction may occur as part of the embankment construction works.
Cuts	Removal of soil and rock to maintain the grade of the alignment design. A total of 48 cuts are proposed with a total aggregate length of approximately 36.3 km. Cut lengths range from 0.09 to 3.45 km. The maximum cut depth is 29.7 m (cut ID 310-C37, Ch 172.65 km to Ch 174.94 km) and the mean cut depth is 8.9 m along the entire rail alignment. Of these 48 cuts, at least seven are considered to be locations where groundwater is anticipated to be encountered. Five of these seven cut sections were selected for predictive modelling as they represent the highest potential to intersect groundwater. Cuts are proposed in all the main geological units.	Cuts have potential to intersect the existing groundwater table. Drawdown of groundwater levels at cut location may occur due to seepage.
Bridge and pilings	Total of 34 rail bridges are proposed to cross roadways and waterways. Cast in Place (CIP) pilings are expected to be used for each bridge.	Pilings are proposed to extend to depths ranging from 5 to 35 mbgl and span widths of 20 to 30 m. Piling designs are founded in soil, alluvium and bedrock of the Surat and Clarence - Moreton basins.
Borrow pits	Shallow excavations at key designated locations near the Project to source soil, sand and gravel. ARTC have identified 12 potential borrow pit locations. The viability and feasibility of accessing material from these locations will be confirmed during the detail design phase of the Project (post-EIS).	A more detailed assessment of the potential to intersect groundwater will be completed by ARTC during the detail design phase of the Project (post-EIS).

7.2 Conceptual groundwater models

Key aspects of the hydrogeological regime within the impact assessment area are summarised below, and a conceptual understanding of the hydrogeological regimes within the impact assessment area are presented on Figure 7.2 and Figure 7.3. Conceptualisation is divided broadly into two sections of the Project:

- Ch 30.60 km (NS2B) – Ch 117.0 km: characterised by the Surat Basin consolidated strata and overlying Cainozoic unconsolidated sediments of the Border Rivers Alluvium; and
- Ch 117.0 km – Ch 206.9 km: characterised by the Clarence-Moreton consolidated strata and overlying Cainozoic MRV and unconsolidated sediments of the Condamine Alluvium.



Horizontal lateral scale for borehole offsets: 1:60,000

Horizontal longitudinal scale as determined by chainage markers on C/L

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BORDER TO GOWRIE

Figure 7.1 Construction profile

The groundwater conceptualisations are a representation of the groundwater systems which incorporate an interpretation of the geological and hydrogeological conditions. Further, the conceptualisations consolidate the current understanding of the key processes of each groundwater system, including the influence of stresses, to assist in the understanding of potential changes/impacts on the systems as a result of the Project.

7.2.1 Main hydrostratigraphic units

As shown in Figure 7.2 conceptual site model (CSM) Section A, the Project initially traverses the Border Rivers Alluvium followed by the westward dipping Kumbarilla Beds and WCM in the Inglewood area. Deep cuts discussed in Section 7.1 (Construction Methodology), are incised into the weathered bedrock in this area with potential to intersect shallow groundwater. Further north of Inglewood, the Project traverses the Border Rivers Alluvium associated with Canning Creek tributaries and intermittent subcrop of the WCM where one deep cut (>10 mbgl) is proposed (i.e. Ch 67.0 km and Ch 117.0 km).

Beyond Millmerran, the Project traverses predominantly WCM subcrop with no significant cuts proposed (refer Figure 7.3 CSM Section B). The Condamine Alluvium is then crossed where bridge sections with deep pilings up to 35 mbgl are proposed across Grasstree Creek, the Condamine River, and the Condamine River North Branch.

7.2.2 Levels and flow

The water table in the Border Rivers Alluvium is shallow and generally follows topography, with localised drawdown observed in areas of groundwater abstraction. The water table is typically a subdued version of topography within the WCM, with the depth to groundwater increasing beneath topographic highs.

Groundwater flow of the Border Rivers Alluvium with respect to the rail alignment is inferred towards the southwest. Groundwater flow in the WCM in the Condamine to Gowrie area (i.e. Ch 115.0 km to Ch 206.0 km) is generally towards the northwest yet between Millmerran and Yelarbon flow direction is inferred towards the west - southwest (OGIA 2016a). Available groundwater level data suggest that there is potential for groundwater flow from the basalts to the WCM (UQ 2014). This is likely exacerbated by depressurisation of the coal seams which can induce flow from the adjacent units.

7.2.3 Recharge

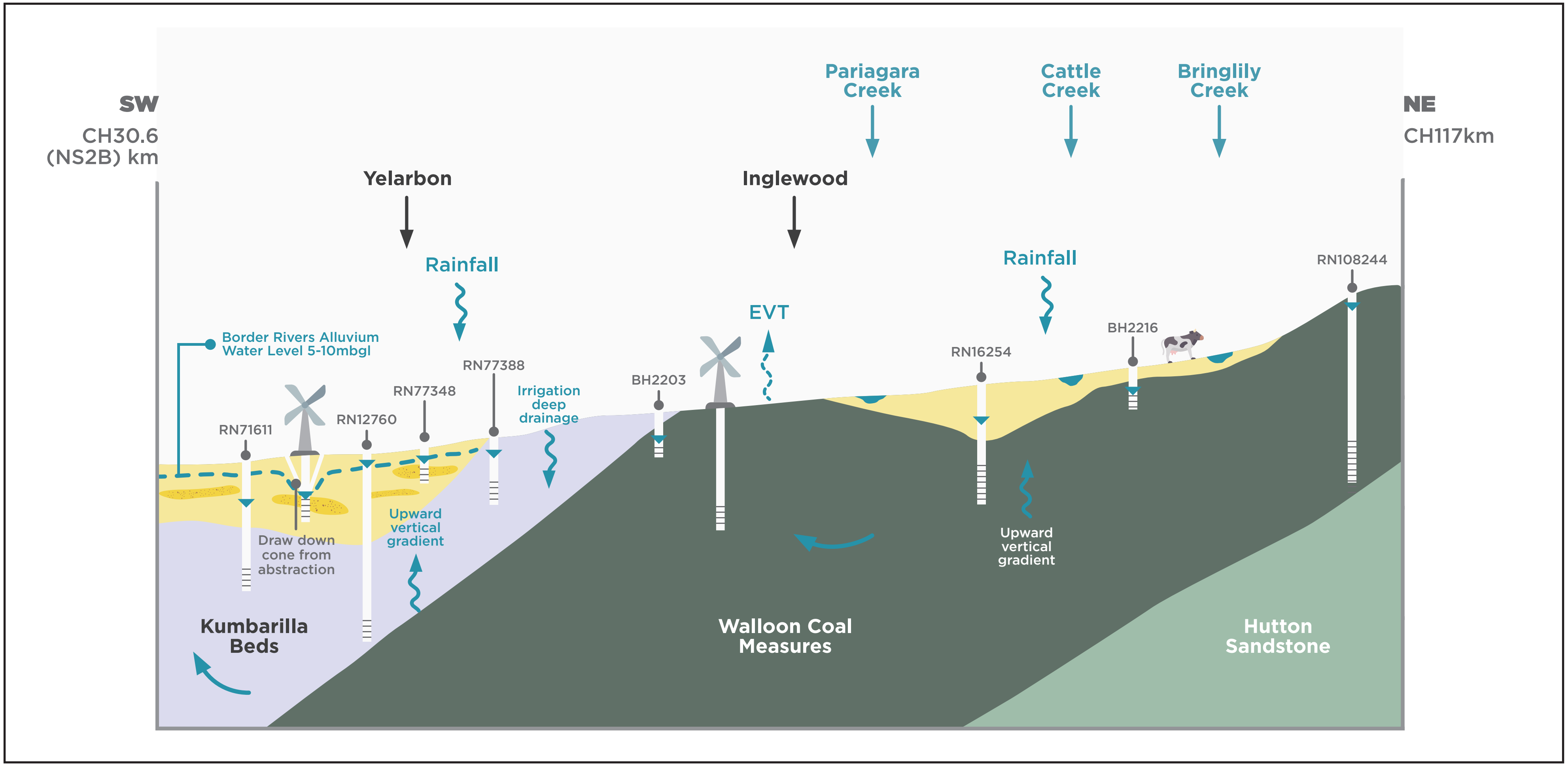
In general, recharge to alluvial aquifers is anticipated to occur from both rainfall and by seepage from ephemeral watercourses. Sub-cropping rock below permeable alluvium may also act as a source of recharge due to upward discharge of groundwater (Golder, 2019c).

Primary recharge to the WCM is considered to be through seepage from the overlying and underlying units and via direct rainfall infiltration in areas of subcrop. Primary recharge to the MRV is considered to primarily be via direct rainfall infiltration and local vertical leakage from the underlying units along with adjacent flow through from the Condamine Alluvium after large rainfall events.

7.2.4 Discharge

The primary discharge mechanisms in the alluvium are extraction, as baseflow to the adjacent surface water features, and local leakage into the underlying units. Evapotranspiration from vegetation growing in the creek beds and along the banks, and seepage to the underlying units from the alluvial/colluvial sediments are also considered to be primary discharge mechanisms from this unit.

Primary discharge mechanisms in the WCM are considered to include bore extraction where the WCM locally act as an aquifer and vertical seepage into the under and overlying units. Primary discharge mechanisms from the MRV are considered to include bore extraction and local vertical leakage to deeper units.



Legend

- Border Rivers Alluvium
- Kumbarilla Beds
- Walloon Coal Measures
- Hutton Sandstone
- **mbgl** Metres below ground level
- Inferred groundwater flow direction
- Standing Water Level (SWL)
- Water table/Potentiometric level
- Recharge
- Evapotranspiration (EVT)
- Groundwater Abstraction

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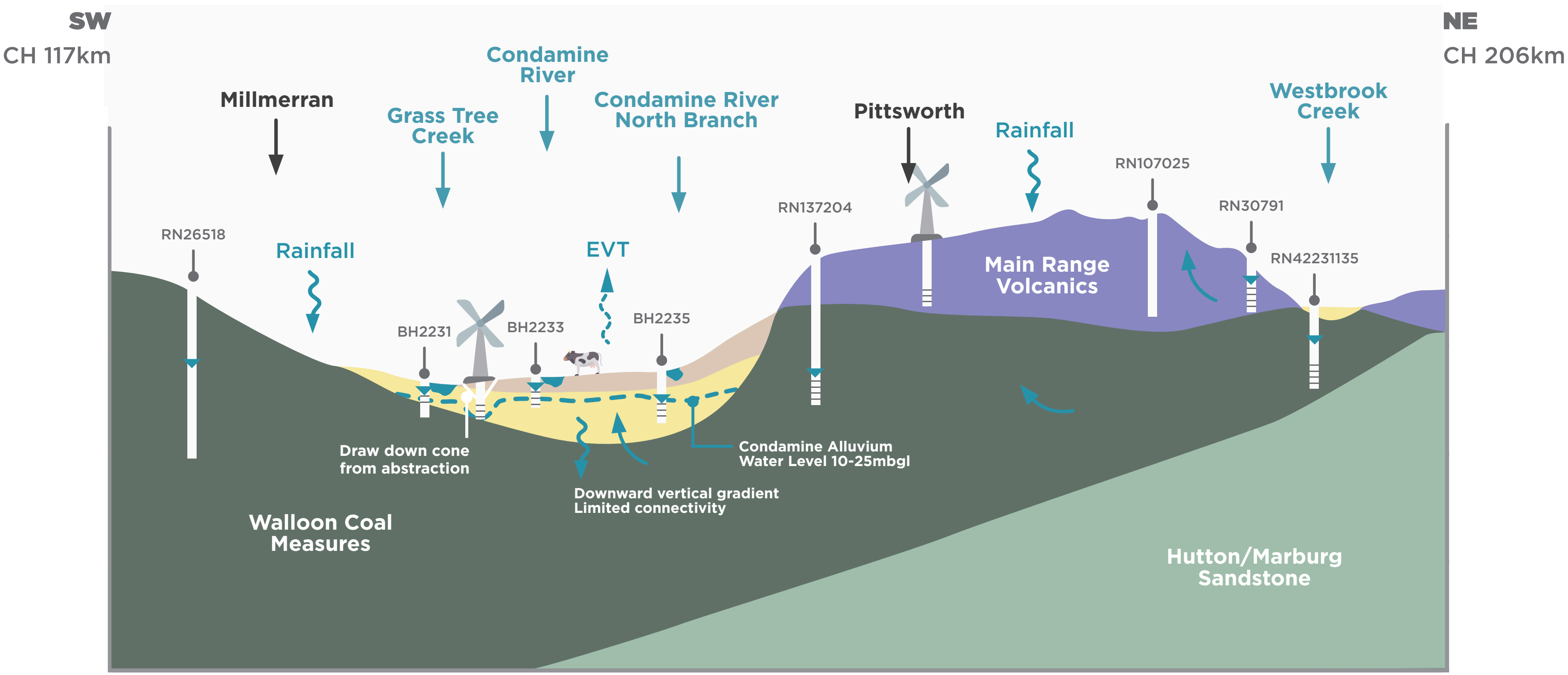
Figure 7.2 - Hydrogeological CSM – Section A



Legend

- Condamine Alluvium Sheetwash Clays
- Condamine Alluvium Sands & Gravels
- Main Range Volcanics
- Walloon Coal Measures
- Hutton/Marburg Sandstone
- Inferred groundwater flow direction
- Standing Water Level (SWL)
- Water table
- Recharge
- Evapotranspiration (EVT)
- Groundwater Abstraction

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Figure 7.3 Hydrogeological CSM – Section B

7.3 Predictive modelling

A groundwater model is a simplification of a complex system and its behaviour developed to gain an understanding of likely responses to future changes of the system and understanding the uncertainty in those responses.

Numerical predictive models have been developed to support the hydrogeological design and impact assessment for the Project. These local-scale groundwater models were developed as two-dimensional cross-sectional models oriented perpendicular to the Project alignment. The methodology and modelling are discussed in detail in the *Inland Rail – NSW/QLD Border to Gowrie 100% Feasibility Design Scope of Works - Hydrogeological* (Golder, 2019c) is attached in Appendix B. The primary objectives of the predictive modelling include:

- Assess potential groundwater drawdown due to drainage of cuts
- Estimate groundwater seepage rates for cuts
- Assess groundwater quality parameters to inform reference design for earthworks and cuts.

In order to develop the cross-sectional models, the 48 cuts required for the Project were considered in terms of representativeness of the cut across the Project. Of the 48 proposed cuts, seven are anticipated to encounter groundwater.

Out of seven deep cuts, five indicative cuts along the Project alignment were identified as best representing the local geological conditions and worst-case potential impacts on groundwater resources (deepest cuts into each stratigraphy). The indicative cuts that were subject to 2-D modelling are listed in Table 7.2. These indicative cuts were subsequently modelled to evaluate potential extent of drawdown, changes to flow regime and to estimate potential seepage rates.

The vertical rail alignment and the earthworks design for the Project will continue to be developed and refined through the detail design process. This may result in modifications to the location and dimensions (depth, width and length) of cuts that are currently included in the reference design and have been subject to predictive numerical modelling. Consequently, revised 2-D modelling of deep cuts will be required through the detail design process to confirm potential drawdown and seepage rates, and ensure that appropriate controls are included in the design.

Table 7.2 Cuts selected for predictive modelling

Cut ID	Model section, chainage (km)	Reason for selection	Closest watercourse/water bore	Cut length (m)
310-C08	57.67	Deepest cut in C1-Jw (XW) model ground	Non-perennial Macintyre Brook to the southeast (1,400 m). Nearest registered bore is BH2308 (1,710 m)	3,450
310-C25	114.46	Deepest cut in C2-Qs/Jw (XW) model ground	Non-perennial tributary of Nicol Creek to the south (230 m). Nearest registered bore is BH2323 (460 m)	380
310-C31	164.60	Deepest cut in C3-1-Jw model ground, with the most significant variation in topography	Non-perennial tributary of Condamine River (North Branch) (320 m). Nearest registered bore is BH2337 (535 m)	1,680
310-C37	174.52	Deepest cut in C3-3-Tm model ground	Perrier Gully Tributary (560 m). Nearest registered bore is RN19886 (360 m)	2,290
310-C44	188.91	Deepest cut in C3-5-Tm model ground	Non-perennial tributary of Westbrook Creek to the north (355 m). Nearest registered bore is BH2345 (42 m)	1,500

Source: Golder (2019c)

The five models were set up to represent the range of hydrogeological conditions that may be encountered during construction and operation of the Project. A summary of the modelled cut locations and the corresponding design details is presented in Table 7.3.

Table 7.3 Summary of numerical models/locations where cuts may encounter groundwater

Cut ID	Model section, chainage (km)	Median centreline elevation along cut (m AHD)	Cut depth (mbgl)	Median groundwater elevation at cut (m AHD)	Estimated depth of cut below the median groundwater elevation (m)
310-C08	Ch 57.67 km	314.3	17.4	309.7	12.8
310-C25	Ch 114.46 km	451.3	15.4	436.6	0.7
310-C31	Ch 164.60 km	474.0	29.5	454.3	9.8
310-C37	Ch 174.52 km	548.1	29.7	541.9	23.5
310-C44	Ch 188.91 km	509.3	26.4	505.5	22.6

Each model was developed to consist of between three to four geologic/hydrogeologic layers, depending on the in-situ profile, in order to simulate drawdown/seepage between stratigraphic units. The geological layers of the model sections are presented in Table 7.4. The SEEP/W finite element software package was selected to construct the required numerical models. The SEEP/W software was selected as it allows for:

- Assessment of groundwater flow in porous media
- Simple saturated steady-state simulations
- Analysis and design for subsurface dewatering systems.

There are inherent uncertainties in the adoption of any numerical modelling method, as the process involves development of a simplified representation of a real system. Sensitivity analysis was incorporated into the methodology to account for potential uncertainties in the 2-D modelling, such as heterogenous geological conditions, variable aquifer characteristics (as encountered in the alluvium and MRV) and paucity of location-specific data. Due to these known uncertainties, the numerical models are considered to be Class 1 (Barnett et al. 2012), which is defined as having a high degree of uncertainty. However, the numerical simulations undertaken for this assessment are considered to be suitable for developing coarse relationships between groundwater extraction locations and rates and associated impacts (Barnett et al. 2012).

The predictions generated by numerical models are not unique and multiple combinations of setups and parameters can achieve reasonable sensitivities when calibration data is limited. Sensitivity analysis was performed to compare model outputs with different sets of reasonable parameter estimates to allow for more accurate predictions. Sensitivity analysis also tested the robustness of the model to changes in parameters. The various parameters were adjusted during the sensitivity testing until the simulated groundwater levels best aligned with data obtained from published sources as well as that obtained from Project hydrogeological investigations. The sensitivity analysis provided for greater accuracy in the output model predictions and for some of the uncertainty in numeric modelling to be negated.

The numerical models developed are considered an initial assessment of the Project on groundwater resources. Revised 2-D modelling of deep cuts will be required through the detail design process to confirm potential drawdown and seepage rates and ensure that appropriate controls are included in the design.

Table 7.4 Geological layers of model selections

Cut ID	Model section, chainage (km)	Ground model	Layer 1	Layer 2	Layer 3	Layer 4
310-C08	57.67	C1-Jw(XW)	Topsoil	Dense Clayey Sand/Sandy Clay	Dense to very Dense Sand or Very Low Strength Sandstone	N/A
310-C25	114.46	C2-Qs/Jw(XW)	Topsoil	Stiff to Hard Sandy Clay	Hard Lateritised Clay	N/A
310-C31	164.60	C3-1-Jw	Topsoil	Stiff to Hard Clay	Sandstone/Mud stone	Sandstone and Shale

Cut ID	Model section, chainage (km)	Ground model	Layer 1	Layer 2	Layer 3	Layer 4
310-C37	174.52	C3-3-Tm	Topsoil	VL-L Strength Basalt	High to Very High Strength Basalt	N/A
310-C44	188.91	C3-5-TM	Topsoil	Stiff to Hard Clay	VL-L Strength Basalt	High to Very High Strength Basalt

Source: Golder 2019c

7.3.1 Available data and hydraulic parameters

Hydraulic properties were estimated for input parameters into the SEEP/W models using results from aquifer hydraulic conductivity tests undertaken at 12 bore locations installed for the Project (refer Section 6, Appendix B). Hydraulic characteristics of an aquifer define the attributes of the unit which permit groundwater to flow and the likely pathways of flow. There are various methods to ascertain aquifer hydraulic characteristics from a groundwater well. Hydraulic conductivity tests were undertaken as a component of the reference design geotechnical investigation in the form of slug tests.

A slug test is the addition or removal of a volume of water (a 'slug') from a well while measuring the recovery of the well's water level over a period of time. The results of the slug tests performed at project wells was considered with regional literature values particularly where limited or no tests were performed for a specific hydrostratigraphic unit along the rail alignment. Each hydrostratigraphic unit is considered in isolation to determine the most accurate value for input into the model. That is, one value for each test (and rock type) was determined from the average value of different interpretations.

Site-specific values were compared to local modelling studies' values and literature data, then statistical analysis was undertaken to derive hydraulic conductivity values. As a result of assessment of the relevant literature data and site-specific K values, a hydraulic conductivity value was then assigned to each model layer/hydrostratigraphic unit. This dataset includes results from regional datasets to allow for sufficient parameter selection. For example, a typical K value of 60 metres per day (m/d) has been adopted for the Quaternary aquifer units for all five models (Golder, 2019c).

Table 7.5 presents the hydraulic conductivity values assigned to each model layer based on the results of the site-specific slug test results.

Table 7.5 Hydraulic parameters*

Cut ID	Model section, chainage (km)	Layer 1	Layer 2	Layer 3	Layer 4
310-C08	57.67	8.2×10^{-6} (highest measured K value)	1.0×10^{-8} (estimated K for clay)	3.7×10^{-9} (sandstone value)	N/A
310-C25	114.46	8.3×10^{-6} (highest measured K value)	1.0×10^{-8} (estimated K for clay)	1.0×10^{-8} (estimated K for clay)	N/A
310-C31	164.60	8.3×10^{-6} (highest measured K value)	1.0×10^{-8} (estimated K for clay)	3.7×10^{-9} (sandstone value)	3.7×10^{-9} (sandstone value)
310-C37	174.52	8.3×10^{-6} (highest measured K value)	7.0×10^{-7} (K value for basalt)	1.0×10^{-8} (estimated value)	N/A
310-C44	188.91	8.3×10^{-6} (highest measured K value)	1.0×10^{-8} (estimated K for clay)	7.0×10^{-7} (K value for basalt)	1.0×10^{-8} (estimated value)

Table notes:

1 Hydraulic conductivity values are in metres per second (m/s)

Source: Golder 2019c

7.3.2 Model assumptions

A groundwater model is a simplified representation of the real environment, and as such, assumptions are required to simplify aspects to meet the objectives of the predictive modelling, particularly in instances of limited data. Objectives of the numerical modelling were to identify the seepage into cuts and drawdown as a result of project works. The following assumptions were made in order to develop the models for the Project, for the model scenarios, as follows.

Assumptions for all models:

- It was assumed that pumping/extraction from bores and watercourses nearby will not have an impact on the calculated pressure distributions (groundwater levels). This allows for uninfluenced predictions of groundwater flow/seepage to be determined.
- At the modelled locations, 1 per cent of assumed annual rainfall (6.5 mm/year) was assigned to the upper model surface as boundary condition.
- The estimated drawdown is assumed to be relevant only to the construction phase when the cut face will be exposed. Ongoing drawdown after the construction phase is not anticipated as the cut faces will not be exposed.

Upper range (conservative) model assumptions:

- The estimate of expected hydraulic conductivity (K) of model layers was increased by one order of magnitude
- Estimated assumed rainfall rate was doubled to inform upper range recharge values
- Expected groundwater elevation estimates at the right and left side of the model sections (refer Section 7.3.3) were increased by two metres as a conservative approach.

It is noted that the upper range scenario was not modelled but used to derive maximum seepage values for cuts. These scenarios, and assumptions, are further discussed in the sections below.

7.3.3 Boundary conditions

Boundary conditions represent locations in the model where water flows into or out of the model region due to external factors. These external factors can include lakes, streams, recharge, and wells. To determine boundary conditions for the models, static water levels were plotted against surface elevation to establish the correlation between these two parameters. The result was used to assess the constant head (water level) boundary condition which was then assigned to the left and right side (boundary of assessment) for each model section, based on local topography. One percent of the assumed rainfall was assigned to the upper model surface as boundary condition (6.5 mm). Seepage face boundary condition was assigned to the cut surfaces as this where seepage is most anticipated to occur. These conditions represent the steady-state models from which various conditions can be captured with scenario simulations. For example, high- and low-seepage simulations include the steady-state where precipitation is one percent, then doubled for high-seepage predictions.

As discussed in the section above, a set of models were also developed to assess the upper range of values to estimate conservative seepage values. Boundary conditions adopted for the upper range scenarios are included in Section 7.3.2.

Figure 7.4 through Figure 7.8 depict the geometry and boundary conditions for the five predictive models at the selected representative cuts.

Note for all plates: red dots are the constant head boundary conditions on the left and right sides of the model; blue is rainfall on top of the model; light blue is the seepage face.

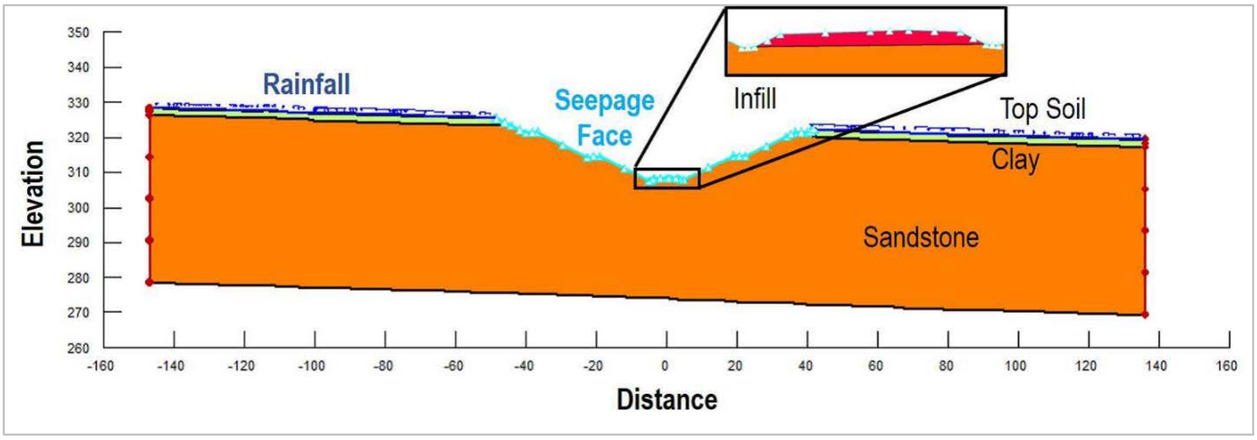


Figure 7.4 Geometry and boundary conditions at Ch 57.67 km (cut 310-C08)

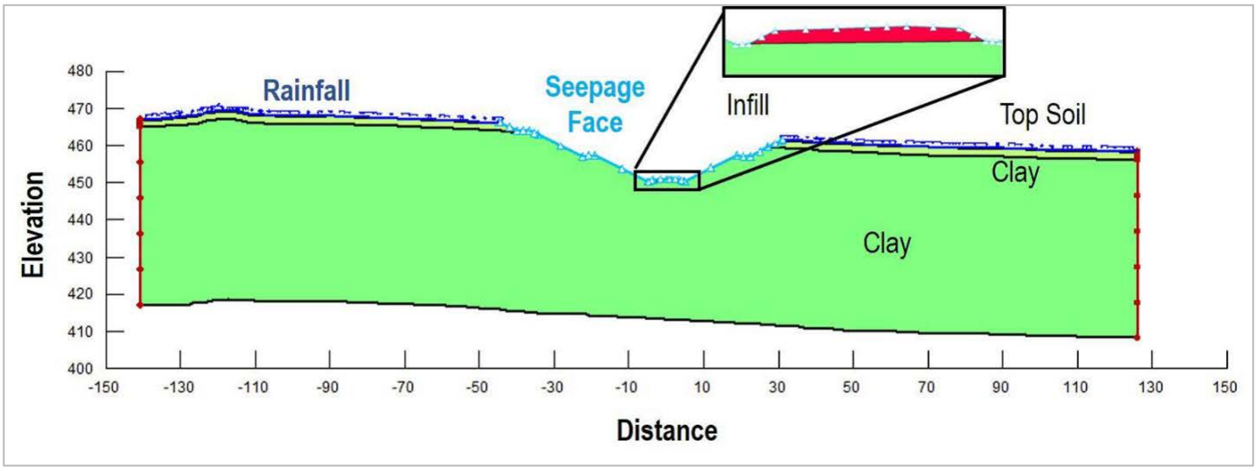


Figure 7.5 Geometry and boundary conditions at Ch 114.46 km (cut 310-C25)

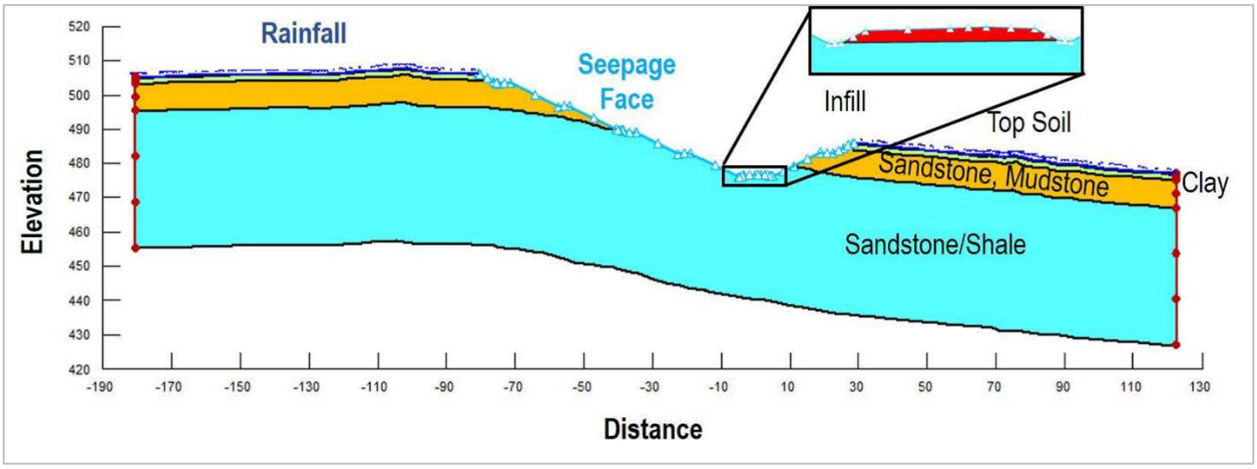


Figure 7.6 Geometry and boundary conditions at Ch 164.60 km (cut 310-C31)

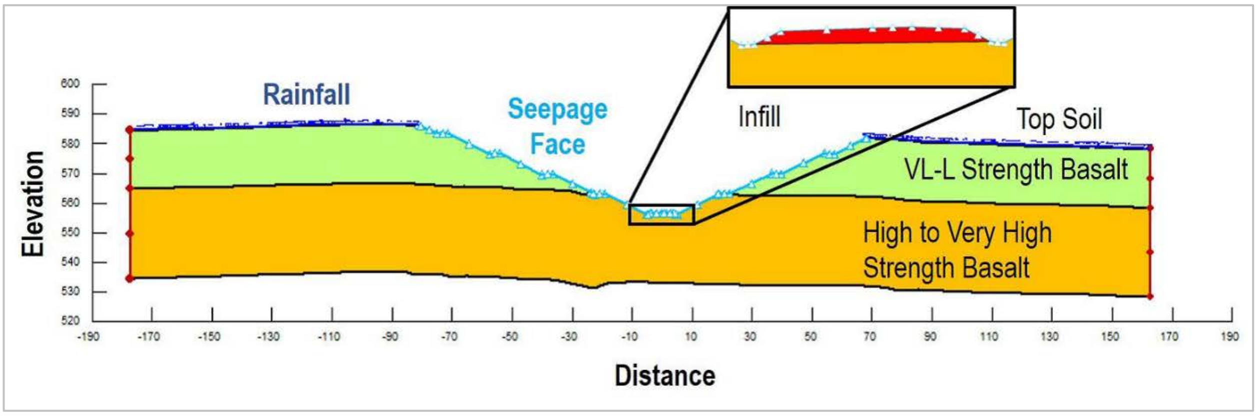


Figure 7.7 Geometry and boundary conditions at Ch 174.52 km (cut 310-C37)

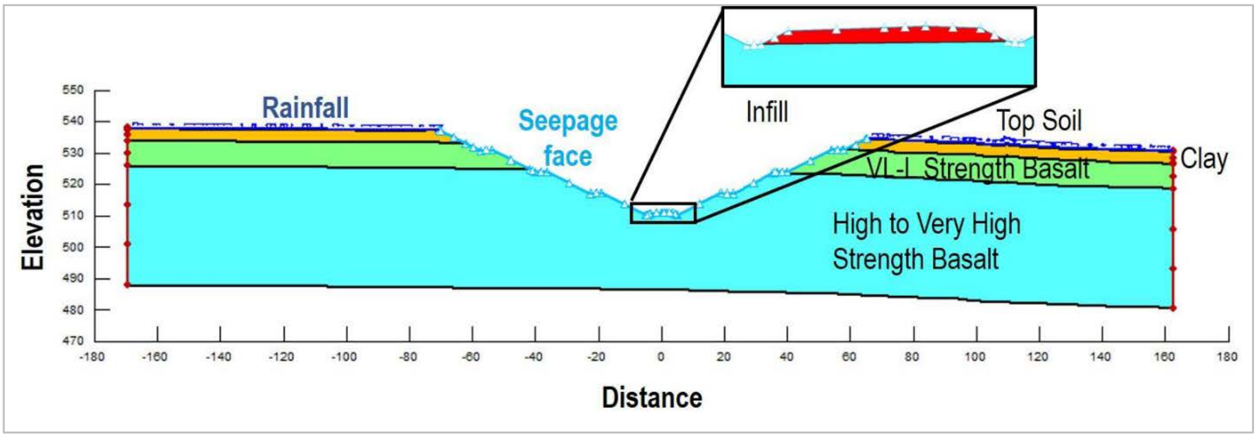


Figure 7.8 Geometry and boundary conditions at Ch 188.91 km (cut 310-C44)

7.3.4 Model results

The results of the modelled scenarios for steady-state and upper values are presented in this section. Water quality of seepage is discussed below.

Seepage rate estimates were obtained for the entire length of each cut, through the multiplication of modelled seepage rates by the total length of cut, as specified in Table 7.2. The modelled geology and cut geometry for each section modelled have been extrapolated across the entirety of each cut such that calculated seepage rates are considered to be conservative estimates.

The estimated seepage results are presented in Table 7.6.

Table 7.6 Seepage estimates to cuts based on predictive modelling

Cut ID	Model section, chainage (km)	Cut length (m)	Cut depth (mbgl)	Expected seepage for entire cut (m^3/year)	Upper range seepage for entire cut (m^3/year)
310-C08	57.67	3,450	17.4	1,750	11,100
310-C25	114.46	380	15.4	30	280
310-C31	164.60	1,680	29.5	260	740
310-C37	174.52	2,290	29.7	7,100	105,000
310-C44	188.91	1,500	26.4	1,870	17,500

Source: Golder 2019c

Predictive simulations indicate:

- Seepage is concentrated at the bottom of the cuts, on both sides of infill material
- Initial inflow of seepage will be higher than the average rate predicted for steady-state scenarios then will plateau
- Seepage values simulated are considered to be low and attributed to the low K values applied, based on an average of site-specific data
- Temporary increases in seepage may be observed in cuts with sandy soil or weathered sandstone following rainfall events
- Seepage of groundwater from bedrock is anticipated to be low except where enhanced by weathering of fractures.

Estimated seepage rates, as included in Table 7.6 (base-case), are generally low; the upper range values (most conservative) range from 280 m^3/year (cut 310-C25) to 105,000 m^3/year (cut C310-C37) which equates to 0.01 litres per second (L/s) (cut 310-C25) to 3.3 L/s (cut 310-C37). It is anticipated that seepage water, in general, will evaporate due to local climate conditions and relatively small volumes when considered with the length of the cuts (refer Section 4.4). Cut 310-C37 is predicted to encounter seepage volumes of 7,100 m^3/year to 105,000 m^3/year which equates to rates of 0.23 L/s and 3.3 L/s across the entire surface of a 2.29 km cut, to 29.7 m depth. Such a large estimated range is expected to be refined during detail design when additional site-specific data hydrogeological data is combined with the finalised design for model re-calibration and re-run of predictive simulations. This will aide in refinement of the GMMP (refer Section 9.3) and inform the potential requirement for seepage management options.

Table 7.7 presents the predicted drawdown results where the range in drawdown extent represents the upper value steady-state results. It is noted the predictive model did not include for aquifer heterogeneity to account for variable characteristics within an aquifer. The predicted extent of drawdown at cuts 310-C08, 310-C37 and 310-C44 are shown on Figure 7.9, Figure 7.10, and Figure 7.11, where drawdown is in metres calculated at the centreline of the rail alignment for each model.

Modelling results indicate that drawdown is only expected to occur at three of the five modelled locations. In these locations, there are no registered bores located outside of the Project footprint that are also within the extent of predicted drawdown. At the locations where drawdown is anticipated to occur, the maximum extent of drawdown is predicted to range from 15 m to 80 m from the centre of the Project alignment.

Table 7.7 Predicted drawdown values at modelled cuts

Cut ID	Modelled section location (chainage) (km)	Estimated drawdown at rail centreline (m)	Extent of drawdown from centreline (m)	Drawdown threshold applied* (m)
310-C08	57.67	3.7	Up to 15	2
310-C25	114.46	<1.0	N/A	N/A
310-C31	164.60	<1.0	N/A	N/A
310-C37	174.52	12.2	Up to 60	5
310-C44	188.91	11.7	Up to 80	5

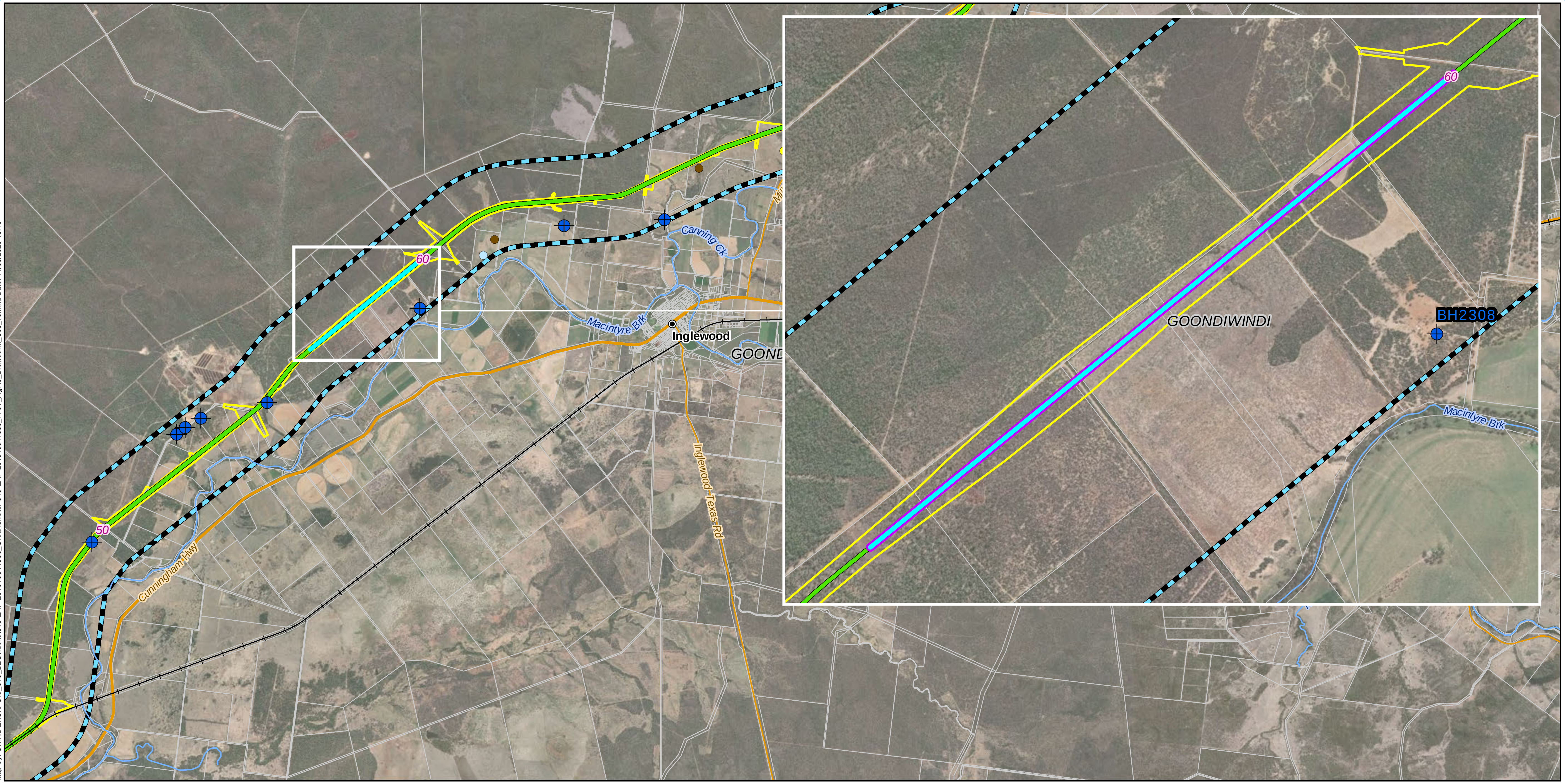
Table note:

* Drawdown thresholds of 2 m for unconsolidated aquifers and 5 m for consolidated aquifers are from the *Water Act 2000*

As only three of the five cuts considered to be worst-case predicted drawdown (refer Table 7.7, cuts C08, C37, C44) and only two cuts predicted seepage (refer Table 7.6, cuts C31 and C7), numerical model simulations of the remaining two cuts was not considered warranted.

The numerical simulations undertaken in part for this study are considered to be suitable for developing coarse relationships between groundwater extraction locations and rates and associated impacts (Barnett et al 2012). Further, these models are considered an initial assessment of the Project on groundwater resources. The numerical model will be updated with additional information gathered during the detail design phase.

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



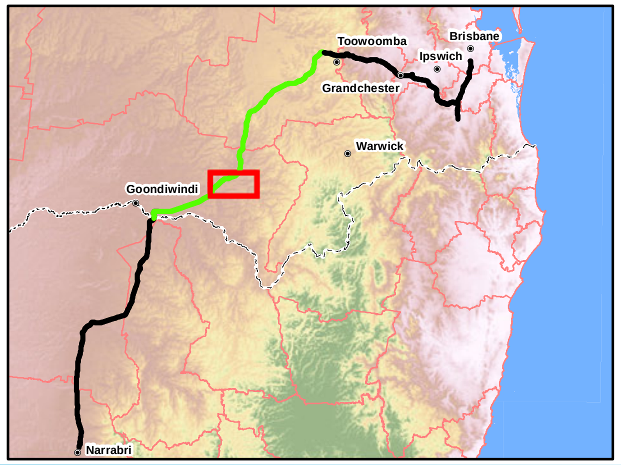
Map by: GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig7.9_Drawdown_C08_v3.mxd Date: 11/05/2020 15:48

Legend

- 5 Chainage (km)
- Localities
- Border to Gowrie alignment
- Cut 310-C08
- Existing rail (operational)
- Major roads
- Minor roads
- Watercourses
- Predicted (preliminary) groundwater drawdown (2m)
- Project footprint
- Groundwater impact assessment area
- Cadastre
- Local Government Areas
- Site Investigation Bores

Registered Bores

- Alluvium
- WCM
- Hutton Sst



A3 scale: 1:100,000

0 0.75 1.5 2.25 3 3.75km

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Integrating Community, Environment and Engineering

Issue date: 11/05/2020 Version: 3

Coordinate System: GDA 1994 MGA Zone 56

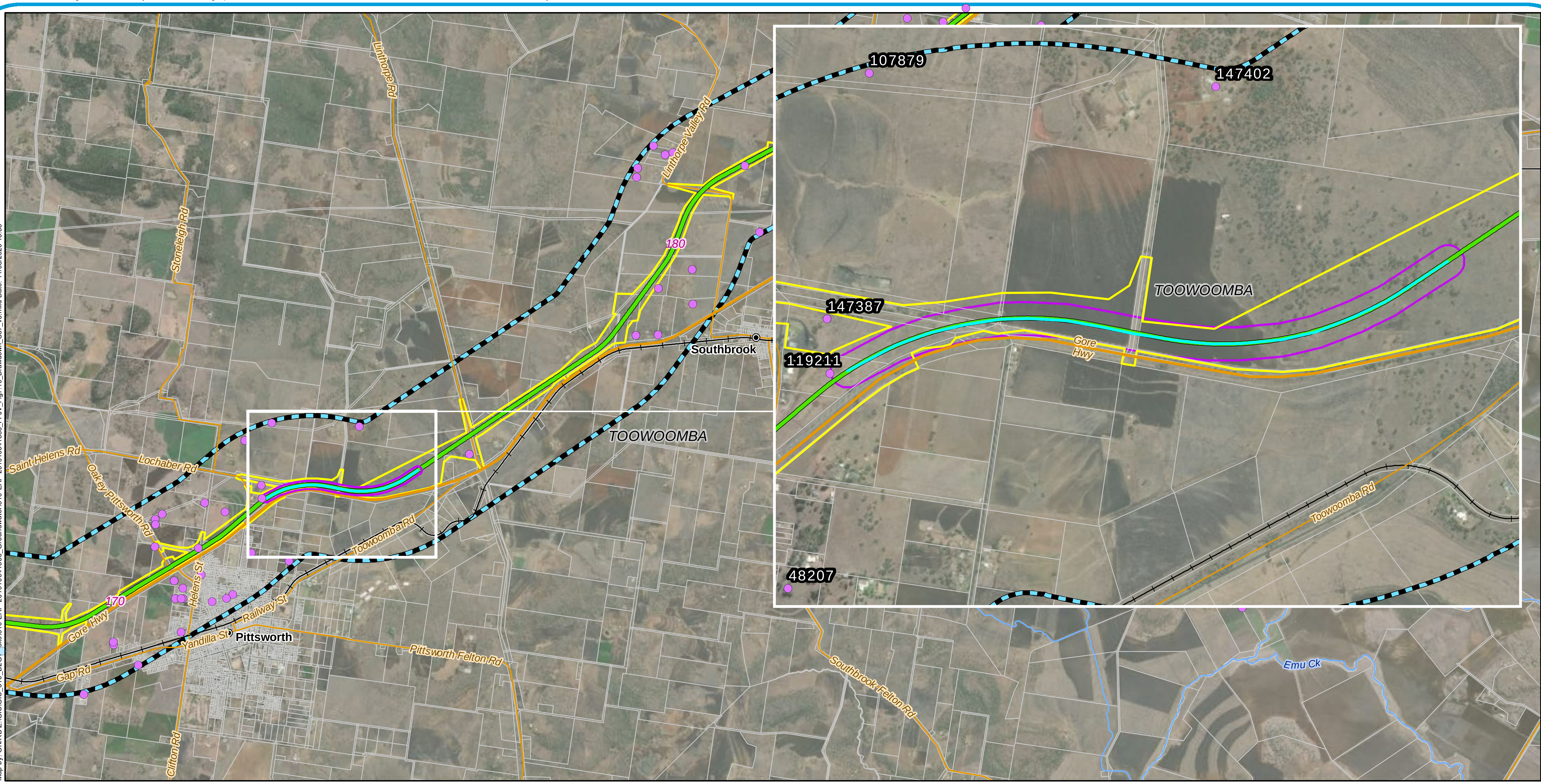
Border to Gowrie

Figure 7.9:

Predicted (preliminary) groundwater drawdown at Cut 310-C08

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

Map by: GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig7.10_Drawdown_C37_v3.mxd Date: 11/05/2020 15:53

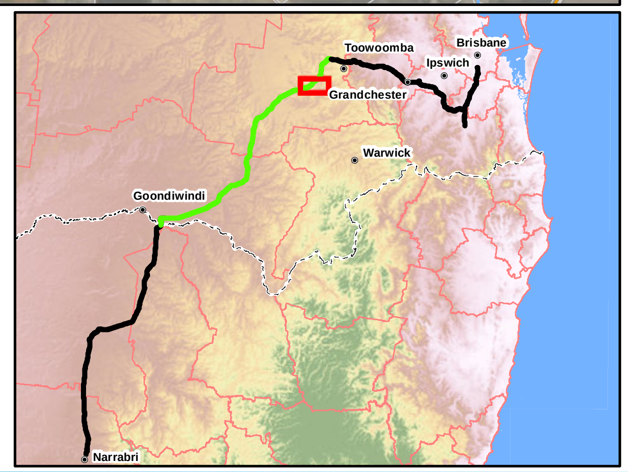


Legend

- 5 Chainage (km)
- Localities
- Cut 310-C37
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Watercourses
- Predicted (preliminary) groundwater drawdown of 5m
- Project footprint
- Groundwater impact assessment area
- Cadastre
- Local Government Areas

Registered Bores

- MRV
- WCM



A3 scale: 1:60,000

0 0.45 0.9 1.35 1.8 2.25km

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Integrating Community, Environment and Engineering

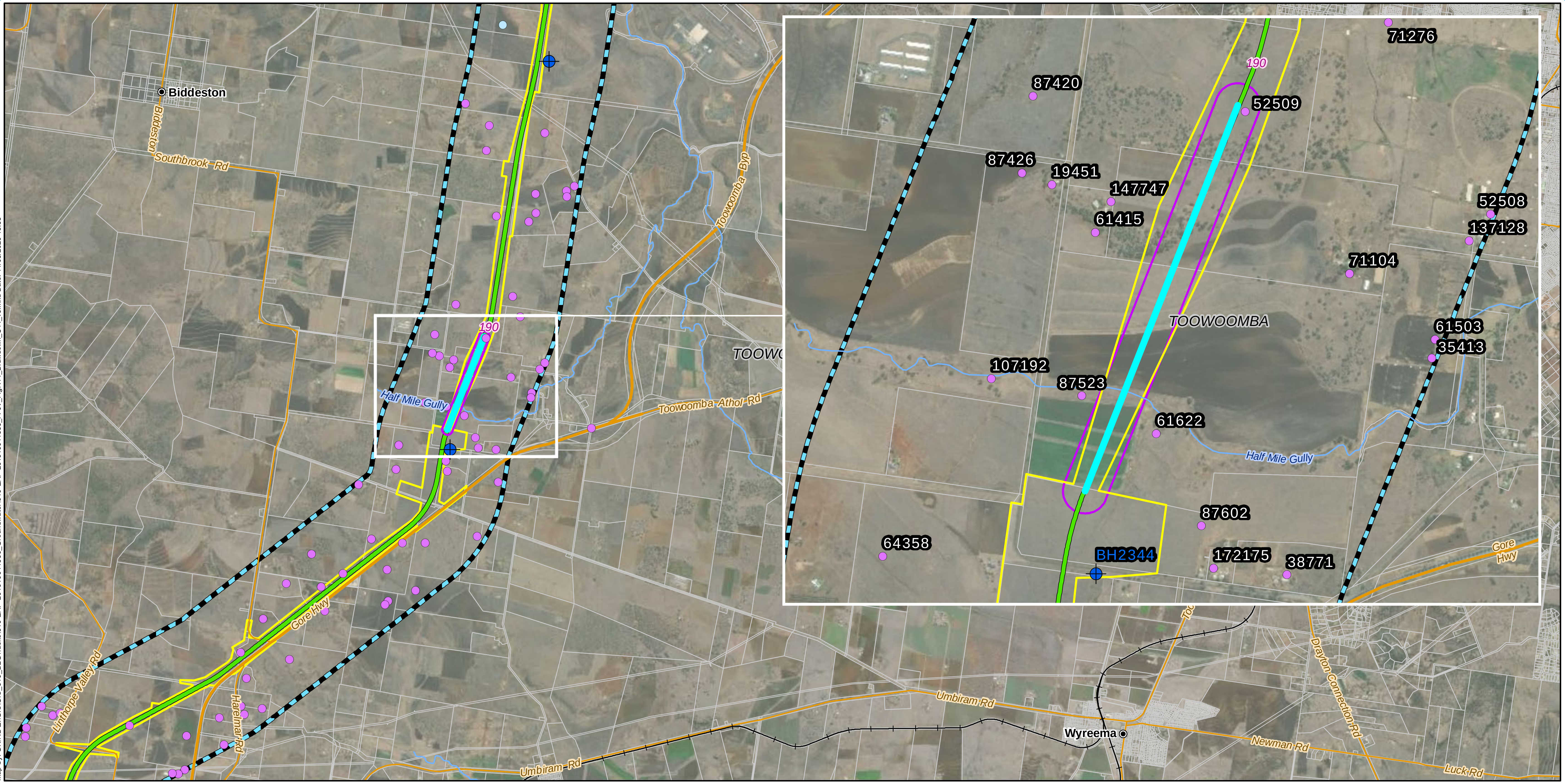
Issue date: 11/05/2020 Version: 3

Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 7.10:
Predicted (preliminary) groundwater drawdown at Cut 310-C37

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



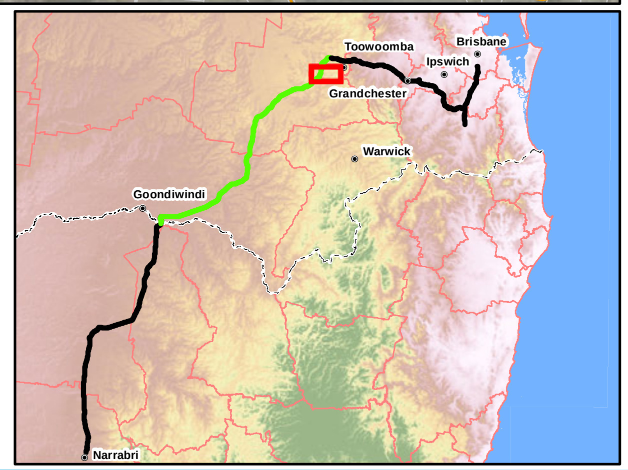
Map by: GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig7.11_Drawdown_C44_v3.mxd Date: 11/05/2020 15:58

Legend

- 5 Chainage (km)
- Localities
- Cut 310-C44
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Minor roads
- Watercourses
- Predicted (preliminary) groundwater drawdown of 5m
- Project footprint
- Groundwater impact assessment area
- Cadastre
- Local Government Areas
- Site Investigation Bores

Registered Bores

- MRV
- WCM



A3 scale: 1:63,000

0 0.45 0.9 1.35 1.8 2.25km

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Issue date: 11/05/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 7.11:
Predicted (preliminary) groundwater drawdown at Cut 310-C44

8 Potential impacts

8.1 Construction

Construction for the Project includes several activities which have the potential to impact on groundwater resources. These activities include site preparation, bulk earthworks (cut and fill sections), drainage construction, haul road and access track construction, bridge pilings and the excavation of borrow pits for construction materials.

The location of these proposed activities along the Project alignment are presented on Figure 7.1. These potential impacts are discussed below in terms of impacts on groundwater resources and quality. Mitigation measures to minimise impacts on groundwater during the construction phase are provided in Section 9.

8.1.1 Groundwater resources

8.1.1.1 Site clearing and grading

Site clearing and grading activities could potentially impact on shallow groundwater resources due to:

- Removal of vegetation reducing evapotranspiration, which can influence the groundwater discharge (i.e. result in higher groundwater levels)
- Compaction of ground resulting in reduced groundwater recharge
- Alteration of possible existing areas where ponding surface water occurs naturally, which could reduce groundwater recharge in these areas.

EVs with potential to be impacted include: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, cultural and spiritual values.

The Project footprint has been delineated to include the minimum extent of land required to safely and efficiently construct and operate the Project. The Project alignment has also been aligned to maximise the use of existing rail corridor, where possible. As a consequence, approximately one third of the total Project alignment is located in existing rail corridor. The total area proposed to be cleared and graded for construction purposes is considered to be negligible in comparison to the total recharge surface area of the alluvial aquifers which underlay the Project. Consequently, there is likely to be little impact on the groundwater resources due to site clearing and grading activities

8.1.1.2 Loss or damage to existing groundwater bores, including impaired access

Existing groundwater bores within the Project footprint are likely to be decommissioned to enable construction and operation of the Project. Groundwater bores that are not decommissioned may be damaged or become inaccessible due to temporary or permanent Project activities.

EVs with potential to be impacted include: irrigation, stock water, farm supply/use, drinking water.

Thirty (30) registered bores are located within the Project footprint. It is anticipated that each of these registered bores, in addition to any unregistered bores within the Project footprint, will need to be decommissioned to enable construction of the Project. Decommissioning of bores will be in accordance with the Minimum Construction Requirements for Water Bores in Australia – Edition 3 (National Uniform Drillers Licensing Committee 2012).

During the detail design phase, landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint. Where a groundwater bore is expected to be decommissioned or have access to it impaired as result of the Project, ‘make good’ measures will be agreed in consultation with the affected landowner.

These measures could include:

- Provision of an alternate water supply/new bore
- Changing the bore pump so that it is better suited to the decreased water level in the bore
- Deepening the bore to allow it to tap a deeper part of the aquifer
- Reconditioning of the water bore to improve its hydraulic efficiency
- Increase monitoring of the bore water levels and efficiency to provide a level of confidence to the landowner that the impacts are being effectively managed.

Mitigation measures to prevent impact on such unregistered groundwater bores are presented in Section 9.2.

8.1.1.3 Drawdown due to seepage

Drawdown of localised groundwater levels may occur as a consequence of seepage from the exposed face of cuts that intersect the underlying groundwater table. This drawdown has the potential to temporarily affect the availability of groundwater from registered bores in proximity to the works, which are not otherwise decommissioned by the Project. Drawdown also has potential to affect GDEs within the radius of impact.

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

As discussed in Section 7.2, predictive modelling results indicate that drawdown of the water table may be experienced at three deep cuts (i.e. C08, C37, and C44) as a consequence of seepage (refer Table 7.7). There are no registered bores located outside of the Project footprint that are also within the extent of predicted drawdown.

- Where the productivity of an established bore is identified as being impacted by Project activities, 'make good' measures will be agreed in consultation with the affected landowner. Such measures may include:
- Changing the bore pump so that it is better suited to the decreased water level in the bore
- Deepening the bore to allow it to intersect a deeper part of the aquifer
- Reconditioning of the water bore to improve its hydraulic efficiency
- Increased monitoring of the bore water levels and efficiency to provide a level of confidence to the landowner that the impacts are being effectively managed

Seepage from the faces of cuts will be minimised via the application of engineering controls. For example, the reference design has allowed for the application of a 300 mm drainage blanket to be applied to the face of all cuts where groundwater is encountered within 2 m of the base of the cutting. Alternative seepage control measures will be considered and assessed through the detail design, on a cut-by-cut basis.

8.1.1.4 Subsidence/settlement

Subsidence/settlement of compressible substrates and possible damage to adjacent structures, such as embankments, culverts and utilities.

EVs with potential to be impacted include: aquatic and terrestrial ecosystems.

Deep cuts, in which the water table is expected to be encountered (refer Section 7)., are located within competent substrate, such as basalt and sandstone where the likelihood of settlement is less probable than in unconsolidated substrates.

8.1.1.5 Construction of new fill embankments

Establishment of new embankments may cause the obstruction of natural drainage pathways, resulting in more frequent inundation of areas upstream of the embankments. This more frequent inundation could result in groundwater mounds forming underneath these areas.

Groundwater mounding may also result from the compacting of soils following the addition of embankment soils. In addition, groundwater depressions may form in areas which formerly received recharge (i.e. down gradient of the emplaced embankments).

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

There are 77 embankment sections (fill) in the reference design (refer Figure 7.1). The subgrade beneath these embankments is primarily Cainozoic Alluvium and MRV, with some overlaying the WCM. The depth to groundwater is typically over 5 m for the Border Rivers and Condamine Alluvium and WCM with the risk of mounding considered to be generally low in this substrate.

Where embankments are located on the MRV, groundwater mounding is possible given the potential shallow depth of the MRV aquifer and degree of ground water level fluctuations observed in Section 4.7.2.2 (over 10 m). Impacts on groundwater as a result of embankments may include:

- Diminished quality/ease of contamination near surface
- Increased water levels in shallow units can act as baseflow outside of high rainfall events.

8.1.1.6 Establishment of borrow pits

Temporary borrow pits may be established as a source of material for construction of the Project. The pit locations range from within the temporary footprint to up to 11 km from the Project and are depicted on Figure 8.1.

Subject to their location, shallow groundwater may be intersected during the development of borrows pits, particularly if depths of greater than 5 mbgl are required. These localised interactions with the water table could impact on the hydraulic regime (i.e. disrupt groundwater flow or induce drawdown).

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

Twelve potential/existing borrow pit locations have been identified. More detailed feasibility assessments of each borrow pit location will be undertaken during the detail design phase of the Project (post-EIS) to determine material usability, volumes, environmental and social impacts (including groundwater).

Following assessment, locations where groundwater is identified as likely to be intersected will be considered less viable than borrow pit locations where groundwater is unlikely to be intersected.

8.1.1.7 Construction water supply

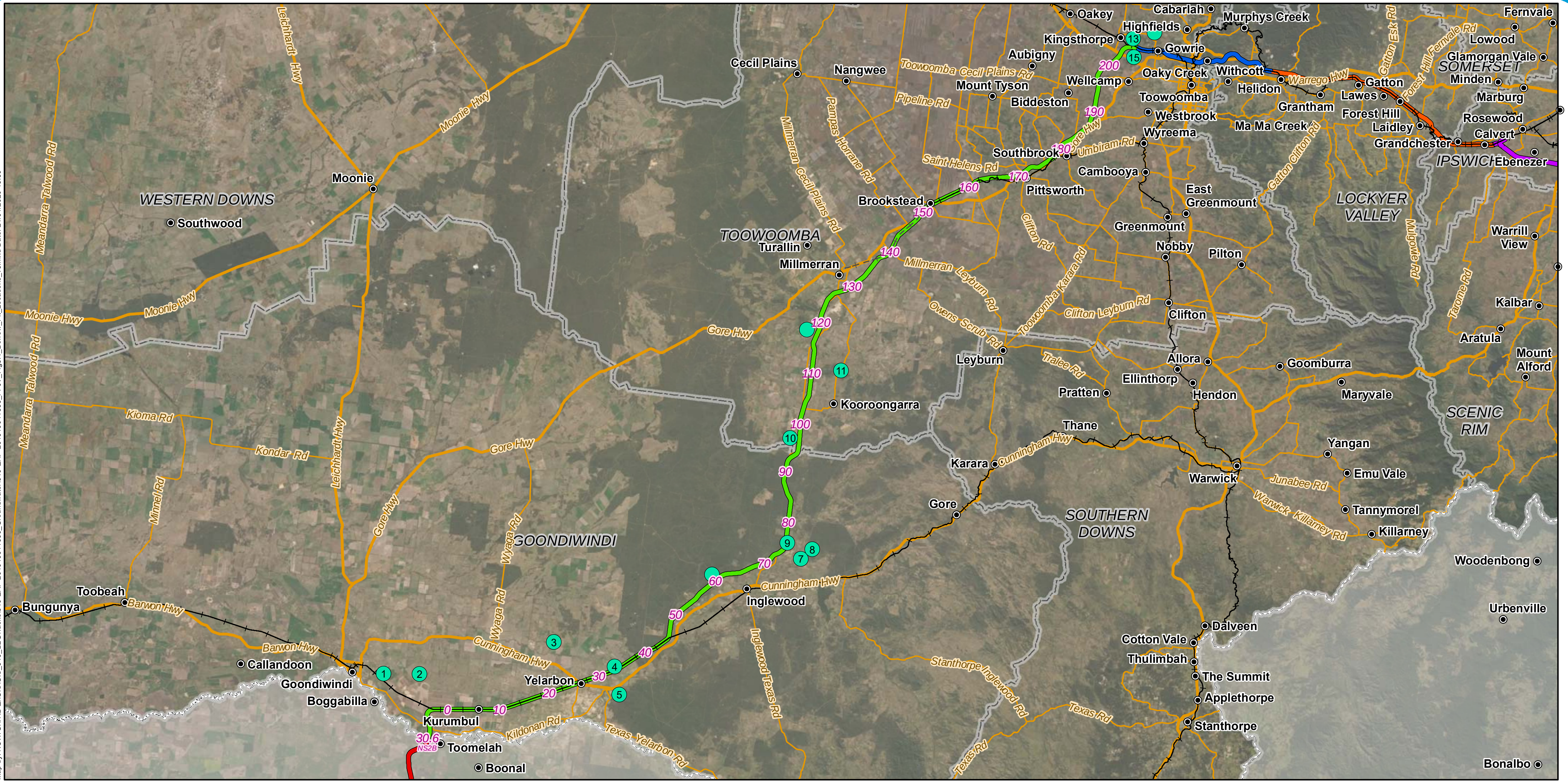
Significant volumes of water will be required for various activities associated with construction of the Project, including for earthworks, concrete production, track works and the operation of non-resident accommodation camps. A summary of the estimated water requirement by construction activity is presented in Table 8.1.

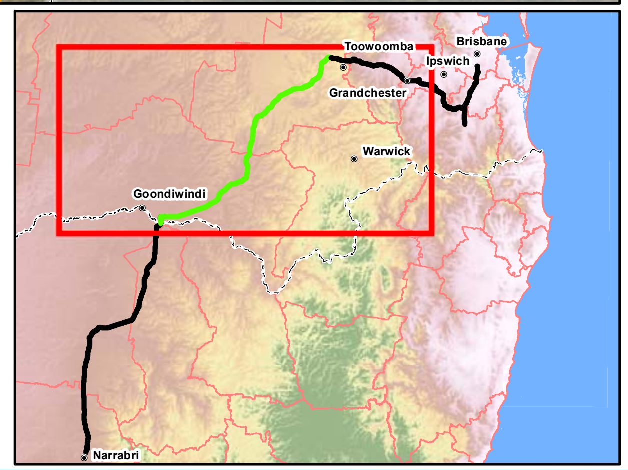
The quality characteristics of water used by the Project during construction will be dependent on its intended use. The water quality requirements for the various activities associated with construction of the Project are summarised in Table 8.2.

Potential impacts to groundwater elevations may occur where bore water is sourced to supply water for construction activities.

EVs with potential to be impacted: Irrigation, stock water, farm supply/use, drinking water.

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





Map by: NCW/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig8.1_Borrow_Pit_Locations_v3.mxd Date: 24/04/2020 15:59

Legend

- 5 Chainage (km)
- Localities
- Borrow Pits
- North Star to NSW/QLD border alignment
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Helidon to Calvert alignment
- Calvert to Kagaru alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- NSW/QLD border
- Local Government Areas

1. B1 Cemetery Road
2. B2 Moorooble Lane
3. B4 Woodcocks Road
4. B5 Taits Red Ridge
5. B6 Texas-Yelarbon Road
6. B7 Bybera Road
7. B8 Fosters Road
8. B9 Mosquito Road
9. B10 Millmerran-Inglewood Road
10. B11 Kooroongarra-Andersons Road
11. B12 Kooroongara Road
12. B13 Heckdendorfs Road
13. B14 Kingsthorpe-Glencoe Road
14. B15 Gowrie-Lilyvale Road
15. B16 Leeson Road

A3 scale: 1:800,000

0 6 12 18 24 30km

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Border to Gowrie

Figure 8.1: Potential borrow pit locations

Table 8.1 Preliminary estimated of water requirements and potential water sources for construction activities

Construction activity	Estimated water requirement (ML)
Rail	
Material conditioning	1,225
Dust suppression and revegetation [1]	613
Haul road and laydown area maintenance	490
Rail total:	2,328
Roads	
Material conditioning	110
Dust suppression and revegetation [1]	55
Haul road and laydown area maintenance	44
Roads total:	209
Track works	
Dust suppression during ballast dropping	1.30
Dust suppression during tamping and regulating	0.86
Track works total:	2.16
Concrete [2, 3]	
Precast concrete	4.8
Wet (bulk) concrete	10.2
Concrete total:	15.0

Table note:

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

Table 8.2 Water quality requirements for construction activities

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

Commercial and private land uses in the region have a strong reliance on access to groundwater for domestic and agricultural purposes. This reliance on groundwater as a resource is even stronger during periods of drought, as is currently being experienced. Information from the Queensland water entitlements database (DNRME, 2018c) and consultation feedback from DNRME indicates that the alluvium and MRV aquifer units in the area are close to full allocation through existing water entitlements (refer Section 4.7.6).

The use of groundwater to supplement the construction water demand for the Project is not preferable due to:

- The existing pressure placed on groundwater as a resource in the region
- The licensing and approval requirements to establish new groundwater bores

- The flow rates required to meet construction water demands are unlikely to be appropriately met through reliance on groundwater
- Challenges regarding the management of groundwater quality.

The use of existing sustainable groundwater allocated entitlements to supplement the construction demand for the Project may be considered if private owners of registered bores have capacity under their water entitlement that they wish to sell to ARTC or the Principal Contractor under private agreement. Therefore, the volumes extracted would be within the existing licensing limits and the extent of drawdown experienced would be localised and consistent with that which is currently permissible for each licensed bore.

Domestic needs will be prioritised above construction water supply and existing sustainable allocated water entitlements will be sourced where possible. The buying or sharing of groundwater from existing water license/entitlement/permit is an option to be considered in the instance bore water is selected as a preferred source of construction water.

As the alluvial and MRV aquifers within the impact assessment area are currently near or overallocated, it is unlikely that a temporary water permit would be issued for the additional take of water from these units.

In the instance a temporary water permit is warranted during construction, the licensed extraction volume would be within the allowable extraction limits for the relevant Water Plan. Therefore, the Project is not expected to impact on, or alter, the identified relevant Water Plans or other plans under the Water Act outside of their designated use and objectives.

8.1.1.8 Dewatering

Dewatering is the process of actively pumping groundwater to locally lower groundwater levels in proximity to excavation or other sub-surface works to temporarily create a dry working environment. Dewatering may be required where sub-surface works encounter groundwater, primarily during construction.

Temporary excavations during construction (i.e. trenching, boring for piles etc.) may encounter groundwater. In these instances, it may be necessary to extract the water from the excavation in order to maintain structural integrity of the excavation and to enable safe establishment of the planned infrastructure.

Piling for the establishment of bridge piers can cause alteration of aquifer parameters (lower permeability), altered groundwater flow patterns (mounding or drawdown up and down gradient of the piles; upward leakage along the pile/soil interface) and reduction in groundwater resources through extraction of wet soil/rock during piling.

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

The maximum extent of drawdown (both vertically and laterally) due to seepage from deep cuts during the construction phase is discussed in Section 7.3.4. The maximum lateral extent is estimated to be between 15 m (C08) to 80 m (C44) from the rail alignment centreline and can be used to infer EVs potentially impacted by this drawdown. Dewatering may be required in some capacity at cut location C37, if the seepage rate is near or above the results of the modelled simulations; however, based on the proposed construction methods for piling, active dewatering is not anticipated (refer Section 8.1.1.9).

A temporary water permit will be required for any dewatering that cannot be managed via construction/engineering techniques. In the instance a temporary water permit is warranted during construction, the licensed volume is expected to be within the allowable extraction limits for the relevant Water Plan. Therefore, the Project is not expected to impact on, or alter, the identified relevant Water Plans or other plans under the Water Act outside of their designated use and objectives.

Potential aquatic GDEs (low to moderate potential) may be locally impacted by drawdowns estimated from selected cuts identified by Golder (2019c). A review of the potential aquatic GDEs from the BoM GDE Atlas indicated that no potential aquatic GDEs are mapped in proximity to cuts where drawdown is anticipated (C08, C37, and C44). Regardless, predictive modelling results suggest drawdown will not extend outside the impact assessment area.

Potential terrestrial GDEs may also be locally impacted by drawdown. Only cut C08, between Ch 56.6 km and Ch 60.0 km, has a potential terrestrial GDEs identified in proximity (refer Figure 4.34). Given that a maximum drawdown radius of 15 m is predicted from the C08 cut centre line, the impact is considered to be wholly within the Project footprint and therefore unlikely to result in impact on this potential GDE.

If dewatering is required during construction, the duration of the impacts is likely to be temporary as the construction works are limited in duration. Impact is not anticipated to extend long after construction works are completed, if at all, dependant on the localised recharge of the highest yield seepage cut.

8.1.1.9 Bridges and piling

The Project includes 29 bridge sections with structural support from CIP pilings. The expected subgrade for bridges and piling works includes Cainozoic alluvium, WCM, and the MRV.

Piling associated with ground improvement works is proposed to stabilise sub-surface conditions at bridge locations along the rail alignment. The piling works are expected to involve a CIP technique, with concrete emplaced via a tremie line or other pumping method. This technique allows for the removal of augered soil/rock while pumping concrete or grout through the hollow stem to stabilise the ground.

The pilings will have span lengths ranging from 20 to 30 m and be installed to depths ranging from 5 to 35 mbgl with pile diameters of 900 to 1,500 mm.

The potential impacts of the piling work during construction activities, on groundwater resources, may include:

- Alteration of aquifer parameters (lower permeability) - the potential impact of altered aquifer parameters is considered limited due to the small area of influence within the saturated sediments compared to the overall extent of alluvium aquifer. This will be a temporary/localised construction impact
- Altered groundwater flow patterns (mounding or drawdown up and down gradient of the piles; upward leakage along the pile/soil interface) – with spacing of the piles such that throughflow in the hydrostratigraphic units intersected by the piles, groundwater flow patterns will not be markedly influenced. Spacing will be sufficient such that mounding (on the upgradient side) or dewatering (due to a reduction in the throughflow on the downgradient side of structures) is not expected to occur
- Reduction in groundwater resources through extraction of wet soil/rock during piling - the potential reduction in groundwater levels due to water being brought to surface is considered limited as the CIP augering method allows for concrete slurry to be pumped through the hollow stem auger. As a result, the CIP method restricts the amount of groundwater brought to surface.

EVs with potential to be impacted include: Aquatic and Terrestrial Ecosystems, Irrigation, Stock Water, Farm Supply/use, Drinking Water, Cultural and Spiritual Values.

Based on previous experience, only minor volumes of groundwater (within the wet sediment/soil/rock) will be brought to surface, e.g. 5 to 10 litres per 20 m deep auger hole. It is therefore unlikely that active dewatering will be necessary in support of the proposed piling methodology, and that only minor volumes of groundwater (as a slurry with soil/rock) will need to be managed at each pile/drill site.

8.1.1.10 Groundwater flow

Potential impacts on groundwater flow from construction activities may include:

- Deep cuttings could create voids which intersect shallow groundwater and perturb the antecedent groundwater flow regime. This is possible at the deep cut locations discussed in Section 7
- Piles or other structures spaced closely together have potential to influence the natural groundwater flow regime. However, the foundation pilings associated with bridges for this project will be spaced a distance apart to be of sufficient spacing and diameter to avoid impacts on existing groundwater flow.
- Reduced permeability of the substrate beneath embankments may modify the flow direction of shallow groundwater in portions of the alluvium and possibly the saturated portion of weathered bedrock.

EVs with potential to be impacted include: Aquatic and Terrestrial Ecosystems, Irrigation, Stock Water, Farm Supply/use, Drinking Water, Cultural and Spiritual Values.

It is possible for the antecedent groundwater flow regime to be interrupted to deep cut locations, particularly at C08, C37, and C44; however, the length of the cuts in comparison to the overall aquifer is negligible. Further, C37 and C44 are predicted to intersect the MRV aquifer which, due to the fractured nature of this aquifer, is unlikely to be impacted outside of the localised area to the cuts.

The foundation pilings associated with bridges for this Project will be spaced a distance apart to be of sufficient spacing and diameter to avoid impacts on existing groundwater flow. The distance/spacing is cut/bridge-specific and will be finalised during the detail design phase.

8.1.2 Groundwater quality

8.1.2.1 Contamination and accidental discharge

During construction, contamination of groundwater may arise as a consequence of :

- Unintended spills and leaks (accidental discharge) of hydrocarbons (oils, fuels and lubricants) and other chemicals related to the use of heavy plant and equipment
- Water mixtures and emulsions related to washdown areas (accidental discharge)
- Upward seepage along piles/soil interfaces of saltier groundwater from the deeper confined aquifers into the fresher alluvium aquifers
- Groundwater bores installed for environmental monitoring or water supplies have the potential to create a vertical pathway between aquifers if not installed correctly or if the bores deteriorate due to abandonment. In such instances, potential impacts may include:
  - Mixing of different hydraulic heads
  - Mixing of different groundwater qualities
  - Contamination of non – flowing bores from surface runoff into the bore
  - Uncontrolled flow and wastage from groundwater under pressure.

Potential contamination of the shallow aquifers could occur via inflow into bridge pile boreholes which intersect the water table. However, this source of contamination is considered unlikely as pilings will be grouted to surface for ground stability and therefore are not anticipated to act as a conduit for surface contaminants to groundwater resources.

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

Direct infiltration of contaminants in areas of low relief with shallow water levels is likely to be reduced due to the dominant fine-grained sediments of the soil profile (clays and silts).

The ephemeral nature of the majority of surface water bodies along the Project is also likely to reduce the chance of contaminants in surface water infiltrating into shallow aquifers during dry months.

If used in sufficient volume, water applied during the construction phase of the Project has the potential to infiltrate past the root zone and contribute to rising water tables/levels in shallow aquifers. Leakage (accidental discharge) from water storage areas may also contribute to rising water levels.

8.1.2.2 Acid rock drainage and potential acid sulphate soils

Intersection of sulphide-bearing rocks in cuts or use of sulphide-bearing materials in embankment fill could present an acid rock drainage (ARD) risk following exposure of the rocks to oxygen and subsequent runoff which could impact on EVs (i.e. aquatic GDEs and groundwater users).

ARD occurs naturally when sulphide minerals are exposed to air and water. Rainfall infiltration into cuttings with sulphide-bearing minerals above the saturated zone may also pose an acid rock drainage risk even if the entire cut is in the unsaturated zone (above groundwater) where leachate may impact on the environment. The resulting drainage (leachate) may be neutral to acidic with dissolved heavy metals and significant sulphate levels.

Potential acid sulfate soils also present a risk though excavation of cuts in soils susceptible to acid forming conditions which can then result in leached condition entering the environment.

EVs with potential to be impacted: Aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

Geology within the Project footprint indicates a potential for the Kumbarilla Beds and WCM to host disseminated sulphide minerals (i.e. pyrite), particularly within shale and mudstone units. Given that cuts will primarily be into the weathered to extremely weathered units portions of the Kumbarilla Beds and WCM, the risk could be naturally mitigated as sulphides minerals may have already been oxidised.

Unweathered areas of the Kumbarilla Beds and WCM will be avoided, where possible, through the detail design phase.

8.2 Operations

This section provides a discussion of the potential impacts on groundwater resources and related EVs as a consequence of operation of the Project.

8.2.1 Groundwater resources

8.2.1.1 Loss or damage to existing groundwater bores, including impaired access

Once constructed, the Project may result in long-term access restrictions to existing landowner bores due to the severance of properties.

EVs with potential to be impacted: Irrigation, stock water, farm supply/use, and drinking water.

During the detail design phase, landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint.

Where possible, the detail design will be developed to provide continued access to private infrastructure, including groundwater bores, across the rail corridor.

Where a groundwater bore is expected to have access to it impaired as result of the Project, ‘make good’ measures will be agreed in consultation with the affected landowner (refer Section 8.1.1.2). Such measures may include the provision of an alternate water supply/new bore (most likely outcome for private bores within Project footprint).

8.2.1.2 Embankments

Mounding of groundwater levels may result due to long-term surface loading of alluvial soils from embankments and other constructions along the Project alignment where groundwater is shallow.

Possible areas for compressible alluvial soils include localised portions of Macintyre Brook, Canning Creek, and Condamine River floodplains associated with abandoned river channels and tributaries.

It is expected these impacts will be localised due to the linear nature of the Project and the typical depth to groundwater, based on available information, being greater than 5 mbgl in the alluvium.

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

8.2.1.3 Dewatering

Temporary excavations during maintenance of infrastructure (e.g. trenching) may encounter groundwater. In these instances, it may be necessary to extract the water from the excavation in order to maintain structural integrity of the excavation and to enable safe establishment of the planned infrastructure.

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.

If dewatering is required in support of maintenance activities, the duration of the impacts is likely to be temporary. Impact is not anticipated to extend long after the maintenance works are completed, if at all, dependant on the localised recharge of the of the affected aquifer unit.

8.2.1.4 Alteration of existing groundwater flow pathways due to new infrastructure of modified landform

Long-term impacts on groundwater flow are not anticipated given the spacing of the pilings for the rail alignment.

Localised impacts may occur in the vicinity of the three deep cuts predicted to have long-term seepage. However, due to the limited cut extent when compared to the overall aquifer, it is expected the groundwater flow regime will re-equilibrate to the cuts constructed in/through unconsolidated sediments. Flow within the fractured MRV are expected to be limited to the cut and immediate vicinity.

8.2.1.5 Maintenance works (operation) water supply

The Project's operational water requirements are anticipated to be minor relative to the construction phase requirements. Water may be required to support localised maintenance activities, such high pressure cleaning of culverts. The volumes required will be dependent on the specific activities and frequency of undertaking, and therefore cannot be quantified at this stage of the Project.

Maintenance works are not expected to be reliant on groundwater for the sourcing of water.

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

- Legal access
- Volumetric requirement for the activity
- Water quality requirement for the activity
- Source location relative to the location of need.

8.2.2 Groundwater quality

Contamination of groundwater may arise as a consequence of unintended spills and leaks (accidental discharge) of hydrocarbons (oils, fuels and lubricants) and other chemicals related to maintenance activities (accidental discharge) or rail incidents (e.g. loss of load).

EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, cultural and spiritual values.

In the instance a spill or leak (accidental discharge) occurs during normal operation activities, the impact is likely to be superficial in nature and not expected to impact on shallow aquifers. Maintenance crews and emergency response teams will be equipped with spill kits and environmental response equipment to intercept spills and leaks and prevent such incidents from impacting groundwater.

9 Mitigation measures

This section provides discussion of mitigation measures and controls that have been incorporated into the reference design development process, as appropriate and where possible (refer Section 9.1), as well as those measures that are proposed to be adopted for future phases of Project delivery (refer Section 9.2 and Section 9.3).

9.1 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 consequence, 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 reference design or otherwise implemented during the reference design phase for the Project, are summarised in Table 9.1.

Table 9.1 Initial mitigation measures of relevance to groundwater

Aspect	Initial mitigation measures
Groundwater resources	▪ The Project utilises the existing South Western Line and Millmerran Branch Line rail corridors as much as possible (71.2 kilometres), thereby minimising the need to develop land and impact on water resources that have not previously been subject to disturbance for transport infrastructure purposes. ▪ Geotechnical and groundwater 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 groundwater field data has been used to derive design criteria for structures and rail formation. This has enabled the Project to be designed to cater for field verified geotechnical and groundwater conditions. ▪ Design and ratings of earthworks in support of culverts, viaducts, and bridges are in accordance with *AS 5100 Bridge Design* and *AS 7363 Railway Structures* and other applicable Australian Standards. ▪ The reference design has allowed for the application of a 300 mm drainage blanket to be applied to the face of all cuts where groundwater is encountered within 2 m of the base of the cutting. Alternative seepage control measures will be considered and assessed through the detail design, on a cut-by-cut basis. ▪ The reference design has been developed to achieve as close to a net balance in earthworks as is practicable, thereby reducing the potential to impact water resources (e.g. dewatering of cuttings and embankment placement). 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.
Groundwater quality	▪ The Project footprint has been minimised to that required to safely and efficiently construct and operate the Project, thereby minimising the spatial opportunity for Project activities to interface with groundwater ▪ Groundwater sampling was conducted on all 30 monitoring bores installed for the Project for the collection of baseline water quality, durability, and salinity parameters. This data has been used to establish design criteria for structures and rail formation.

9.2 Proposed mitigation measures

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

Table 9.2 identifies the relevant project phase, the aspect to be managed and the proposed mitigation measure. The mitigation measures presented in Table 9.2 have then been factored into the assessment of residual impact significance, as documented in Table 10.1

Table 9.2 Proposed groundwater mitigation measures relevant to groundwater resources and quality

Delivery phase	Aspect	Mitigation and management measures
Detail design	Interaction with groundwater by elements of the Project	■ Further geotechnical and hydrogeological investigations will be undertaken in parallel to the detail design process to ensure site-specific geotechnical and groundwater conditions are reflected in the finalised design solution. Investigations will be targeted to specific locations, such as: – Locations of bridge abutments – Locations of significant cuts – Locations of significant fill ■ Predictive numerical modelling will be re-run using additional information obtained from further geotechnical and hydrogeological investigations, in addition to finalised cut dimensions. This revised modelling will be completed to better understand seepage estimates and groundwater level variation resultant from cuts. The reference design provides for a minimum 300 mm drainage blanket to be applied in all cuttings where there is known or suspected groundwater to within 2 m of the base of the cutting. Seepage analysis will be used to advise the design of drainage blanket specifications, or alternative more effective seepage control measures, on a cut-by-cut basis. ■ Site inspections of proposed cut locations will be conducted to visually examine surface outcrops for sulphide minerals or remnant products indicative of sulphide mineralisation. This would inform the need for management of potential ARD from cuttings in sedimentary units prior to construction works. ■ The management of ARD (leachate) potential, if identified through additional site investigation, would be in accordance with Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia 2016). ■ Culverts and embankments will be designed to minimise pre-loading and compaction of alluvial sediments. This will reduce the risk of altering shallow groundwater levels and recharge patterns. The current embankment designs allow for openings (i.e. culverts and bridge spans) near creeks and rivers to assist with flow. ■ Where embankment height allows, toe benching and drainage blankets are to be provided for all transverse slopes greater than 7 degrees (1V:8H). ■ Where embankment height allows, full embankment benching is to be provided for all transverse slopes greater than 14° (1V:4H).
	Impacts to registered bores	■ Landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint that may be decommissioned to enable construction and operation of the Project. Where a groundwater bore is expected to be decommissioned or have access to it impaired as result of the Project, 'make good' measures will be agreed in consultation with the affected landowner.
	Sourcing of construction water	■ The construction water requirements (i.e. volumes, quality, demand curves, approvals requirements and lead times) will be confirmed as the construction approach is refined. The ultimate water sourcing strategy for the Project will be documented in a Construction Water Plan developed for the Project. The Construction Water Plan will be developed involving all levels of government and other entities. In developing the Construction Water Plan, ARTC will investigate and assess sustainable water solutions to support the Project that will not impact on the function of business, industry and communities along the Project alignment. Sources of construction water will be finalised as the construction approach is refined during the detail design and tender phases of the Project (post-EIS) and will be dependent on: – Climatic conditions in the lead up to construction – Confirmation of private water sources made available to the Project by landowners under private agreement – Confirmation of access agreement with local governments for sourcing of mains water.

Delivery phase	Aspect	Mitigation and management measures
		▪ The use of groundwater to supplement the construction demand for the Project may be considered if private owners of licensed/registered bores have capacity under their water licence or entitlement that they wish to sell to, or trade with, ARTC under a private agreement.
	Groundwater quality	▪ Continue collection of baseline groundwater monitoring data (levels and quality) from monitoring bores established for the Project through the EIS process, as well as from additional bores installed through the detail design process, in accordance with the Baseline GMMP (refer Section 9.3). Data will be collected to provide a robust dataset for characterisation of the primary aquifers of relevance over a time sufficient to identify seasonal variation trends. ▪ Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and Sampling Manual* (DES, 2018e) and *Groundwater Sampling and Analysis – A Field Guide* (Geoscience Australia, 2009). ▪ Collected data will be used to establish a groundwater condition baseline for the Project against which construction phase impacts can be monitored and compared (refer Section 9.3). Baseline groundwater monitoring data will be used to: – Derive location/bore specific groundwater monitoring procedures – Establish location/bore specific impact thresholds – Establish responses to impact threshold exceedances, including 'make good' agreements. These details will be incorporated into the Construction GMMP, which will be subject to approval from DNRME and DES prior to implementation. ▪ A Contaminated Land Management Sub-plan will be developed and incorporated into the CEMP. This Sub-plan will document management controls for works on land that is known or suspected of being contaminated and outline the process to identify, document and manage contaminated sites.
Pre-construction	Impacts to registered bores	▪ There are 30 registered bores within the Project footprint for the reference design. These bores, plus unregistered bores that also occur within the Project footprint, are likely to be decommissioned for the progression of the Project. Bores identified within the Project footprint will be decommissioned in accordance with the *Minimum Construction Requirements for Water Bores in Australia – Edition 3* (National Water Commission, 2012).
	Sourcing of construction water	▪ Private agreements will be negotiated to secure access to registered bores for use of sustainable groundwater supplies during construction, if required by the Project as part of the construction water strategy (refer above)
Construction	Water resources	▪ The Construction GMMP will be implemented (refer above and Section 9.3) ▪ Opportunities to re-use/recycle water during construction will be identified and implemented where feasible.
	Sourcing of construction water	▪ In circumstances where groundwater access is secured through private agreement, the licensed capacity of existing bores will not be exceeded. Flow and volume monitoring during extraction will be required for each bore, with extraction logs maintained.
	Groundwater quality	▪ 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. ▪ Opportunities to treat and re-use contaminated materials within the rail corridor will be assessed and subjected to a risk assessment. ▪ Vehicle and plant maintenance will be undertaken in designated laydown areas, on hardstand surfaces. This will minimise risk of contaminants from incidental spills or leaks (accidental discharge) from entering aquifers via infiltration or surface runoff. ▪ Refuelling will only occur at designated locations within the Project footprint and sited at suitable separation distances from sensitive receptors, including surface water features and drainage lines. These refuelling locations will be equipped with on-site chemical and hydrocarbon absorbent socks/booms and spill kits.

Delivery phase	Aspect	Mitigation and management measures
		■ Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social and environmental receptors such that offsite impacts or risks from any foreseeable hazard scenario will not exceed the dangerous dose for the defined land use zone (i.e. either sensitive, commercial/ community, or industrial, in accordance with the intent of the SPP). ■ 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 required to be stored and used in support of construction, including volumes of each – 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. ■ Chemicals stored and handled as part of construction activities will be managed in accordance with: – The WHS Act and Regulation, – AS 2187 Explosives – storage, transport and use – AS 1940:2017 Storage and Handling of Flammable and Combustible Liquids – AS 3780:2008 The Storage and Handling of Corrosive Substances – The requirements of chemical safety data sheets. ■ Spill kits will be available at all work fronts and laydown areas in the event of a spill or leak. All vehicles and machinery will have dedicated spill kits. These refuelling locations will be equipped with on-site chemical and hydrocarbon absorbent socks/booms and spill kits. ■ Drilling and excavation activities during construction will make use of drilling fluids and chemicals that are environmentally neutral and biodegradable. Mobile plant, drill rigs and equipment will be maintained in accordance with manufacturer requirements and inspected frequently to minimise breakdowns and decrease the risk of contamination. ■ All excavated material which is suspected to contain sulphides will be stockpiled, lined and covered and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to off-site disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required, in accordance with the Project's spoil management strategy.
	Encountering PASS and/or ARD	■ All excavated material which is suspected to contain sulphides will be stockpiled, lined and covered and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to off-site disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required, in accordance with the Project's spoil management strategy. ■ If ARD potential is identified through pre-construction investigations (refer above), seepage water from the relevant deep cuts will be sampled at weekly intervals to monitor for the occurrence of acid rock oxidation. This monitoring will involve the on-site screening of the seepage water for pH (trending down) and EC (trending up) and comparison to the baseline groundwater results. Further laboratory analyses for the key analytes (i.e. pH, TDS, EC, TSS, alkalinity, and dissolved metals) will be required if pH and EC trends indicate the potential for oxidation occurring and will be used to validate the presence or absence of ARD potential to mitigate potential leachate to the environment. ■ If ARD-contaminated discharge water/leachate is found to be generated from the deep cuts, this water may need to be impounded in ponds and neutralised via treatment with hydrated lime or dilution prior to release into the surrounding catchment or other discharge mechanism.

Delivery phase	Aspect	Mitigation and management measures
Operation	Impacts to registered bores	▪ An Operation GMMP will be developed in consultation with the relevant regulatory agencies to specify the groundwater monitoring requirements, if any, over the initial operation years of the Project (refer Section 9.3). The need for monitoring during operation will be informed by groundwater observations and data collected during construction of the Project.
	Groundwater quality	▪ Appropriate controls are to be in place to prevent environmental incidents including leaks/spills from refuelling activities and locomotive operations and to protect the environment in the event of an incident. All fuel and chemical spills will be dealt with in a manner consistent with relevant health and safety guidelines. ▪ Procedures for the management of hazardous chemical spills and leaks will be developed and incorporated into the Operation EMP for the Project.

9.3 Groundwater management and monitoring program

The following GMMP is recommended to provide an on-going assessment of the potential impacts discussed in Section 9.1. The GMMP incorporates principles of performance assessment and adaptive management; a structured, iterative process for decision making. The GMMP will be assessed and updated before the commencement of each future Project phase (pre-construction/baseline, construction and operation) such that the GMMP for subsequent phases is based on the outcomes of the previous phase. This process of GMMP development and development over sequential Project phases is shown on Figure 9.1.

An indicative network of monitoring bores for the Baseline MMP is summarised in Table 9.3.

9.3.1 Baseline groundwater management and monitoring program

The Baseline GMMP's primary objective is to develop a robust baseline dataset from which all subsequent monitoring will be assessed against to identify impacts. This dataset will also inform the development of Project-specific WQO trigger values. The Baseline GMMP will be developed and implemented during the detail design stage to inform refinement of design and ensure a suitable groundwater baseline dataset is established before the commencement of construction.

The pre-construction/baseline dataset is to be the reference dataset for future groundwater monitoring and, as such, may be supplemented with existing groundwater data inclusive of, publicly available and verified data. A continuation of the EIS groundwater monitoring is currently ongoing to inform natural seasonal variations within the aquifers. This monitoring will continue in anticipation of the formal Baseline GMMP being established.

The indicative network is subject to landowner negotiations and access and will be refined during the detail design phase. If bores specified in Table 9.3 cannot be accessed, or are unsuitable for monitoring for other reasons, an alternative existing bore may be nominated. In the absence of a suitable alternative existing bore, dedicated environmental monitoring bores may be installed. These environmental monitoring bores would be sited in locations to provide adequate coverage up and down hydraulic gradient in areas of potential groundwater impact and to further understand the heterogeneity of the Condamine Alluvium.

The baseline dataset will be compiled, and the Construction GMMP developed, prior to the commencement of the construction of the Project.

The following provides a framework for groundwater level and quality monitoring, data management and reporting from which the Baseline GMMP will be developed.

9.3.1.1 Groundwater level monitoring

Groundwater levels for bores within the indicative monitoring network are to be monitored using automated pressure transducers (groundwater level loggers) to record measurements at least every 12 hours. This is particularly required to establish the baseline groundwater dataset from which potential impacts can be assessed during construction and operation of the Project and to allow for identification of groundwater users in proximity to the Project.

Manual measurements on all bores within the indicative monitoring network is proposed monthly during establishment of the baseline groundwater dataset to allow for a quality control check against the pressure transducers as this will be the basis of comparison for the Project. Pressure transducer data will be downloaded on a bimonthly basis, during the Baseline GMMP, to coincide with groundwater quality monitoring and manual water level measurements.

Data collected during the baseline groundwater monitoring program will account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is important for the alluvial aquifers as the water levels in these sediments are key to the design, construction, and operation of the Project; are the most likely to vary over time due to climate and local groundwater abstraction; and will allow for identification of non-project related influences on groundwater levels. For example, dewatering/pumping for construction works/water supply being undertaken for works at Commodore Mine expansion project may create an area of influence measurable in proximity to the Project with potential to impact on groundwater resources and/or private bores. This information is important to capture to ensure discernibility between the impacts of the Project and those from other influences.

The baseline monitoring program will be completed in enough time prior to commencement of construction works to allow for assessment of the data and the development of the Construction GMMP.

9.3.1.2 Groundwater quality monitoring

Groundwater quality samples will be collected from bores within the indicative monitoring network on a bimonthly basis (to coincide with the groundwater level monitoring program, refer Section 9.3.1.1). Groundwater samples will be subject to in-field and laboratory analyses. The quality data collected during the baseline program will be used to assess potential impacts of the Project on local groundwater resources and on proposal-specific WQOs through all stages of the Project.

Data collected during the baseline groundwater monitoring program will account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is especially applicable to the shallow aquifers that are hydraulically connected to surface water as after the dry season (negligible recharge), a first-flush/flow of recharge to these sediments can result in markedly different quality from data collected within and after the wet season.

The baseline quality dataset will also be used to indicate the potential for ARD prior to construction works and inform the suitability of local groundwater for construction water purposes, if required.

Field parameters to be collected during sampling include:

- pH
- EC
- Temperature,
- redox potential
- DO.

The following analytical suite is suggested for laboratory analyses for the baseline groundwater quality dataset and is considered sufficient to identify potential ARD and establish a baseline for future monitoring of Project impacts:

- pH, EC and total dissolved solids
- Major anions (i.e. HCO_3^-, Cl^- and SO_4^{2-})
- Major cations (i.e. Ca^{2+}, Mg^{2+}, Na^+, K^+ and Si)
- Dissolved and total metals (i.e. Al, As, B, Cd, Cr, Cu, Mn, Pb, Ni, Se, Mo, Ag, Zn, Fe and Hg)
- Nutrients (i.e. ammonia, nitrite, nitrate, TN and TP).

The baseline (pre-construction) monitoring program will be completed in sufficient time prior to commencement of construction works to allow for assessment of the data, including trends; this data will be utilised to develop groundwater quality trigger levels (warning and action levels).

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and Sampling Manual* (DES, 2018) and *Groundwater Sampling and Analysis – A Field Guide* (Geoscience Australia, 2009) unless an updated version is available prior to commencement of the baseline monitoring program.

9.3.1.3 Data management and reporting

The following data and reporting requirements would be implemented:

- All groundwater data will be validated with suitable quality assurance and quality control (QA/QC) protocols applied
- Monitoring data will be assessed on a quarterly basis initially to identify trends and compare to trigger levels (baseline and pre-construction). This will also enable the Baseline GMMP to be revised, if required.

9.3.2 Construction groundwater management and monitoring program

The Construction GMMP will be developed using a risk-based approach with monitoring and sampling requirements dependent on the likelihood of construction activities encountering groundwater and the location of such activities. Monitoring will be localised to areas where construction activities have potential to impact on groundwater quality and/or levels, as identified in Section 8. The localised task and risk-based monitoring will be performed at locations (distance and depth/aquifer) up- and down-gradient of the site where construction activities are occurring. For example, where construction activities are surficial in nature no monitoring of deep aquifers would be warranted; however, surficial construction tasks may require TDS and pH monitoring within the alluvial aquifers to ensure the baseline levels are not impacted as a result of local works (task-specific monitoring).

The surface water monitoring program for the Project will be utilised to inform and compliment the Construction GMMP. For example, in the instance a surface water sample, in an area of known hydraulic connectivity with the alluvial aquifers, returns an elevated result during construction phase, this may trigger a groundwater sample to be procured from the local alluvial aquifer to inform of any impacts. However, if surface water quality results are within / below acceptable values, sampling of the alluvial aquifers in this area may not be warranted, construction task, WQO, and residual significance-dependant.

9.3.3 Operation groundwater management and monitoring program

The Operation GMMP will be based on groundwater data and observations collected during construction of the Project. Monitoring may be warranted over the initial years of construction if construction data indicates that local groundwater conditions are yet to return to baseline and/or stabilise following completion of construction activities. Monitoring may also be warranted in response to a spill/incident. Operation monitoring results will be assessed against the Construction GMMP and baseline dataset, as appropriate.

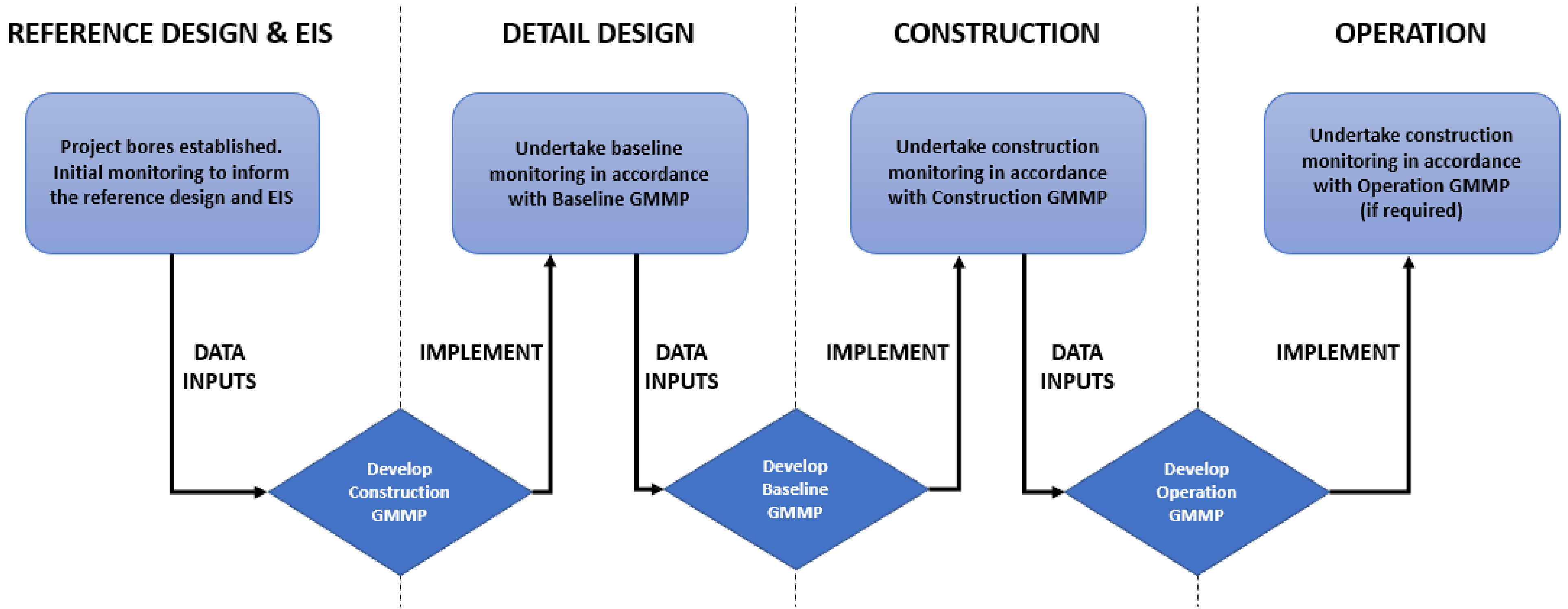


Figure 9.1 Development and implementation of the groundwater management and monitoring program over sequential Project phases

Table 9.3 Indicative GMMP network of monitoring bores

Chainage (km)	Bore ID	Easting[1]	Northing[1]	Bridge or Cutting ID	Aquifer	Screen interval (mbgl)	Monitoring type	Rational
55.0	310-BH2206	302299	6853323	C08	WCM	16.7 to 25.7	Water levels and quality	Monitor water levels and quality surrounding deep cutting C08
59.0	310-BH2308	305930	6855563		WCM	9 to 14.45	Water levels and quality	
136.0	310-BH2231	338076	6918598	Dry Creek bridge	Alluvium	11.4 to 17.4	Water levels and quality	Background alluvium levels for bridge structure
142.8	310-BH2233	340530	6922012	Condamine River rail bridges	Alluvium	9.5 to 12.5 and 18.5 to 24.45	Water levels and quality	Background Condamine Alluvium levels - monthly data available from DNRME
143.0	RN42231089	338799	6922879		Alluvium	XXXX	Water levels only	
143.2	310-BH2234	340696	6922345		Alluvium	17 to 24.5	Water levels and quality	
148.8	310-BH2235	344710	6926073	Condamine River North Branch rail bridge	Alluvium	31.0 to 40.0	Water levels and quality	Background alluvium levels for bridge structure
172.6	RN119211	365749	6935428	C037	MRV	66 to 75	Water levels and quality	Landholder bore within the Project footprint and down gradient of C037.
173.0	RN56564	366137	6934525		MRV	XX to 56	Water levels and quality	Background levels and quality for C037
188.0	310-BH2344	377527	6944383	C044	MRV	9 to 14.95	Water levels and quality	Background levels and quality for C044
188.6	RN35264	377548	6944943		MRV	XX to 62.4	Water levels and quality	Within C044 drawdown envelope.
189.8	RN52509	378064	6946048		MRV	6 to 43	Water levels and quality	Within C044 drawdown envelope.

Table note:

1 MGA94 Z56

XX = unknown construction detail

9.3.4 Summary

A summary of the monitoring and requirements of the GMMP is presented in Table 9.4.

Table 9.4 Summary of groundwater management and monitoring program requirements

GMMP requirements	Baseline (pre-construction)	Construction	Operation
Groundwater level monitoring	▪ Pressure transducers/level loggers record measurements 12 hourly intervals ▪ Pressure transducer data downloaded bimonthly ▪ Manual measurements monthly	A Construction GMMP will be developed at the end of the baseline period and will be subject to review and approval by DNRME and DES. Groundwater level monitoring will be conducted at the locations, and frequency nominated in the approved Construction GMMP.	An Operation GMMP will be developed at the end of the construction period and will be subject to review and approval by DNRME and DES. Groundwater level monitoring will be conducted at the locations, and frequency nominated in the approved Operation GMMP.
Groundwater quality monitoring	▪ Bimonthly	Groundwater quality monitoring will be conducted at the locations, and frequency nominated in the approved Construction GMMP.	Groundwater quality monitoring will be conducted at the locations, and frequency nominated in the approved Operation GMMP.
Reporting	▪ Quarterly data comparison	Annual reporting proposed. Subject to DNRME/DES approval of the Construction GMMP	Annual reporting proposed. Subject to DNRME/DES approval of the GMMP

10 Impact assessment

Potential impacts to groundwater values associated with construction and operation of the Project are outlined in Table 10.1. These impacts have been subjected to significance assessment as per the methodology in Section 3.2.

The initial impact assessment assumes that the design considerations (or initial mitigation measures) factored into the reference design phase (refer Table 9.1) have been implemented.

Additional mitigation and management measures (refer Table 9.2) were then applied as appropriate to future phases of the Project to reduce the level of potential impact and derive a residual significance of impact.

The initial and residual significance of potential impacts are presented in Table 10.1 to demonstrate the effectiveness of mitigation measures.

The majority of potential impacts related to groundwater are considered temporary in nature and primarily associated with the construction phase of the Project. The likelihood of a material impact on current groundwater conditions and users is considered to be low.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. In the few locations where construction activities have the potential to intersect shallow groundwater, construction techniques have been identified for the Project such that any impacts are considered to be mitigated and managed through the adopted engineering controls.

Beyond the construction stage of the Project, the potential long-term impacts on groundwater are considered to be from:

- Ongoing operation of the Project where potential impacts are likely to be surficial in nature and, through standard rail practices and procedures, not considered to impact on the shallow alluvial aquifer or the sedimentary aquifers
- Changes to groundwater levels and flow due to embankment loading and ongoing dewatering or drainage of deep cuttings
- Long-term discharge and/or management of dewatering volumes to potential sensitive receptors, in terms of volume above baseline conditions or salinity issues
- Possible restricted access to pre-existing landowner bores.

Engineering controls that will be implemented through detail design, in combination with the GMMP, are generally considered sufficient to mitigate potential impacts to groundwater EVs. Residual impacts will be managed through consultation with impacted landowners and implementation of suitable water source alternatives or compensation.

10.1 Significance assessment

Table 10.1 presents the significance assessment with respect to the Project on groundwater resources.

Table 10.1 Significance assessment summary for groundwater

Aspect	Phase	Initial significance[1]			Residual significance[2]	
		Sensitivity	Magnitude	Significance	Magnitude	Significance
Impacts to existing bores (registered and non-registered)	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Moderate	Moderate	Low	Low
Subsidence/consolidation due to groundwater extraction or dewatering and/or loading	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low	Low	Low
Altered groundwater levels (increase or decrease) affecting groundwater users and GDEs (incl. impacts due to embankments and seepage to cuts)	Pre-construction and construction	Moderate	Low	Low	Moderate	Low
	Operation		Low	Low	Low	Low
Altered groundwater flow regime	Pre-construction and construction	Moderate	Moderate	Low	Low	Low
	Operation		Low	Low	Low	Low
Contamination or altered water quality impacting vulnerable groundwater resources (spills or induced flow, borehole intersections. Upwards leakage along pile/soil interface)	Pre-construction and construction	Moderate	High	High	Moderate	Moderate
	Operation		Low	Low	Low	Low
ARD impacting on EVs (i.e. GDEs)	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low		
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low	Low	Low

Table notes:

1 Includes implementation of initial mitigation measures specified in Table 9.1.
2 Assessment of residual significance once the mitigation measures specified in Table 9.2 have been applied.

11 Cumulative impacts

11.1 Approach

It is a requirement of the ToR for this Project that the potential cumulative impacts be considered. This section provides a discussion on the potential for cumulative impacts in relation to groundwater.

The approach used to identify and assess potential construction phase cumulative impacts of the Project is as follows:

- A review of the potential impacts identified within the assessment. The environment at the time of the ToR is the baseline, prior impacts from past land use has not be considered.
- A preliminary list of projects for consideration in the cumulative impact assessment was collated with timelines to demonstrate the temporal relationship between projects. This preliminary list of projects was compiled through consideration of the following:
  - Projects subject to assessment under the EP Act or SDPWO Act, with an Initial Advice Statement published by DES or Department of State Development, Tourism and Innovation (DSDTI)
  - Projects listed in GRC and TRC development application databases
  - Development within Priority Development Areas and State Development Areas
  - Economic Development Queensland development projects
  - Community Infrastructure Designation projects
  - Projects within the public register of environmental authorities
  - DTMR infrastructure projects
  - Private infrastructure facilities
  - Development in accordance with Regional Planning Interests
  - The Inland Rail projects immediately adjacent to the Project, being the North Star to NSW/QLD Border and Gowrie to Helidon projects
- The preliminary list of projects was assessed to identify those that meet one of the following criteria:
  - Projects that have been approved but where construction has not commenced
  - Projects that have commenced construction subsequent to issuance of the ToR for the Project, but have potential for overlap in construction activities with the Border to Gowrie Project
  - Projects that have been completed subsequent to issuance of the ToR for the Project
  - Are operational developments that have future plans for expansion
- Projects that were excluded from further assessment were:
  - Existing projects, with no known plans for expansion. Such projects are typically considered part of the 'existing environment' and have been accounted for in the impact assessment of each specific matter.
  - Proposed projects that have not been developed to the point that details of their scale, size, location and core activities would be publicly available.
- Where there is a potential overlap in impacts (either spatially or temporally), a cumulative impact assessment was undertaken to determine the nature of the cumulative impact. Where possible, the assessment method was quantitative in nature however qualitative assessment has also been undertaken.

- An assessment matrix method (further detailed in Section 11.2) has been used to determine the significance of cumulative impacts with respect to beneficial or detrimental effects.
- Where cumulative impacts are deemed to be of ‘medium’ or ‘high’ significance, additional mitigation measures are proposed, beyond those already proposed by the relevant technical impact assessments.

11.2 Assessment matrix

The significance of cumulative impacts has been determined by using professional judgement to select the most appropriate relevance factor for each aspect in Table 11.1. The sum of the relevance factors determines the impact significance and consequence which are summarised in Table 11.2. For example if an environmental value (such as groundwater) is considered to have a probability of impact of 2, duration of impact of 3, magnitude/intensity of impact of 1 and a sensitivity of receiving environment of 1 the significance of impact would be Medium (2+3+1+1 = 7).

Table 11.1 Assessment matrix

Aspect	Relevance factor		
	Low	Medium	High
Probability of impact	1	2	3
Duration of impact	1	2	3
Magnitude/Intensity of impact	1	2	3
Sensitivity of receiving environment	1	2	3

Table 11.2 Impact significance

Impact significance	Sum of relevant factors	Consequence
Low	1-6	Negative impacts need to be managed by standard environmental management practices. Monitoring to be part of general project monitoring program.
Medium	7-9	Mitigation measures likely to be necessary and specific management practices to be applied. Targeted monitoring program required, where appropriate.
High	10-12	Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Targeted monitoring program necessary, where appropriate.

11.3 Cumulative impact assessment

Twenty three (23) 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 Table 11.3; the location of these projects in proximity to the Border to Gowrie Project are depicted on Figure 11.1.

Table 11.3 Projects initially considered for cumulative impact assessment

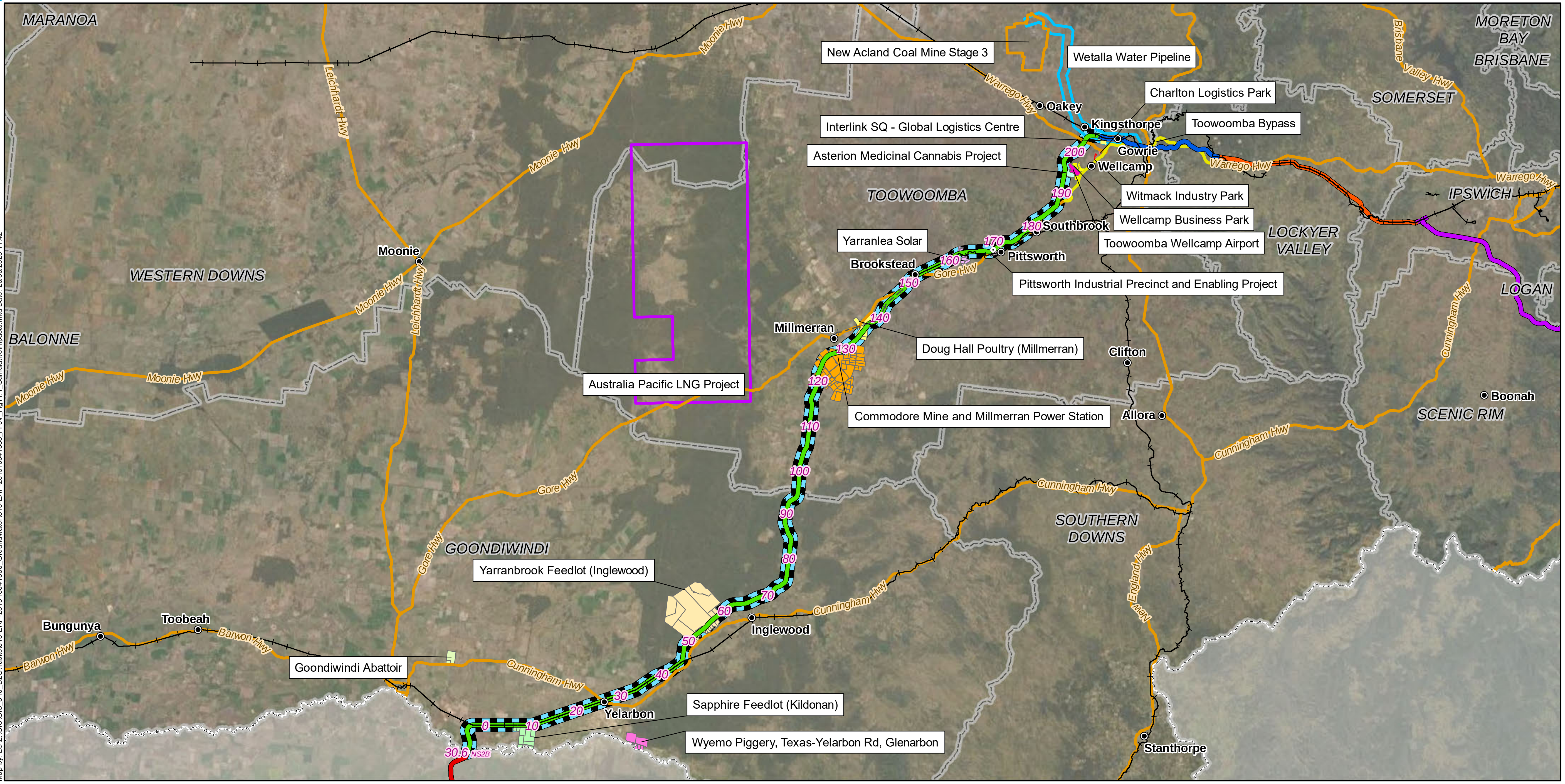
Projects	Location	Description	Status	Construction dates
Wetalla Water Pipeline	From the Wetalla Wastewater Reclamation Facility in Toowoomba to the New Acland coal mine, 35 km northwest of the city Adjacent to north of the Project footprint	A 45 km underground water pipeline to supply up to 5,500 megalitres of treated waste water to the New Acland coal mine	EIS approved with conditions in 2008 The Wetalla Water Pipeline is completed and operational	2010 to 2013
New Acland Coal Mine Stage 3	35 km northwest of Toowoomba 18 km north of the Project footprint	Expansion of the existing New Acland open-cut coal mine to up to 7.5 Mtpa	EIS approved with conditions in 2014, but currently subject to legal challenge	The mine is operational. Stage 3 expansion works will proceed if legal proceeding end favourably for New Acland Coal.
Australia Pacific LNG Project	Walloons gas fields (approximately 20 km west of Millmerran) 13 km west of the Project footprint	Integrated LNG project. The Walloons gas fields, located to the west of the Project, supplies Coal Seam Gas to support the LNG Facility on Curtis Island.	EIS approved with conditions in 2011	Project started operation in 2015, but subject to continual gas field development
Toowoomba Bypass (formerly the Toowoomba Second Range Crossing)	The 41 km-long bypass route extends from the Warrego Highway at Helidon Spa in the east to the Gore Highway at Athol in the west, via Charlton. 1 km to south and east of the Project footprint	This bypass takes heavy vehicle through-traffic around the north of Toowoomba	Opened in September 2019	2015 to 2019
InterLinkSQ	13 km west of Toowoomba Adjacent to south of the Project footprint	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.	Under construction	2018 to unknown Assumed to continue development until Inland Rail is operational
Toowoomba Wellcamp Airport	Wellcamp, QLD 1 km east of the Project footprint	Airport servicing Toowoomba, promoting interstate, intrastate and international connection for the Darling Downs, Granite Belt, Surat Basin and Southern Downs regions	Operational	2013 to 2014
Wellcamp Business Park	Wellcamp, QLD 1.5 km east of the Project footprint	A 500 ha industrial and commercial park that forms part of the Toowoomba Enterprise Hub. The Business Park is located in close proximity to the Toowoomba Wellcamp Airport and other major transportation infrastructure.	Operational	2013 to 2014

Projects	Location	Description	Status	Construction dates
Witmack Industry Park and Charlton Logistics Park	Wellcamp, QLD 3 km southeast of the Project footprint (Witmack Industry Park) Charlton, QLD 3 km south of the Project footprint (Charlton Logistics Park)	The Witmack Industry Park is a large industrial land development that offers large size industrial land parcels. Businesses situated within the Witmack Industrial Park include the Toowoomba Pulse Data Centre. The Charlton Logistics Park is part of the Toowoomba Enterprise Hub and provides fully serviced 2 ha sites and is well situated for potential transport and logistics operators due to its proximity to transport infrastructure.	Operational	2016 to 2018
Asterion Medicinal Cannabis Facility	Wellcamp, QLD 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.	Under construction	2020 to 2021
Commodore Mine and Millmerran Power Station	Domville, QLD Intersects the Project footprint, located primarily to the east	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	2001 to 2003 Subject to annual maintenance shutdown and continual pit expansion. Also potential for coal reserves to be accessed beyond the current footprint
Pittsworth Industrial Precinct and Enabling Project	Pittsworth, QLD 500 m to the south of the Project footprint	Road and sewerage upgrades at the Pittsworth Industrial Precinct to allow for industrial land for industries servicing agriculture and the wider region	Operational	2017 to 2019
Doug Hall Poultry	Millmerran, QLD Intersects the Project footprint, located primarily to northwest	Poultry farming operation with capacity of approximately 20,000 chickens. Operations include egg grading, a feedmill with output of 1,500 tonnes per week, piggery, cropping and solar farm.	Operational	N/A
Yarranbrook Feedlot	Whetstone, QLD Intersects the Project footprint, located predominantly to north	Cattle feedlot licenced for 25,000 head	Operational	N/A

Projects	Location	Description	Status	Construction dates
Sapphire Feedlot	Kildonan, QLD Adjacent to the south of the Project footprint	Cattle feedlot which currently has a 6,000 head capacity, with plans to expand to 8,700 and in the future	Operational	N/A
Wyemo Piggery	Glenarbon, QLD 8 km south of the Project footprint	Piggery with approval for 55,000 pig units	Approved with conditions by GRC	Unknown
Yarranlea Solar	Yarranlea, QLD Intersects the Project footprint, generally extends equally to north and south	Solar Farm which will have a generation capacity of up to 100 MW once completed	Operational	2018 to 2019
Goondiwindi Abattoir	Goondiwindi, QLD 13 km north of the Project footprint	A new beef Abattoir located on the outskirts of Goondiwindi with beef processing of up to 72,000 tonnes per year	Approved with conditions by GRC	Unknown
North Star to NSW/QLD Border (Inland Rail)	Rail alignment from North Star, NSW to the NSW/QLD border Adjoins the Project footprint to the south	New 37 km rail corridor to connect North Star (NSW) to the QR South West Rail Line just north of the NSW/QLD border	Reference design and draft EIS	2021 to 2024
Gowrie to Helidon Project (Inland Rail)	Rail alignment from Gowrie to Helidon, QLD Adjoins the Project footprint to the north	New 26 km dual gauge track between Gowrie (north-west 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.	Reference design and draft EIS	2021 to 2025
Helidon to Calvert (Inland Rail)	Rail alignment from Helidon to Calvert, QLD 26 km to the east of the Project footprint	New 47 km dual gauge rail line connecting Helidon (east of Toowoomba) with Calvert (near Ipswich), via Placid Hills, Gatton, Forest Hill, Laidley and Grandchester, extending through the LGAs of Lockyer Valley and Ipswich City. The project includes a 1.1 km tunnel to create an efficient route through the steep terrain of the Little Liverpool Range.	Reference design and draft EIS	2021 to 2025
Calvert to Kagaru (Inland Rail)	Rail alignment from Calvert to Kagaru, QLD 70 km to the southeast of the Project footprint	New 53 km dual gauge track from Calvert to Kagaru to provide convenient access for freight to major proposed industrial developments at Ebenezer in the City of Ipswich, and at Bromelton near Beaudesert in the Scenic Rim Region. The project includes a 1.1 km tunnel through the Teviot Range.	Reference design and draft EIS	2021 to 2025

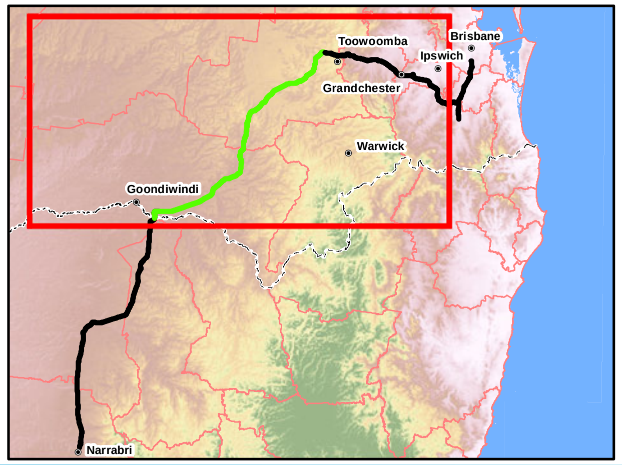
Projects	Location	Description	Status	Construction dates
Kagaru to Acacia Ridge (Inland Rail)	Rail alignment from Kagaru to Acacia Ridge, QLD 113 km to the southeast of the Project footprint	Enhancements to, as well as commissioning of, dual gauge operations along the existing interstate track between Kagaru and Acacia Ridge. The project involves 49 km of existing track to be enhanced enabling double-stacking capability along the existing interstate route both south from Kagaru to Bromelton and north from Kagaru to Brisbane's major intermodal terminal at Acacia Ridge. It extends across three LGAs of Scenic Rim, Logan and Brisbane.	Reference design and EIS	2021 to 2025
Cross River Rail	Brisbane, QLD 120 km to the east of the Project footprint	New 10.2 km passenger rail line from Dutton Park to Bowen Hills, which includes 5.9 km of tunnel under the Brisbane River and the CBD. The Project will include four new underground stations at Boggo Road, Woolloongabba, Albert Street and Roma Street, and upgrades to Dutton Park and Exhibition stations.	Construction	2019 to 2024

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



Legend

- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Border to Gowrie alignment
- Gowrie to Helidon alignment
- Helidon to Calvert alignment
- Calvert to Kagaru alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- NSW/QLD border
- Groundwater impact assessment area
- Local Government Areas



A3 scale: 1:900,000

0 6.5 13 19.5 26 32.5km

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Issue date: 26/05/2020 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 11.1:
Projects considered for cumulative impact potential

Map by: LS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_FFJV_Fig11.1_CumulativeImpacts.mxd Date: 26/05/2020 11:42

Projects and operations surrounding the groundwater impact assessment area were evaluated in terms of the potential of each to impact groundwater receptors of relevance to the Project.

Cumulative impacts to groundwater are most likely occur where multiple projects intersect and/or take groundwater from the same shallow aquifer units. The resultant impacts to groundwater may be:

- Change in groundwater levels
- Reduction in groundwater quality, including from contamination

Impact modelling indicates that no registered bores located outside of the Project footprint are expected to experience groundwater drawdown as a consequence of Project activities. Therefore, due to the localised potential of groundwater impacts associated with the Border to Gowrie Project and the distance and nature of many of the surrounding projects considered, only four of the initial 23 projects are considered to have potential to result in cumulative impacts to groundwater. These projects are:

- Commodore Mine and Millmerran Power Station
- North Star to NSW/QLD Border Project (Inland Rail)
- Gowrie to Helidon Project (Inland Rail)
- Asterion Medicinal Cannabis Facility

An assessment of cumulative impacts that may arise from these projects in combination with the Project is presented in Table 11.4, with a summary of how potential cumulative impacts would be managed. This assessment has concluded that the construction phase cumulative groundwater impacts of the Project are expected to be of **Low Significance**. The following factors contributed to this determination:

- Commodore Mine and Millmerran Power Station
  - There is potential for overlap of dewatering impacts on shallow aquifers intersected by Project cuttings and dewatering from the Commodore Mine open pit. However, if drawdown occurs due to the Project in proximity to the Commodore Mine, it will due to localised and temporary dewatering activities. As such, cumulative impacts to groundwater levels are considered unlikely.
  - Cumulative impacts on the quality of groundwater within shallow aquifers may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small. Therefore, the likelihood of impact to groundwater is considered to be low.
- North Star to NSW/QLD Border Project (Inland Rail)
  - There are no major cuts into the Border Rivers Alluvium required for the North Star to NSW/QLD Border Project. Therefore, drawdown impacts are likely to be restricted to localised and temporary dewatering activities. As such, cumulative impacts to groundwater levels in the Border Rivers Alluvium are considered unlikely.
  - Cumulative impacts on the quality of groundwater within the Border Rivers Alluvium may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small. Therefore, the likelihood of impact to groundwater is considered to be low.
- Gowrie to Helidon Project (Inland Rail)
  - Both projects, at the point of interface, overlie the MRV. However, neither of the projects require cuts with potential to encounter groundwater at this location. Therefore, drawdown impacts are likely to be restricted to localised and temporary dewatering activities. As such, cumulative impacts to groundwater levels in the MRV are considered unlikely.
  - Cumulative impacts on the quality of groundwater within the MRV may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small. Therefore, the likelihood of impact to groundwater is considered to be low.

- Asterion Medicinal Cannabis Facility
  - Both projects, at the point of interface, overlie the MRV. However, due to the nature of the development, the Asterion Medicinal Cannabis Facility is expected to have very little or no interaction with groundwater in the area. Therefore, cumulative impacts to groundwater levels are considered unlikely.
  - Cumulative impacts on the quality of groundwater within the MRV may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small. Therefore, the likelihood of impact to groundwater is considered to be low.

Table 11.4 Assessment of groundwater cumulative impact

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
North Star to NSW/QLD Border Project	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts during construction to groundwater levels is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts during construction to groundwater quality is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▪ The development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring. ▪ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
Gowrie to Helidon Project	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts during construction to groundwater levels is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts during construction to groundwater quality is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▪ The development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring. ▪ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
Asterion Medicinal Cannabis Facility	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts during construction to groundwater levels is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts during construction to groundwater quality is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▪ The development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring. ▪ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			

<table>
<tr><th>Project</th><th>Potential cumulative impact</th><th>Impact characteristic</th><th>Relevance factor</th><th>Sum of relevance factors</th><th>Impact significance</th><th>Comments and management measures</th></tr>
<tr><td rowspan="8">Commodore Mine and Millmerran Power Station</td><td rowspan="4">Change in groundwater levels</td><td>Probability of impact</td><td>Low (1)</td><td rowspan="4">6</td><td rowspan="4">Low</td><td rowspan="4">The potential for cumulative impacts during construction to groundwater levels is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.</td></tr>
<tr><td>Duration of the impact</td><td>Medium (2)</td></tr>
<tr><td>Magnitude/intensity of the impact</td><td>Low (1)</td></tr>
<tr><td>Sensitivity of receiving environment</td><td>Medium (2)</td></tr>
<tr><td rowspan="4">Groundwater quality and contamination</td><td>Probability of impact</td><td>Low (1)</td><td rowspan="4">6</td><td rowspan="4">Low</td><td rowspan="4">The potential for cumulative impacts during construction to groundwater quality is considered to be low, therefore specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through:
▪ The development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.
▪ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.</td></tr>
<tr><td>Duration of the impact</td><td>Medium (2)</td></tr>
<tr><td>Magnitude/intensity of the impact</td><td>Low (1)</td></tr>
<tr><td>Sensitivity of receiving environment</td><td>Medium (2)</td></tr>
</table>

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

12 Conclusions

This report has been prepared to evaluate potential impacts of the Project on groundwater resources and addresses the ToR requirements with respect to groundwater. This chapter has identified existing conditions of the impact assessment area in accordance with industry standard methodology and relevant legislation. Through an assessment of existing conditions, project activities with the potential to adversely impact on groundwater resources were identified.

Project activities, throughout the Project lifecycle, can impact on groundwater resources via:

- Loss or damage to existing landowner bores or groundwater use from the bore (quality/yield degradation)
- Groundwater level reduction
- Alteration of aquifer parameters and/or flow patterns
- Subsidence/settlement of compressible substrates
- Contamination/reduction of groundwater quality
- ARD
- Groundwater level mounding
- Alteration to groundwater recharge/discharge mechanisms.

The majority of potential impacts related to groundwater for the Project are considered temporary in nature and related to the construction phase of the Project. All potential impacts to groundwater resources through Project activities are considered to be manageable with the implementation of mitigation measures specified in Section 9.2.

In the few deep cut locations where construction activities have the potential to intersect shallow groundwater (cuts C08, C37, and C44), construction techniques have been identified for the Project such that impacts are considered to be appropriately mitigated and managed through the adopted engineering controls.

Implementation of a GMMP that embraces adaptive management principles, as detailed in Section 9.3, will ensure that specific potential impacts identified for each phase of the Project can be managed based on specific activities, locations, and WQOs to protect groundwater resources and users.

The potential for cumulative impacts to groundwater levels and quality due to other projects occurring in the vicinity of the Project has been assessed. The likelihood of cumulative impacts to these aspects is considered to be low due to the largely localised and temporary nature of impacts to groundwater that may arise due to the Project.

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